English Version

Abstract

An irrigation system should enable the efficient management of applied water. For this it is necessary to evaluate the performance of the system in operation. This study aimed to evaluate the uniformity of distribution, consumption of electricity and water depth applied by a center pivot irrigation system in function of the relative position of the lateral line. It was tested three positions of lines collecting water: incline of 3.45%, level and slope of 11.78%. The experimental design was completely randomized design with three repetitions at each position tested. It was applied the analysis of variance followed by Tukey test. The average coefficient of uniformity of Heermann & Hein was 90.02%, describing the uniformity of water distribution as very good. The mean weighted depth of irrigation applied was 5.84 mm, varying in each test significantly (5%) between the positions of slope versus incline and level. It was concluded that the position of the lateral line significantly influenced the uniformity of distribution, water applied and energy consumption.

Uniformity of distribution of water and water depth applied in central pivot system in function of the relative position of the lateral line

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Keywords: water application; irrigation control; rotation; center pivot

Introduction

In agriculture, the correct application of water in crops is essential, since their development is connected to this condition. Irrigation is noteworthy as one of the major techniques available nowadays which is installed to elevate the yield levels in the country.

The main goal of an irrigation system is to provide conditions to produce economically what is obtained by the increase of the yield and reduction of the costs by unit produced. In this aspect, the parameters which express the quality of irrigation must be understood as decision-making compounds of the planning process and operation of the irrigation systems (FRIZZONE, 1992).

The knowledge of the equipment performance, mainly related to the uniformity of water distribution and water depth applied, is indispensible to develop measures with allow to save water and energy.

When only the necessary irrigation depth is applied to an area (considering that this depth corresponds to the mean depth), due to the lack of uniformity, a fraction of this area is irrigated in excess, while in other area it occurs a deficit of water, In the fraction with excess, a part is stored in the root region for the plant use and another part is lost by deep perchlorination, transporting also part of the nutrients of that layer. In the fraction with deficit, all the infiltrated water is considered stored in the root region, although in lower quantity than the water needs of the plants.

On the other hand, if the mean depth of irrigation applied is higher than the necessary, it may even eliminate the fraction with irrigation deficit, however the cost of the irrigation increases, and it may become even economically impracticable, besides the aggravation of the nutrient leaching. Therefore, the uniformity of the irrigation water distribution must be analyzed not only as simple information of dispersal, but also as an important parameter in the economical evaluation of the irrigation (ZOCOLER, et al., 2004).

FRIZZONE and DOURADO NETO (2003) cite that uniformity has effect on the crop yield, and it is considered one of the main factors in the operation of irrigation systems. The experiment or evaluation constitutes the way to collect the necessary data to make the decision about improvements to introduce in order to increase the efficiency of

Received on: 15 out. 2009. Accepted for publication on: 05 mar. 2010.

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the irrigation system. The experiment of irrigation systems are conducted to evaluate the performance of them, with the following fundamental objectives: (a) determine the current efficiency of the irrigation system; (b) determine how effective is the operation of the system; (c) obtain information which enable the comparison of various methods of irrigation, systems and forms of operation, as a base to take management decisions.

SOUZA et al. (2002b), cited by COSTA (2006), when studying the effect of the uniformity of water distribution on the water consumption in a center pivot irrigation system, concluded that there is a possibility of save water in 25.9% when the system passes the Christiansen Uniformity Coefficient – CUC – from 64.8% to 85.6%.

Currently, the water pumping has become a major parcel of the production cost, which forces the farmer who uses irrigation to seek alternatives which enable to reduce costs. Electric engines are the equipments which consume the larger part of the electric energy used in the irrigation systems, and the wrong dimensioning of these equipments may cause a larger consumption of electric energy (AZEVEDO, 2003). In the irrigation systems, usually the electric engines used to activate the pumps are dimensioned to achieve the maximum flow demand associated with the maximum manometric height.

In this context, it was objective of this work to evaluate in an equipment of sprinkling irrigation of the type center pivot the uniformity of distribution, water depth applied and consumption of energy concerning the position of the lateral line.

Material and methods

The experiments were conducted during December 2009 and January 2010 in the Farm Nossa Senhora Aparecida, in the municipality of Coronel Macedo, state of São Paulo, whose geographic coordinates are: 23° 41' South latitude, 49° 11' West longitude and 630 m of altitude.

