EVALUATION OF ENVIRONMENTAL PARAMETERS OF A PHYTOTRON FOR CANNABIS CULTIVATION.

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Abstract

A phytotron is a space in which plant material is sought to be cultivated, in this particular case Cannabis Sativa L., simulating optimal environmental conditions, through equipment in charge of controlling and modifying variables such as temperature, relative humidity, light conditions, irrigation, ventilation and extraction. For this work, a closed room was adapted by installing a mobile platform that graduates the LED lighting at different heights, establishing the minimum height at 80 cm, a hydraulic network for irrigation and humidifiers. In addition, an electrical network was installed to control heating, lighting, extraction, and ventilation, controlled by means of a Human Machine Interface (HMI) placed at the entrance door, where the temperature and relative humidity variables are monitored. Based on these variables, decisions are made regarding the programming and requirements of the plant. The equipment was evaluated in day/night cycles with plants and without plants inside, where there was continuous air exchange, heating on during daylight hours and foggers off. In the test without plants, it was possible to obtain a maximum internal temperature of 32.3°C and a minimum of 24.6; and with plants, a maximum internal temperature of 28.5 and a minimum of 24.4 °C was observed. Likewise, a maximum RH of 66.5% with plants and 51.6% without plants was observed. Regarding the measured radiation tests, an average of 740.6 µmol m-2 s was obtained for the four lamps at 30 cm. These values allow, together with other variables, the calculation of the potential evapotranspiration which will allow a system design. most suitable and efficient irrigation in indoor systems.

Keywords: temperature, radiation, HMI, PLC lighting, indoor, cannabis.

INTRODUCTION.

In Colombia there is currently a regulatory framework that is considered one of the most complete at the international level, and which includes measures that range from seed, cultivation, transformation, generation of added value, and safe access by research and development that improves the performance and quality of products, this is how indoor trends represent an alternative for productivity and efficiency.

This indoor cultivation methodology allows greater control of environmental conditions considering the current climate variability that continues to increase. Furthermore, they represent a cost and energy efficiency challenge, as lighting-related costs are estimated to comprise 60% of the total energy used for indoor cannabis production. (Rodriguez-Morrison et al, 2021). According to Mills (2012), approximately 13,000 kW/h/year of electricity are required to operate a standard production module (1.2x1.2x2.4 m chamber), where lighting, ventilation and air conditioning represent 33%, 27 % and 19%, respectively, of the carbon footprint generated from indoor cannabis production.

On the other hand, the vapor pressure deficit (VPD), is a technique used to adjust temperature and humidity to optimal values, increasing plant performance and achieving maximum growth. This is because as the VPD increases, the plant's stomata become smaller, thus slowing down photosynthesis and absorbing less CO_2 and vice versa. Therefore, to increase the VPD, the environment can be heated by means of a heater, de-unify the environment and increase the light intensity either by lowering the lights or adding more lights and in the opposite case of decreasing the DPV, the lights can be moved or removed. illumination. (Grossiord. et. al, 2020)

In its different stages of development from germination, vegetative, flowering, harvest, drying and curing, specific requirements must be considered that prevent the loss of the organoleptic properties of the flower, seed or fibers depending on their use. Each of these requires optimal characteristics for cultivation such as temperature (20-25° C), relative humidity (60-70%), photoperiod (from 16 h light/ 8 h darkness to 12 h light/ 12 h darkness) and light intensity (400-700 nm) and which vary depending on their variety and which will be key in the design (López et al., 2014). As recommended by (Lumigrow, 2017), cannabis plants have the highest demand for PPFD in the flowering stage with an average value of 700-800 μmol m^{-2} s^{-1} and a minimum value in the germination stage and cloning by cuttings with an average value of 150-200 μmol m^{-2} s^{-1} . Now, for cannabis plants, the photoperiod hours vary according to their stage (18 or 12 light hours).

