Article

Effect of orientation and container shape on the growth and development of chile ancho pepper cultivated in greenhouse

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Abstract

In this work the effect of solar radiation on greenhouse environmental conditions and effect on the substrate placed in containers vertically and horizontally for chile ancho pepper cultivation was analyzed. It was found that during the months of August 26 to October 17, there is a solar radiation between 246.91 (9:00 h) to 642 (12:00 h) W m^{-2}. The above, induced inside the greenhouse a differential CO_2 content at 9:00 h (853 ppm). In growth and yield of the chili plant, the plants cultivated in horizontal containers stood out the height (98.88 cm) and in dry weight (34.08 g) per plant. Horizontal containers showed a greater correlation between root and volume fresh weight variables of 99%, while the lowest was between leaf area and yield. Therefore, we conclude that in greenhouse chili cultivation it is recommended to use horizontal containers facing south to make efficient their yield by at least 25%.

Keywords: *Capsicum annuum* L., chile ancho pepper, greenhouse, temperature, tezontle.

Reception date: February 2019
Acceptance date: April 2019

Introduction

In Mexico there is a great diversity of the *Capsicum* genus, which are characterized by living in different climatic conditions, its production is the most important horticultural activity in Mexico and all types of chilli cultivated in the country (with the exception of habanero pepper and manzano chilli), belong to the species *Capsicum annuum*, the most important commercial species in the world. For optimal cultivation, favorable environmental conditions are required, one of which is temperature, which influences its growth, its fertility, and even the dimensions of the fruit. Rodríguez *et al*. (2005) mentions that the pepper or chilli, requires an optimum temperature of germination that goes from 25 to 30 ºC. During the day between 14-25 ºC and at night of 20-21 ºC, causing a good vegetative growth in the first stages of growth.

After the transplant the roots will only develop well if the soil temperature is 22 to 24 ºC. For good growth, a daytime air temperature equal to or greater than 28-30 ºC is required. While for fructification it is approximately 15 ºC, causing a minimum biological temperature close to 11 ºC. The temperature was of previously mentioned ranges generate irreversible damages (stunted growth, fall of fruits and young flowers and necrosis of the leaves). A temperature above (35 ºC) can damage the development of the flowers, the fruit set and the later development of the fruits, especially when the plants are old.

According to Cooper (1973); Cornillon and Obeid (1993); Gómez (2003) mentions that the optimum temperatures to create a good balance between vegetative growth and fruiting are between 22-23 °C per day and 18-19 °C at night, the temperature of the soil must range between 15 and 20 °C (Rodríguez *et al*., 2005). When grown under greenhouse conditions, another factor to consider is the substrate which, one of the most used is the tezontle and according to Baca *et al*. (1991), is a material considered as inert from the chemical point of view, whose saturation extract has a pH close to neutrality, its cation exchange capacity is very low, has good aeration, moisture retention that varies with the diameter of the particles, is generally free of toxic substances and has good physical stability (Bastida, 1999).

The classification of the growth rates and the concentrations of nutrients in the leaves are the same as the classifications in the average temperatures of the root zone; that is, day and night (Gómez *et al*., 2003) the temperatures in the substrates sand and tezontle show a behavior of increase of the temperature from 11:00 to 15:00 h with a value up to 53 °C, affecting the temperatures of the root and therefore the total chile ancho pepper yield, especially in the months with the highest temperature. Therefore, interest has grown in comparing different systems and substrates for the production of chile ancho pepper in greenhouse, in terms of yield and optimization in the use of water and nutrients (Inden and Torres, 2004).

In this work, the effect of solar radiation on the temperature of the black tezontle substrate in relation to the orientation and direction of the greenhouse in the development of root, plant and chile ancho pepper yield in black polyethylene containers, in vertical and horizontal position is evaluated.

Materials and methods

Greenhouse conditions

The research was carried out in a greenhouse of the Campus-SLP, of the Postgraduate School in Salinas de Hidalgo, San Luis Potosí. With a surface of 120 m^2 chapel type, metallic with a glass covering, zenithal vents and side windows, with orientation of the Northeast greenhouse, to the Southwest. At coordinates 22° 35” north latitude and 101° 45” west longitude, at an average altitude of 2 200 m (Flores, 1985).

