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Irrigation water productivity in the cultivation of bean under production conditions

Dania Rodríguez Correa, Camilo Bonet Pérez, Pedro A. Guerrero Posada, Bárbara Mola Fines, Gerónimo Avilés Martínez, Charissa Martínez Der

Ministerio de la Agricultura, Filial IAgric, Camagüey, Cuba

Abstract: On a global scale, agriculture is the largest consumer of water, with reports indicating that it annually consumes 70% of the total water used on the planet, being necessary to increase the efficiency of use, so in this sense, efforts are being made in the world to obtain more food with less water. The objective of this research was to evaluate the behavior of irrigation water productivity in the cultivation of beans. The study was carried out in the Basic Unit of Cooperative Production (UBPC) "Victoria II", belonging to the Camagüey Agricultural Enterprise, in which irrigation was carried out using central pivot machines on reddish-brown Fersialitic soil. The results obtained show irrigation water productivity values in a range between 1.90 and 7.70 m^3 /kg in equal soil conditions, irrigation technology and crop, which confirms the incidence of other factors unrelated to irrigation. The results obtained in different irrigation systems show insufficiencies in the management practices of the technology, being necessary the implementation of good agricultural practices.

Key words: water-yield ratio; water use; irrigation

1 Introduction

Freshwater is an increasingly scarce resource in the world, the loss of its quality, as well as the growing competition from the urban and industrial sectors, determine a marked decrease in its availability. In this sense, it is increasingly important to adopt management strategies that contribute to the rational use of this resource (Riccetto et al., 2017).

Agriculture in the world is the largest consumer of water, according to FAO (2011) cited by (Herrera, López, & Gonzaléz, 2011), it uses globally 70% of water, while, in some parts of Asia, Africa and the Middle East it reaches values between 80 and 90%.

In the particular case of Cuba, the water situation is not similar in all territories, and although it is not facing a period of extreme crisis as in other countries, the effects of climate change and prolonged droughts in recent years make it necessary to take appropriate measures (Rodríguez, 2013). In Cuban agriculture, irrigation is a factor that boosts yields since the non-homogeneous distribution of precipitation imposes a period of low rainfall during the year (from November to April) where only 20% of the annual precipitation occurs on average, and this period coincides with the optimum for the growth and development of most agricultural crops (Cisneros et al., 2015).

The low efficiency in the operation of irrigation systems constitutes one of the most acute problems affecting irrigated areas in Cuba and in many other countries that develop irrigated agriculture (López et al., 2011).

For the regions of the world, increasing the productivity of water used in agriculture constitutes the greatest potential for improving food security and reducing environmental costs. During the last few years, the productive results obtained in irrigated areas in the province have not been in correspondence with the productive potential, particularly in bean crops.

The bean crop has become one of the fundamental grains in the diet of the Cuban people, the production systems in Cuba have gone through different moments of instability, being necessary to increase bean production as part of the importsubstitution policy (Villalobos et al., 2016).

The present study is carried out with the objective of evaluating the behavior of irrigation water productivity in the bean crop. The study is carried out in the Basic Unit of Cooperative Production (UBPC) "Victoria II", belonging to Empresa Agropecuaria Camagüey.

2 Material and method

The research was developed during the period between 2016 - 2017, in areas of the Basic Unit of Cooperative Production (UBPC) "Victoria II', belonging to Empresa Agropecuaria Camagüey, which is geographically located in the municipality of Camagüey, between the coordinates N (310.00-315.00) and E (403.00- 408.00) on the San Serapio map sheet (4680-II-A) at scale 1:25,000, bordering to the north with the Lesca military polygon, to the south with the Nuevitas road, to the east with the road to the pollera La Lucha and to the west with the Granja Estatal de Nuevo Tipo (GENT) Victoria I (Figure 1).

Figure 1. Satellite image UBPC Victoria II Source: https://www.google.com.cu Internet 2020

The UBPC Victoria II has a total area of 403 ha, of which 74.4 ha are irrigated with center pivot machines and 112.7 ha with semi-stationary sprinkler irrigation systems for a total area under irrigation of 187.1 ha (Rodríguez et al., 2018).

The source of supply for irrigation is the Borges micro-dam, with a useful water volume for irrigation of 1.76 Hm^3, from which water is supplied to the entire irrigation system (Figure 2).

The study area is dominated by the reddish-brown Fersialitic soil type, with undulating topography, which facilitates erosion and degradation conditions (Instituto de Suelos-Camagüey, 2010). Table 1 shows the hydrophysical properties of the soil.

