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EVALUATION OF CENTER PIVOT IRRIGATION SYSTEMS UNDER EGYPTIAN CONDITIONS

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Abstract

Four center pivot systems naming CPS1, CPS2, CPS3 and CPS4 were evaluated for improving water distribution uniformity during year (95/96). The selected systems covered areas ranged from 2 fed to 150 fed. Water distribution uniformity DU, coefficients of uniformity of Critiansen CU_c, Wilcox and Swailes CU_w, Benani and Hore CU_B, coefficient of variance CV and both of the application effeciency AE and system efficiency SE were studied. It was found that average value of uniformity coefficient CU_a of CU_c and CU_B can be considered as a suitable parameter to evaluate CP system under Egyptian conditions, in addition of coefficient of variation CV. Results indicated that the change of distribution uniformity Du ranged from 3% to 13% was due to operating the tested systems for two seasons. The change in the average uniformity coefficient CU_a ranged from 0.7% to 8.9% resulting in the system efficiency changed from 8% to 13% depending on the amount of water applied (under 100% of setting speed). System maintenance specially after each season is essential to maintain high efficiency of the CP systems. Paper presented the most constrains which limited the expansion of CP system in Egypt.

INTRODUCTION

The center pivot system was introduced in some Egyptian desert areas in Salheia, and West Noubaria since 1981. About more than 450 center pivots are still working until now. Several center pivots were replaced by other irrigation systems due to the problems facing center pivot operation under Egyptian conditions.

Current systems supply water, herbicides, insecticides and other chemicals in a manner that fits the timely need of the crops, reducing growing requirements for irrigation and chemicals application. The CP is considered a capable system to irrigate sandy soils, which was not previously considered feasible for agricultural production. Mechanical system such as the center pivot minimize problems concerning the variability of the soil intake and water holding capacity. Center pivot systems require efficient management to determine the operating pattern of the systems. The most important performance criterion for an irrigation system is the uniformity of application. Radi (1994) evaluated different types of irrigation systems in sandy soils. He found that Du and CU for CP systems in different locations in Noubaria, ranged from 51.8 to 76.5 for Du and ranged from 66.4 to 84.5 for CU.

The CU and DU uniformity parameters facilitate describing the actual distribution of the applied water. Marlk *et al.*, 1986, compared the coefficient of variance CV with the CU and recommended that CV is more appropriate for comparing the distribution for center pivot irrigation systems. Heerman *et al.*, 1992 stated that in the most cases (60 CP systems tested) the normal distribution better describing the data. It has been recommended for analyzing the value of increasing irrigation system performance. They studied and investigated four distribution functions namely: normal, lognormal, uniformed and specialized power. They also concluded that CV is not an indicator of how well the data can be represented by a theoretical distribution. Heerman *et al.*, (1992) reported that a level of CU and DU is generally selected for accepting a design and operation of the system. The manufacturers of center pivot system widely use the Christiansen uniformity coefficient to compare the irrigation uniformity. They also stated that the benefit of improving the center pivot system with lower CV values can be analyzed with the assumption of normal distribution.

Hill and Keller (1980) estimated the attainable irrigation uniformity and calculated the optimum amounts of water applied to maximize profit, for selected types of irrigation systems. The optimum application was influenced by the capital cost of the irrigation system, uniformity and efficiency of irrigation, expected impact of system type on crop yield, and vlaue of crop. They added that results analysis showed that improvements in irrigation system uniformity should be mandatory to maintain profitable irrigation. Varlev (1976) analyzed the impact of irrigation uniformity on yield and the importance of considering the water-yield relation for over as well as under irrigation. Whenever irrigation supplied more than 60 to 80% of the total water it was impossible to attain the same yield with a nonuniform irrigation system by simply increasing the depth of application. Von Bernuth (1983) developed relationships between the coefficient of uniformity giving high economic return and the depth of applied water under a situation of deficit irrigation. He demonstrated that the greatest the depth of applied water (up to the plant water requirement) and the greater the crop value, the higher the coefficient of uniformity that could be economically justified.

Improvement of uniformity under a center pivot system requires investment, either in capital out lay for system improvement or maintenance. Furthermore it is necessary to consider the concept of uniformity of water applied related to uniformity of yield. The objective of this paper is to study the improvement of uniformity of center pivot system and to identify the suitable parameters of uniformity for evaluation of CP cystem. Based on the performance study, the drawbacks which eliminated expansion of center pivot in Egypt could be specified.

