ORIGINAL ARTICLE

Variability of Agroclimatic Factors and Irrigation Rate in Protected Cultivation of Pepper (*Capsicum annuum*)

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Variabilidad de factores agroclimáticos y gasto de riego en cultivo protegido del pimiento *(Capsicum annuum)*

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ABSTRACT: The objective of the present work was to find the relationship between uniformity of irrigation flow and agro-climatic factors with the yield, during pepper growing in greenhouse. The study was carried out in brown soil with carbonates, in a module of three greenhouses, Granma-1 Model, placed at “Valle del Yabú" Agricultural Company, in Villa Clara Province. In each greenhouse, six soil beds were formed with three irrigation branches with non-compensating Twin Drip drippers. For the study, 27 sampling points were taken, evenly distributed in the three greenhouses. The wind speed, temperature and relative humidity were measured with the Kestrel 5000 micro weather station. For the sampling of dripper flow, rain gauges were located at each experimental point and the irrigation coefficient of uniformity was determined. As a result, wind speed, relative humidity and temperature, inside the greenhouse, showed spatial variability values that satisfy the crop requirements. The coefficient of uniformity of irrigation rate was considered as acceptable with value of 71.2%, as a consequence of the obstruction of drippers, denoting a wide variability of irrigation rate without the presence of water flood or dry soil.

Keywords: Soil, Drip, Wind, Temperature, Moisture.

RESUMEN: El presente trabajo tuvo como objetivo determinar la relación entre la uniformidad del caudal de riego y la variabilidad de los factores agroclimáticos con el rendimiento durante el cultivo del pimiento en casas de cultivo. El estudio se llevó a cabo en un módulo de tres casas de cultivo protegido modelo Granma-1, perteneciente a la Empresa Agropecuaria "Valle del Yabú", en la provincia Villa Clara sobre suelo pardo con carbonatos. Dentro de cada casa se conformaron seis canteros con tres ramales de riego con goteros no autocompensantes modelo *Twin Drip*. Para el estudio se tomaron 27 puntos de muestreo, distribuidos uniformemente en las tres casas de cultivo. La velocidad del viento, temperatura y humedad relativa se midieron con la micro estación meteorológica *Kestrel 5000*. Para el muestreo del gasto de los goteros se instalaron pluviómetros en cada punto experimental y se determinó el coeficiente de uniformidad. Como resultado se evidenció que la velocidad del viento, la humedad relativa y la temperatura en el interior de la casa de cultivo mostraron valores de variabilidad espacial que satisfacen los requerimientos del cultivo. El coeficiente de uniformidad del gasto de riego obtuvo un valor de 71,2%, catalogándose de aceptable, como consecuencia de la obstrucción de goteros y denotando una amplia variabilidad del gasto en el área cultivada sin la presencia de encharcamiento ni zonas de suelo seco.

Palabras clave: suelo, goteo, viento, temperatura, humedad.

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INTRODUCTION

The efficient application of water is based on achieving the minimum possible losses by percolation and surface runoff. The amount of water applied in each irrigation, must be sufficient to cover the water consumed by plant in the period between irrigations, covering the inevitable losses. The uniformity of irrigation depends on the uniform distribution of water and nutrients provided by fertigation. A non-uniform application of water adversely influences the crop, because it does not receive the adequate proportion of nutrients with the corresponding effects on yield. (Ajete Gil *et al.*, 2011; Caro *et al.*, 2015; Reyes-Requena *et al.*, 2023).

The consumption of water by plants is conditioned by the effect of climatic conditions such as: temperature, solar radiation, wind speed, among other factors, which cause the release of water vapor from the soil to the atmosphere, from the plant by excess transpiration and from the soil by the evaporation process. These losses of water together, from the plant and the soil, are called evapotranspiration. (Cun *et al.*, 2012).

The cultivation of vegetables in greenhouse makes it possible to control the temperature, the amount of light and the rational application of irrigation; it is also possible to incorporate an optimal chemical and biological control to protect the crop. With protected grow, it has been possible to increase production per unit of area, reaching higher yields and better quality of the products that are grown in open field. (Mesa Bocourt *et al.*, 2013; Ramos-Tamayo *et al.*, 2023).

In the protected production of pepper *(Capsicum annuum)*, the contribution of water and a large part of the nutrients is carried out using the drip irrigation technique, adjusting the fertigation parameters to the phenological state of the plants, as well as the environment (Rodríguez *et al.*, 2008; Liang *et al.*, 2011). Considering the advantages of drip irrigation in protected cultivation conditions and the agrotechnical requirements of pepper, the objective of this work was to determine the relationship between the uniformity of the irrigation rate and agro-climatic factors with the yield during the growing of pepper in greenhouses.

MATERIALS AND METHODS

The study was carried out in a module of three greenhouses, belonging to "Valle del Yabú" Agricultural Company, in Villa Clara Province, located at 22° 27' 02.4" N latitude, 80° 00' 44.7" W longitude and 22 meters above sea level of altitude. The greenhouses were Granma-1 model of 12 m wide and 46 m long for an area of 540 m², a height of 4.4 m at the top and 35% shading mesh on the sides and front (Figure 1a). They are located on a brown soil with carbonates or Cambisol (FAO, 2012).