In the farm three equipments of irrigation are installed. They are center pivot machines of the trend Valley named PC-07, PC-08 and PC-09. These equipments are linked by a single adductor and work interspersed with the same pumping system, which is commanded by a starter with Frequency Inverter. The experiments were performed on the pivot named PC-09 (Figure 01).

The main characteristics of the irrigation equipment evaluated are: circular area irrigated:

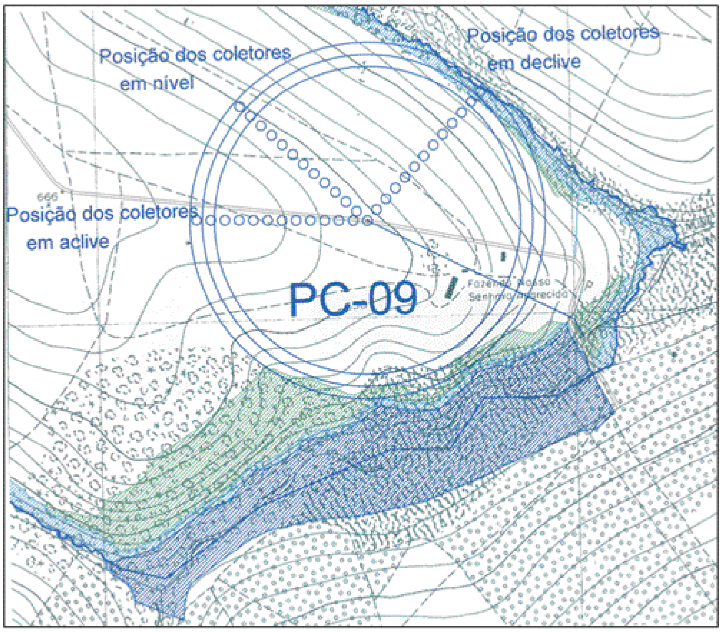

Figure1. Planialtimetric map of the area of location of the center pivot and disposition of collecting lines.

43.94 ha; period (relay 100%): 6.87 h; total depth: 338.59 $m^3.h^{-1}$; length of lateral line: 347.55 m; total radius irrigated: 473.0 m; gap between the pump and the center of the pivot: 51.0 m. It was tested three positions to the experiment: acclivity of 3.45%, level and slope of 11.78%. The experiments were executed according to the project of the rule number 04:015.08-008 from Associação Brasileira de Normas Técnicas – ABNT from 1998, by installing two radial lines of collectors, in regular and constant spacing, perpendicular to the lateral line pathway of the equipment, with 3 angles degrees of opening between lines. In order to perform the tests, the percentage relay of the equipment was adjusted to 100%.

The climate data collected during the experiment were: wind speed and evaporation. In order to verify the speed and temperature during the experiments, it was used a portable digital Thermo-Anemometer of the brand Instrutherm, model TAD-500, with speed reading from 0.3 to 45.0 m s^{-1} and accuracy of ± 3%. The evaporation during the period of each experiment was measured using control collectors installed adjacent to the pivot base. The values obtained were added to the water depth collected, according to the determination of the ABNT rule for this kind of experiment, completing thus the total water depth applied by the equipment.

The pressure in the pumping system was verified with the use of a manometer Bourdon with reading of 0 to 21.00 $kgf.cm^{-2}$ and accuracy of ± 1%. In the pivot point (riser tube) and in the extremity of the equipment (before the pressure regulator) it was also measured the pressures with manometer Bourdon in accordance with the ABNT rules for investigation of deviation from the technical project.

The experiment design was completely randomized, with the replications for each position tested. It was applied the analysis of variance followed by Tukey test.

Results and discussion

The climate data registered in field, wind velocity and evaporation of the rain gauge (collectors) are shown in Table 1. Concerning the wind velocity during the experiments, it was verified that the measured values did not exceed the allowed in the project of rule, in which wind velocity above 3.0 m s^{-1} invalidated the tests. The values observed during the experiments did not exceed 2.7 m s^{-1}.

