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EVALUATION OF THE CENTRAL PIVOT MACHINE AND IRRIGATION QUALITY IN THE CPA "CUBAN-BULGARIAN FRIENDSHIP"

EVALUACIÓN DE LA MÁQUINA DE PIVOTE CENTRAL Y CALIDAD DEL RIEGO EN LA CPA "AMISTAD CUBANO BÚLGARA

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Abstract

The present investigation was carried out at the CPA" Amistad Cubano Búlgara, in the municipality of Güines. Mayabeque Province, with the objective of evaluating the operating parameters of an electric central pivot machine, as well as the irrigation regime of the bean crop, using the Pluviopivot software. The result was that the irrigation machine irrigated with poor uniformity in the 2022-2023 campaign, since the weighted uniformity coefficient reached values of 77.47%, with irregularities in the average water layer, where 38.65% of the irrigated areas did not received the minimum required irrigation standard and 29.70% received a standard higher than that required. Other problems found were the presence of leaks, a deficiency in the drive system and the inadequate distribution of the nozzles, all of which leads to the area being classified as inadequately watered. Finally, a proposal was made for a group of actions aimed at solving the current problems and thereby contributing to the sustainable management of water, in order to increase agricultural yields with less environmental impact.

Keywords: Sustainable water management, irrigation systems, Evaluation of irrigation quality

Resumen

La presente investigación se realizó en la CPA" Amistad Cubano Búlgara, en el municipio de Güines. Provincia Mayabeque, con el objetivo de evaluar los parámetros de explotación de una máquina de pivote central eléctrica, así como el régimen de riego del cultivo del frijol, utilizando el software Pluviopivot. Se obtuvo como resultado que la máquina de riego regó con mala uniformidad en la campaña 2022-2023, pues el coeficiente de uniformidad ponderado alcanzó valores de 77.47%, con irregularidades de la lámina media de agua, donde el 38.65% de las áreas regadas no recibieron la norma de riego mínima requerida y un 29.70 % recibieron una norma superior a la requerida. Otros problemas encontrados fue la presencia de salideros, deficiencia en el sistema motriz y la inadecuada distribución de las boquillas, todo lo cual conlleva a que el área sea catalogada cómo inadecuadamente regada. Por último, se realizó la propuesta de un grupo de acciones orientadas a solucionar los problemas presentes y con ello contribuir a la gestión sostenible del agua, con el fin de aumentar los rendimientos agrícolas con menor impacto ambiental.

Palabras clave: Gestión sostenible del agua, sistemas de riego, Evaluación de la calidad del riego

Introduction

The use of irrigation for crop production is an activity as old as the emergence of man. This is reaffirmed in the Bible where it is mentioned that it originated at the same time as man, and in the same place.

Archaeological discoveries give evidence of the use of irrigation by communities in territories today occupied by countries such as Egypt, Iran, China, and Turkey (Fraga, 2011). These practices allowed various civilizations to permanently establish themselves in arid, semi-arid and desert areas during the period of development of a crop,

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a situation that led to the possibility of a sedentary life and therefore, to the division of the activities of the individuals of a community. In this way, human settlements and societies originated, which led to the evolution of agriculture and its irrigation systems, until reaching the emergence of automated irrigation systems (Israelsen and Hansen, 1967; Fraga, 2011).

Nowadays, modern center pivot machines (CPM) and front-advance irrigation systems have been developed that are significantly different from the self-propelled system that emerged in 1948 by Frank Zybach. The expansion of these techniques is highlighted by their potential to apply water efficiently, high degree of automation, and lower use of labor (relative to other irrigation methods). Likewise, it has the capacity to apply water and soluble nutrients in a wide range of soils, crops and topographic conditions (Enrique et al., 2021).

While Cuba, according to data from MINAG (2010), has an irrigated area of 800,000 ha, which represents 26% of the total cultivable area. The most widespread techniques are surface irrigation with 68% of the total area, followed by sprinkling (19%), irrigation machines (7%) and localized irrigation (6%). Regardless of the efficiency demonstrated by these systems (Santos et al., 2010), it is necessary to know their technical status. With this, you can have control of its working parameters to positively influence its proper functioning (uniform delivery of the irrigation standard), as well as detect any irregularities and possible solutions to mitigate or eliminate them.