Weather

The climate belongs to the BS1KW class corresponding to the least dry of the dry ones (BS1), average rainfall from May to October of 300 to 400 mm, according to the DGTN cartography (cited by Flores, 1985), this time is where it occurs from 82.75 to 84.88% of the annual total. The rainiest month is September and follow in decreasing order June, July, August, May and October. The warmest month is May and the coldest January (climate office Detenal, cited by Fortanelli, 1981).

Sowing and planting chili

For the preparation of the seedling, the variety pepper ‘Ancho Magno’ (HYB, Caloro Seeds) was used, which was germinated in peat moss substrate in trays of unicel (May 15, 2011) seedling height is 10 to 15 cm. These were placed in a substrate of black tezontle with particles of 0.3 to 0.7 cm from the region of Cerritos of San Luis Potosí, the container consisted of black polyethylene bags or containers of a volume of 4 L and were placed vertically and horizontal. A total of 48 vertical containers and 48 horizontal containers were placed with 16 containers per line with a total of 96 containers, placing one plant for each container. During the cultivation, the plants were guided vertically by a thread (polypropylene raffia).

Irrigation and nutritive solution

The irrigation system consisted of drippers (2 l h), which were connected to a secondary hose of 16 mm and a spaghetti that ended in a bayonet which was fixed to the south side of each container. Additionally, control drippers were established in the line, placing a container with a dropper (at the end) to determine the total amount of water used, draining 25%, the input pH was measured and the CE that the solution had. It used the nutritive solution recommended by Hewit and Smith, modified by Gómez, (1995) which was administered in two concentrations according to the phenological stage of the crop, as indicated in Table 1.

Table 1. Nutritious solution applied to the cultivation of chile ancho pepper.

Applied nutrition	Nutritious solution (ppm)	
	Start of cultivation	End of the crop
N	323	219
P	121	116
K	389	400

Applied nutrition	Nutritious solution (ppm)	
	Start of cultivation	End of the crop
Na	4	4
Cl	0	0
S	41	53
Fe	1.44	1.44
Mn	0.9	0.9
Cu	0.12	0.12
Zn	0.1	0.1
Bo	3.91	3.91
Mn	0.05	0.05

Temperature sensors

Four sensors (two centimeters deep) were placed in the containers, located according to the cardinal points and were connected to a Dataloger, which recorded the behavior of temperature and relative humidity during the critical period of the crop.

Variables analyzed

For the data analysis, 20 repetitions (10 horizontal and 10 vertical) were randomly used, from the following variables to: plant height, was measured from the base of the stem to the tip of the furthest leaf using a metal tape measure three meters long. For the fresh/dry weight of the plant the plant was cut from the base of the stem, the fruits were harvested and the fresh weight of the plant was determined by placing it in a stove at a temperature of 60 °C until constant weight for its dehydration and by difference the weight was determined. For the foliar area, the leaves of the plants were cut to draw in contour of the paper sheet, the leaf was taken to a foliar area integrator and the square centimeters of each plant sampled were obtained.

Fruit yield

The harvest began in August until November, where it is more abundant and with representative size to market it, therefore, the fruits were cut and weighed (digital scale). To determine fresh and dry weight, the fruits were subjected to 55 °C in a greenhouse adapted by heat convection by means of solar energy.

Root behavior

At the root of each plant the fresh weight was determined by means of dehydration in the oven at 60 °C until constant weight and to determine the volume of the root, it was taken in a 500 ml test tube and placed 200 ml of water.

Analysis of data

Some data of the morphological variables were submitted to the Anova, using the Statistical Analysys System (SAS) program. Comparisons of means were also made; through, of the Tukey test, with the probability of error of 5%. In the end, all the variables were correlated.

Results and discussion

Solar radiation and effect in the greenhouse

The climate (Table 2) outside the greenhouse (during the experiment), prevailed a temperature of 20.90 to 37.96 °C, with a rainy period from June to September (average precipitation of 300 mm), a solar radiation between 246.91 (9:00 h) to 642 (12:00 h) W m^{-2}. During cultivation, a greater presence of CO_2 was observed at 9:00 h (853 ppm) inside the greenhouse and decreased as the hours of the day progressed, with the lowest concentration at 12:00 h. The above is possibly due to the moving air that is generated by the difference of a temperature effect Marier (2012) between the outside and inside of the greenhouse.

