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ORIGINAL ARTICLE

Impacts of Wind Pumping on Sprinkler Irrigation for Garlic Cultivation

Impactos del bombeo eólico en el riego por aspersión para el cultivo del ajo

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ABSTRACT: In order to determine the economic-productive, energy and environmental impacts of wind pumping in sprinkler irrigation for garlic cultivation, the investigation was carried out at "La Cuchilla" farm during 2016-2017, 2017-2018 and 2018-2019 cycles. The mass of the bulbs was 27.47 g, 27.81 g and 27.70 g, respectively, to average 27.66 g and the diameter of the bulbs reached values of 3.92 g, 4.01 g and 3.85 g, respectively. The production volume was 231,400.00 pesos per hectare, the annual costs amounted to 18,929.77 pesos per hectare and the net benefit was 212470.23 pesos per hectare. The favorable production cost per peso of 0.08 cents with a value of 11.22 obtained in the Benefit-Cost ratio was much higher than the unit was. A multi-blade mill was utilized for pumping water instead of a LEPONO brand motorized pump, used by farmers in the region. It has a flow rate of 60 L min-1, maximum head 70 m, turning speed 3400 rpm and current intensity consumed by the 11 A motor and allowed an energy saving of 27.66 kWh corresponding to 146.77 kg of CO2 equivalent per hectare no longer emitted into the atmosphere.

Keywords: energy, wind pumping, atmosphere, sprinkling, benefit.

RESUMEN: Con el objetivo de determinar impactos económicos-productivos, energéticos y ambientales del bombeo eólico en el riego por aspersión para el cultivo del ajo se realizó la investigación en la Finca "La Cuchilla". La masa de los bulbos fue de 27,47 g; 27,81 g y 27,70 g respectivamente para promediar 27,66 g, el diámetro de los bulbos alcanzó valores de 3,92 g; 4,01 g y 3,85 g durante los ciclos 2016-2017, 2017-2018 y 2018-2019, el volumen de producción fue 231400,00 pesos por hectárea, Los costos anuales ascendieron a 18929,77 pesos por hectárea, el beneficio neto es de 212470,23 pesos por hectárea, el costo por peso de producción favorable de 0,08 centavos, se obtuvo un valor de 11,22 en la relación Beneficio - Costo, muy superior a la unidad. La utilización del molino multipala para el bombeo de agua en lugar de una motobomba de marca LEPONO, utilizada por campesinos de la región, con caudal de 60 L min^{-1}, carga máxima 70 m, velocidad de giro 3400 rpm, intensidad de la corriente que consume el motor 11 A, permitió un ahorro energético de 27,66 kWh, esto representa 146,77 kg de CO_2 equivalente por hectárea que se dejó de emitir a la atmósfera.

Palabras clave: energético, bombeo eólico, atmósfera, aspersión, beneficio.

INTRODUCTION

Wind energy has shown a certain superiority compared to traditional energy sources, which is why it is considered one of the most precious, clean, abundant, cheap, inexhaustible renewable energy sources that is also part of the environment (Chang, 2011). It is predicted that due to greenhouse gas emissions, an increase in global warming between 1.4 and 5.8 °C will be reached by the end of the century, for which all the economies and ecosystems of the world will suffer serious consequences, if the necessary measures to mitigate this problem are not taken (World Bank, 2013; Chou *et al.*, 2017). There is a worldwide interest in the protection of the environment, the mitigation of the impact that man has generated on it and the rational use of natural resources. There is also a global benefit for encouraging the use of renewable energies as a means of reducing dependence on fossil fuels, mitigating additional risks, such as progressive pollution and the increase in greenhouse gases they generate (Tsai y Kuo, 2010; Gallego *et al.*, 2018). The energy sector is key to sustainable development, as well as in the fight against climate change (Correa *et al.*, 2016; Chou *et al.*, 2017). Based on the above, the objective of the work is to determine the economic-productive, energy and environmental impacts of wind pumping in sprinkler irrigation for garlic cultivation.

