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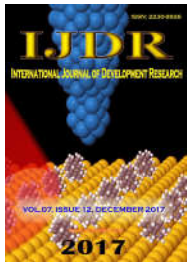

ORIGINAL RESEARCH ARTICLE

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BELL PEPPER PERFORMANCE WITH RECYCLED NUTRIENT SOLUTION

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ABSTRACT

Mexican growers of greenhouse bell pepper (*Capsicum annum* L.) have adopted productions systems developed for other countries with climatic and socioeconomic conditions different from Mexico. This study examines the effects of different soilless systems on yield and nutrient solution use of bell pepper under low technology greenhouse in Tehuacan, Puebla, South Central Mexico. The experiment design was a complete random block with four repetitions; the experimental unit was 3 m^2 which included 9 plants. The soilless systems treatments were OSS; open soilless system; CSS1; closed soilless system 1 controlled by electrical conductivity; CSS2; closed soilless system 2 controlled by the concentration of K, Ca, NO3_ and P ions. Fruit weight and total dry weight were similar between three treatments. But yield was statistically significantly different for OSS with CSS1 but no differences were found between OSS with CSS2. Around three hundred liters for square meters were saved in closed soilless systems compared with OSS and this one expended near twenty liters mores for kilogram of fruit, also six to twelve percent were the nutrient saved in closed soilless systems.

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INTRODUCTION

The production of bell pepper in Mexico is carried out with the adoption of imported production systems that do not consider the environmental characteristics of Mexico or the greenhouses technology (Sánchez-Del Castillo, *et al*., 2017). Among them the soilless system culture, which may or may not use substrate as support. These systems are divided into two main types of nutrient solution management; if it is recycled, they are called closed and open when the solution remaining is discarded directly into the environment (Massa, *et al*., 2010). Open soilless systems can be controlled relatively simply, because problems due to nutrient deficiency, toxicity, or salinity are unlikely (García *et al*., 2007). In these systems at least 10% of the solution is drained directly into the environment, which can contaminate groundwater by the nutrients contained in the hydroponic solution. In addition, water and fertilizers are wasted because plants do not use nutrients in the same way or at the same time (Sánchez-Del Castillo, *et al*., 2014b). Closed hydroponic systems are used in a number of countries, especially where it is not permitted to directly send the nutrient solution to soil or water bodies (Van OS, 1999). The control of these systems is complicated, for it is necessary to regulate the pH, the electrical conductivity, the nutrient content, the amount of water and disinfect the solution. The mass balance approach has been used to account for the amount of incoming ions and the quantity that emerge (Bugbee, 2004), or by means of the electrical conductivity, assuming a balance between anions and cations. In Mexico closed soilless systems are practically not used because expensive cost equipment, management and the lack of production systems specially designed for the conditions of the country. In the case of bell pepper, the reuse of nutrient solution is further complicated by its high susceptibility to

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water stress (Ferrara, *et al*., 2011). Therefore, it is necessary to develop a production system suitable for most of the bell peppers greenhouse growers in Mexico, where the reuse of nutrient solution is considered, to make it more competitive with the saving of inputs and environmentally friendly.

MATERIALS AND METHODS

Research work was carried out from March to December 2014, the total time of transplant to harvest was 249 days, approximately 36 weeks. In a greenhouse of 27 m of width by 40 m of length, type tunnel with skirt and zenithal ventilation. It is located in San Pablo Tepetzingo Tehuacan, Puebla. The coordinates of the greenhouse were the following 18 ° 24' 50" north latitude and 97 ° 20' 27" longitude west, with an altitude of 1402 above sea level, the total annual rainfall was 502 mm and the average annual temperature of 20.2° without presence of frost (data obtained of the meteorological station of the Technological University of Tehuacan). Orion bell pepper variety of Enza Zaden ™ was evaluated; it is characterized by being precocious and has a package of resistances for open field. It is cultivated mainly to harvest in green, is blocky type, in tests compared to other varieties resulted in high yield (Reséndiz-Melgar *et al*., 2010). The seeds were placed for germination in polystyrene trays, as substrate, a mixture of peat moss and perlite in a ratio of 1: 1 (v: v) was used. Irrigation was performed using self-compensating drippers with an expenditure of 1 liter · hour $^{-1}$, which was regulated by time and volume daily, and irrigated to field capacity before transplant. The irrigation ended by accumulating between 20% and 30% drainage per day.