Table 2 shows the results of the uniformity of distribution to the experiments. It can be verified that there was only significant difference between the positions of level to slope. It was not an expected result. It was expected no difference between the positions or that it at least occurred between the lines of slope and acclivity, since with the reduction of rotation and flow in the condition of acclivity there could have been a less uniform distribution in the extremity of the lateral line, which is where there is more influence of the range between depths and, consequently, the coefficient of uniformity. Although, the values obtained classified the uniformity of application, according to ABNT, as good (between 85 and 89%) in the position acclivity and level and very good (above 90%) in slope. These high values

Table 1. Values of wind velocity and evaporation during the experiments.

Positions	Replication	Collectors evaporation (mm)	Wind velocity (m s^{-1})
Acclivity	1	0.17	0.60
	2	0.00	0.10
	3	0.07	0.30
Level	1	0.20	0.50
	2	0.07	1.00
	3	0.13	1.30
Slope	1	1.40	2.70
	2	1.00	1.60
	3	0.50	2.70

Table 2. Coefficient of distribution uniformity.

Positions	Replication	Pump rotation		Distribution uniformity		
		(rpm)	mean	CUH(%)	average	Tukey
	1	1610		89.66		
Acclivity	2	1608	1610	89.48	89.75	ab
	3	1611		90.11		
	1	1616		88.45		
Level	2	1607	1613	88.98	88.93	b
	3	1615		89.38		
	1	1637		92.53		
Slope	2	1632	1634	90.22	91.39	a
	3	1634		91.44		

Equal letters do not differ at 5% of probability, by Tukey test

of uniformity are caused, probably, by the good performance of the pressure regulators and the use of radioactive emitters. These emitters work with the same service pressure than the fixed emitters; however, they have higher irrigated radium, enabling a larger overlap over the emitters and, consequently, better result in the uniformity of distribution.

ZOCOLER et al. (2004), when evaluating a center pivot irrigation machine in three operation positions, verified that the position of the lateral line did not influence the uniformity of water distribution in the referred equipment.

Table 3 shows the results of water flow collected on the experiments. It can be verified that there was a significant difference only between the position of acclivity and slope. The increase in rotation in the position of slope and, consequently, in the flow is justified by the initial program of the key. When it identifies a decrease in manometric height by the sensors installed in the outlets of the pumping set made an increase in rotation until it achieves the pressure pre-established. Thus, the characteristic curve of the pump under higher rotation provided an increase in flow due to the new point of work, as it can be seen in Figure 2.

However, there was no significant difference between the position in level and slope. This occurred, possibly, in a threshold situation, in which a small fraction of the flow which was smaller in the position in level (for example: in replication 1 if instead of 5.86 mm it was 5.70 mm, i.e., 0.16 mm less) would promote significance between this and the position of slope. Another explication to the fact that the increase in the flow did not occur in the same ratio than the increase of rotation in the slope position consists in the fact that the increase of flow from the emitters do

Table 3. Flow of irrigation in the experiments.

Positions	Repetições	Pump rotation		Collected irrigated flow		
		(rpm)	Mean	(mm)	Mean	Tukey
	1	1610		5,55		
Acclivity	2	1608	1610	5,67	5,56	b
	3	1611		5,47		
	1	1616		5,86		
Level	2	1607	1613	5,70	5,65	ab
	3	1615		5,38		
	1	1637		6,48		
Slope	2	1632	1634	6,65	6,31	a
	3	1634		5,81		

Equal letters do not differ at 5% of probability, by Tukey test not respond linearly to the addition of pressure, but for its square ration $(\Delta H)^{0,5}$. Allied to that there is the acting of the pressure regulators which also oppose to the increase in flow when the pressure increases, and, finally, the magnitude of rotation variation between those positions was only 1.49%.

According to Figure 2, the curves for each rotation were positioned together with the respective points of operation inside the margin allowed by the program (to 10% above or below the reading of rotation in the display of the starter).