Now, a phytotron or culture chambers are closed and controlled spaces where cultivation trials or tests are carried out under monitored and controlled conditions. In this sense, they allow the range of parameters to be varied to simulate atmospheric conditions. Being a closed space, light, both in quality (spectrum) and quantity (intensity), plays an important role in the cultivation of cannabis in controlled environmental systems, where seedlings capture light and assimilate CO_2 and water in dry matter. through photosynthesis (Dan, Shengxi, & Jie, 2019). The most widely used lighting technologies for indoor cannabis production are high intensity discharge (eg high pressure sodium) and light emitting diodes (LED).

Lydon (1987) found a significant linear relationship between THC content in floral tissue and UVB dose. Rodriguez, et. al (2021) it appears that the harvest index increased linearly from 0.56 to 0.73 as the APPFD increased from 120 to 1800 μmol m^{-2} s^{-1} in addition, the yield of the cannabis inflorescence is proportional to the intensity of Light Within the range of practical indoor PPFD levels, the more light provided, the greater the proportional increase in performance (Rodríguez, et. al, 2021). The water deficit leads to closed stomata that limit the absorption of CO_2, followed by less energy use and an excessive absorption of light energy, which is why the evaluation and implementation of the lighting, hydraulic, and electrical systems are of great importance both in as costs in productivity, which is why this work was carried out based on these systems under a controller programmed in the required parameters of the plant.

MATERIALS AND METHODS

Localization & specifications

The automated phytotron unit is located in the Agricultural Engineering Laboratory of the National University of Colombia and is a space of 6.5 m2 and 19 m-3 that can accommodate 8 cannabis (Cannabis sativa L.)) plants with a control system that allows programming of light cycles, temperature, relative humidity, irrigation and ventilation. The control system is performed by a Flexipanel with HMI (Human Machine Interface) and PLC (Programmable Logic Controller) function integrated in a single device. The heating system is made up of a 1000W portable heater and an internal fan, this is located at the entrance of the air duct. Measurements were made with plants and without plants and measurements were taken on 5 consecutive days in each of the forms.

Sensors

The variables PAR, air temperature, and RH were measured by sensors. For air temperature and RH, the Rixen brand TRH-303 sensor was used. This sensor incorporates a high accuracy (±0.3°C) RTD reference Pt100∧ IEC751 thin film resistance thermometer and a highly stable polymer thin film capacitor to measure relative humidity (±2%).

Additionally, a FLIR brand thermographic camera was used to determine the operating temperature of the electrical panel, which does not exceed 41.4 °C when all the systems are operating and therefore does not require cooling strategies. Net radiation was measured using a four-component net radiometer (NR01; Hukseflux, The Netherlands). All sensors were scanned at 5 s intervals and 5-minute averaged readings were recorded.

Hydraulic system

For the irrigation system within the phytotron unit, a derivation from the drinking water network was made inside the laboratory to the two solenoid valves (Model 075DV, Rainbird brand) corresponding to the irrigation system and the misting system. For the internal network, they used 9 linear meters of ½-inch PVC pipe. The type of irrigation that was designed and used was drip with Netafim brand PCJ drippers. Additionally, Netafim brand CoolNet Pro-055 nebulizers were installed, which are connected to a derivation of pelletized polyethylene hose.

Lightning

The light requirements of the plant, a 2x2 m platform was built in mobile aluminum profiles with pulleys and guy wires through a pulley on the wall. This platform can be moved from the ceiling to 1.55 cm from the ground. 4 Phlizon 100 W lamps were used, 3 of the PL-1000 model and 1 of the PH-F4 model, which are waterproof and humidity-proof and have a maximum air temperature of 40°C. In addition, it allows manipulating and optimizing the spectra of light, which could be useful to model the profile of cannabinoids and thus improve the yields of specific compounds (Dan, Shengxi, & Jie, 2019). To determine the density of PAR photons received by plants, a Delta OHM HD 2102.2 radiophotometer connected to the LP 471 PAR probe was used. PPFD measurements were made for 3 and 4 Phlizon lamps of 100 W (3 of model PL-1000 + 1 of model PH F4 4) and the variation in height between the lamps and the sensor at 0.3-0.8-1.5 m and the optimal lighting platform at 32 measurement points in a mesh of 7x4 units.