The nutrient solution used, from one week after emergence to the end of the cycle, contained the following elements and concentrations (mg • L $^{-1}$): N 215; P 60; K 202; Ca 235; Mg 60; S 217; Fe 3; B 0.6; Mn 0.5; Cu 0.1; Zn 0.1, with an electrical conductivity of less than 3 dS / m and pH between 6 to 6.5, as suggested by Sánchez and Escalante (1988). The transplant was carried out 45-day-old-seedlings (April 14, 2014), when seedlings had formed two to three leaves in black polyethylene bags as containers, with dimensions of 40 cm by 40 cm with one plant per container. The substrate used was red volcanic sand which in Mexico is called *tezontle*, up to 4 mm thick. The bags were placed on polypropylene corrugated plastic hydroponic gutters, which carried the drained solution into 1,100 liter containers. The plants were managed on four stems and guided by raffia strands held on wire held in the structure of the greenhouse at a height of 4 m, each branch presented its own line. Plant density was 3 plants · m^{-2}, with a topological arrangement of double-row lines at 0.4 m distance between plants and 1.8 m between rows. The experimental design was a complete random block with four repetitions; the experimental unit was 3 m^2, which included 9 plants. Three different treatments were examined: the first consisted of an open soilless system (OSS) where the drained solution was stored in the containers mentioned for analysis but without recycling of the nutrient solution drained. The second treatment was a closed soilless system (CSS1), where the drained solution was stored and recycled by adjusting it with the addition of nutrient solution or water without solution until reaching an electrical conductivity of 3 dS / m. The third treatment was also a closed soilless system, but the adjustment of the solution was also made with the ions K, Ca, NO3- and P (CSS2).

K, Ca and NO3- were quantified with HORIBA LAQUAtwin ionometers of the B-731, B-751 and B-741 models, respectively. For the P, a Hanna instruments HI83200 multiparametric photometer was used. Electrical conductivity and pH were measured with a Hanna instruments HI 98129 portable meter. From the drained solution the ions were quantified, to know the nutrient saving. The response variables were: the average fresh fruit weight expressed in kilograms; the yield produced per square meter expressed in kilograms; the total dry weight plant in grams, for which the leaves, stem and root of each plant were placed in a drying oven at 70 ° C for 48 hours, until constant weight is obtained with addition of the dry weight of all fruits produced per plant, obtained with estimators from fresh weight. The estimators were calculated by a calibration of twenty fruits with linear regressions between dry weight and fresh weight. The data obtained were analyzed with variance analysis (ANOVA) and comparison of means (Tukey, $p \leq 0.05$).

RESULTS AND DISCUSSION

Yield in kilograms per square meter was significantly higher in the open soilless system (OSS) compared to the closed soilless system controlled by the electrical conductivity (CSS1). Only electrical conductivity was not enough to avoid the problems of closed soilless systems. As was the lower yield, which may have been due to an imbalance in nutrient content (Savvas *et al*., 2008). However, no differences were observed compared the closed soilless system controlled with ion measurement (CSS2), it could be that the more specific controls of K, Ca, NO3- and P would help to maintain performance. With the progressive reuse of the drained solution, a suboptimal solution was avoided as with happen for closed soilless systems (Neocleous and Savvas 2016). Because the longer renewal time of the nutrient solution, increase the negative effects on yield in the closed hydroponic systems (Ko et al., 2013b). In the study, the adjustment of the irrigation solution was made with drained nutrient solution, so it always represented the lowest proportion, which could allow similar yields between the OSS and CSS2 treatments. However, it was not enough for the control of the electrical conductivity of the CSS1 treatment that if it had a lower yield, probably due to the presence of other unanalyzed ions that maintained the electrical conductivity but did not represent a nutrient, such as Na ions and Cl (López *et al*., 2003).

