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PERFORMANCE OF SMALL – SIZED CENTER- PIVOT SPRINKLERS IN NEW LANDS

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ABSTRACT

This investigation dealt with small center-pivot sprinkler "CPS" (90-m boom, 50-100 m^3/h, and 9.7 fed coverage) in new lands.

The "coefficient of uniformity" and "distribution uniformity" were 83 and 72 % respectively for the low-discharge CPS (50 m^3/h), which are less (by 13-18 %) than reported in other literature. Values were even less with the high-discharge CPS (100 m^3/h). More attention should be paid, in future work, to lower-discharge CPS systems with improved uniformity.

Soil moisture was more pronounced near the top layer (0-25cm). This is typical for sprinkling, especially on green cover, and help in cutting down deep-percolation losses.

It is recommended to pay more attention to adjusting CPS systems (of the low discharge small types) for more uniformity, and to take advantage of cutting down percolation losses, especially in medium-size new lands.

Key Words :

Center-pivot sprinkler sprinkling, sprinkler irrigation, sprinkler system emission uniformity (EU), Coefficient uniformity (CU)

I. INTRODICTION

Agricultural planning for remote and reclamation areas demands a great attention, especially if water, labor or energy are limiting factors. Water availability and irrigation management are among the most restrictive constraints to expansion. In some of the Egyptian expansion

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projects (Nubareia for instance), the max. Allotted water requirement is limited to 5000 m^3/fed/y (fed=4200 m^2). In this case, no other systems than dripping or sprinkling can be used.

Although dripping uses some 30% less water than sprinkling, the latter has other advantages, among which are: (1) less labor requirement especially with pivot systems, (2) it tolerates rougher terrain due to using higher pressure, (3) humidification of arid conditions, and (4) reduction of deep percolation losses especially in permeable soils.

The center-pivot systems (CPS) have the main advantages of: (1) reduced capital cost per unit area, and (2) reduced labor demands. However, its main disadvantages are: (1) high pressure and power, and (2) mechanical complexity to drive the boom tractive wheels. The CPS, which were customary in Egypt, are of large sizes (500 m boom ~ 150 fed coverage area). However, common holdings in the country require smaller systems.

Awady et al. (1986) stated that appropriate sprinkling should fulfil such requirements as: (1) irrigation efficiency, (2) simplicity of operation, and (3) other advantages of saving wasted lands, climatic humidification, etc… Abdel - Latif (1992) found that sprinkling increased sugar beet yield by 50% over traditional irrigation, while reducing water consumption.

Steiner et al. (1983) mentioned that center-pivot sprinkler are important irrigation systems in the great plains of the United States. Several thaousand systems have been installed since the early 1950because center-pivot irrigation systems offered improved efficiencies over existing surface irrigation methods, lower lober requirements. Development of center pivot-system opened up new areas to irrigation, allowing development in regions that have soil types and topographies unsuitable for surface irrigation methods. However, sprinkler irrigation systems are more capital and energy intensive than surface systems. Rapid increases in energy costs and insert rates are causing irrigators and researchers to examine closely the efficiencies of center pivot system.

Application rate was determined by measuring the flow rate of water at the center of the pivot and the rate of travel of the irrigation system at a known radius. Depth of water applied, D, is calculated as :

$$D = QR^{-1} A^{-1} = \frac{\text{Volume of water}}{\text{Time}} \times \frac{\text{Time}}{\text{Distance}} \times \frac{\text{Distance}}{\text{Area}}$$

$$D = \frac{\text{Volume of water}}{\text{Area}}$$

Where :

Q : flow rate (m^3/h),

R : the rate of movement of the pivot (m^2/min)

A : the area of the field watered per unit distance traveled (m^2/m)

Wilmes et al. (1993) defined the factors of centre pivot usage growth due to: automation is built into the centre pivot allowing for irrigation of the most efficient and uniform methods of applying irrigation water if the system is properly designed and managed. The design of a center pivot irrigation system includes: specifying the type of sprinkler to install, the flow rate per unit area (capacity) required to meet crop demands, length and diameter of the center pivot lateral, type of energy source used to pump irrigation water, the pressure required at the pivot to operate the chosen sprinkler package.

The objectives of this research are to set small-size pivot systems for proper functioning, and study their characteristics and suitability for medium-size areas in sandy soils and remote areas. Data collected are intended for further use in comparing between different irrigation-systems.

II. MATERIALS AND METHODS

2a- Experimental Site and Setup

Experimental were run at the experimental farm in Anshas of the "Nuclear Research Center, Atomic Energy Authority of Egypt". Latitude is

30° 36′, with min. and max. Temperature of 15 and 28 centigrade respectively during tests.

Texture and characteristics of the soil under study of the experimental field are shown in Table 1.

Table (1): Characteristics of the soil under Study for Inshas area.