In the specific case of the "Miguel Soneira Ríos" Agricultural Company, in the municipality of Güines, Mayabeque Province, it has 40 central pivot machines. However, they do not all have the same technical state, which leads to their inadequate functioning and therefore to the delivery of non-uniform water (irrigation standard), as well as the unnecessary expenditure of water and energy resources. All of which leads to the need for evaluation, based on an in-depth analysis of its operating indicators, in order to guarantee the appropriate use of water and contribute to the sustainable production of agricultural foods.

Given the above, in this investigation the operation of the Central Pivot Machine "Pino 1" is evaluated in the cultivation of beans (*Phaseolus vulgaris* L.), in relation to the sprinkler chart and the rainfall in order to verify its technical indicators and its efficiency for irrigation.

Materials and Methods

Characterization of the studied area

The "Cuban-Bulgarian Friendship" Agricultural Production Cooperative (Figure 1) is located in the Güines municipality, Mayabeque province. It is located at the geographical coordinates: 22°50`49.99" N, 82°04`08.11" W and 22 °47`54.35" N, 82°01`51.24" W according to the North Cuba coordinate system and Lambert Conformal Conical projection (PCCL). Bordered to the north by the CCS

"Miguel Camacho", to the south with the UBPC "Restituto Alonso", to the east with the town of Güines and to the west with the UBPC "Sierra Maestra" belonging to the municipality of Melena del Sur.

The productive unit is dedicated to various crops, it has a total area of 643 hectares, of which 241 hectares are irrigated with a central pivot.

To determine the uniformity of water distribution in the field from the central pivot irrigation machines, the rain gauges were located 3 m apart from each other, as established in the Cuban Standard ISO 11545 (2007). The mathematical expressions used to determine the quality of irrigation are the following:

$$CU_H = 100\left[\frac{\sum_{i-1}^{n} Li - V \cdot Si}{\sum_{i=1}^{n} Li \cdot Si}\right] \quad (1)$$

Where:

CU_H = Heerman and Hein uniformity coefficient (%).

n = Number of collectors used.

i - order number assigned for a particular manifold, starting with the manifold closest to the beginning of the field (i = 1) and ending with i = n for the manifold furthest from the pivot.

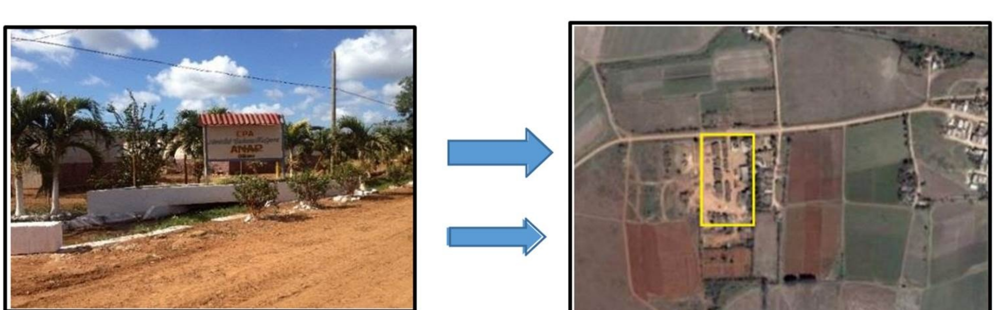

FIGURE 1. Location of the "Cuban - Bulgarian Friendship" cooperative

Yes- Distance from collector i to the starting point (Pivot).

Li- Sheet of water collected in collector i (m3. ha-1).

Table 1 shows the values in which the CUH can be classified according to SIAR (2003).

TABLE 1. CU_H values to classify risks.