The average yield of bell pepper produced in Mexico is about 7 kg • m^{-2} (Grijalva *et al*., 2008), the work was higher for all treatments, and similar to those achieved with intermediate technology (Cantliffe and Vansickle 2001, Jovicich *et al*., 2004), although smaller compared to those produced in high technology ranging from 25 to 30 kg m^{-2} year^{-1} (Cantliffe and Vansickle 2001; Heuvelink *et al*., 2004). For the technological level used the yields can be considered acceptable for the three treatments. No statistically significant differences were found between any of the soilless systems studied for the fruit weight and the total dry weight. In order for a closed hydroponic system could be implemented in Mexico, it is necessary that its management is not complicated to the grower (Sánchez-Del Castillo, *et al*., 2014b), with regard to this work only with the storage and adjustment of the solution is feasible to implement it without impairing the fruit quality. Water savings were estimated at about 350 L m^{-2} for closed soilless systems which is almost 30% of the volume of water consumed.

Table 1. Comparison of the means of bell pepper plants for the three treatments of hydroponic systems

Treatment	Yield	Fruit Weight	Total Dry Weight
	kg m^{-2}	g	g
OSS	11.92 a	214.75 a	1019.00 a¶
CSS1	10.32 b	193.00 a	941.00 a
CSS2	10.77 ab	195.00 a	956.75 a
MHSD	1.33*	21.83 n.s	83.50 n.s
CV%	5.59	5.00	3.95
Block	n.s	n.s	n.s

* Means within columns with the same literal are statistically the same according to Tukey P≤0.05; OSS: open soilless system; CSS1: closed soilless system controlled by electrical conductivity; CSS2: closed soilless system controlled by the concentration of ions K, Ca, NO3- and P; CV: coefficient of variation; MHSD: minimum honest significant difference.

Table 2. Bell pepper performance for water and nutrient solution used in the three treatments

Treatment	Irrigation Volume	Drained Nutrient Solution	Recycled Nutrient Solution	Eficciency of water used
	L m^{-2}	L m^{-2}	L m^{-2}	L kg^{-1} of fruit
OSS	1287	342	0	108
CSS1	1279	0	358	89.2
CSS2	1291	0	349	87.5

Table 3. Amount of nutrients applied and saved throughout the production cycle in bell pepper for the three treatments of hydroponic systems used

Treatment	Nutrient applied g m^{-2}				Nutriente saved g m^{-2} (%)			
	N	P	K	Ca	N	P	K	Ca
OSS	277	77	260	302	0 (0)	0 (0)	0 (0)	0 (0)
CSS1	275	77	260	301	16 (6)	7 (9)	20 (8)	36 (12)
CSS2	278	78	261	303	18 (6)	6 (8)	23 (9)	30 (10)

