RESEARCH CONCERNING CENTER-PIVOT SPRINKLER IRIGATION SYSTEM WITHIN SUD-SOLONET IRRIGATION SYSTEM

CERCETĂRI PRIVIND IRIGAŢIA PRIN ASPERSIUNE CU INSTALAŢII AUTODEPLASABILE TIP PIVOT CENTRAL, ÎN CONDIŢIILE SISTEMULUI DE IRIGAŢIE SUD-SOLONEŢ, JUDEŢUL IAŞI

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Abstract: *This research refers to center-pivot irrigation systems of the latest generation with lengths of 300 m and 400 m, respectively, which are equipped with both a set of wobbler sprinklers along the pipeline and a gun sprinkler in the downstream end. It includes measurements made in the field of watering pattern and uniformity of water applications, analysis of droplet diameter, evaporation losses and water application efficiency, the risk of runoff following applications on specific land slopes, and soils and agricultural conditions within Sud-Solonet system.*
Key words: center-pivot irrigation, application uniformity, application efficiency, risk of run-off.

Rezumat: *Cercetările se referă la irigarea cu instalaţii tip pivot central, de ultimă generaţie, având lungimi de 300, respectiv 400 m, echipate cu un set de microaspersoare oscilante şi cu aspersor de mare presiune în capătul aval.Au fost efectuate masuratori in teren ale pluviometriei si uniformitatii,analize privind finetea ploii,randamentul udarilor ,riscul excesului de apa si scurgerilor la suprafata solului,ca si al formarii crustei in urma udarilor*
Cuvinte cheie: instalaţie de irigaţie tip pivot, uniformitatea udărilor, randamentul udărilor, risc de scurgere la suprafaţă.

INTRODUCTION

Recently, many irrigation systems in our country are increasingly using center-pivot machines. The use of this type of machinery is ubiquitous with large irrigated farms, especially with crops of high yield and profitability. Although the necessary investments for these systems are large, they are effective due to several advantages: high productivity, high quality applications, and flexible irrigation with light and frequent applications that correspond to various water needs during the growing season. However, the disadvantage of water application with center-pivot systems is that the average application rate increases from pivot point to the extremity, where the rate may be so high that runoff problems at soil surface may occur. This may happen specifically when irrigation is done in conditions of clay soils or sloped lands. In addition, the end-gun sprinkler irrigation is problematic during windy conditions and its application profile is sensitive to the wet sector angle.

These types of systems are used in several arrangements such as South-Solonet, Albita-Falciu, and the Big Island of Braila. The latest generation systems exhibit low pressure sprinklers, positioned at equal distance along the lateral length, with a gun impact sprinkler at the downstream end of the lateral pipeline. The irrigated surface has a circular shape with a radius equal to the operative length of the equipment. Since these machines are replacing the older sprinkler laterals in actual irrigation plots with tertiary conduits at 600 m or 800 m, the best operation length of the center pivot equipment is 300 m and 400 m, respectively.

The center pivot machines have automated systems to maintain alignment of the lateral pipeline during travel and adjust the rotation speed to ensure various water application amounts. The investment cost for this equipment is proportional with its length and the irrigated area increases with the square of the operation length. Thus, the specific investment per irrigated area (lei/ha) is lower as the center pivot length is greater. However, with increased lateral pipe length, the pressure at the head at pivot point has to increase and so does the operation (consumed energy) cost. The state of minimal total costs (initial investment, energy, operation, maintenance, etc) for irrigation results in an optimal length for the center-pivot equipments of 400 m.

The research herein refers to some aspects that define the irrigation performance of center- pivot systems in South-Solonet arrangement conditions in Iasi County.

MATERIAL AND METHOD

The studies were conducted during the summer of 2009 and they refer to center-pivot systems with 300m and 400m length. The water application uniformity was determined using collector cans positioned on the soil surface (on a field route strip) 5 m apart in a radial pattern, from pivot point out to the edge of the wetted circle of the 400m lateral length system. In addition, the stationary wetting pattern was measured at several rotating-spray sprinklers. The subsequent analysis refers to the droplet diameters, the sprinkler jets evaporation losses, the water application efficiency, and the application intensity at various distances away from the pivot point.

