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Effect of Windbreak Trees on the Irrigation Quality in Sprinkler Irrigation Systems

Efecto de la cortina rompevientos en la calidad del riego en sistemas de riego por aspersión

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ABSTRACT: Irrigation technologies based on the application of water in the form of artificial rain are characterized by water losses due to evaporation and wind erosion, which can be reduced by using windbreaks. To assess the effect of windbreaks on water loss in medium-pressure sprinkler irrigation systems, as well as their influence on soil moisture conservation, an evaluation was conducted on a sprinkler irrigation system used for Mombasa grass. Sampling points were established at distances of 20, 50, and 70 m from the windbreak. Observations were made at the emitter placement height and during irrigation hours. Wind speed ranged from 2.8 to 3.6 m/s. After the windbreaks were implemented, wind speed decreased to between 1.8 and 3.4 m/s. As a result of this reduction, the average discharge efficiency increased from 60% to 73%, while the average irrigation uniformity increased from 71% to 80%. During the same period, greater soil moisture retention was also observed. These results translate into greater water availability for the crop and improved moisture distribution in the field.
Keywords: Wind, Uniformity, Efficiency, Use of Water.

RESUMEN: Las tecnologías de riego basadas en la aplicación del agua en forma de lluvia artificial se caracterizan por las pérdidas de agua producidas por efecto de la evaporación y el arrastre por el viento, las cuales pueden reducirse con el empleo de cortinas rompe vientos. Con el objetivo de valorar el efecto del empleo de cortinas rompevientos en el comportamiento de las pérdidas de agua en sistemas de riego por aspersión de media presión, así como su influencia en la conservación de la humedad del suelo, se realizó una evaluación en un sistema de riego por aspersión en el riego de pasto Mombasa. Se establecieron puntos de muestreo a distancias de 20, 50 y 70 m de la cortina rompevientos, las observaciones se realizaron a la altura de colocación de los emisores y durante las horas de ejecución del riego. La velocidad del viento se comportó en un rango entre 2,8 y 3,6 m/s, una vez implementadas las cortinas rompevientos se redujo al rango entre 1,8 y 3,4 m/s, como consecuencia de la reducción de la velocidad del viento la eficiencia de descarga media se incrementó desde un 60% hasta un 73%, en tanto la uniformidad de riego media se incrementó desde un 71% hasta un 80%; en el mismo periodo, se observó también mayor conservación de la humedad del suelo. Estos resultados se reflejan en una mayor disponibilidad de agua para el cultivo y una mejor distribución de la humedad en el campo.
Palabras clave: viento, uniformidad, eficiencia, uso del agua.

INTRODUCTION

Much has been written about the beneficial role of forests in the environment. Healthy forests clean the air and regulate the climate, sustaining life: they benefit people, plants, and animals, and are vital for ecological balance. They regulate the climate by acting as carbon sinks, absorbing large amounts of carbon dioxide (CO_2) from the atmosphere and storing it as biomass in their trunks and branches, and releasing oxygen through photosynthesis, thus helping to mitigate climate change (Bruijnzeel, 2004).

The same author explains that trees act like enormous sponges, absorbing rainwater during wet seasons and releasing it during dry seasons, filtering the water that enters rivers, lakes, and the underground aquifer, removing pollutants and improving the quality of streams and the health of basins, and acting as a barrier against floods.

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They consider (Loaiza and Osorio, 2009) Forests are one of the world's most valuable resources and are home to more than half of all terrestrial animal and plant species. They serve as refuges for wildlife, encourage the establishment of other species, create microclimates and improve the environment; they filter the air, provide us with clean air, and play a fundamental role in regulating temperature.

For their part (Blaschke et al., 2000) They believe that trees benefit the ecosystem in various ways: they channel rainwater and fog to the soil through their leaves, branches, and trunks; they form fertile soils; they control erosion; they reduce soil temperature; they regenerate nutrients, thus contributing to soil conservation and recovery; and they also help prevent water loss during irrigation when using overhead irrigation technologies. These authors report that, in the case of livestock ecosystems, the role of forests is particularly important. Trees can provide protection from cold winds and adverse weather for livestock, as well as shade. When properly managed in a livestock operation, they can help reduce livestock stress. Furthermore, incorporating trees into forage systems offers livestock farmers additional income from forest products.