One way to save water in pepper production is to not water field capacity (Ismail, 2010), but it is not highly recommended for the susceptibility to saline stress and water stress in greenhouse pepper production (Rameshwaran *et al*., 2016). However, we used almost four times more water to produce one kilogram of fruit, compared to other works (Ko *et al*., 2013a). Due to the high temperatures and radiation at the site, it is necessary to quantify and reduce evapotranspiration, as well as to adjust solutions and irrigations (Costa *et al*., 2007). This is common in the production of greenhouses in Mexico because most do not have automatic climate control. Similarly, the containers used for hydroponic production in Mexico are bags like the ones in the present study that could be improved if they were closed to reduce evaporation. The amount of nutrient applied for the three treatments was similar because of the way the irrigations were controlled and the reused solutions adjusted. The percentage of nutrients saved was between 6% and 12% individually. Other works with pepper report higher savings with 78% (Ko *et al*., 2013b) or more than 80% (Giuffrida and Leonardi, 2012). With other crops nutrient savings in closed hydroponic systems are also relevant, in tomatoes, savings of 20-50% of fertilizer (Sánchez-Del Castillo *et al*., 2014b) and 25% for cucumber have been obtained (Sánchez-Del Castillo, *et al*., 2014a). The low nutrient reused may was due to the absorption by the plant and possibly to its being left in the substrate, as has been reported in other studies (Pineda *et al*., 2011). Although in greenhouse production it is common to keep the amount of irrigation water constant, the level of nutrients and the electrical conductivity constant, the absorption by the plant is not constant, so a way to optimize the use of water and nutrients, is to adapt the system to the needs of the plant, which could be adjusted by environmental parameters (Marcelis *et al*., 2005).

Conclusion

The present work examined a relatively simple way of saving nutrients and water, as well as to avoid that the fertilizers were disposal directly to the environment. Drained water and nutrients can be reused with the use of portable ionometers for ions measures, which can be accessed by soilless bell pepper growers. Also they could be able of obtain similar yield to those obtained with open soilless systems. In this way a more efficient use of water could be made, mainly due to the scarcity of this resource in the south central Mexico and saving in fertilizer, that allows being less harmful to the environment and more competitive.

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REFERENCES

Bugbee, B. 2004. Nutrient management in recirculating hydroponic culture. Acta Hort. (ISHS). 648:99-112.

Cantliffe, D.J. and Vansickle J.J. 2001. Competitiveness of the Spanish and Dutch greenhouse industries with the Florida fresh vegetable industry. *Proc. Fla. State Hort. Soc.* 114: 283-287.

Costa, J. M., Ortuño, M. F. and Chaves, M. M. 2007. Deficit irrigation as a strategy to save water: physiology and potential application to horticulture. *Journal of integrative plant biology*. 49(10), 1421-1434.

-Ferrara, A., Lovelli, S., Di Tommaso, T. and Perniola, M. 2011. Flowering growth and fruit setting in greenhouse bell pepper under water stress. *Journal of Agronomy*. 10:12-19.

García, E. G., Pérez, M. L. and Jasso, E. G. 2007. Evaluación de dos sistemas hidropónicos (abierto y cerrado) con relación al uso de solución hidropónica reciclada y producción de jitomate de exportación. Tecnólog@ l: 55-66.

Giuffrida, F., and Leonardi, C. 2012. Nutrient solution concentration on pepper grown in a soilless closed system: yield, fruit quality, water and nutrient efficiency. *Acta Agriculturae Scandinavica, Section B-Soil and Plant Science*. 62(1): 1-6.

Grijalva, C. R. L., Macías, D. R. and Robles, C. F. 2008. Productividad y calidad de variedades y densidades de chile bell pepper bajo condiciones de invernadero en el noroeste de Sonora. *Biotecnia* 10: 3-10.

Heuvelink E., Marcelis, L. F. M. and Körner, O. 2004. How to reduce yield fluctuations in sweet pepper. Acta Horticulturae 633: 349-355.

Ismail, S. M. 2010. Influence of deficit irrigation on water use efficiency and bird pepper production (*Capsicum annum* L.). *Meteor. Environ. Arid Land Agric*. Sci. 21:29-43.

Jovicich, E., Cantliffe, D. J., and Stoffella, P. J. 2004. Fruit yield and quality of greenhouse-grown bell pepper as influenced by density, container and trellis system. *HorTechnology* 14: 507-513.

Ko, M. T., Ahn, T. I., Cho, Y. Y. and Son, J. E. 2013a. Uptake of nutrients and water by paprika (*Capsicum annuum* L.) as affected by renewal period of recycled nutrient solution in closed soilless culture. *Horticulture, Environment, and Biotechnology*. 54(5): 412-421.