Soil depth (cm)	Particle size distribution % Sand C.	F.	Silt	Clay	Bulk density g/cm³	$CaCO_3$ %	EC (mmhos)/cm	O. M.*	pH
0-15	64.30	21.46	8.2	4.00	1.68	0.84	0.45	1.2	7.2
15-30	69.11	18.60	6.9	4.01	1.70	0.60	0.32	0.78	7.4
30-60	70.32	23.10	3.5	2.50	1.74	0.38	0.48	0.20	7.5
60-90	71.00	24.00	2.8	1.82	1.76	0.27	0.21	0.11	7.7

O. M.*: Organic matter

2b- Center-pivot Systems

Measurements were taken from two different center-pivot sprinkler sets (Zimmatic electric-driven). Each set is 90 m-long, with end gun to increase the irrigated area (9.7 fed). Specifications of the sets are as follows:

Set 1: Discharge 50 m^3 /h.

Set 2: Discharge 100 m^3/h.

Pressures: Near center ~ 0.28 and at boom end 0.27 Mpa.

2c: Determination of the Water-Distribution Uniformity

Result were used in calculating the coefficient of uniformity (CU) which can assist in system design and selection (ASAE Standards, 1997). Collected water from catch cans were measured using graduated cylinders (1.0 L capacity, graduated every 25 mL). Height of collector was about 40 cm, with a surface area of 530 cm^2. Brims of catch cans were shaped so as to prevent splashing of water to the outside.

Collectors were spaced on a single leg, 3 m apart, perpendicular to the travel direction of the boom, as shown in Fig. 1. Each can location and two replication.

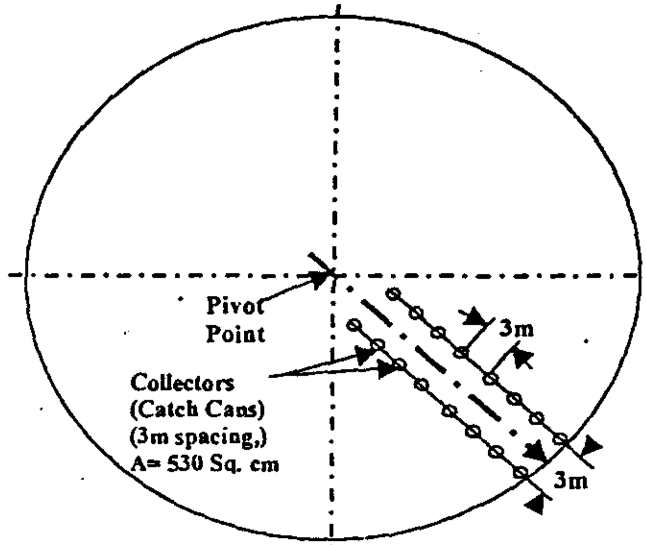


Fig. (1) Layout of catch cans under center-pivot sprinkler.

The distribution uniformity (DU) was calculated according to the least quarter formula, as follows:

$$DU = LQ/M,$$

Where "LQ" is the average of the lowest ¼ of the irrigation amount, and "M" is the average of the total amount of irrigation.

The "CU" was also calculated according to the christiancen formula.

$$CU = 1 - (D/M),$$

Where "D" is the average of the absolute deviations of the irrigation amounts from the mean.

2d-Determination of the Soil-moisture distribution under the Centre-Pivot system

Soil moisture contens were determined using Neutron Moisture Meter (CPN 503 DR, 50 mci). Four access tubes were installed on soil randomly under the system. The data were collected within a rotation cycle of the boom (100 m^3/h discharge). Measurements were taken prior to irrigation and after 1, 2 , and 24 h from last irrigation. Readings were taken at three soil depths: 20, 50, and 75 cm. Data in table 2 show the calibration relations of the readings (IAEA, 1976) at different soil depths.

Table (2):Neutron Moisture Meter calibration relations for different depths.

Soil depth (cm)	Linear equation (y = a + bx)	Correlation coefficient (%)
25	C. R* = 0.2009+0.0412 θv **	99.99
50	C. R* = 0.2948+0.0284 θv	99.99
75	C. R* = 0.2734+0.03313 θv	99.44

*C. R: Count ratios for Neutron Moisture Meter model CPN 503 DR (50 mci).