RESULTS AND DISCUSSIONS

The center-pivot system with the 300 m lateral length is composed of five spans, while its inside diameter is 136.22 mm. Its flow rate is 120 cubic meters per hour and the operational pressure measured at the supply point is 2.5 bars. A booster pump is positioned at the downstream end of the lateral pipe to raise the pressure and help perform the irrigation function of the end gun sprinkler with a 15 mm nozzle diameter and a throw angle of 24°. The operational pressure inside the lateral pipe at the downstream end is 1,59 bars ahead of the booster pump and 3,71 bar passes the pump. Rotating –spray sprinklers distribute the water on the basic circular area out to the end gun sprinkler. These are spaced at nearly equal distances using flexible hose reaching 1-1,3 m above the soil surface. The nozzle size of the rotating–spray sprinklers gradually increases from pivot point to the end of the lateral pipe. A pressure regulator is positioned at each drop. The end gun sprinkler provides irrigation of a circular belt and it reaches a main circular irrigated area to 33,3 ha (that corresponds to an effective radius of 326m).

The second researched equipment has a lateral pipe length of 400 meters and is composed of seven spans and the end gun sprinkler with the same characteristics as the previous one. The inside diameter of lateral pipe is 160mm and the flow rate is 200 cubic meters per hour. The effective radius of the circular wetted area including end gun sprinkler is about 425m and the wetted area of a complete rotation is 56.7 ha. The water distribution is performed with the same type of rotating–spray sprinklers, having a set of nozzle diameters larger than previous equipment due to the increased length of the lateral pipe. If the systems are supplied throughout the season by the same hydrant, the specific application rate is 3,58 m^3/ha/hour. The water application amount is regulated by adjusting the rotation time, according to the following relationship:

$$m = \frac{T \cdot Q}{10 \cdot S_u} \quad \text{(mm)}$$

where : T is rotation time (hours); Q-flow rate of equipment; S-circular irrigated area (ha).

Water application uniformity

One of the main irrigation parameters is the application uniformity. The center pivot machines have uniform water distribution throughout the area irrigated with spray sprinklers; this condition is ensured by the specific design of the nozzle such as the size and the spacing of the sprinklers and an appropriate application pattern of each spray sprinkler. In addition, the pressure regulators ensure constant working pressure at each spray sprinkler, regardless of its position on lateral length and the land slope, along the lateral pipe. In windy conditions, the disturbances to uniformity may occur, but the influence of wind is reduced by the low positioning of the sprinklers above ground surface. The end gun impact sprinkler has a long and high throw and these features cause a high sensitivity to wind influence, which may adversely affect the application uniformity.

The radial application uniformity was established for the 400m length equipment by measuring of water amounts collected at different distances from pivot point. The radial coefficient of uniformity was computed with Hermann and Hein formula (Dukes, Perry, 2006):

$$C_u = 100\left[1 - \frac{\sum_{i=1}^{n} D_i \left|h_i - \overline{h}\right|}{\sum_{i=1}^{n} D_i * h_i}\right] \quad (\%)$$

where:

D*i* - radial distance to collector “i”; h_i - depth of catch at Di (mm); h - average depth of catch.

Analysis was performed within all wetted radius of equipment and it was separated by the radius of the irrigated area with spray sprinklers and with the gun sprinkler. The result of the entire application uniformity is expressed by Cu= 80% value, and for circular area wetted by spray sprinklers of Cu =92 %. Gun sprinkler application uniformity was moderately affected by wind influence. Relying upon these results, the irrigation is suitable for vegetables and crops with deeper root system (e.g. alfalfa, corn, sugar beet).

Drop size distribution

Small size droplets increase drift and evaporation losses and intensify the disruptive effects of the wind, with regard to the application uniformity. Conversely, droplets too large impact on the soil surface by dissolving soil clods or sealing over the soil and crop. In both events, the irrigation efficiency is significantly lowered.

Average droplets diameter d_{50} depends on the ratio of nozzle diameter and water pressure at sprinkler outlet. Moreover, with rotating spray sprinkler, the droplet size is a function of the deflector profile, the number and form of its grooves (Kinkaid et al., 1996). The average droplet diameter of rotating spray sprinklers with nine grooves of water throw, such as those with these facilities, is between 0.8 to 0.9 mm. Thus, we can assume that the water application is done with medium droplets and low kinetic energy.

Regarding the gun sprinkler, its droplets have an average diameter d_{50} of about 1.4 mm .The index of rain quality established with $K_p = \frac{d}{H}$ (d – nozzle diameter, mm; H – working pressure head, m) is 0.4 value, which corresponds to an average size droplet rain, recommended for field crops and grasses and for sandy and loamy soils.

