Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 12 June 2022
https://doi.org/10.14295/CS.v13.3638

Performance of colored bell pepper cultivars under different concentrations of nutrient solution

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Abstract

Knowledge on the nutritional requirement of the crop under cultivation systems adapted to local realities, in addition to the adequate availability of nutrients in nutrient solution, is of fundamental importance both for plant growth and for the production of quality fruits. Thus, the objective of this study was to evaluate the production performance of colored bell pepper cultivars in an open hydroponic system under different concentrations of nutrient solution. The experiment was carried out in a greenhouse at IFAL, Piranhas Campus, in a completely randomized experimental design with four replicates and in split plots, with plots containing three concentrations of nutrient solution (75%, 100% and 125%) and subplots containing three bell pepper cultivars (All Big, Sucesso and Beti-R). Concentration of nutrients at 75% of the standard nutrient solution differed from the other concentrations for plant height, stem diameter, leaf area and fresh and dry mass of the plant. The total number of fruits and number of marketable fruits were higher in the Beti-R and Sucesso hybrids when subjected to concentrations of 75% and 100%, respectively. The total yields of the Beti-R and Sucesso hybrids were higher at the concentration of 75%, with maximum values of 24.19 t ha^{-1} and 17.11 t ha^{-1}, respectively. The concentration of 100% of the standard solution promoted higher results for the All Big cultivar.

Keywords: *Capsicum annuum* L., Fertigation, hydroponics, plant nutrition

Introduction

Bell pepper (*Capsicum annuum* L.), belonging to the Solanaceae family, is a semi-perennial species of high commercial and nutritional value, being classified among the ten most important vegetables in the Brazilian market (Furtado et al., 2017). In the Northeast, bell pepper has a strong presence in cooking, besides being one of the main crops of family farming, contributing to the income of small and medium producers in the region.

Colored bell pepper fruits have gained space in the food marketing, reaching better prices due to the new needs and changes in the eating habits of consumers (Santos et al., 2018). Most bell pepper fruits are green, but the color changes when they ripen, with the green and red fruits being the most commercialized (Bernardo et al., 2018; Thuphairo et al., 2019).

Technologies aimed at increasing yield are applied to the cultivation of bell pepper (Sediyama et al., 2014), with emphasis on cultivation in a protected environment using hydroponic systems (Santos et al., 2017). This has attracted the attention of producers due to the reduction of costs and labor, since it promotes a reduction in the incidence of pests and diseases and the possibility of obtaining better fruit quality (Marques et al., 2019).

According to Oliveira Filho et al. (2018), although the commercial growth of colored bell peppers is evident, there is little information on their nutritional requirements, due to the number of varieties on the market, making it difficult to select specific cultivars for the producing regions. In this context, among the most important aspects of bell pepper production, the appropriate nutritional management stands out, which is an important factor for the growth and development of any crop (Raturi et al., 2019).

Soilless cultivation requires adjustment of the

Received: 07 October 2020
Accepted: 20 April 2021

composition of nutrients of the nutrient solution to the crop of interest. Souza et al. (2018) highlight that, in order to obtain high yield, nutrients must be supplied in appropriate quantities and proportions at all stages of the cycle. Thus, the use of a nutrient solution that meets the nutritional requirements of the crop is the first step towards successful production (Castoldi et al., 2014).

Bell pepper cultivation is usually difficult and fruit production is not always satisfactory. Nitrogen and potassium are some of the nutrients most extracted by bell pepper plants, which contribute to plant growth and fruit quality (Felisberto et al., 2016; Zeist et al., 2018).

In this context, this study aimed to evaluate the performance of colored bell pepper cultivars grown in hydroponic system with different concentrations of nutrient solution.

Material and Methods

The experiment was conducted in a greenhouse of the Federal Institute of Education, Science and Technology of Alagoas (IFAL), Piranhas Campus, from November 2019 to April 2020. The study area is located at the coordinates 9° 37' 20.83"S and 37° 45' 83"W, at an altitude of 181 m. According to Köppen's classification, the climate of the region is BSh (dry semi-arid), with average annual temperature between 26 and 30 °C (Barros et al., 2012). Data of rainfall, maximum air temperature, relative humidity and global solar radiation are presented in Figure 1, according to data from the IFAL weather station, Piranhas Campus.