FIELD PROCEDURES

Field data :

Four center pivot systems naming CPSI, CPS2, CPS3 and CPS4 were evaluated during summer season 95 and re-valuated at the end of winter season 95/96. The CPS1 system was recently installed in the Experimental Farm of Faculty of Agriculture - Ain Shams - Univ. "Shalaquan" Qaluobia governorate (clay loam soil). The other three center pivot systems were already installed in Dina Farm, West Noubaria, in 1986-1992. Before evaluation, the systems were calibrated to determine the actual performance of each CP. The CPS1 received minor adjustment for a few number of nozzles. Other CP systems require adjustment and replacement of many nozzle sizes according to the catalog of each system. The relation between setting speed and both water uniformity parameters and system efficiency were studied (for the CPS1 only) to determine appropriate depths of application for scheduling center pivot irrigation. In the current paper setting speed was used to facilitate changing the system discharge. Table 1 shows the specifications of studied systems.

Table 1. Specifications of the studied center pivot systems.

Specification	CPS I	CPS 2	CPS 3	CPS 4
Length, m.	42	108	360	450
Actual irrigated area, fed.	2	50	100	150
Pressure at pivot, bar	2.5	2.5	3.0	5-6
Ave. system flow rate, m^3/h	3.5	190	200	200
Clearance, m	1.8	2.8	2.8	2.8

Procedures

Experiments were conducted in bare land (no crop) in the afternoon and the time at which the tests run were selected where wind speed was virtually calm. One radial line of catch cans was arranged for testing each system. For CPS1, CPS2 catch can spaced 2.6 m and 6 m respectively. The first can was positioned at 1.5 m and 4.5 m from the pivot respctively, while the last can was positioned beyond the end of the outermost head of the sprinkler head. For the CPS3 and CPS4 the can spacing was 9 m, with the first can at 4.5 m from the pivot, and last one was also beyond the reach of the outermost of the sprinkler head. The catch cans were weighted by multiplying the can position number by the water receiving depth, since receiving points represent progressively larger area as the distance from the pivot increases. Data of flow measurements and machine speed were recorded. For evaluating the system performance the following steps were taken.

Measures of uniformity :

1. Coefficient of uniformity

The field data was used to determine Christiansens uniformity CU_C (1942), Willox and Swailes CU_W (1947) and Benani and Hore CU_B (1964) as follows:

$$CU_C = \left[1 - \frac{\sum_{i=1}^{n} (X - \overline{X})}{\overline{X}}\right] * 100$$

Where

X = water depth in catch can number i, cm.

$\overline{X}$ = average water depth in can for number n of cans.

$$CU_W = \left[1 - \frac{S}{\overline{X}}\right] * 100$$

Where : S = standard deviation.

$\frac{S}{\overline{X}}$ = coefficient of variance.

$$CU_B = [1 - (0.63\ CV)]\ * 100$$

After the CP passes the position of the catch cans, the amount of water in cans were measured to determine the water depth. The quarter of the cans received the least amount of water considered for DU calculations.

2- The Soil Conservation Service 1982, uses a weighted procedure to determine distribution uniformity DU. The DU is defined as the ratio of the average water depth received by quarter of total number of cans which received the least amount of the water to average depth of the water by system catch multiplied by 100. The application efficiency AE (mean depth in catch cans divided by mean pumped depth), and system efficiency SE (AE * DU) were calculated. The CV has been recommended to be more appropriate than the CU in certain conditions (Solomon, 1984, Marek *et al*, 1986). Performance paramenters were determined to facilitate specifying system adjustment for one year operation. All the recommendations of meansurement are in accordance with the method used in this analysis.

According the calculation of DU, AE and SE were calculated as follows:

$$DU = \frac{\text{average weighted low quarter catch}}{\text{Average weighted system catch}} \times 100$$

$$AE = \frac{\text{Average water depth system catch}}{\text{Average pumped water}} \times 100$$

$$SE = DU \times AE$$

3- Finally the reasons of CP poor performance were recorded to identify the drawback related to center pivot operation maintenance, and management that limit the spread in using center pivot in Egypt.

RESULTS AND DISCUSSION

The preliminary calcuations of CU showed the considered CU_S and CU_B for computing CU was better than the considered CU_W. Consequently CU_a was calculated as the average of CU_S and CU_B, while CU_W was eliminated from calculations. The uniformity parameters CU_a, DU and CV in addition to application efficiency AE and system efficiency SE were considered for performance evaluation of CP systems as shown in Table 2. Figs, 1-7 show the water depth catch can along the CP.