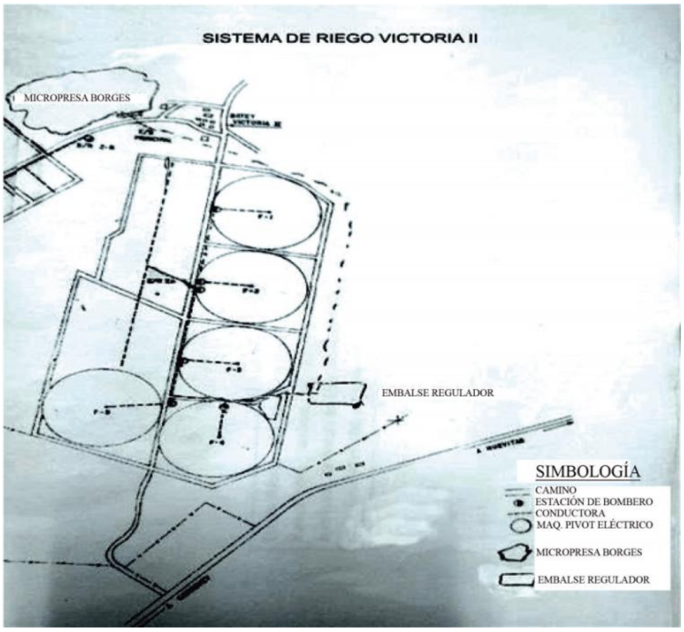

Figure 2. Layout of the irrigation systems UBPC Victoria II

Table 1. Hydrophysical properties of soils

Depth (cm)	Apparent density (g/cm^3)	Porosity (%)	Field Capacity (% bss)	Infiltration rate (mm/h)
00-20	1.26	52.4	31.4	21
20-30	1.26	52.4	34.9	21

Source: Instituto de Suelos-Camagüey (2010)

The research was conducted for the bean crop because it is one of the most representative in the production unit, the variety of bean used in the research was La Cuba-154, a variety adapted to drought conditions and low fertility, with a planting frame of 0.70 x 0.15 m, the work was carried out in accordance with the provisions of the Technical Instructions of the Minag Bean (2000) but could not guarantee the complete technological package which affected the nutrition and plant protection of the crop.

The central pivot machine, similar to the Bayatusa model, has the following characteristics: 4 towers, 202 m long, 2.90 m pivot height and 102 diffuser nozzles; prior to the study the technical conditions of irrigation were reviewed, including distribution of nozzles according to machine model, working pressure and nozzle height, also the hydraulic evaluation of the machines was performed according to the procedure described in the Cuban Standard NC ISO 11545: 2012. (2012), obtaining values of Coefficient of Uniformity (Cu) according to the Heermann and Hein equation, it was also determined the Application Efficiency from:

$$Efa = {}^{Ld}\!/_{La}\,(100) \qquad (1)$$

where:

Efa. Application efficiency (%); Ld. Water sheet discharged from the pivot (mm); La. Water sheet applied to the soil (mm).

The farms included in the evaluation are identified with numbers 1 to 5, corresponding to the central pivot machines with the same numbering.

Irrigation scheduling was carried out according to the parameters traditionally used in the UBPC for this crop. During the season, rainfall was measured using a standard rain gauge.

Irrigation water productivity indicators were calculated using the following expression (Molden et al., 2003, cited by González et al. (2014).

$$P = Mt/R \quad (2)$$

where:

P. productivity of water applied per irrigation (m^3/kg); Mt. total gross irrigation standard applied in the evaluated crop cycle (m^3/ha); R. yield obtained for the crop of the evaluated area (kg/ha).

3 Results and discussion

In the evaluation of the central pivot machines, the values of Uniformity Coefficient and Application Efficiency shown in Table 2 were obtained; during the tests, the wind speed remained in the range between 2.4 and 3.8 m/s.

Table 2. Evaluation results of central pivot machines

Pivot No.	CU (%)	Efa (%)
1	78	72
2	75	70
3	80	70
4	72	66
5	76	67

Tornes et al. (2009) state that for this type of pivot machine, values of uniformity coefficients higher than 85% are acceptable; Tarjuelo (2005) considers values between 80 and 90% as adequate when wind speeds are lower than 7 m/s. In relation to efficiency, Resolution No. 17 of INRH-Cuba (2020) establishes the value of 80% as acceptable; in both parameters the values obtained are lower than the established limits, which is attributed to the effect of the prevailing winds during the evaluations.

Table 3 shows the area of the crop in each farm, the irrigation standards applied and the production results obtained.

Table 3. Irrigation standards applied and yields obtained

Finca	Area (ha)	NBT (m^3/ha)	Yield (kg/ha)
1	12.4	2,171	1,119
2	3.1	3,540	612
3	9.3	3,304	1,290
4	12.4	3,658	475
5	12.4	2,183	524

NBT. Total gross irrigation standard

When analyzing the irrigation norms applied, it is observed that in all cases they are lower than the 3,875 m^3/ha recommended for this crop in the province of Camagüey according to Resolution No. 17 of the INRH-Cuba (2020); this should not be interpreted as a water deficit for the crop since during the campaign there was a total of 145 mm of rainfall distributed throughout the crop cycle.