ZOCOLER et al. (2004), when evaluating the effect of the position of the lateral line of a center pivot irrigation equipment on the applied water depth

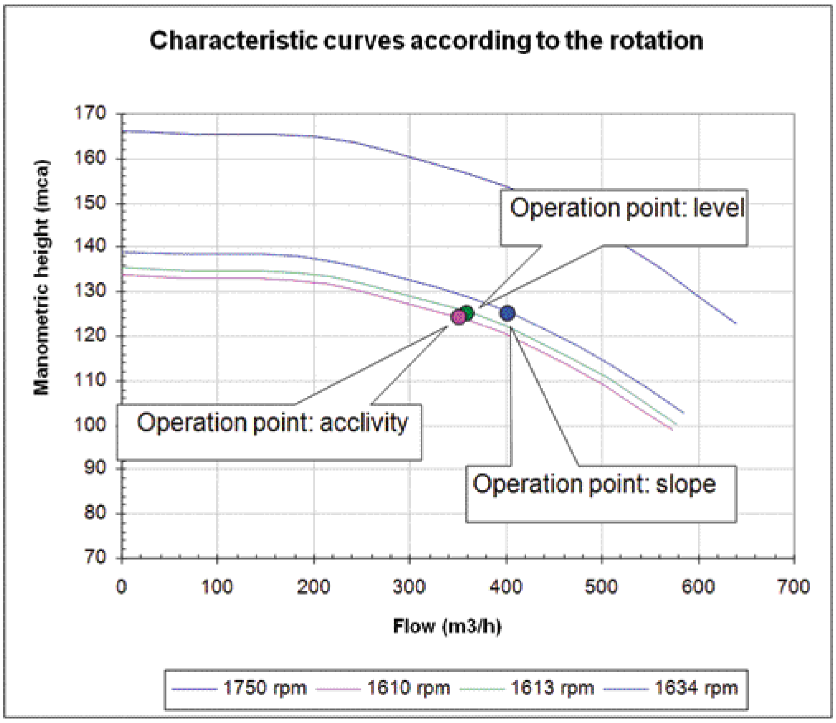

Figure 2. Operation point Hman (mca) x Flow ($m^3 h^{-1}$) according to pressures measure in the pumping system and floe calculated by the weighted mean depth to Experiment 1.

Table 4. Values of potency in the pump set.

Positions	Replications	Pump rotation (rpm)	Pressure pumping (mca)	Engine frequency (Hz)	Engine tension (V)	Engine Potency		
						(kW)	Mean	Tukey
Acclivity	1	1610	124.50	54.1	342.0	162.0	165.56	B
	2	1608	123.00	54.1	342.0	168.3		
	3	1611	123.00	54.1	342.0	166.4		
Level	1	1616	125.00	54.5	343.0	169.4	167.50	B
	2	1607	125.00	54.1	340.0	166.6		
	3	1615	125.00	54.3	343.0	166.5		
Slope	1	1637	125.00	55.1	348.0	186.5	182.16	A
	2	1632	125.00	55.0	347.0	180.8		
	3	1634	125.00	55.0	347.0	179.2		

Equal letters do not differ at 5% of probability, by Tukey test concluded that, despite the extremity of the center pivot range 24.37 m vertically between the positions of acclivity and slope, there was no significant effect of the position in this variable.

In Table 4 it can be verified the parameters related to the energy consumption of the pump system during the experiments. It was verified that there was no significance between the values of potency developed by the engines (kW) between the positions of experiment in acclivity and level, however regarding the slope these values were significant (level of 1%). This comparison is done since rotation and consumption have a direct relation, because, to maintain the torque constant, the frequency inverter must maintain the ratio V/F constant, i.e., in the case there is a chance in the web frequency (HZ), tension (V) must chance in the same proportion so that the ratio keeps in the same proportion. In this case, since the output pressure of the pump set was pre-established, there was the need to increase the rotation to maintain the pressure constant and consequently there was an increase in consumption.

Conclusions

According to the conditions developed, it may be concluded that:

The conditions of operation (positions) of the equipment to the experiments influenced the values of distribution uniformity, water depth applied and energy consumption.

Although the results of distribution uniformity had been classified as good and very good the increase of rotation in the slope position showed a wrong predisposition of the started, since together with the increase of rotation there was an increase in the energy consumption.

The values of water depth applied to the experiments were above those specified in the technical information provided by the equipment manufacturer, showing the necessity to evaluate the irrigation equipments after the installation. Thus, it can improve the performance of them not only in the question of application of water but also in the consumption of electric energy.

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