In each greenhouse, six beds were set up for the cultivation of pepper *(Capsicum annuum)* with dimensions of 1.20 m wide and 45 m long. The planting frame of 1.20 m x 0.20 m was used, for a living area of 0.24 m² per plant. Three branches of 16 mm in diameter and 43 m long were used for each soil bed, with non-self-compensating drippers Twin Drip model with a flow rate of 2 L/h at a pressure of 10.0 mca.

For the study, 27 sampling points were taken, uniformly distributed in the houses of the module. For this, three points were established for each selected soil bed, located in the center and 5 m from the ends, four replicas were made per each measurement. The wind speed, temperature and relative humidity were measured with the Kestrel 5000 micro weather station (Figure 1c). For the analysis of the temporal behavior of the variables, three measurements were made with an interval of 15 days between them, during the fruiting stage of the crop. To determine the variability of crop yield, the average number of fruits per plant was used in five of the neighboring plants at each previously defined measurement point.

The dripper flow rate was sampled according to the procedure described by Merrian & Keller (1978), for which rain gauges were installed at each experimental point, and the uniformity coefficient was also determined according to the following equation:

(a) (b) (c)

FIGURE 1. Greenhouse (a); flow rate measurement (b) and relative humidity, temperature and wind speed measurement (c).

$$CU = \frac{Q_{25}}{Q_n}*100 \quad (1)$$

where:

CU:System Uniformity Coefficient (%),

Q_{25}:Average value of the 25% of the dripper with the lowest flow rate (ml),

Q_n:Average value of the total number of drippers (ml).

RESULTS AND Y DISCUSSION

The measurements obtained for the agro-climatic variables inside the greenhouses, the rate of the emitters, as well as the yield per pepper plant are shown in Table 1. The average values reached are in the adequate range for the requirements of this crop in greenhouses as reported in several studies (Pérez *et al.*, 2018; Rodríguez & Hernández, 2021). The wind speed reached an average value of 1.42 km/h. However, the spatial distribution (Figure 2a) shows that more than 70% of the area had wind velocity below 1km/h, being zero in many places. In this range, the wind speed is considered as low, having beneficial behavior for the crop because it does not favor the movement of the plants in production and avoids the physical damage of leaves and fruits, as well as the abortion of flowers and breaking of branches (Michels-Mighty *et al.*, 2020).

Spatial Variability of Wind Speed and Temperature

Figure 2a shows the spatial variability of the wind speed inside the greenhouses. The maximum values were found distributed in three fundamental points located in the first and the third section of the installation in the range of 2 to 2.5 km/h. However, it was in the first section, where the highest speed in wind circulation were reached, with a tendency of decreasing in the corners. This behavior responds mainly, to the effect of the position of zenithal windows, by means of which, air circulation and relative humidity control are guaranteed. Also, the geographical position of the greenhouses have relation with the wind direction inside of them.

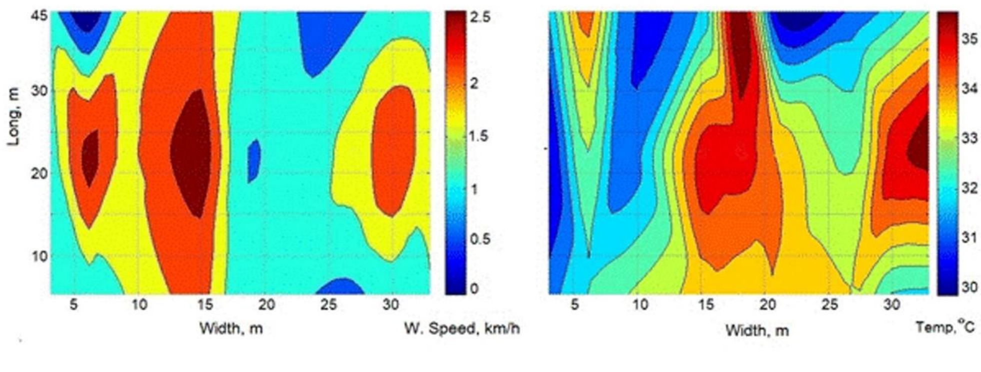
The temperature inside the greenhouses reached an average of 33.02°C, which is defined as optimal temperature for the development of this type of crop (Díaz *et al.*, 2010). In this sense, the authors highlight that plants can dry out quickly if the temperature is higher than 40°C and combination of solar radiation and temperature could raise the soil temperature up to 50°C. As shown in Figure 1b, the highest values were found in a small area at the center and at side of the greenhouses, reaching values in the range between 30 to 35.4ºC.