RESULTS AND DISCUSSION

The behavior of the phytotron was evaluated in terms of its systems and the repercussion on the environmental variables to be measured, likewise a mapping of the radiation of the lighting was carried out before carrying out the hygrothermal tests to define the place of the plants. Initially, it was carried out with three and then with four lamps, finding a positive variation in the increase in radiation by 34.2% at 80 cm and 29.5% at 1.5 m when adding a lamp.

Records of relative humidity, internal and external temperature and vapor pressure deficit (VPD) were obtained for the conditions with plants and without plants (Table 1). These variables are fundamental in decision making, such as temperature, where Pate (1999) determined that temperature can play an important role in determining cannabinoid content. On the other hand, Sikora et.al (2011) determined that air humidity has no influence on the CBD content of industrial hemp.

Table 1. Experimental values with plants and without plants in the phytotron

	WITHOUT PLANTS				WITH PLANT			
	HR%	T int (°C)	T ext (°C)	DPV (Kpa)	HR (%)	T int (°C)	T ext (°C)	DPV (kPa)
Máx	51.57	32.26	19.58	3.37	66.53	28.52	21.98	1.76
Mín	34.87	24.55	18.07	1.50	45.65	24.43	20.41	1.31
Media	43.73	27.73	18.79	2.29	56.63	26.45	21.02	1.53
D.E	2.30	0.51	4.56	0.54	7.38	1.49	0.53	0.16
CV	0.08	0.03	0.10	0.24	0.13	0.06	0.03	0.11

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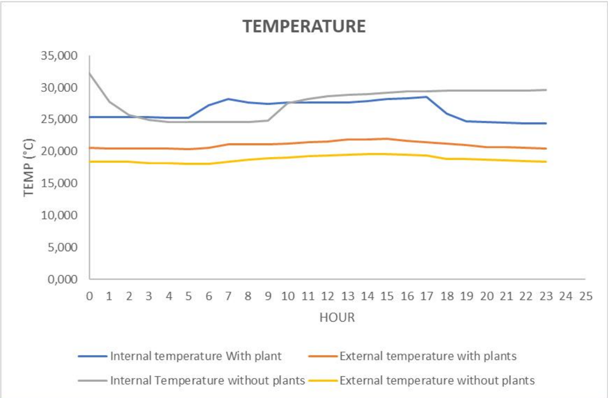
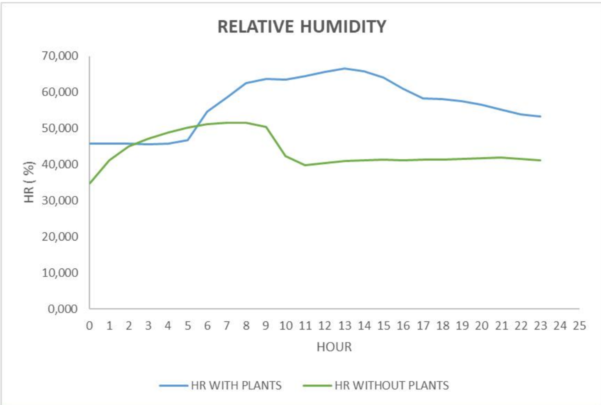
(A)



(B)



(C)

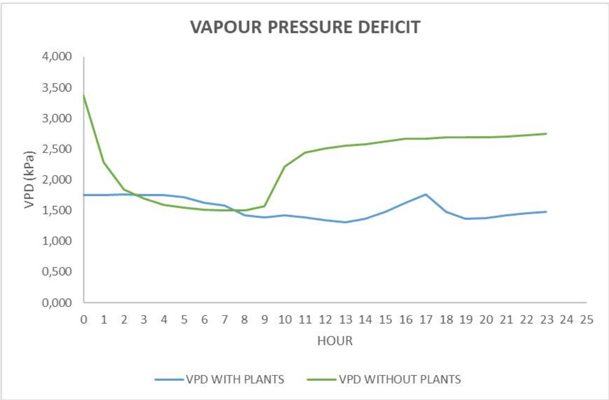


Figure 1. (A) Internal and external temperature with plants and without plants; (B) Relative Humidity with plants and without plants; (C) Vapor Pressure Deficit with plants and without plants.