**θv %: Volumetric soil water content %.

III. RESULTS AND DISCUSSION

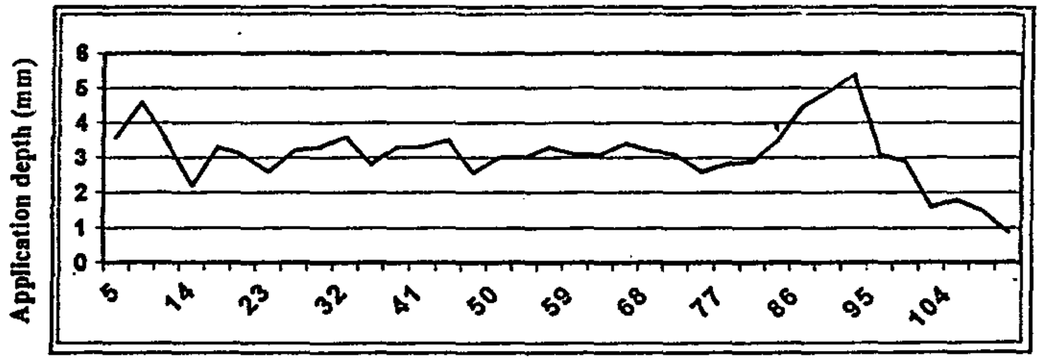
3a- The 50 m^3/h Center-Pivot Systems (CPS)

The obtained results for "CU and DU" of water under the system were 83.0 and 71.9 % respectively. The applied water-depth distribution along the radial direction in mm is shown in Fig. 2. Some excessive application rates are noticed near the two ends of the boom. The middle portion is more uniform (between 14 and 81 m from center as shown in Fig.3). The end-gun (at 90m) gave poor water distribution. These irregularities can, in principle, be alleviated in good design by changing nozzle discharges or spacing at certain points. Solomon (1988) mentioned, however, slightly better uniformities (DU ~ 75-90%).

3b-The 100 m^3/h CPS

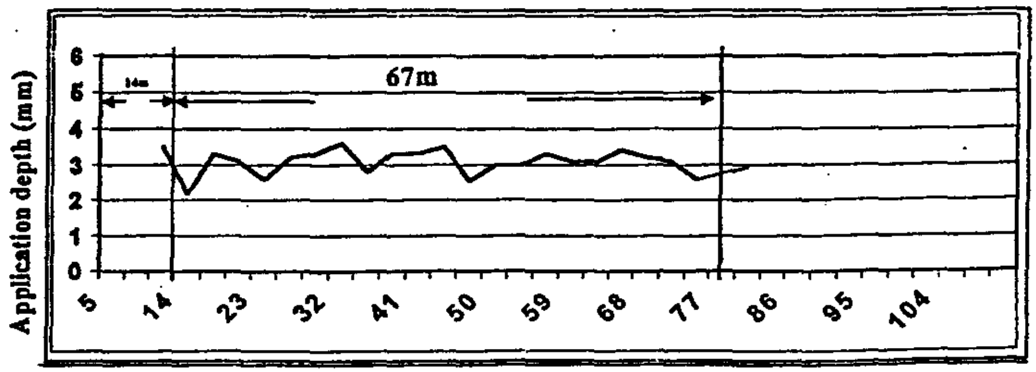
The resulting "CU and DU" values were 57.3 and 62.4%. The distribution of the water applied depth in mm is shown in Fig.4.

Apparently the distribution is less uniform than the CPS with 50 m^3/h discharge. The tail end essentially delivered less water than near the center. This may be due to greater head-losses along the boom.



Distance from center (m)

Fig.2: Water distribution under the 50 m^3/h CPS



Distance from center (m)

Fig.3: Water distribution for the middle portion of the 50 m^3/h CPS

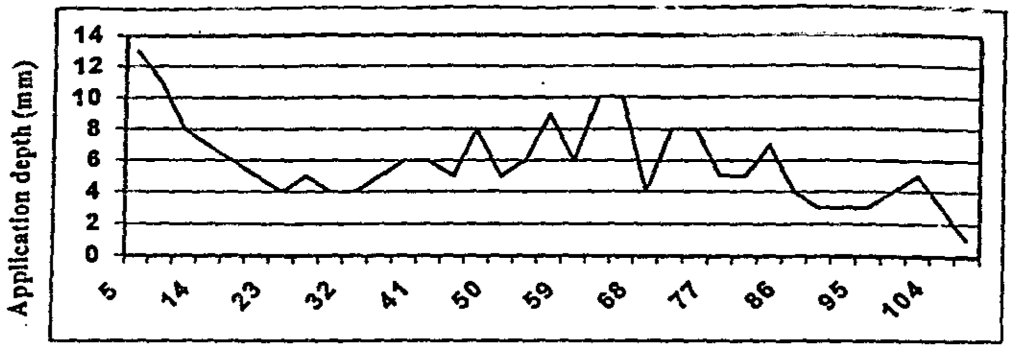


Fig. 4: Water distribution under the 100 m^3

3c-Soil-moisture Distribution under the CPS

Fig.5 shows that soil moisture increased near the soil surface (25cm) and subsurface (50cm) after irrigation in all cases (which is typical for sprinkler irrigation in sandy soil). There was no excessive deep percolation, since water applied did not exceed field capacity for the mentioned soil depth. Also, the land was cultivated with "Berseem clover" for seven years and was rich with organic material at the surface retaining more moisture there. Add to that, berseem roots consume available water from active-root depths 50-60cm (Doorenbos and Pruitt, 1975). The system is thus more appropriate for shallow-rooted crops.