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MATERIALS AND METHODS

The investigation was carried out in "La Cuchilla" Farm, located in Sabicú Community, at "Primero de Enero" Municipality, Ciego de Ávila Province, between coordinates 21°52' North Latitude and 78°18' West Longitude, with an area of 7.5 ha (Figure 1) and where different crops are grown such as tomato, garlic, beans, corn, cassava, banana, lemon and mango.

The economic evaluation of the irrigation system was carried out based on the analysis of the costs incurred in the production of the crop and the benefits obtained. The equations used were the following:

$$B_n = \left(V_p - C_a\right) \quad (1)$$

$$V_p = R \cdot P_v \quad (2)$$

$$C_a = G_{sal} + G_{amor} + G_{agua} + G_{fert} + G_{cult} + G_{prep-suelo} \quad (3)$$

$$G_{amor} = C_s \cdot K_a \quad (4)$$

$$K_a = \frac{r}{(1+r)^T - 1} \quad (5)$$

$$G_{agua} = \frac{\left(V_{agua} \cdot P_{agua}\right) \cdot 10^3}{A_p} \quad (6)$$

$$C_{pp} = \frac{C_a}{V_p} \quad (7)$$

$$B/C = \frac{B_n}{C_a} \quad (8)$$

Where:

Bn: the net benefit (\$ ha^{-1})
Vp: the volume of production (\$ ha^{-1})
Ca: Annual exploitation cost (\$ ha^{-1})
Ac: Crop area (ha)
R: Crop yield (t ha^{-1})
Pv: Sales price of the crop (\$ t^{-1})
Pagua: Price of applied water (\$ m^{-3})
Gsal: Salary expenditure of the workers (\$ ha^{-1})
Gamor: Amortization expense (\$ ha^{-1})
Cs: Total cost of the system (\$ ha^{-1})
Ka: Amortization coefficient (adim.)
r: Bank interest rate (adim.)
T: Lifetime of the installation (years)
Vwater: Volume of water (m^{-3})
Gagua: Water consumption expenditure (\$ ha^{-1})
Gfert: Fertilizer expenditure (\$ ha^{-1})
Gcut: Expenditure on cultural activities (\$ ha^{-1})
Gprep-soil: Soil preparation cost (\$ ha^{-1})
Cpp: Cost per production weight (\$ ha^{-1})
B/C: Cost-benefit ratio (adim.)

A Benefit-Cost ratio greater than a unit indicates that the variant under study is economically advantageous. The calculation of energy savings due to the use of the multi-blade mill was estimated from the energy consumption if an electric motor was used, the power of the pump and the pumping time according to the procedure used by Charpentier (2017). The equations used were the following:

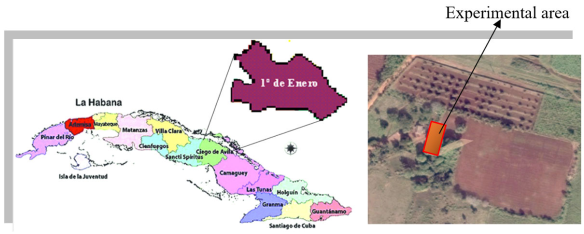

FIGURE 1. Location of the experimental area.

$$Ce_B = P_B \cdot T_B \quad (9)$$

$$P_B = \left(\frac{I \cdot V}{1000}\right) \quad (10)$$

$$T_B = T_r \cdot N_r \quad (11)$$

Where:

CeB: Pump energy consumption (kWh)
PB: Pump power (kW)
TB: Pumping time (h)
I: Intensity of the current consumed by the motor (A)
V: Voltage of the motor that supplies the pump (V)
Tr: Irrigation time (h)
Nr: Irrigation number (h)

The calculation of indirect greenhouse gas emissions from electricity consumption was determined using an electrical emission factor that considers the generation of power plants that deliver energy to the national electricity grid (Secretaría de Medio Ambiente y Recursos Naturales-México, 2021). The equation used was the following:

$$CO_2e = \left(\frac{F_{ee} \cdot Ce_B}{1000kWh}\right) \quad (12)$$

Where:

CO2e: Amount of equivalent CO2 that is no longer emitted into the atmosphere (t)
Fee: Electric emission factor (0.494 tCO2e MWh^{-1})
CeB: Pump energy consumption (kWh)

RESULTS AND DISCUSSION

Agroproductive Analysis of the Crop

The analysis of the mass of the bulbs during the 2016-2017, 2017-2018 and 2018-2019 campaigns is shown in Figure 2, with results of 27.47 g, 27.81 g and 27.70 g, respectively, for an average of 27.66 g. This result is similar to that found by Pupo et al. (2016) in an experimental plot in areas of "Los Pérez" Farm of "Niceto Pérez García" Strengthened Cooperative of Credits and Services, in the municipality of Las Tunas, between 2011 and 2014. They found mass values of the bulbs of 21.78 g and 22.80g with the application of FitoMas E® and FitoMas E®+EcoMic®, respectively.

The diameter of the bulbs showed values of 3.92 g, 4.01 g and 3.85 g during 2016-2017, 2017-2018 and 2018-2019 cycles, respectively, for an average of 3.93 g (Figure 3). Bulb diameter values of 4.0 cm or higher were found by (Muñoz *et al.*, 2010) in 55% of the samples evaluated in studies carried out in Cuba with Creole clones. Regarding the diameter of the bulb, it is necessary to consider that it is an indicator that directly influences the quality of the product for marketing, food consumption and use as propagation material (Castellanos *et al.*, 2004; Diriba *et al.*, 2014).

In Figure 4, it is observed that in the three campaigns evaluated the crop yield reached values of 4.38 t ha^{-1}, 4.51 t ha^{-1} and 4.46 t ha^{-1} , respectively, with an average of 4.45 t ha^{-1}. These yields were higher than the average reported in Cuba by Izquierdo & Gómez (2005) as well as Izquierdo & Gómez (2007), which was 2.0 t ha^{-1}.

Other authors such as García *et al.* (2014) reported higher yields of 6.41 t ha^{-1}, with the combined treatment of FitoMas E® + 300 kg of N ha^{-1}. In the southern area of Las Tunas, yields higher than 5 t ha^{-1} were achieved with the use of different plant growth stimulants and in Sancti Spíritus, 6.81 t ha^{-1} were achieved with the application of *Azospirillum brasilense* (González & Rodríguez, 2003)

The combined effect of the size of the bulbs, the planting season (temperature and photoperiod) and soil moisture, which must be maintained in the range of productive moisture throughout the cycle, are factors that favor yields in garlic cultivation (Muñoz *et al.*, 2010).

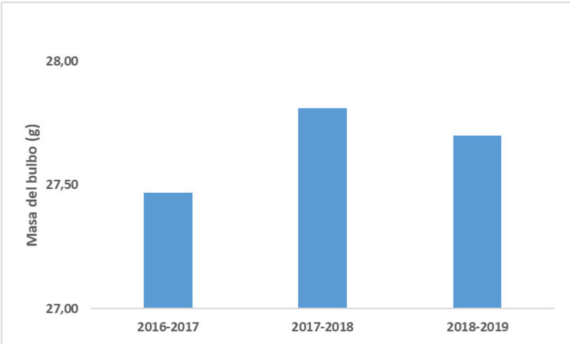

FIGURE 2. Mass of the bulbs.

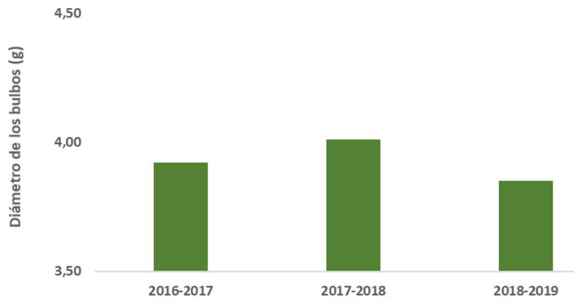

FIGURE 3. Diameter of the bulbs.