Radiation measurements with four (4) lamps at 30 cm height, gave an average of 740.6 µmol/m2 s. This data is in the range of the maximum need for PAR radiation, which is the flowering stage, compared to the others. However, it is not completely uniform since at the edges not close to the walls the radiation level is somewhat below 700 µmol/m2 s (Figure 2). In addition, its efficacy could be visually corroborated because the 20 plants in the flowering stage did not present light deficiencies.

	3 lights				4 lights				%Variation			
0.8 m height	82.11	125.69	147.91	129.13	126.49	231.9	240.1	209.6	54,0	84,5	62,3	62,3
	127.19	195.18	265.6	216.8	190.22	264.7	347.9	267.2	49,6	35,6	31,0	23,2
	144.23	265.9	339	264.4	186.95	277.2	353.4	337.2	29,6	4,2	4,2	27,5
	150.35	268.1	381.3	293.1	185.5	256.9	339.8	332.6	23,4	[illegible]	[illegible]	13,5
	130.88	209	287.3	275	169.73	251.4	309.7	274.9	29,7	20,3	7,8	0,0
	102.5	153.46	207.8	199.73	149.84	204.6	277.5	262.1	46,2	33,3	33,5	31,2
	71.42	95.44	111.56	110.35	113.43	154.48	184.48	197.03	58,8	61,9	65,4	78,6
1.5 m height	92.21	111.08	120.47	111.57	132.76	15741	163.16	149.58	44.0	41.7	35.4	34.1
	103.46	122.96	132.56	125.13	145.66	168.84	168.69	159.29	40.8	37.3	27.3	27.3
	111.73	138.18	144.59	139.95	149.38	172.01	175.84	168.9	33.7	24.5	21.6	20.7
	113.76	140.79	150.23	143.01	148.44	174.14	175.43	165.63	30.5	[illegible]	[illegible]	15.8
	106.89	133.02	141.36	132.94	138.47	162.72	167.8	156.82	29.5	22.3	18.7	18.0
	91.86	109.59	120.24	112.48	122.83	145.8	150.66	139.41	33.7	33.0	25.3	23.9
	75.37	91.48	95.97	89.21	107.28	125.65	128.46	117.78	42.3	37.4	33.9	32.0

+34.2% (0.8 m height)

+29.5% (1.5 m height)

4 lights - 0.3 m height			
609.3	739.3	753.3	709.2
685.9	783.5	866.6	776.5
686.3	799.2	879.2	856.1
683.9	781.0	865.2	848.2
658.2	764.1	827.5	781.7
622.7	700.4	778.2	751.5
570.7	630.1	662.9	664.8

Figure 2. Photosynthetic Photon Flux Density (PPFD) measurements at the height of the lighting platform of 0.3 m, 0.8 m and 1.5 m from the sensor

CONCLUSIONS

This HMI designed system allows it to be friendly and intuitive for any user who operates the equipment, it also allows control and programming of each one of the variables independently for the required environment, considering the limitations for extreme internal and external conditions. It was proved that the maximum possible internal temperature is 32.26 C without plants and 28.52 C with plants. This decrease is due to the fact that the plants help to cool the environment due to the thermal exchange that occurs with the substrate, due to the fact that in their natural process of evapotranspiration relative humidity is increasing. This can be controlled passively with the external conditions which were between 18 and 21 C. In addition, the rate of moisture gain/loss in sensible heating/cooling is about twice that in the latent heating/cooling stage maintaining activates the ventilation of the phytotron.

This experiment allows other cannabis varieties to be evaluated in the future at different phenological stages and measuring productivity and efficiency variables such as those mentioned above. Additionally, it is important to think about other variables to monitor, such as infiltration, soil temperature, CO2, among others. This space must also be linked to the previous (germination) and subsequent (drying, curing and transformation) processes. In addition, it is important to keep in mind that changes in one factor cause the adjustment of other factors because these environmental variables are connected and directly affect the plant.

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