Table 2. Effect of solar radiation on the presence of CO_2, accumulated time in s h^{-1} of irrigation and internal temperature of the greenhouse during chili cultivation.

Solar radiation time of the day	(W m^{-2})	Presence of CO_2 (ppm)	Accumulated seconds per hour of irrigation	Interior of the greenhouse (°C)
		26-31 of August		
06:00	0	977.6	47.67	21.66
09:00	246.91	1062.16	853.08	21.71
12:00	426.97	997.04	484.58	26.68
15:00	415.68	879.91	387.12	31.36
18:00	80.5	699.86	602.71	32.6
06:00	0.01	65.58	55.87	20.9
		01-30 of September		
09:00	311.6	64.09	503.52	21.71
12:00	642.75	40.48	246.3	28.53
15:00	401.24	38.19	409.85	32.33
18:00	52.8	37.67	457.4	33.06
		01-17 of October		
06:00	0	59.4	853.08	21.71
09:00	258.11	997.04	484.58	19.24
12:00	441.11	39.79	382.53	30.45
15:00	352.79	37.41	562.6	37.96
18:00	18.89	40.74	369.29	37.77

As the temperature, the resting time and the size of the plant increased, it also occurred in the accumulated time in seconds of irrigation during the crop, being the highest of up to 853.08 s (necessary for irrigation application). Regarding the temperature, at 3:00 pm, the highest temperature was reached, reaching 37.96 in the month of October, probably due to lack of rainfall compared to the month of August-September.

Temperature of the containers with respect to orientation

On the south side, the containers showed a difference in temperature starting at 11:00 in the morning when temperatures begin to be distant, and it is greater in vertical containers. The temperature for the vertical containers on the south face was 43 °C and the horizontal ones were 33 °C, the difference was 10 °C at the same time. Abbott and Gouth (1987); Spiers (1995), indicate that the growth of the root in the blueberry is controlled by the temperature of the soil, for this they mention that the radical system of the bilberry develops better when the temperatures of the ground are between 14 to 18 °C, which may be similar in the cultivation of chile ancho pepper. Considering five readings (starting at 6:00 and ending at 6:00 and ending at 6:00 pm), the containers showed differences in temperature (Table 3).

Table 3. Behavior of the temperature of the container placed vertically and horizontally applied to a chile ancho pepper crop under greenhouse conditions.

Hour	Temperature (°C) of the substrate in the vertical container				Temperature (°C) of the substrate in the horizontal container			
Side	North	South	East	West	North	South	East	West
Date	26-31 of August							
6:00	18.57	19.15	18.79	19.1	18.72	18.63	19.1	18.92
9:00	22.86	25.03	26.18	23.12	23.45	24.18	24.32	22.53
12:00	28.04	31.13	31.9	30.11	30.48	30.25	29.09	28.03
15:00	32.49	39.1	34.75	37.64	34.97	33.19	31.75	34.52
18:00	29.82	34.09	31.28	32.38	29.94	29.3	29.12	30.08
Date	01-30 of September							
6:00	17.43	20.26	17.64	18.02	17.89	17.25	17.87	17.91
9:00	23.31	29.11	29.11	23.82	23.42	25.79	25.05	22.55
12:00	33.39	45.32	40.27	35.48	35.28	41.74	37.7	33.15
15:00	35.4	42.19	37.68	43.6	34.55	42.25	34.67	38.7
18:00	31.8	34.49	32.77	36.96	30.49	31.42	29.71	31.54
Date	01-17 of October							
6:00	15.69	16.26	15.8	16.14	16.03	15.58	16.48	16.35
9:00	24.54	25.8	27.23	24.3	23.04	24.63	24.18	22.04
12:00	41.23	46.04	44.78	40.83	39.94	49.66	44.24	38.77
15:00	39.92	45.67	40.79	45.16	41.76	46.96	40.14	43.18
18:00	32.21	33.6	32.15	35.15	32.82	32.91	31.73	33.29

The side with respect to the south and east in both positions (vertical and horizontal) reach the highest temperature, projecting the horizontal container facing south with 49.66 °C at 12:00 h (followed by vertical containers in the same location with 46.04 °C). Averaging the temperatures during the day, the vertical containers to the south reached a higher average (34.27 °C), data almost similar to the horizontal containers to the south (33.94). The lowest average temperature during the day was presented by both containers facing north and east, with the vertical container being slightly lower, facing north (26.34 °C).