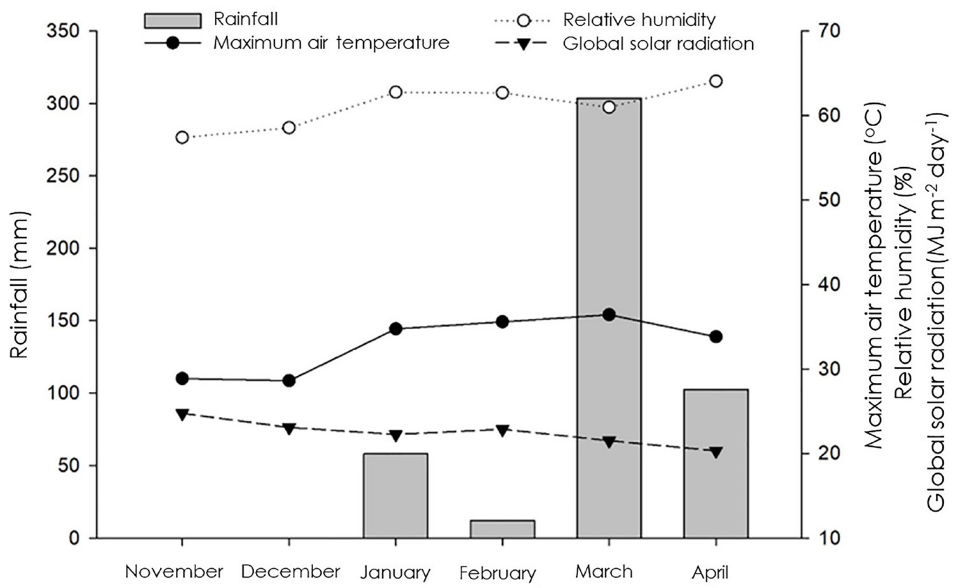

Figure 1. Values of rainfall, maximum air temperature, relative humidity and global solar radiation during the experiment with bell pepper (*Capsicum annuum* L.) from November 2019 to April 2020, in the municipality of Piranhas, Alagoas, northeastern semi-arid region of Brazil. Data obtained from the automatic weather station of the Federal Institute of Alagoas, Piranhas Campus (Inmet, 2021).

The experiment was conducted using a completely randomized design in split plots, with treatments consisting of three concentrations of nutrient solution (75%, 100% and 125%) in the plots and three bell pepper cultivars (All Big, Sucesso and Beti-R) in the subplots, with four replicates, totaling 36 experimental units. All units were considered useful for evaluation.

The cultivar All Big is characterized by its fruits with square shape and green color, having firm and thick pulp and sweet flavor (Araújo et al., 2009; Santos et al., 2017). The fruits of the hybrids Sucesso and Beti-R are characterized by rectangular shape and thick pulp, showing yellow and red colors, respectively (Isla, 2019; Sakata, 2020).

The bell pepper seedlings were produced in expanded polystyrene trays of 162 cells, containing the commercial substrate Tropstrato®, in which three seeds were planted per cell. Subsequently, the trays were placed in a greenhouse, receiving manual irrigation twice a day. Thinning was performed at 20 days after sowing (DAS), selecting the seedling with better development. At 35 DAS, the seedlings with better leaf and root development were transplanted.

The nutrient solution was prepared following the proposal of Hoagland and Arnon (1950), with modification according to nutritional requirements of the crop, at three concentrations of nutrients (Table 1). Micronutrients were supplied with the commercial fertilizer ConMicros

Standard®, whose amounts of micronutrients present in 25 g of the fertilizer were: Boron = 0.40 g; Copper = 0.40 g; Iron = 1.81 g; Manganese = 0.40 g; Molybdenum = 0.09 g; Nickel = 0.08 g and Zinc = 0.18 g. The fertilizers were added in three polyethylene boxes with capacity of 500 liters each and, daily, the pH and electrical conductivity of each solution were measured using a pH meter (Hedao, PH-009 model) and a portable conductivity meter (Instrutherm, CD-880 model), keeping a pH of 6.0 ± 0.5. The recorded values of initial electrical conductivity and used for replacement were: 1.20 mS cm^{-1} for the concentration of 75%, 1.61 mS cm^{-1} for the concentration of 100% and 2.01 mS cm^{-1} for the concentration of 125%.

Table 1. Fertilizers used to prepare the nutrient solutions proportional to each concentration evaluated.

Concentration	Calcium nitrate	Potassium nitrate	Magnesium sulfate	Potassium sulfate	Monopotassium phosphate	ConMicros®
	g 1.000 L^{-1}					
75%	631.8	296.2	400.4	66.1	33.3	18.8
100%	842.4	394.9	533.9	88.2	44.5	25.0
125%	1053.0	493.6	667.4	110.2	55.6	31.3

The cultivation system adopted in the experiment was open-loop hydroponics, set up in a greenhouse covered with 50% shade net (Sombrite®). One plant was placed in each 12-L plastic pot containing inert substrate (coconut shell fiber). At the bottom of the pots, a 5-cm-thick layer of crushed stone was placed, covered by a polyethylene screen. Then, the volume of the pots was completed with 2 kg of the substrate. The pots were arranged in rows, with spacing of 0.8 m between rows and 0.5 m between plants. Fertigation was applied using a drip system, with one emitter of 4.0 L h^{-1} per plant. Fertigation was performed twice a day according to the water needs of the crop by reference evapotranspiration, following the methodology of Trani et al. (2011). Green peach aphid and citrus mealybug (*Myzus persicae* and *Planococcus citri*) were mechanically controlled at 59 days after transplantation (DAT).