Water applications efficiency

Evaporation losses from jet trajectory were assessed with Frost and Schwalen diagram (Cismaru, Gabor, 2004), using average wind speed conditions (approx. 2 m/s), relative humidity 40%, an atmospheric temperature of 30°C, and a working pressure and nozzle diameter that correspond to both categories of sprinklers (rotating spray sprinklers and impact gun sprinkler). For spray sprinklers, evaporation losses amount to approx. 5% of distributed water, with added water intercepted by vegetal cover, which is about the same size (5%). This shows that the water applications efficiency is about 90%. For gun sprinkler water application zone, the evaporation losses are 10%, resulting in an irrigation efficiency about 85%.

The risk of water excess at soil surface and run-off, during and after irrigation

The water application rate to be received at a point of the surface wetted by spray sprinklers is variable in time (histogram) according to the distance away from the pivot, the width of the stationary application pattern of spray sprinklers and the linear rotation speed of the lateral arm. The watering time near the pivot point is longer and the average application rate is lower, unlike the spray sprinkler located at the end of the lateral arm where lower watering time and higher average application rate apply. Peak application rate at any watering point is 4/π times the average application rate at the same point.

To assess the peak and average application rate we considered the following elements of center pivot equipment: all rotating spray sprinklers have constant work pressure with 103 kPa values, the nozzle diameter suitable to position of spray sprinkler from pivot point and the width of application pattern from technical book of equipment [6].

The average water application rate, tacking into account an elliptical profile, was calculated with following formula:

$$i_j = \frac{m_{br} \cdot R_e \cdot O_e}{T_j} = \frac{\pi \cdot T_j \cdot i_{xj}}{4 \cdot T_j} = \frac{\pi}{4} i_{xj}$$

where: i_j – average application rate required at radial distance r_j, mm/hr; i_{xj} – peak application rate at radial distance r_j, mm/hr; m_{br} – gross depth of water required per irrigation, mm; R_e – effective portion of water discharged from sprinklers, most of wich reaches the irrigated soil-plant surface, decimal; O_e – ratio of water effectively discharged through sprinklers to total system discharge, decimal; T_j – application time at radial distance r_j, hours.

The evaluation was done for 100 m, 200 m, 300 m, and 400m from pivot point (for the 400 m length equipment (table 1).

Table 1

Average and peak local application rates at some distances from pivot point (refer to 400 m length equipment)

Lateral lenght (m)	**300**			**400**			
Application time (hr), considering m=30mm	2.0	1.06	0.74	2.0	1.06	0.74	0.54
Average application rate (mm/hr)	14.94	28.28	40.18	14.94	28.28	40.18	55.7
Maximum application rate (mm/hr)	19.03	36.00	51.2	19.03	36.00	51.2	70.95
Nozzle diameter (mm)	5.16	7.14	8.73	5.16	7.14	8.73	9.53
Radial distance (m)	100	200	300	100	200	300	400
Radius of wetted sprinkler area (m)	7.55	7.97	8.1	7.55	7.97	8.1	8.1
Sprinkler flow (m^3/ora)	1.022	1.965	2.789	1.022	1.965	2.789	3.724

This work proves that the maximum local application rate does not depend on the application amount and has the maximum values of 71 mm/hour at the lateral pipe end. The local watering time directly depends on the application amount, which means that the usage of high water applications increases the risk of excess water and run-off on soil surface. To forestall these situations, some measures must be taken such as lower water applications (about 25-35 mm amounts, correlated with land slope size and intake capacity of soils), and measures for storage of temporary excess water, etc.

CONCLUSIONS

1. The applications uniformity of center pivot equipments with a set of rotating spray sprinklers and end gun impact sprinkler is good, even in low – moderate wind conditions, except for the area watered by gun sprinkler where this item is influenced by speed and wind direction.

2. The droplets size of rotating spray sprinklers is medium with low kinetic energy.

3. The water applications efficiency is about 90 % for spray sprinklers irrigated area and 85 % for gun sprinkler irrigated area.

4. The peak application rate has large values towards the end of lateral arms. If the land slope is in the range of 2-10 % and clay loams soils are irrigated, it is required to adopt measures to reduce the risk of excess water and run-off during and after applications, especially during the months of July and August.

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