Morphological behavior of wide chili plants

In growth and yield of the chili plant (Table 4), the plants cultivated in horizontal containers stood out the plant height (98.88 cm) in dry weight of the plant (34.08 g plant), which represented an additional 24% to the containers vertical in the foliar area with almost double (2 958 cm^2), in number of fruits (30% additional) and obviously in yield with an additional 15%. Lorenzo (2000), mentions that when we use plastic container, the temperatures of the radical environment, affects the metabolism and affects the growth and development of the crops, since different processes intervene (cell division expansion, carbon assimilation, respiration, distribution of assimilated) and each one of them has a certain optimal temperature interval, according to species, phenological phase and previous growth conditions. In tomato plants with staircase arrangement (scalariform containers) blunted to three clusters yielded significantly more per unit area, compared to tomato plants in commercial arrangement also to three clusters, which accommodating the containers in the greenhouse it is very important for any crop (Bastida, 2012).

Table 4. Morphological variables and yield of chili plants, grown in vertical and horizontal containers.

Position	Height (cm)	Dry weight of plant (g)	Leaf area (cm^2)	No. of fruits	Total dry weight of fruits (g $plant^{-1}$)	Total yield (g $plant^{-1}$)
Vertical	91.56	25.71	1 776	21	58.3	492.3
Horizontal	98.88	34.08	2 958	32.7	85.5	659.9
CV	12.47	38.31	45.31	26.6	13.1	18.4
Sig.	0.03	0.001	0.0001	0.006	0.001	0.0075

The horizontal containers showed a greater correlation between the variables of fresh root weight and volume of 99% (Table 5). The lowest correlation was found between foliar area and yield, it is shown that the chili plants, even having more leaves, is not a guarantee that they produce more fruit. The vertical containers, in general, showed less correlation between their variables, possibly due to the temperature in the container. The above, coincides with López *et al*. (2000) to demonstrate high temperatures in Spain in greenhouse for crops without soil, due to its low thermal inertia, the temperature in the root zone is close to the air temperature, can in cold periods, limit the development of crops.

Table 5. Correlations of the variables of the vertical and horizontal containers.

Characteristics	Plant height	Leaf area	Root fresh weight	Root dry weight	Root volume	Yield
Horizontal container						
Plant height	-	0.93	0.95	0.95	0.95	0.85
Leaf area	0.9	-	0.9	0.91	0.91	0.68
Root fresh weight	0.83	0.73	-	0.98	0.99	0.92
Root dry weight	0.86	0.81	0.91	-	0.98	0.96
Root volume	0.89	0.79	0.93	0.91	-	0.92
Yield	0.85	0.68	0.92	0.96	0.92	-
Vertical container						

Conclusion

The investigation was carried out in a greenhouse with northeast orientation, to the southwest. The coordinates 22° 35” north latitude and 101° 45” west longitude, at an average altitude of 2 200 meters above sea level. The orientation of the greenhouse and the type of container it influences the best development of plant height, leaf area, fresh and dry root weight, root volume and yield. Being the horizontal container facing south, the one that excelled in performance.

Cited literature

Abbott, J. and Gough, R. 1987. Seasonal development of highbush blueberry roots under sawdust mulch. J. Amer. Soc. Hort. Sci. 112(1):60-62.

Ackley, W.; Grandall, P. and Russell, T. 1958. The use of lineal measurements in estimating leaf area. Proc. Amer. Soc. Hort. Sci. 72(12-13):326-330.

Bastida, A. 1999. El Medio de cultivo de las plantas. Sustratos para hidroponía y producción de plantas ornamentales. Preparatoria Agrícola-Universidad Autónoma Chapingo (UACH). Chapingo, Estado de México. Serie de publicaciones AGRIBOT Núm. 4. 72 p.