At 58 and 174 DAS, plant height (PH, cm), stem diameter (SD, mm) and leaf area (LA, cm^2) were evaluated using a ruler graduated in centimeters and a digital caliper of the Zaas® brand. Leaf area (LA, cm^2) was estimated according to the methodology proposed by Padron et al. (2016) for the bell pepper crop, using the following equation: Leaf Area = 0.57 x LW, where LW is the product of the length and width of the leaves.

Fruit diameter (FD, cm), fruit length (FL, cm) and pulp thickness (PT, mm) were evaluated at the time of the weekly harvests, using a ruler graduated in centimeters and a digital caliper.

To evaluate the fresh and dry mass (g $plant^{-1}$), the plants were separated into leaves, stem and roots. For the dry mass, the vegetative parts were placed in paper bags, dried in a forced air circulation oven at 65 °C for 72 h, and then weighed on a precision scale (0.0001 g). The total mass of fruits (TMF, g $plant^{-1}$) and the total mass of marketable fruits (TMMF, g $plant^{-1}$) were determined using a precision digital scale (0.0001 g). The total number of fruits (TNF) and number of marketable fruits (NMF) were quantified by counting in each plant.

The results of the variables were subjected to analysis of variance, applying the F test, and, when significant, Tukey tests ($p<0.05$) were performed to compare the means of the treatments. The application used was SISVAR, version 5.6 (Ferreira, 2011).

Results and Discussion

For the variables SFM and RFM (Table 2), there was a significant response to the concentration of the nutrient solution ($p < 0.05$), as well as for the variables PH, SD, LA, LFM, LDM, SDM and RDM ($p < 0.01$). Considering the individual effect of cultivars, there was a significant difference for PH and SFM ($p < 0.05$), FL, LFM and LDM ($p < 0.01$). Significant interactions between nutrient solution concentrations and colored bell pepper cultivars were recorded for TNF, NMF, TMF, TY and MY.

Beti-R and Sucesso did not differ from one another regarding the studied variables (Table 3). The cultivar All Big showed lower results in all variables analyzed compared to the other cultivars. A study carried out on the performance of cultivars in the semi-arid region of Bahia obtained similar results, in which the cultivar All Big showed lower production performance and commercially undesirable characteristics, reduced fruit diameter, length and mass, compared to the other cultivars analyzed (Silva et al., 2018). Phenological development and postharvest characteristics of bell pepper cultivars are influenced by environmental conditions, especially at high temperatures. Goldy (2020) analyzed 20 bell pepper cultivars for adaptability in hot season, June to August in Michigan (USA), and found that this condition caused reduction in vegetative and productive growth in the most sensitive cultivars, leading to production of 400 to 600 boxes below expected, in addition to the lower postharvest quality, mainly in terms of fruit length and diameter. According to Santos et al. (2017), fruit length and diameter are the main characteristics in the commercialization of bell pepper, due to the appreciation of the markets for large fruits, including the Brazilian market.

Table 2. Mean squares of the joint analysis of variance for the variables studied in colored bell pepper cultivars subjected to different concentrations of nutrient solution.

Source of variation	DF	Mean squares					
		PH	SD	LA	FL	FD	PT
Concentrations (C1)	2	1,766.33**	74.03**	1,522,946.16**	7.95^{ns}	3.90^{ns}	2.75^{ns}
Residual (1)	6	40.00	1.25	124,607.40	2.31	2.05	0.89
Cultivars (C2)	2	271.00*	2.75^{ns}	359,477.27^{ns}	35.95**	3.05^{ns}	1.79^{ns}
Interaction C1×C2	4	194.83^{ns}	2.03^{ns}	2,142,895.11^{ns}	6.28^{ns}	3.95^{ns}	1.49^{ns}
Residual (2)	18	80.25	1.93	1,060,475,27	4.17	1.56	1.07
CV1 (%)		8.01	7.33	6.82	19.01	26.05	22.17
CV2 (%)		10.53	9.12	19.89	25.51	22.79	24.31
Source of variation	DF	Mean squares					
		LFM	SFM	RFM	LDM	SDM	RDM
Concentration (C1)	2	37,441.09**	37,027.71*	7,174.48*	7,897.64**	14,835.76**	134.33**
Residual (1)	6	2,373.76	3,594.29	887.25	111.40	261.40	9.93
Cultivars (C2)	2	56,512.88**	33,867.22*	312.07^{ns}	4,256.16**	803.55^{ns}	21.38^{ns}
Interaction C1×C2	4	5,390.90^{ns}	6,396,.01^{ns}	621.82^{ns}	1,487.66^{ns}	2,375.87^{ns}	2.30^{ns}
Residual (2)	18	6,294.51	8,800.27	1,626.45	591.45	832.48	15.28
CV1 (%)		17.71	16.04	37.61	12.55	18.47	27.59
CV2 (%)		28.84	25.09	50.92	28.91	32.97	34.22
Source of variation	DF	Mean squares					
		TNF	NMF	TMF	TMMF	TY	MY
Concentration (C1)	2	43.86^{ns}	26.36*	249,737.45*	161,938.72*	156.15*	101.22*
Residual (1)	6	9.23	4.25	26,708.30	19,273.55	16.69	12.04
Cultivar (C2)	2	0.02^{ns}	8.11^{ns}	82,194.56^{ns}	167,854.64**	51,40^{ns}	104.78**
Interaction C1×C2	4	28.86*	23,48**	223,422.72**	243,127.24**	139.62**	151.98**
Residual (2)	18	7.44	4.64	23,473.81	17,744.29	14.66	11.09
CV1 (%)		50.41	41.69	32,49	30.61	32.49	30.61
CV2 (%)		45.27	43.58	30.46	29.37	30.45	29.37