A function of the plots show the location of the improperly performing nozzles or malfunctioning sprinklers. Preliminary test was conducted to locate and adjust the malfunctioning nozzles of the tested systems before executing the evaluation. This means that, some sprinklers were replaced and others were repaired.

It is worth to mention that the determination of system efficiency SE depending on DU and AE was a good indicator to express the performance of the CP system. It is also clear from Table 2. and Figures from 1 a to 7a, there is a relation between the uniformity of water distribution around average catch can depth and the high value of SE. The determination of CV for evaluated systems during one year of operation is very useful. Results indicated that the difference between the lowest and highest CV values ranged between 0.06 to 0.13. These results indicated that the lower CV the higher SE value. Consequently this CV was used as a parameter to pursue the changes in the calibrated system. The system efficiency was influenced by, the flow rate as a function of the system discharge, setting speed, and operating pressure. Comparing the changes in DU, CV, CUa and SE for one year of operation, it may clearly be observed that the CUa is a good indicator to express the status of the system. Whereas the change of the coefficient of uniformity from 93% to 78% is equivalent to a decrease of 46% of the average of applied water as a function of system flow rate. It can be concluded that improving the coefficient of uniformity will improve the system efficiency which may reduce the operating costs. For Zea maise each mm of water deficit was assumed to reduce grain yield by 19.8 kg/ha (Berrelt and Skogerboe 1973). In conclusion improvement of water uniformity is one of the most critical management decisions, the operator can make.

Table 2. The uniformity parameters, application efficieny AE and system efficiency SE for center pivot systems.

System	Setting speed, %	Ave. catch depth, cm	Ave. pumped depth, cm	CUa, %	CV, %	DU, %	AE, %	SE, %
CPS1	25a*	0.93	0.96	93.0	0.11	83	97	81
	25*b	0.83	0.94	87.5	0.20	82	88	64
	50a	0.75	0.76	90.9	0.14	84	99	83
	50b	0.71	0.75	84.7	0.21	81	95	77
	75a	0.68	0.61	87.9	0.17	82	95	80
	75b	0.55	0.60	80.4	0.23	77	92	71
	100a	0.47	0.49	83.9	0.22	77	96	71
	100b	0.45	0.49	83.2	0.24	74	92	68
CPS2	100a	0.50	0.52	85.0	0.22	79	94	74
	100b	0.50	0.52	77.8	0.32	65	94	61
CPS3	100a	0.44	0.50	91.6	0.13	86	88	76
	100b	0.42	0.50	85.7	0.21	76	84	64
CPS4	100a	0.41	0.49	91.7	0.12	88	84	74
	100b	0.40	0.48	82.8	0.25	73	83	61

(*) Data during summer 1995. (**) Data after winter 1995/1996.

Based on observations and the data of the field testes of center pivot systems for during two continuous seasons the following drawbacks were recorded:

1. Main spare parts of the CP system are not available.

2. Experienced persons for operation and maintenance of the center-pivot are not available.

3. High price cost of the center pivot.

4. The center pivot may become out of order when one of the front towers breaks down.

5 - Accurate data about the optimum depth of applied water and irrigation scheduling of the center pivot system are not available.

SUMMARY AND CONCLUSION

Four types of center pivot system were evaluated for determining the uniformity of water distribution. From the field tests data it can be concluded that the average of CUc and CU_B is considered as a good indicator for coefficient of uniformity. Meanwhile coefficient of variance CV is a good indicator to express the changes of CP systems status. Under Egyptian conditions it is necessary to carry out maintenance at the end of each season to maintain high efficiency of the system, and to improve the uniformity of water application. The main breakdown of center pivot systems under Egyptian conditions was determined by analyzing the field data and observations from system sites.

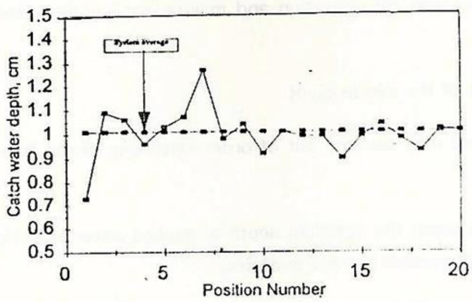

Fig. 1.a. Profile of catch water depth of CPS 1 for summer 95.