Bastida, C. O. A. 2012. Métodos de cultivo hidropónico de Jitomate (*Solanum lycoprsicum* L.) Bajo Invernadero basados en doseles escaleriformes. Tesis de Maestría en Ciencias en Horticultura. Universidad Autónoma Chapingo (UACH). Chapingo, Estado de México. 15-110 pp.

Baca, C. G. A.; Alcalde, B. S.; Martínez, G. A. J. R. y Barrera, I. D. 1991. Efecto de la solución nutritiva, riego, el sustrato y la densidad de siembra en tres cultivos hortícolas en la hidroponía al aire libre. II Melón y Jitomate. Agrociencia. 2:33-55.

Bravo, L. Á. G.; Cabañas, B. C.; Mena, C. J.; Velásquez, R. V.; Rubio, S. D.; Mojarro F. D. y Medina G. G. 2002. Guía para la producción de chile seco en el altiplano de Zacatecas. Secretaría de Agricultura, Ganadería y Desarrollo Rural, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Zacatecas. Publicación técnica núm. 1. 38 p.

Cooper, A. J. 1973. Root Temperature and plant growth: a review, commonwalth bureu of horticulture and plantation Crops. East Malling, Maidstone, Kent, UK. ISBN: 0851982719. 73 p.

Cornillon, P. 1987. Influence de la temperatura des racines sur la croissance et la nutrition des plantes. *In*: les cultures sol. 2da (Ed.). Editorial INRA. Paris, Francia. 221-234 p.

Cornilion, P. and Obeid, S. 1993. Influence of root temperature and phosphorus content in the substrate on muskmelon growth. Adv. Hortic. Scien. 7(2):69-72.

Flores, F. J. L. 1985. Evaluación de tierras en el área de estudio del CREZAS-CP. Tesis profesional. Universidad Autónoma Chapingo (UACH). Chapingo, Estado de México. 407 p.

Fortanelli, M. J. 1981. Sistemas de producción de cosechas de riego en cañadas y planicies de inundación aledañas a San Luis Potosí. 289 p.

Gómez, G. A. 1995. Cultivo hidropónico de jitomate en agua salina y relaciones de K y NO_3 en la solución nutritiva. Tesis Maestría, Colegio de Postgraduados. 10 p.

Gómez, G. A. 2003. Influencia del calentamiento de la disolución nutritiva sobre la productividad de pepino (*Cucumis sativus* L.) mediante el procedimiento de bajo coste en cultivos sin suelo. Tesis Doctoral. Almería, España. 140 p.

Inden, H. and Torres, A. 2004. Comparison of four sustrate on the growth and quality of tomatoes. Proceedings of the XXV International Horticultural Congress. Parte 3, Tema 513.

Lorenzo, P. 2000. Calefacción de invernaderos en el sudeste español. Caja Rural de Almería y Junta de Andalucía. 11-13 pp.

López, J. C.; Arco, M.; Puerto, H. y Pérez, J. 2000. Calefacción de Invernaderos en el sudeste español. Caja Rural de Almería y Junta de Andalucía. 28-34 pp.

Marier, A. 2012. Tipos de sistemas hidropónicos. http://www.keywordspy.com.es-/editorials/articles/78c16be893/los_seis_tipos_principales_de_sistemas_hidrop%C3%B3nicos.

Nkansah, G. O. and Ito, T. 1995 a. Effect of air and root-zone temperatures on physiological Characteristics and yield of heat-tolerant and non heat-tolerant tomato cultivars. J. Japan Soc. Hort. Sci. 64(2):315-320.

Nkansah, G. O. and Ito, T. 1995 b. Comparison of mineral absorption and nutrient composition of heat-tolerant and non heat-tolerant tomato plants at different root-zone temperatures. J. Hortic. Sci. 70(3):453-460.

Rodríguez, M. J.; Huerta, De la P; Olvera A. y Fernandez R. S. 2005. Participación comunitaria para el rescate *in situ* del chile poblano (*Capsicum annuum*, L.) en dos comunidades rurales de Puebla, México. Unión de productores de chile poblano de Juárez Coronaco y San Matias Tlalancaleca; Puebla, México *In*: Memorias de la Segunda Convención Mundial del Chile. 359-360 p.

Spiers, J. M. 1995. Sustrate temperatures influence root and shoot growth of southern highbush and rabbiteye blueberries. HortSci. 30(5):1029-1030.