PH - plant height; SD - stem diameter; LA - leaf area; FL - fruit length; FD - fruit diameter; PT - pulp thickness; LFM - leaf fresh mass; SFM - stem fresh mass; RFM - root fresh mass; LDM - leaf dry mass; SDM - stem dry mass; RDM - root dry mass; TNF - total number of fruits; NMF - number of marketable fruits; TMF - total mass of fruits; TMMF - total mass of marketable fruits; TY - total yield; MY - marketable yield. DF - degrees of freedom. CV - coefficient of variation. ^{ns}, *, ** - not significant, significant at 5 and 1% probability levels, respectively.

Table 3. Mean values of plant height (PH), fruit length (FL), leaf fresh mass (LFM), leaf dry mass (LDM), stem fresh mass (SFM), total mass of marketable fruits (TMMF) and marketable yield (MY) of colored bell pepper cultivars in hydroponic system.

Cultivars	PH (cm)	FL (cm)	LFM (g plant^{-1})	LDM (g plant^{-1})
All Big	74.16 b	6.01 b[1]	198.79 b	62.55 b
Sucesso	79.16 a	9.03 a	294.77 a	92.56 a
Beti-R	83.66 a	8.99 a	331.75 a	97.27 a

	SFM (g plant^{-1})	TMMF (g plant^{-1})	MY (t ha^{-1})
All Big	336.07 b	318.24 b	7.95 b
Sucesso	350.91 ab	536.37 a	13.41 a
Beti-R	434.60 a	506.12 a	12.65 a

[1]Means followed by the same letter in the columns do not differ statistically from each other by Tukey test at 5% probability level.

For the individual effect of the nutrient solution concentrations, it was observed that the LA showed a mean value of 92.66 cm at the concentration of 75%, differing from those obtained at the concentrations of 100% (74.83 cm) and 125% (69.50 cm) (Table 4). Results obtained by Oliveira et al. (2014) evaluating bell pepper seedlings with nutrient solution showed higher plant height at the concentrations of 60 to 85% of the nutrient solution, corroborating the results obtained in the present study.

As observed for PH, SD at the nutrient solution concentration of 75% showed the highest value (18.06 mm), differing from the SD obtained at the other concentrations (Table 4). A mean value of 14.38 mm was recorded at the standard concentration (100%), while the concentration of 125% led to a value of 13.33 mm. It is verified that salinity in the nutrient solution is due to high levels of ions of salts or fertilizers, and consequently greater conductivity (Souza et al., 2018). The reduction of diameter may be related to the high electrical conductivity present at the highest concentrations of nutrient solution, influencing the vegetative growth of the plants (Santos et al., 2020; Miceli et al., 2020).

Table 4. Mean values of plant height (PH), stem diameter (SD), leaf area (LA) and leaf fresh mass (LFM) under different concentrations of nutrient solution.

Concentrations	PH (cm)	SD (cm)	LA (cm^2)	LFM (g $plant^{-1}$)
75%	92.66 a[1]	18.06 a	5.587.46 a	339.41 a
100%	74.83 b	14.38 b	4.977.30 b	247.22 b
125%	69.50 b	13.33 b	4.963.76 b	238.67 b

[1]Means followed by the same letter in the columns do not differ statistically from each other by Tukey test at 5% probability level.

LA showed a similar behavior to that observed for the other variables. The standard concentration (100%), 4,977.30 cm^2, and the concentration of 125%, (4,963.76 cm^2), had lower means of LA, differing from the results obtained at the concentration of 75% (5,587.46 cm^2) (Table 4). With the increase in the electrical conductivity from 1.44 dS m^{-1} (75% solution) to 2.36 dS m^{-1} (125% solution), there was a decrease in the variables evaluated. In a study with the tomato crop, cultivars Cereja Pendente Yubi, Santa Amélia and Santa Adélia, Santos et al. (2016) concluded that plant development is affected by the toxicity resulting from the accumulation of soluble salts, which is observed in the results obtained in the present study, given the higher electrical conductivities at the highest concentrations of solutions, 1.84 and 2.35 dS m^{-1}, respectively. For LFM, the concentration of 75% differed from the others with the highest accumulation of leaf fresh mass (339.41 g $plant^{-1}$), while the lowest accumulation was obtained at the concentration of 125% (238.67 g $plant^{-1}$) (Table 4). For LDM, the values ranged from 67.11 to 113.64 g $plant^{-1}$, with the lowest result for the concentration of 125% and the highest result for 75% of the nutrient solution (Table 5).