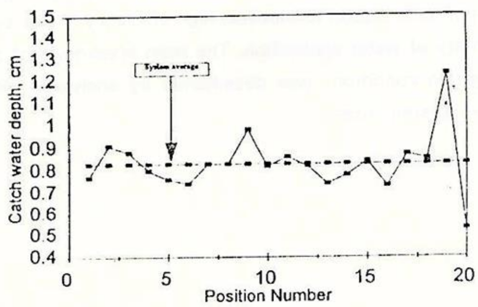

Fig. 1.b. Profile of catch water depth of CPS 1 after winter 95/96.

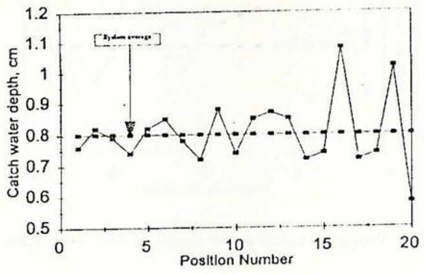

Fig. 2.a. Profile of catch water depth of CPS 1 for summer 95.

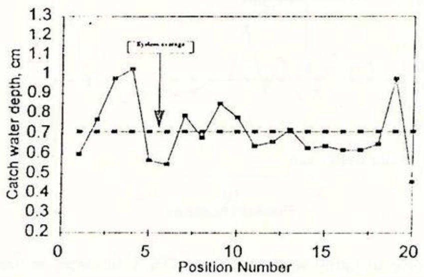

Fig. 2.b. Profile of catch water depth of CPS 1 after winter 95/96.

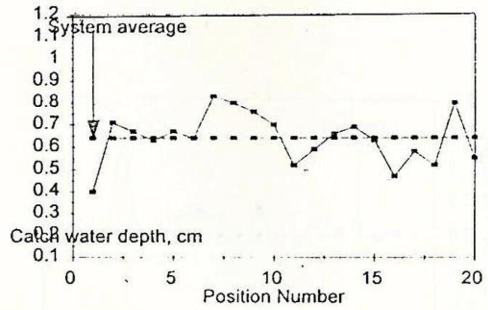

Fig. 3.a. Profile of catch water depth of CPS 1 for summer.

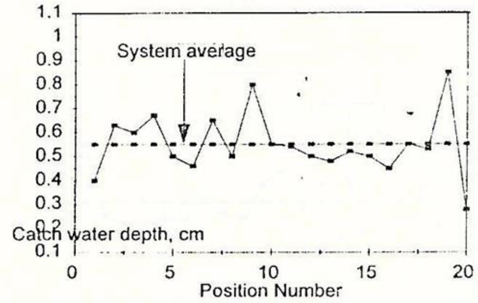

Fig. 3.b. Profile of catch water depth of CPS 1 for after winter.

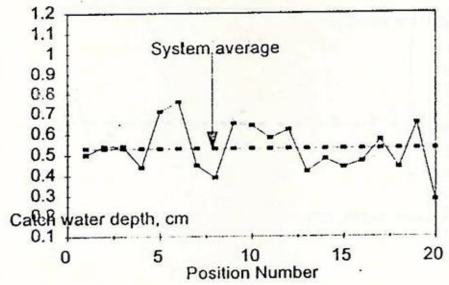

Fig. 4.a. Profile of catch water depth of CPS 1 for summer.

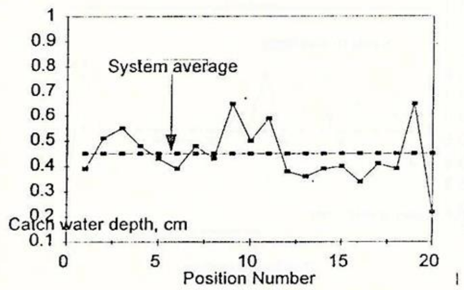

Fig. 4.b. Profile of catch water depth of CPS 1 after winter.

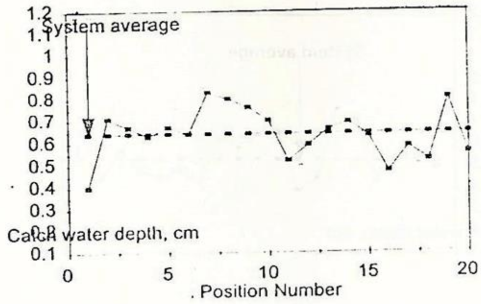

Fig. 5.a. Profile of catch water depth of CPS 2 for summer 95.