CU_H	Attitude
< 80 %	Unacceptable
80-85 %	Acceptable
85-90 %	Good
> 90 %	Very good

Similarly, to determine the average collected height or weighted average sheet applied, the following expression was used:

$$AMR = V = \frac{\sum_{i-1}^{n} Li \cdot Si}{\sum_{i=1}^{n} Si} \quad (2)$$

Where:

V = AMR- Average collected height (weighted average sheet) (m3. ha-1)

To determine the quality of irrigation, the conditions are established for the areas irrigated adequately (ARA), excessively (ARE) and insufficiently (ARI) used by Pérez Leira et al. (2003) and Duani (2012). These are defined in the following way:

$$0.90\,(AMR) \leq ARA \leq 1.10\,(AMR);$$

$$ARE \geq 1.10\,(AMR); ARI \leq 0.90\,(AMR)$$

Leaving: $ARA + ARE + ARI = 100\%$

To calculate ARA, ARE and ARI, we started from the criterion that each reading is representative of a ring-shaped area, which is delimited by its two neighboring distances with respect to the pivot, R1 (anterior) and R2 (posterior); and that said area increases as it moves away from the pivot.

$$A_{ai} = \pi \cdot (R_2 - R_1)^2 \quad (3)$$

Where:

A_{ai}- Annular area (m2) corresponding to the reading Li

R_2- External radius of the ring (m), calculated as (Si+e/2)

R_1- Inner radius of the ring (m), calculated as (Si - e/2)

e- Space between collectors

The calculations were executed based on Microsoft Excel for this work. Subsequently, the analysis of the results obtained was carried out; if irregularities were found, they were compared with the sprinkler chart of each machine and the corresponding changes were proposed.

Steps to evaluate the operation of the MPC

1. Check if the sprinklers are the same brand and know the condition in which they are.
2. Placement of the collectors (vessels) according to spacing.
    - Sprinklers - 5 m
    - Nozzles - 3 m
3. Measure the volume of water collected in the collectors once the irrigation has finished, and the last drop of water has stopped falling into them (it is determined using a graduated cylinder).
4. Calculation of the average water depth (AMR).
5. Calculation of the uniformity coefficient.
6. Determination of the situation of the areas under irrigation and quantification of them (adequately irrigated area (ARA), excessively irrigated area (ARE) and insufficiently irrigated area (ARI).

Irrigation rules

Tables 2 show the irrigation rules for growing beans (*Phaseolus vulgaris* L.)

Results and Discussion

Table 3 shows the main problems detected in the Pino 1 machine after the physical-technical review with the manufacturer's technological chart. These are mainly related to leaks, the drive system and the improper placement of the nozzles.

The operation of this machine according to SIAR (2003) is unacceptable with a uniformity coefficient CUH = 77.47 %. This is corroborated when evaluating the areas under irrigation, where 38.65% of the irrigated areas did not receive the minimum required irrigation standard and 29.70% received a standard higher than that required. It can be seen that insufficient deliveries are concentrated in the last two thirds of the length of the machine and excessive deliveries in the first two thirds (see figure 2).

TABLE 2. Irrigation standards for Bean Crops.

Development phase	Net Standard (m^3. ha^{-1})	Interval (days)	Nº of irrigation
Sowing-Budding	400-500	4	2
Budding-Start Flowering	200-250	6	5
Flowering- Maturation	300-350	5	8
Maturation- Harvest	200-250	7	2

TABLE 3. Efficiency indicators of the MPC Pino 1

Machine	Problem Bank				Machine. Cert.	Rainfall Test
	Leaks	System Motive	Electric system	Downspouts and nozzles		
Pino 1	Problem	Problem	Problem	Problem	No	Yes

This shows that 68.35% of the irrigation in the MPC studied is inadequate, with only 31.65% classified as adequate irrigation area (ARA), the rest is classified as Excessive Irrigation Area (ARE) or insufficient irrigation area (ARI)., as explained above, indicators that lead to the area being classified as inadequately irrigated (Tarjuelo, 2005), a fact that is reflected in the uniformity coefficient (Table 4), which affects the proper development of the bean crop. Similar results are obtained by Rankine et al (2021) when modeling the irrigation potential of cassava cultivation.

The uniformity coefficient is not a reliable indicator on its own to make a judgment about the operation of the machine. In this sense, it is necessary to carry out a comprehensive analysis of all the parameters since the problems can fundamentally be associated with the pressure that the pump provides to the system and/or with the placement of nozzles of a certain diameter in a position that requires one higher or lower (Tormes et al., 2009; Pérez et al., 2003).