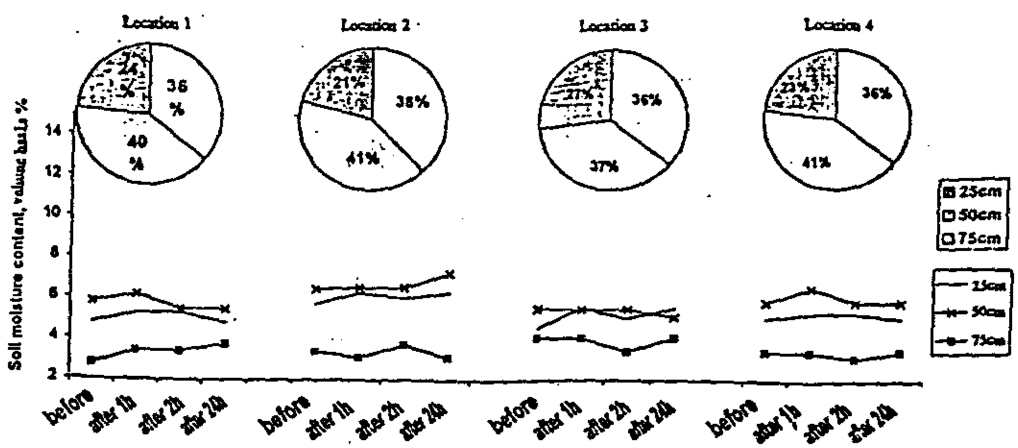


Fig.5: Soil moisture distribution for 4 different locations under CPS of high discharge (100 m^3 / h)

IV. CONCLLISION AND RECOMMENDATIONS

This investigation dealt with small center-pivot-systems "CPS" (90-m boom plus end gun, 50-100 m^3 /h, 9.7 fed coverage) in new lands. It aimed at setting the systems for proper functioning, studying their characteristics, and to prepare database for comparing between different systems, in the future.

The "coefficient of uniformity" and "distribution uniformity" were 83 and 72 % respectively for the low-discharge CPS (50 m^3/h) as previously defined in section "2c". These are less by 3-18 % compared with estimates given in other literature. The high- discharge CPS (100 m^3/h) gave even less uniformities:57 and 62 % respectively. Better uniformities should be sought in future works, especially with lower-discharge CPS adopted.

Soil moisture was more near the soil top layer (0-25cm). This is typical for sprinkling in general, in addition to vegetative cover, and helps prevent deep percolation losses, especially in sandy soil.

In conclusion, small CPS fit medium-sized holdings. They need care in adjusting for uniformity of water distribution, and have the advantage of cutting down the deep-percolation losses in sandy soil.

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أداء أجهزة ري بالرش محورية صغيرة في الأراضي الجديدة

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ملخص البحث

تناول البحث جهازي ري بالرش صغيرين (طول الذراع ٩٠م ، م. تصرف٥٠،٠٠١م٣ /س ، مساحة تغطية ٩,٧ فدان) في أراضي جديدة.

بلغ "معامل الإنتظامية " و " انتظام التوزيع " ٨٣ ، ٧٢ % علي الترتيب،حسب التعريف المعطي بالبحث ، للجهاز منخفض التصرف (٥٠ م٣ / س) ، وهي قيم تقل عن المذكور فى مراجع أخرى بنحو ٣–١٨%.

وقلت الإنتظامية عن ذلك للجهاز عالي التصرف (١٠٠ م٣/ س). لذا يوحي بالاهتمام بالأنظمة ذات التصرف المنخفض مع تحسين إنتظامها.

لوحظ ارتفاع الرطوبة الأرضية قرب الطبقة السطحية (صفر – ٢٥ سم). وهذا متوقع للري بالرش وخصوصاً في الأراضي المستزرعة بغطاء نباتي ، ويساعد ذلك علي تقليل فقد المياه بالتسرب العميق .

في الختام يوصي البحث بالاهتمام بأنظمة الرش المحورية الصغيرة وقليلة التصرف وبتحسين انتظامية التوزيع الناتج منها ، والاستفادة من تقليلها لفقد المياه بالتسرب العميق ، وخصوصاً في المساحات المتوسطة بالأراضي الجديدة.

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علي الترتيب: أستاذ مساعد وأخصائي ، القسم الزراعي لبحوث الأراضي والمياه مركز البحوث النووية ، هيئة الطاقة الذرية ، القاهرة.