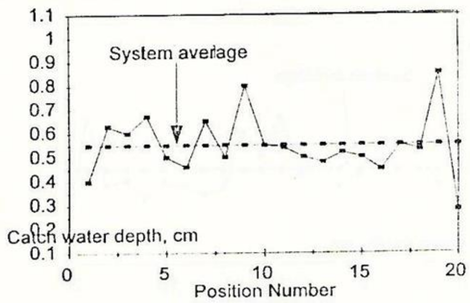

Fig. 5.b. Profile of catch water depth of CPS 2 after winter 95/96.

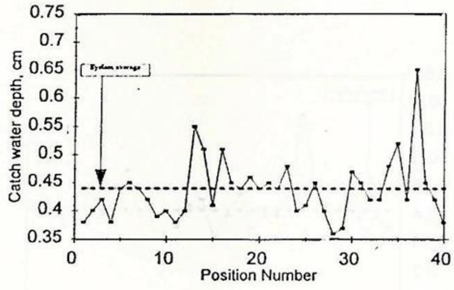

Fig. 6.a. Profile of catch water depth of CPS 3 for summer 95.

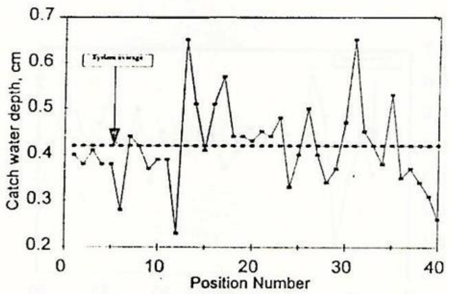

Fig. 6.b. Profile of catch water depth of CPS 3 after winter 95/96.

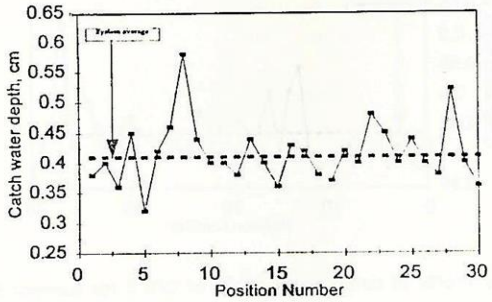

Fig. 7.a. Profile of catch water depth of CPS 4 for summer 95.

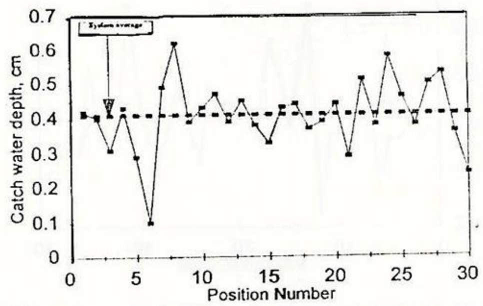

Fig. 7.b. Profile of catch water depth of CPS 4 after winter 95/96.

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تقييم أجهزة الرى المحورى تحت الظروف المصرية

جمال حسن السيد و وائل محمود مختار سلطان

معهد بحوث الهندسة الزراعية ، مركز البحوث الزراعية - الجيزة .

اجريت الدراسة الحالية لتقويم أربعة أجهزه للري المحورى المصممه لمساحات ٢ - ٥٠ - ١٠٠ - ١٥٠ فدان. وكان احد هذه الأجهزة يعمل بالأراضى الطينية / الطميية بمنطقة شلقان - القليوبية والأنواع الأخرى تعمل بالأراضى الرملية بمنطقة غرب النوبارية.

اعتمد التقويم على دلائل الانتظامية لكل من : Benami and Hore-Christiansen-Wilcox and Swailes كما تم حساب معامل الاختلاف CV لكل جهاز وكذلك كفاءة الجهاز كما تم تقدير كفاءة الأنتظامية DU لكل جهاز من الأجهزه تحت الدراسة وجمعت البيانات الحقلية أثناء موسم الزراعة الصيفى عام ١٩٩٥ وفى نهاية الموسم الشتوى ٩٥ / ٩٦ .

وقد أظهرت نتائج الدراسة انه يمكن تحسين انتظامية التوزيع مع رفع كفاءة النظام بأجراء الصيانة الدورية فى نهاية كل موسم زراعى.

كما ان استخدام معامل الاختلاف كمدلول للتغيير فى اداء النظام يعتبر مدلولا جيدا بالأضافة الى ان معامل انتظامية التوزيع الناتج من المتوسط الحسابى لكل من CU_C , CU_B يعتبر مناسباً لتقويم نظام الرى المحورى تحت الظروف المصرية. كما تم تحديد العوامل المؤثرة التى تحد من انتشار استخدام الرى المحورى فى مصر.