Soil and water resources require special attention in livestock areas, because neither fertile soils nor groundwater sources are usually abundant, while surface water sources are not always close to irrigation areas or animal concentration points; at the same time, soils are often highly compacted, which limits the efficiency of irrigation or rainfall water use.

Given this situation, trees are essential. Forests are fundamental to the water cycle: they help maintain high water quality, influence the quantity available, and contribute to reducing water-related risks such as landslides, floods, and droughts.

They have expressed Bonet et al. (2023) Given that water is an increasingly scarce natural resource, it is essential that irrigation water be applied efficiently in order to increase agricultural production with a lower water demand. Several authors, such as Cisneros-Zayas et al. (2019). They highlight the fundamental role of wind in the losses due to evaporation and drag produced during the irrigation application process.

Multiple studies indicate that, during irrigation, both the uniformity of distribution and the efficiency of water application are affected by the wind, and subsequently, the rate of decrease in the soil moisture level is also related to the influence of the wind on the evaporation process.

It is common to characterize the various irrigation technologies by certain uniformity and efficiency values; however, Keller et al. (1981) cited by Bonet-Pérez et al. (2023). They indicated that uniformity depends much more on the management of irrigation systems than on the type of system used.

With the aim of assessing the effect of using windbreak curtains on the behavior of water losses in medium pressure sprinkler irrigation systems, as well as their influence on soil moisture conservation, an evaluation was carried out in a sprinkler irrigation system in the irrigation of Mombasa grass.

MATERIALS AND METHODS

The study was carried out on the La Victoria farm belonging to the CCS "Evelio Rodríguez" in the municipality of Jimaguayú.

The municipality of Jimaguayú belongs to the province of Camagüey. It is located between 21° 05' 00" and 21° 22' 00" North latitude and 77° 36' 00" and 78° 03' 00" West longitude. It is bordered to the north by the municipality of Camagüey, to the east by the municipality of Sibanicú, to the west by the municipalities of Vertientes and Camagüey, and to the south by the municipality of Najasa (Figure 1). The terrain is predominantly flat; however, in the northeast, there are small hills belonging to the Sierra de Maraguán mountain range, as well as other small, isolated elevations scattered throughout the municipality. The elevation ranges from 40 to 200 meters above sea level (Agramonte-Almanza et al., 2022).

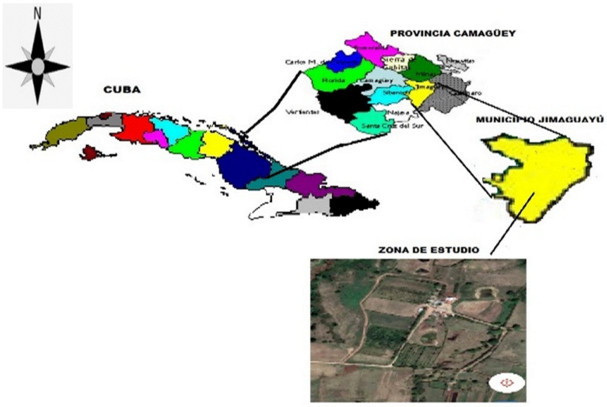


Figure 1. Map of Cuba, Camagüey province, Jimaguayú municipality, La Victoria farm. Source: https://www.bing.com, quoted by Mola (2023)

The climate is classified as tropical humid, inland plains with seasonal wetting, high evaporation and high temperature, with a marked seasonality of rainfall.

The average wind speed is 3.14 m/s; the highest average wind speeds are recorded during the dry season, ranging between 3.2 and 3.6 m/s, with the latter occurring in February. During the rainy season, May and July show the highest readings at 3.1 m/s, while in the remaining months, values range between 2.3 and 2.9 m/s. Strong wind gusts occur during the rainy season, associated with severe local storms and heavy rainfall (INSMET-Cuba, 2022).

The predominant soils in the municipality are the Brown soils without carbonates in various manifestations with 41.01% of the total area, characterized by generally having little effective depth, topography that ranges from undulating to slightly undulating (Mola, 2023).

The reference area selected for the study was the "La Victoria" farm belonging to the "Evelio Rodríguez" Credit and Services Cooperative (CCS), located on the Las Mercedes map sheet, in areas adjacent to the town of El Guayabo, which occupies a total area of 144.01 ha (Institute of Soils and Fertilizers, 2019, taken from Mola (2023)).

Its main business is cattle ranching, especially milk production, although it also produces various crops for self-consumption and sale to the state. Figure 2 shows a diagram of the farm's structure, and Table 1 shows its soil composition.