In this regard, in Figure 2 it can be seen that at 6.5 m and 57.5 m there are two maximum points that correspond to standards of 810.08 m3. ha-1, these points provide an excessive norm as a result of leaks that exist in those positions.

Likewise, at the maximum points located between the distances 93.5 m and 126.5 m, excessive sheets are also delivered (419.77 - 648.06 m3. ha-1), this also occurs at the distance 195.5 m with a delivery of 618.61 m3. ha-1, due to inadequate placement of the nozzles.

Table 5 shows the irrigation standards that the machine should have delivered according to planning in the cultivation phase. It can be seen that the delivery of water was greater than the needs of the crop based on the main soils present in the study area. As can be seen, of the 254.1 m3. ha-1 necessary for the development of the crop, 353.92 m3 was delivered. ha-1; This applied standard rises considerably as a result of the existing leaks in the machine and the inadequate placement of the nozzles throughout the machine.

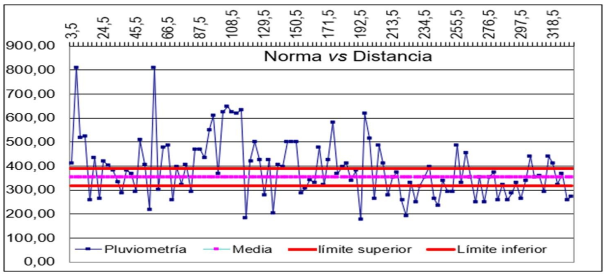

FIGURE 2. Norm and Distance Relationship of "Pino 1"

This situation not only considerably increases water consumption and thus economic costs (Sánchez et al., 2022 and Cruz et al., 2022), but also contributes to the degradation of the Red Ferralitic soils present in the study area. and the washing of its nutrients, which coincides with the results reported by Vargas (2009) and Rodríguez et al. (2020), a situation that can also contribute to the contamination of groundwater (Falcón, 2019, Yesenia, 2023 and Velandia, 2023).

Main solutions

Once the main problems in the "Pino 1" MPC were detected and the main causes that caused them were analyzed, it was possible to suggest a group of actions to solve them. Among them the following stand out:

- Repair 104 Kw Electric Board.
- PCL with problem in four towers.
- Replace three motor reducers.
- Eliminate leaks in the press and pivot joint.

TABLE 4. Efficiency indicators of the "Pino1" MPC.

Machine	AMR (m^3. ha^{-1})	CU_H (%)	CU_V (%)	$UD_{25\%}$ (%)	ARA (ha)	ARA (%)	ARI (ha)	ARI (%)	ARE (ha)	ARE (%)
Pino 1	353.92	77.47	70.39	73.61	14.35	31.65	17.52	38.65	13.46	29.70

TABLE 5. Irrigation standards of the MPC "Pino 1"

Development phase	Net Standard (m3. ha-1)	Standard to be delivered (m3. ha-1)	Applied standard (m^3. ha^{-1})
Sprouting-Start Flowering (bean)	200-250	254.1	353.92

- Replace four wheel reducers.
- Change of 8 Transmission Kits.
- Change of the downspouts and nozzles for a Cuban module.
- Bring the MPC to its working pressure.
- Perform the rainfall test again.
- If the ARA results are not within the correct range (ARA=70-80%), soil sampling should be done to observe how moisture is distributed throughout the machine after irrigation, it may be uniform and thus There would be no need to make any correction to the MPC.

Conclusions

As a result of the investigation, it was found that the “Pino 1” Central Pivot Machine presents poor irrigation uniformity, with uniformity coefficient values of 77.47%, with the insufficiently irrigated area being 17.52% and the excessive irrigation. (ARE) of 29.70%.

Among the main indicators of deficiency were problems related to the presence of leaks, deficiency in the drive system and inadequate distribution of nozzles, all of which leads to the area being classified as inadequately irrigated.

The actions proposed to solve the problems present in the “Pino 1” MPC contribute to sustainable water management in order to increase agricultural yields with a lower environmental impact.

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