Table 5. Mean values of leaf dry mass (LDM), stem fresh mass (SFM), stem dry mass (SDM), root fresh mass (RFM), leaf dry mass (LDM) and root dry mass (RDM) under different concentrations of nutrient solution.

Concentrations	LDM	SFM	SDM	RFM	RDM
	g $plant^{-1}$				
75%	113.64 a[1]	428.77 a	127.36 a	105.48 a	14.80 a
100%	71.64 b	375.12 ab	74.34 b	75.00 ab	11.36 ab
125%	67.11 b	317.70 b	60.84 b	57.12 b	8.10 b

[1]Means followed by the same letter in the columns do not differ statistically from each other by Tukey test at 5% probability level.

In general, the effect of electrical conductivity due to the salts causes several physiological changes in the plants. In bell pepper, several symptoms have already been observed, including: reduction in stomatal conductance, photosynthesis, chlorophyll deficiency and consequently reduction of dry mass (Ziaf et al., 2009; Sá et al., 2016). It is verified that the reductions in the development and production in bell pepper cultivars with moderate sensitivity are attributed to the deleterious effects resulting from the ions present at the highest concentrations of nutrient solution, leading to reduction of fresh and dry mass in bell pepper. In this context, Nunes et al. (2013) and Sá et al. (2016) observed that there is loss of biomass due to the reduction of gas exchange and efficiency of photosystem II in tomato and bell pepper crops, resulting from the accumulation of salts in the apoplast of leaf cells.

With the increase in the concentration of nutrients, there was a decrease in SFM, with a variation between 317.70 and 428.77 g $plant^{-1}$ and highest mass obtained at the concentrations of 75% and 100%, whose mass accumulation did not differ (Table 5). In SDM, there was also a reduction according to the increase in nutrient concentrations. The standard concentration (100%) led to a value of 74.34 g $plant^{-1}$, but the highest mass was promoted by the concentration of 75% (127.36 g) (Table 5). According to Sharma et al. (2018), the accumulation of mass in the bell pepper crop grown in hydroponic systems is correlated with the ideal pH of the solution from 5.5 to 6.0 and EC from 0.8 to 1.8 dS m^{-1}. For example, tomato crop in hydroponic system reduces growth and yield when the nutrient solution EC is above 2.5-4.0 dS m^{-1} (Zhang et al., 2016).

The RFM obtained the highest result at the concentration of 75% of the nutrient solution (105.48 g $plant^{-1}$), followed by the standard concentration (100%), with 75 g $plant^{-1}$. The increasing concentration on colored bell pepper plants also caused reduction in RDM for the crop. The highest mean value was obtained at the concentration of 75% of the nutrient solution (14.80 g $plant^{-1}$), with the lowest result at the concentration of 125% (8.10 g $plant^{-1}$). The high use of fertilizers can lead to soil and/or substrate salinity (Nunes Junior et al., 2017), causing reductions in the production and root development of bell pepper plants. This has also been observed by other authors in hydroponic cultivation (Cosme et al., 2011; Gomes et al., 2011) with tomato crop.

In relation to TNF, the hybrid Beti-R showed higher production at the concentration of 75% of the nutrient solution, with 10.50 fruits per plant, while at the concentration of 100% the cultivars All Big (9.25) and Sucesso (7.0) obtained higher TNF, differing from the cultivar Beti-R. It is observed that the higher the nutrient concentration, the lower the TNF (Table 6).

Table 6. Total number of fruits (TNF) of colored bell pepper cultivars under nutrient solution concentrations.

Cultivars	Concentrations		
	75%	100%	125%
	Total number of fruits		
All Big	4.75 ABb[1]	9.25 Aa	4.00 Ba
Sucesso	6.75 Aab	7.00 Aa	4.25 Aa
Beti-R	10.50 Aa	4.50 Ba	3.25 Ba

[1]Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically from each other by Tukey test at 5% probability level.

These results corroborate those obtained by Nunes et al. (2013), who found that the nutrient solution EC above 1.2 dS m^{-1} resulted in lower production of fruits of bell pepper grown on coconut fiber substrates. Despite the reduction of TNF at the highest concentration, there was no nutritional disorder in bell pepper fruits. However, the reduction in the number of fruits at the highest concentrations is possibly due to the migration of Na^+ and Cl^- to the photoassimilates, leaves and later to the fruits. Similar results have been obtained by Unlukara et al. (2015), Oliveira et al. (2018) and Santos et al. (2019), who found reduction in TNF with bell pepper cultivated in hydroponic system.

Similar results were obtained for NMF. The cultivar Beti-R reached 9.25 marketable fruits per plant at the concentration of 75% of the nutrient solution (Table 7), while the cultivar All Big, as well as the hybrid Sucesso, were inferior and did not differ from each other.