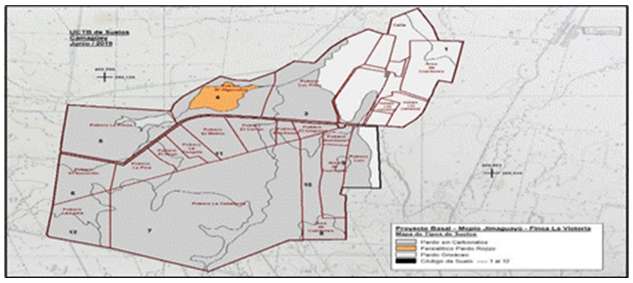


Figure 2. La Victoria Farm Scheme. Fountain: Mola (2023).

Table 1. Soil composition of the La Victoria Farm

Soil type	Area (ha)	% of total
Brown without carbonate	113.82	79.04
Grayish brown	27.36	19.00
reddish-brown Fersialitic	2.83	1.96
Total	**144.01**	**100.00**

Source: Soil Institute (2019), cited by Mola (2023)

The predominant soil in the irrigation system area is Pardo without carbonate; the Uniformity Coefficient and Discharge Efficiency evaluations were carried out after the establishment of the windbreak curtains and the results were compared with those that had been obtained before the establishment of said curtains.

Information on irrigation uniformity (CU) and discharge efficiency (Ed) was available from assessments carried out the previous year, at a time when there was no windbreak curtain.

A line of shrubs had been planted along one end of the area, coinciding with the position from which the prevailing winds originated, and which at the time of the evaluation reached an average height of 2.20 m. New determinations of Cu and Ed were carried out, allowing for a comparison of the results obtained with and without the use of windbreaks.

To determine the irrigation quality parameters, the Christiansen uniformity coefficient and the Discharge Efficiency (Christiansen, 1942 and Keller et al., 1981) were used, taken from Rodríguez et al. (2025).

$$CU = 100 \left[1 - \frac{\sum_{1=1}^{n} |Vi - Vm|}{n}\right] \quad (1)$$

Where: CU (uniformity coefficient in %); Vi (volume collected in each rain gauge in mL); Vm. (average volume collected in mL); n (number of rain gauges)

The Discharge Efficiency was determined from the relationship between the sheet applied by the machine and the sheet collected in the collectors.

$$Ed = \left[Lr/La\right] \ 100 \quad (2)$$

Where: Ed (discharge efficiency in %); Lr (average water depth collected by the collectors in mm); La (water depth applied in mm).

For five consecutive days, three daily wind speed measurements were taken at the height of the irrigation system emitters and at 1.5 m and 3.0 m above that height, between 7:00 a.m. and 5:00 p.m., the period during which irrigation is typically carried out. Measurements were taken at three locations within the irrigated area, distributed along an imaginary line perpendicular to the windbreak, at distances of 20, 50, and 70 m from it. Soil moisture was also monitored by taking samples every 0.10 to 0.30 m at the same locations where wind speed was measured. Sampling was conducted on three consecutive days, beginning the day after irrigation.

Means and instruments used for the evaluations: collectors (50); 50 m measuring tape; 500 mL graduated cylinder with 2 mL accuracy; anemometer; TDR moisture meter.

RESULTS AND DISCUSSION

Table 2 indicates the effect of the windbreak curtain on reducing wind speed depending on the distance from the curtain to the sampling point.

The wind speed after the establishment of the windbreak curtain remained in a lower range than those that occurred before the establishment of the windbreak curtains; however, this effect is less significant as the sampling moves away from the curtain, which was expected according to the way in which the damping effect of the wind speed occurs (Figure 3).

Table 2. Wind speed behavior (m/s) during the daytime before and after the installation of the windbreak curtain

Height (m)	Windbreak distance (m)					
	20		50		70	
	S/crv	C/crp	S/crv	C/crp	S/crv	C/crp
1.0	3.0	1.8	2.8	2.0	3.0	2.7
2.5	3.2	2.6	3.1	2.6	3.2	3.0
4.0	3.5	3.0	3.3	3.0	3.6	3.4
Average	**3.2**	**2.5**	**3.1**	**2.5**	**3.3**	**3.0**

Legend: S/crp and C/crp. With and without use of windbreak curtain. The values shown were within the characteristic range of the study area.