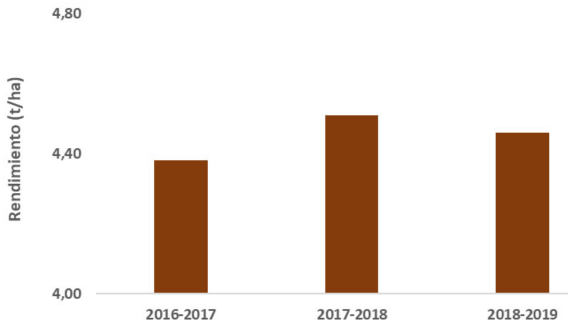

FIGURE 4. Agricultural yield of the crop.

Analysis of Technical Economic Indices

Table 1 shows the fundamental results of the economic technical indices calculated for the wind system with a multi-blade mill for sprinkler irrigation in garlic cultivation. In it, it is observed that the production volume is 231,400.00 pesos per hectare, conditioned by the sale price of garlic with a value of 52.00 pesos per kilogram, according to the Ministry of Finance and Prices MFP-Cuba (2021).

Table 1. Economic technical indices

Economic technical indices	Valor
V_p ($/ha)	231400,00
C_a ($/ha)	18929,77
B_n ($/ha)	212470,23
C_{pp}	0,08
B/C > 1	11,22

The annual costs incurred amounted to 18,929.77 pesos per hectare due to the costs of workers' salaries, amortization of the system, water consumption, fertilizers, cultural activities and soil preparation, among others. A net benefit of 212,470.23 pesos per hectare was achieved with a very favorable production cost per peso of 0.08, which indicates that only eight cents must be spent to obtain a peso of product, at the level of one hectare.

The above explained shows that the wind system with a multi-blade mill for sprinkler irrigation in garlic cultivation is economically advantageous, achieving a value of 11.22 in the Benefit-Cost ratio, which is much higher than unity.

The use of the multi-blade mill for pumping water used instead of a LEPONO motorized pump, widely used by farmers in the region, has a flow rate of 60 L min-1, maximum head of 70 m, turning speed of 3400 rpm, intensity of the current consumed by the motor of 11 A and voltage of the motor that feeds the pump of 110 V. It allowed an energy saving of 27.66 kWh, corresponding to 146.77 kg of CO2 equivalent per hectare that were no longer emitted into the atmosphere (Figure 5).

CONCLUSIONS

The improvement of energy efficiency in agriculture requires a transformation of the energy matrix based on the acceptance of renewable energies as an alternative, like wind energy as it is one of the most advantageous for wind pumping.

Favorable economic indices were achieved in terms of crop yield, production volume, net profit, cost per peso of production and cost-benefit ratio, which validate the effectiveness of the research. The satisfaction criteria offered by different companies and institutions demonstrate the scientific, technological and economic relevance of the results.

Energy saved with the use of this wind pumping system is 27.66 kWh, this represents 146.77 kg of CO_2 equivalent per hectare no longer emitted into the atmosphere.

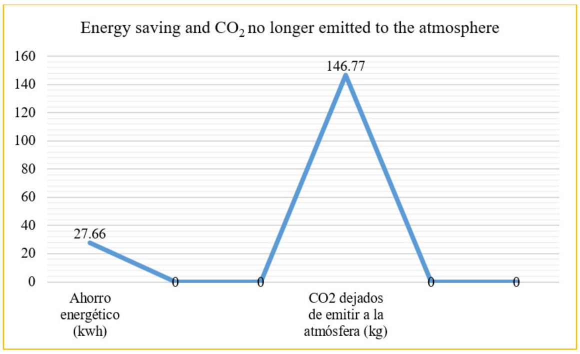

FIGURE 5. Relationship of energy saving and CO_2 not emitted into the atmosphere.

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