Table 7. Number of marketable fruits (NMF) of colored bell pepper cultivars under concentrations of nutrient solution.

Cultivars	Concentrations		
	75%	100%	125%
	Number of marketable fruits		
All Big	2.50 Bb[1]	6.50 Aa	3.00 ABa
Sucesso	6.25 Aab	6.25 Aa	4.00 Aa
Beti-R	9.25 Aa	4.00 Ba	2.75 Ba

[1]Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically from each other by Tukey test at 5% probability level.

For TMF at the concentration of 75% of the nutrient solution, the cultivar Beti-R reached 967 g $plant^{-1}$, differing from the other cultivars (Table 8). However, in the nutrient solution of 100% the cultivars All Big and Sucesso recorded higher production (585.80 and 535.61 g $plant^{-1}$, respectively), not differing statistically from each other. For all cultivars, a decrease was observed with the increase in nutrient concentrations.

According to Lins et al. (2016), the reduction in TMF indicates that plants, despite being cultivated with higher nutritional supply, do not have the capacity to raise photosynthesis to supply a large number of fruits, without affecting the mass of fruits, thus showing a low source:sink ratio.

Table 8. Total mass of fruits (TMF) of colored bell pepper cultivars under nutrient solution concentrations.

Cultivars	Concentrations		
	75%	100%	125%
	Total mass of fruits (g $plant^{-1}$)		
All Big	305.79 Bc[1]	585.80 Aa	332.78 ABa
Sucesso	684.37 Ab	535.61 Aa	460.48 Aa
Beti-R	967.60 Aa	354.00 Ba	300.90 Ba

[1]Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically from each other by Tukey test at 5% probability level.

Similar results were obtained for TMMF, and the cultivar Beti-R stood out for having a higher TMMF compared to the others (906.42 g $plant^{-1}$) at the nutrient solution concentration of 75%. At this same concentration, the cultivar Sucesso recorded 659.74 g $plant^{-1}$, while the cultivar All Big, 159.57 g $plant^{-1}$ (Figure 9). At the standard concentration (100%), the cultivars showed 500.39 g $plant^{-1}$, 323.88 g $plant^{-1}$ and 500.71 g $plant^{-1}$, for All Big, Beti-R and Sucesso, respectively. As observed for TMF, the TMMF recorded a reduction in fruit mass as a function of the increase of nutrients in the nutrient solution

Sharma et al. (2018) point out that, since bell pepper is moderately sensitive to a limit value of electrical conductivity of the solution, maximum of 1.8 dS m^{-1}, higher values of EC cause reduction of yield. Kurunc et al. (2011) and Unlukara et al. (2015) observed that, as the salt concentration increased, the plants corresponded with a reduction in yield, reaching the order of 14%.

Table 9. Total mass of marketable fruits (TMMF) of colored bell pepper cultivars under nutrient solution concentrations.

Cultivars	Concentrations		
	75%	100%	125%
		Total mass of marketable fruits (g plant^{-1})	
All Big	159.57 Bc[1]	500.39 Aa	294.77 ABa
Sucesso	659.74 Ab	500.71 Aa	448.65 Aa
Beti-R	906.42 Aa	323.88 Ba	288.05 Ba

[1]Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically from each other by Tukey test at 5% probability level.

Regarding TY, considering all the harvests performed, it was found that at the concentration of 75% of the nutrient solution, the cultivar Beti-R had higher yield (24.19 t ha^{-1}), differing from All Big and Sucesso; when Beti-R was cultivated at the other concentrations, there was a reduction in yield (Table10). This behavior was not observed in the cultivar All Big, which showed the highest result at the concentration of 100% of the nutrient solution (14.64 t ha^{-1}).

It was observed that the increase in nutrient concentration resulted in lower TY of bell pepper cultivars, and this reduction is due to morphological and physiological damage, caused by the reduction in the osmotic potential of the nutrient solution to the production components in less tolerant cultivars (Azarmi et al., 2010; Bustomi et al., 2014; Shimul et al., 2014; Liu et al., 2014), as the reductions in root development, leaf development, chlorophyll content and consequently yield.

Table 10. Total yield (TY) of colored bell pepper cultivars under nutrient solution concentrations.

Cultivars	Concentrations		
	75%	100%	125%
		Total yield (t ha^{-1})	
All Big	7.64 Bc[1]	14.64 Aa	8.31 ABa
Sucesso	17.11 Ab	13.39 Aa	11.51 Aa
Beti-R	24.19 Aa	8.85 Ba	7.52 Ba

[1]Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically from each other by Tukey test at 5% probability level.

For MY, the nutrient solution concentration of 75%, when analyzed among cultivars, led to higher yields for Beti-R (22.66 t ha^{-1}) and Sucesso (16.49 t ha^{-1}) (Table 11). For the cultivar All Big, it was observed higher marketable yield at the concentration of 100% (12.51 t ha^{-1}). Similar results have been obtained by Nunes et al. (2013) and Santos et al. (2019) in the production of bell peppers using nutrient solutions.