Spatial Variability of Relative Humidity and Crop Yield

The relative humidity reached an average of 77.56%. Figure 3 (a) show that values in the range of 60 to 65% are found in the center of the greenhouses, agreeing with the values obtained in temperature as expected. The optimal relative humidity set point for pepper grow is in between 65 to 85%, at this level the highest growth rates are achieved. Humidity values

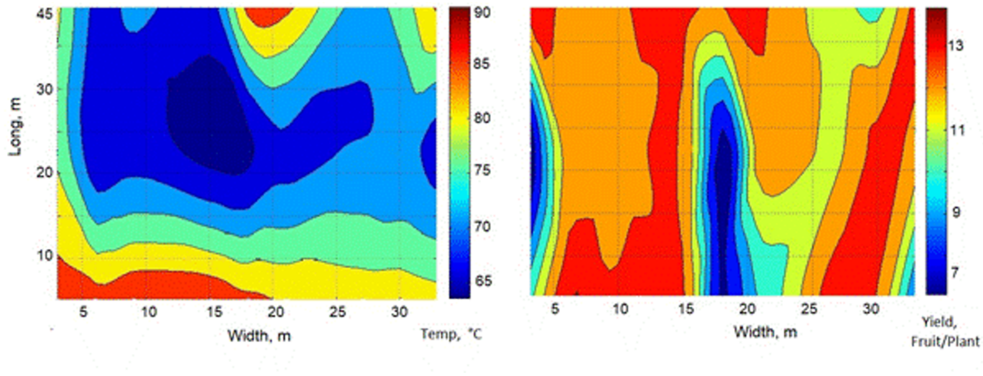
TABLE 1. Results of the measurements inside the greenhouses

	W.Speed km/h	*Temp. ºC*	*Relat.H. %*	*F.Rate* L/h	*Yield* Fruits per Plant
Average	1.42	33.02	77.56	1.945	11.86
Standard deviation	0.58	1.309	8.84	0.32	1.99
Coeff. of variation	40.6 %	3.9%	11.4%	16.9%	16,7%
Minimum	0.0	30.7	63.6	1.2	7.1
Maximum	2.7	35.4	90.0	2.55	13.9



(a) (b)

FIGURE 2. Wind speed (a) and temperature inside the greenhouse (b).



(a) (b)

FIGURE 3. Relative humidity (a) and crop yield (b).

below or above this range affect physiological processes, including plant pollination, slower growth and lower quality of production.

The yield, shows values between 6.7 and 14.7 fruits per plant, having a relatively high coefficient of variation (16.7%), being in correspondence with the results of several studies (Zamljen *et al.*, 2020; Kabir *et al.*, 2021). However, in more than 80% of the area, averages between 11 and 14.7 fruits were obtained.

Uniformity of Irrigation Flow Rate

The uniformity coefficient of the irrigation system was 71.2%, value considered acceptable, despite to be at limit of the denomination according Merrian & Keller (1978). The distribution of the flow rate in the surface of the greenhouses is shown in Figure 4. The values below the nominal rate are dispersed in the area. In all the cases, the emitters provide an amount of moisture over the ground that contribute to maintaining soil moisture, without presence of dry areas which favors the processes of water absorption and redistribution (Ricardez-Miranda *et al.*, 2021). In the same way, in the areas where the spray nozzles delivered values higher than 2 L/h, there was no evidence of waterlogging, proliferation of fungi or other visible affectations in plants or soil. In the inspection of the nozzles, it was observed that the main cause of the irregular distribution was their obstruction by particles and calcium salts.

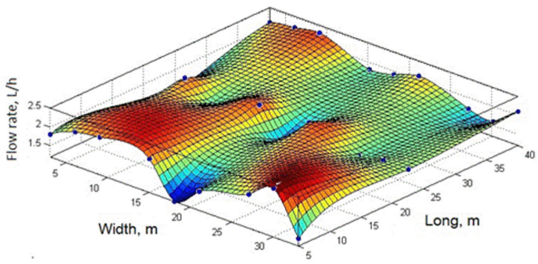


FIGURE 4. Distribution of flow rate in the greenhouse.

The correlation between the agroclimatic factors and crop yield is shown in Table 2. The Pearson coefficient shows a strong correlation of 0.85 between flow rate and yield, with a significant linear relationship from the zero trend of p-value.

CONCLUSION

The agro-climatic factors: wind speed, relative humidity and temperature inside greenhouse showed values of spatial variability that satisfy the requirements of pepper crop *(Capsicum annuum)*. The air circulation inside greenhouse made possible the redistribution of the temperatures, finding areas of zero wind speed to favors the growing process. The uniformity coefficient of irrigation is considered as acceptable (71.2%), showing a wide variability, affected mainly by the obstruction of the drippers.

TABLE 2. Correlation between agroclimatic factors and crop yield

	Yield	Temp	W. Speed	Relat. H.
F. Ratio	0.8526	0.0473	0.1152	0.0083
	0.0000	*0.8146*	*0.5671*	*0.9671*
Yield		0.0979	0.2070	0.0366
		0.6271	*0.3001*	*0.8564*
Temp			0.1518	-0.2046
			0.4498	*0.3059*
W. Speed				-0.3065
				0.1199

First value: Pearson Coefficient

Second value: P-valor

Flooding areas or dry soil were not found. While, the crop yield was 11.86 fruits per plant and showed a strong correlation with the distribution of irrigation flow rate.

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