Table 3. Irrigation quality indicators before and after the establishment of the windbreak curtain

Indicator	Spot						Average	
	1		2		3			
	S/crv	C/crp	S/crv	C/crp	S/crv	C/crp	S/crv	C/crp
CU	69	83	73	81	71	76	**71**	**80**
Ed	60	76	61	72	60	71	**60**	**73**

According to Camejo et al. (2017). The protected area is approximately 15-20 times the height of the curtain, so in this case it was expected that the effect would be more pronounced in the first 35-45 m measured from the curtain; considering that the width of the irrigation area is 100 m, the ideal height of the curtain would have been 5.0 m.

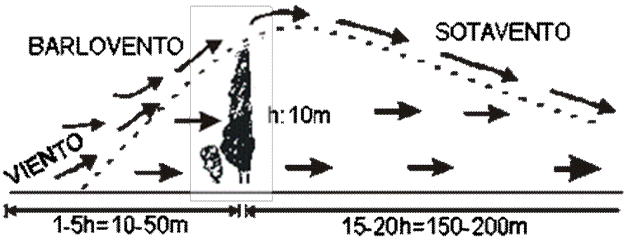


Figure 3. Diagram showing the effect of windbreak height on wind speed reduction over the area. Source: Author's own work

The results of the behavior of the evaluated parameters (CU and Ed) are shown in Table 3.

The positive effect of the windbreak curtain is observed both in the uniformity of irrigation water distribution and in the reduction of losses due to evaporation and runoff; this effect is most pronounced at the point closest to the curtain. These results translate into greater water availability for crops and better moisture distribution in the field; therefore, it can be inferred that greater water productivity and increased agricultural yields can be expected.

Reports of Tarjuelo et al. (2000) they point out that the uniformity of surface irrigation water distribution is highly dependent on the action of the wind, in intensity and direction, constituting the main distorter of the uniformity of distribution.

According to Tarjuelo (2005) during the application of irrigation with sprinkler technologies, water losses that occur both through evaporation and wind drift reach values higher than 10%, and points to wind speed as one of the causes of these losses.

Studies conducted by Rodriguez et al. (2022; 2023) using center pivot irrigation technology, they confirm the influence of wind on irrigation quality.

Wind speed is one of the climatic parameters that influences crop evapotranspiration, with a direct correlation between the two. Table 4 shows the soil moisture behavior at selected points during the days following irrigation.

Table 4. Comparative values of soil moisture (% CC bss) before and after the establishment of the windbreak curtain

Day	S/crv	C/crv
1	95.0	97.0
2	88.6	91.0
3	84.7	88.7
4	78.0	86.1
5	74.0	82.1

CC. Field capacity (22.3% bss. Up to 0.30 m depth)

The values shown are averages of the samples taken down to 0.30 m deep. Based on the results observed in the samples taken, it was found that in Brown soils without carbonate and with the Mombasa grass forage crop, on normal summer days, after irrigation the moisture decreased to the lower permissible limit corresponding to 80% CC in a period of 4 days under conditions without the use of the windbreak, while after its establishment that limit was reached on average 5-6 days after irrigation, due to both the reduction of evaporation from the soil surface and the transpiration of the crop, since wind speed is precisely one of the climatic parameters that affect the water consumption of the plants.

In practice, this means a lower demand for irrigation and therefore water savings and increased productivity, all of which translates into economic benefits for the Production Unit, since it involves fewer pumping hours with the consequent savings in electricity and wages; in this regard, Mujica et al. (2014) based on evaluations carried out on the use of energy in irrigation, a close relationship has been reported between productivity in the use of irrigation water and energy efficiency during the pumping of irrigation systems.

Trees are a tool for adapting to climate change in livestock ecosystems, among other factors due to their protective action on soil and water resources.

CONCLUSIONS

- The use of windbreak curtains helps improve irrigation quality by reducing water losses due to evaporation and runoff in sprinkler irrigation systems, with the consequent increase in water distribution uniformity and discharge efficiency.
- In the case study, CU increases of 71 to 80% were achieved, while in the Ed, the values ranged from 60 to 73%. The effect decreases as the sprinkler's position moves further away from the windbreak.

- The reduction in evapotranspiration that occurs as a result of a lower wind speed obtained as a result of the use of the windbreak curtain, can lead to a lower demand for irrigation and therefore to greater efficiency in the use of water and energy used in it.

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