Table 11. Marketable yield (MY) of colored bell pepper cultivars under nutrient solution concentrations.

Cultivars	Concentrations		
	75%	100%	125%
		Marketable yield (t ha^{-1})	
All Big	3.98 Bc[1]	12.51 Aa	7.37 ABa
Sucesso	16.49 Ab	12.51 Aa	11.21 Aa
Beti-R	22.66 Aa	8.09 Ba	7.20 Ba

[1]Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically from each other by Tukey test at 5% probability level.

Conclusions

Plants with higher growth and fruit yield are obtained at the concentration of 75% of the nutrient solution for the hybrids Beti-R and Sucesso. The standard concentration (100% of the nutrient solution) favored the cultivar All big in obtaining higher results.

Acknowledgments

To IFAL for providing financial support to conduct the research.

References

Araújo, J.S., Andrade, A.P., Ramalho, C.I., Azevedo, C.A.V. 2009. Características de frutos de pimentão cultivado em ambiente protegido sob doses de nitrogênio via fertirrigação. *Revista Brasileira de Engenharia Agrícola e Ambiental* 13: 152–157.

Azarmi, R., Taleshmikail, R.D., Gikloo, A. 2010. Effects of salinity on morphological and physiological changes and yield of tomato in hydroponics system. *Journal Food Agricultural Environment* 8: 573-576.

Barros, A.H.C., Araújo Filho, J.C., Silva, A.B., Santiago, G.A.C.F. 2012. *Climatologia do Estado de Alagoas*. Boletim de Pesquisa e Desenvolvimento. Embrapa, Recife, Brasil. 32p.

Bernardo, D.B.F., Lopes, M.N., Lucena, M.L., Lopes, W.E., Chinelate, G.C.B., Medeiros, E.V. 2018. Caracterização física e físico-química de frutos de pimentão com diferentes colorações comerciais. *Revista Brasileira de Agrotecnologia* 8: 07-12.

Bustomi R.R.A., Senge, M.S.T.R., Suhandy, D., Tusi, A. 2014. The Effect of EC Levels of Nutrient Solution on the Growth, Yield, and Quality of Tomatoes (*Solanum lycopersicum*) under the Hydroponic System. *Journal Agricultural Engineering and Biotechnology* 2: 7-12.

Castoldi, R., Gomes, R.F., Charlo, H.C.O., Melo, D.M., Braz, L.T. 201. Performance of cucumber hybrids cultivated in coconut fiber and soil. *Horticultura Brasileira* 32: 86-90.

Cosme, C.R., Dias, N.D.S., Oliveira, A.M.D., Oliveira, E.M., Sousa Neto, O.N.D. 2011. Produção de tomate hidropônico utilizando rejeito da dessalinização na solução nutritiva aplicados em diferentes épocas. *Revista Brasileira de Engenharia Agrícola e Ambiental* 15: 499-504.

Felisberto, P.A.C., Godoy, L.J.G., Felisberto, G. 2016. Índices de cor da folha para monitoramento nutricional de nitrogênio em plantas de pimentão. *Científica* 44: 207-216.

Ferreira, D.F. Sisvar: a computer statistical analysis system. 2011. *Ciência e Agrotecnologia* 35: 1039-1042.

Furtado, G.F., Cavalcante, A.R., Chaves, L.H.G., Santos Júnior, J.A., Gheyi, H.J. 2017. Growth and production of hydroponic pepper under salt stress and plant density. *American Journal of Plant Sciences* 8: 2255-2267.

Goldy, R.G. 2020. Performance of 20 Bell Pepper Cultivars In Southwest Michigan. *Midwest Vegetable Trial Reports* 19: 02-12.

Gomes, J.W.D.S., Dias, N.D.S., Oliveira, A.M.D., Blanco, F.F., Sousa Neto, O.N.D. 2011. Crescimento e produção de tomate cereja em sistema hidropônico com rejeito de dessalinização. *Revista Ciência Agronômica* 42: 850-856.

Hoagland, D.R., Arnon, D.I. 1950. *The water-culture method for growing plants without soil*. California Agricultural Experimental Station, Berkeley, USA. 347 p.

INMET. Instituto Nacional de Meteorologia. Tabelas de dados das estações: estação automática PIRANHAS (A371). 2021. Available at: <Available at: https://tempo.inmet.gov.br/TabelaEstacoes/A371 >. Accessed on: Jan. 2021.

Isla Sementes. Catálogo de produtos. 2019. https://isla.com.br/media/catalogos/Catalogo%20ISLA%202019.pdf. <Access on: Apr. 06, 2021>

Kurunc, A., Unlukara, A., Cemek, B. 2011. Salinity and drought affect yield response of bell pepper similarly. *Acta Agriculturae Scandinavica, Section B – Plant Soil Science* 61: 514-522.