Ko, M. T., Ahn, T. I., and Son, J. E. 2013b. Comparisons of Ion Balance, Fruit Yield, Water, and Fertilizer Use Efficiencies in Open and Closed Soilless Culture of Paprika (*Capsicum annuum* L.). *Kor. J. Hort. Sci. Technol*. 31: 423-428.

Lopez, J., Santos-Perez, J. and Lozano-Trejo, S. 2003. Mineral nutrition and productivity of hydroponically grown tomatoes in relation to nutrient solution recycling. *Acta Hort*. 609:219-223.

Marcelis, L.F.M. , Brajeul, E., Elings, A., Garate, A., Heuvelink, E. and Visser, P.H.B. 2005. Modelling Nutrient Uptake of Sweet Pepper. *Acta Hort*. 691:285-292.

Massa, D., L. Incrocci, R. Maggini, G. Carmassi, C. A. Campiotti, and Pardossi, C. A. 2010. Strategies to decrease water drainage and nitrate emission from soilless culture of greenhouse tomato. *Agric. Water Manage*. 97: 971-980.

Neocleous, D. and Savvas, D. 2016. NaCl accumulation and macronutrient uptake by a melon crop in a closed hydroponic system in relation to water uptake. *Agricultural water management.* 165: 22-32.

Pineda, P. J., A. A. Ramírez, F. Sánchez-del Castillo, G. A. M. Castillo, A. L. Valdez and Vargas, C.J.M.. 2011. Extraction and nutrient efficiency during the vegetative growth of tomato under hydroponics conditions. *Acta Horticulturae* 893:997-1005.

Rameshwaran, P., Tepe, A., Yazar, A., and Ragab, R. 2016. Effects of drip-irrigation regimes with saline water on pepper productivity and soil salinity under greenhouse conditions. *Scientia Horticulturae*. 199:114-123.

Reséndiz-Melgar, R.C., Moreno-Pérez, E., Sánchez-Del Castillo, F., Rodríguez-Pérez, J. E. and Peña-Lomelí, A. 2010. Variedades de pimiento morrón manejadas con despunte temprano en dos densidades de población. *Revista Chapingo Serie Horticultura*. 16:223-229.

Sánchez-Del Castillo, F. y Escalante, R. E. 1988. Hidroponía. 3a ed. Universidad Autónoma Chapingo. *Chapingo, México. 194 p.*

Sánchez-Del Castillo, F., González-Molina, L., Moreno-Pérez, E. del C., Pineda-Pineda, J. and Reyes-González, C.E. 2014a. Nutritional dynamics and yield of cucumber grown in hydroponics with and without recirculation of the nutrient solution. *Rev. Fitotec. Mex*. 37 (3): 261 – 269.

Sánchez-Del Castillo, F., Moreno-Pérez, E., Pineda-Pineda, J., Osuna, J. Rodríguez-Pérez, J. E. and Osuna-Encino, T. 2014b. Hydroponic tomato (*Solanum lycopersicum* L.) production with and without recirculation of nutrient solution. *Agrociencia* 48: 185-197.

Sánchez-Del Castillo, F. Moreno-Pérez, E. del C., Reséndiz-Melgar, R.C., Colinas-León, M.T. and Rodríguez-Pérez, J. E. 2017. Bell pepper production (*Capsicum annuum* l.) in short cycles. *Agrociencia*. 51:437-446.

Savvas, D., Ntatsi, G. and Passam, H.C. 2008. Plant nutrition and physiological disorders in greenhouse grown tomato, pepper and eggplant. *The European Journal of Plan Science and Biotechnolog*y. 2:45-61.

Van, OS.E.A. 1999. Closed soilless growing systems: a sustainable solution for Dutch greenhouse horticulture. *Water science and technology*. 39: 105-112.

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