According to Rijsberman et al. (2006) cited by González et al. (2011), the high degree to which water conditions agricultural production leads to the need to study the problem of water productivity, since irrigated agriculture currently consumes most of the supply of good quality water, the search for new ways to produce more food with less water offers an answer to the problem of water scarcity.

Water productivity as defined by Molden (1997) cited by González et al. (2011) refers to the physical or economic yield per unit of water consumed by the crop (in kg/m^3 or $weight/m^3$). The numerator can be expressed in terms of grain yield (kg/ha) or in economic terms (weight/ha), while the denominator can be expressed in terms of transpiration, evapotranspiration, applied water and rainfall.

Water productivity is an important concept for understanding the complex soil-plant-atmosphere system and designing good water conservation practices. According to Alata (2005), the term agricultural productivity is intrinsically related to water productivity, which is nothing more than the ratio between the volume of food produced with respect to the water used.

González et al. (2011) have stated that water productivity is a key element in long-term strategic planning of water resources; water management based on productivity parameters can improve water use and contribute to water savings in systems where excessive amounts of water are consumed.

The study evaluated the results of irrigation water productivity in the bean crop under production conditions, using the central pivot machine irrigation technology; the values obtained were compared with results reported for this crop and irrigation technology (Figure 3).

Figure 3. Behavior of irrigation water productivity

González et al. (2014) have reported water productivity values for bean crops irrigated with pivot machines of 2.20 m^3/kg, although this value has been obtained in other edaphoclimatic conditions, for the purposes of making a qualitative assessment it is taken as a reference.

Considering that the area of the crop on eac0 m^3/kg; ch farm is variable, the weighted average value of water productivity was determined, which was 4.3omparing this result with the indicative value, a ratio of 1.95:1.00 was found, that is, practically twice as much water is required to produce one kilogram of beans.

Table 4 indicates the relationship of the irrigation water productivity value achieved in each farm in relation to the reported value (González et al., 2014).

Table 4. Variability of irrigation water productivity

Finca	A	B
1	1.94	0.88
2	5.78	2.63
3	2.56	1.16
4	7.70	3.50
5	4.16	1.89

A. Productivity of irrigation water obtained (m^3/kg); B. Ratio of the obtained irrigation water productivity to the indicative value

The high variability observed in the results obtained for the same crop conditions, soils and irrigation technology in the different farms is significant, with extreme values between 1.94 and 7.70 m^3/kg; irrigation-related factors such as uniformity and application efficiency must have influenced the results, but other agro-technical factors are also present, which are reflected in the yields obtained and therefore in the productivity of irrigation water.

On farms No. 1 and 3, acceptable irrigation water productivity results have been achieved; the pivot machines corresponding to these farms demonstrated the best parameters of Uniformity Coefficient and Application Efficiency, indicating that the irrigation quality of these farms is high, reflected in better utilization of water; however, the non-compliance with the technical standards of the crop affects yields and consequently the productivity of irrigation water.

The irrigation water productivity results obtained demonstrate that acceptable values can be achieved under production conditions if adequate irrigation quality parameters are met and irrigation scheduling is efficient, in addition to completing all other agricultural tasks.

Beans are a crop susceptible to both excess and deficit moisture during their growth cycle. Production indicators are statistically higher when the crop does not suffer from water deficit during its growth cycle (Boicet, 2010, cited by Polón et al., (2014).

These results constitute a first approximation of this efficiency indicator for the use of water used by crops with the same irrigation technology under production conditions for the unit under study in the province of Camagüey.

The average irrigation water productivity values obtained, as well as their irregularity, demonstrate the need for the application of good agricultural practices in an integrated manner as a way to achieve an efficient use of irrigation water.

In general terms, the need to introduce improvements in the operation of the irrigation systems in the Production Unit is defined, which basically includes:

- Irrigation scheduling based on agro-climatic information
- Proper irrigation management when different crops are planted under the same central pivot machine
- Systematic system efficiency evaluations to identify potential irrigation uniformity problems
- Adequate irrigation-agrotechnical linkage, guaranteeing the water needs of the crop during critical stages and proper crop care.

The application of the results of science in food production is an imperative need today. During the Workshop on Food Production with more Science, the following was expressed: "...We must move from science to true innovation. There are things that need thinking. We have to evaluate and think in order to succeed in proposing the application of each result so that they have an impact on the different forms of management" (Díaz-Canel, 2019).

In the country there are results related to irrigation water productivity, it is necessary to start using this indicator in production practice as a tool for assessing the effectiveness of irrigation carried out, so that the results obtained constitute a guide for taking effective measures to achieve better results.

4 Conclusion

• The average value of irrigation water productivity obtained for the bean crop under irrigation with central pivot machines on reddish-brown Fersialitic soil is 4.30 m^3/ kg, which is inadequate and shows much variability among irrigation systems.

• Factors related to the operation of irrigation systems and crop agro-technology influence the results obtained, requiring the application of good practices to achieve a more efficient use of the water available for irrigation.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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