Lins, H.A., Albuquerque, J.R.T., Queiroga, R.C.F., Sá, F.V.S., Pereira, A.M., Silva, A.B., Paiva, E.P. 2016. Biomass accumulation, plant biometrics and fruit production of watermelon according to changes in source/drain relations. *Comunicata Scientiae* 7: 272-279.

Liu, F.Y., Li, K.T., Yang, W.J. 2014. Differential responses to short-term salinity stress of heat-tolerant cherry tomato cultivars grown at high temperatures. *Horticulture Environment Biotechnology* 55: 79-90.

Marques, D.J., Siqueira, J.A.C., Bianchini, H.C., Alves, V.M. 2019. Production of Passion fruit in a semi-hydroponic system under protected cultivation. *Revista Brasileira de Fruticultura* 4: e-094.

Miceli, A., Vetrano, F., Moncada, A. 2020. Effects of foliar application of gibberellic acid on the salt tolerance of tomato and sweet pepper transplants. *Horticulturae* 6: 4, 93.

Nunes Junior, E.S., Medeiros, J.F., Oliveira, F.A., Lima, L.A., Bezerra, F.M.S., Alves, R.C. 2017. Nitrogen and potassium fertigation in bell pepper cultivated in greenhouse using fertigation managements. *Revista Brasileira de Engenharia Agrícola e Ambiental* 21: 186-190.

Nunes, R.L.C., Dias, N.S., Moura, K.K.C.F., Souza Neto, O., Costa, J.S. 2013. Efeitos da salinidade da solução nutritiva na produção de pimentão cultivado em substrato de fibra de coco. *Revista Caatinga* 26: 48-53.

Oliveira, F.A., Alves, R.C., Bezerra, F.M.S., Medeiros, A.S. 2018. Heterogeneous salinity in the root system of bell pepper in greenhouse. *Revista Brasileira de Engenharia Agrícola e Ambiental* 22: 519-524.

Oliveira, F.A., Medeiros, J.F., Linhares, P.S.F., Alves, R.C., Medeiros, A.M.A., Oliveira, M.K.T. 2014. Produção de mudas de pimenta fertirrigadas com diferentes soluções nutritivas. *Horticultura Brasileira* 32: 458-463.

Oliveira Filho, P., Valnir Júnior, M., Almeida, C.L., Lima, J.S., Costa, J.N., Rocha, J.P.A. 2018. Crescimento de cultivares de pimentão em função da adubação potássica. *Revista Brasileira de Agricultura Irrigada* 12: 2814-2822.

Padron, R.A.R., Lopes, S.J., Swarowsky, A., Cerquera, R.R., Nogueira, C.U., Maffei, M. 2016. Non-destructive models to estimate leaf area on bell pepper crop. *Ciência Rural* 46: 1938-1944.

Raturi, H.C., Uppal, G.S., Singh, Sk., Kachwaya, Ds. 2019. Effect of organic and inorganic nutrient sources on growth, yield and quality of bell pepper (*Capsicum annuum* L.) grown under polyhouse condition. *Journal of Pharmacognosy and Phytochemistry* 8: 1788-1792.

Sá, F.V.S., Lima, G.S., Santos, J.B., Ghey, H.R., Anjos Soares, L.A., Cavalcante, L.F., Paiva, E.P., Souza, L.P. 2016. Growth and physiological aspects of bell pepper (*Capsicum annuum*) under saline stress and exogenous application of proline. *African Journal of Biotechnology* 15: 1970-1976.

Sakata Seed Corporation. Catálogo de Hortaliças. 2020. https://www.sakata.com.br/catalogo/catalogo. <Access on: Apr. 06, 2021>

Santos, F.S.S.D., Viana, T.V.D.A., Costa, S.C., Sousa, G.G.D., Azevedo, B.M.D. 2019. Growth and yield of semi-hydroponic bell pepper under desalination waste-water and organic and mineral fertilization. *Revista Caatinga* 32: 1005-1014.

Santos, L., Santos, J.K.B., Santos, E., Santos, T.T., Chagas, A.B., Neves, J.D.S., Barros, R.P., Reis, L.S. 2017. Desenvolvimento de duas variedades de hortaliças da família Solanaceae em solo com diferentes tipos de substratos. *Revista Ambientale* 9: 1-7.

Santos, L.J.S., Divíncula, J.S., Santos, L.A., Vieira, J.H., Carneiro, P.T. 2020. Efeito da salinidade na produção de mudas de pimentão. *Brazilian Journal of Development* 6: 29354-29363.

Santos, P.R., Melo, R.A., Carvalho Filho, J.L.S., Ferreira, I.V.S., Silva, F.S., Lima Filho, F.P., Menezes, D. 2017. Desempenho de linhagens e híbridos de pimentão em dois sistemas de poda no cultivo hidropônico. *Horticultura Brasileira* 35: 129-134.

Santos, T.S., Oliveira, F.A., Costa, J.P.B.M., Souza Neta, M.L., Alves, R.C., Costa, L.P. 2016. Qualidade de mudas de cultivares de tomateiro em função de soluções nutritivas de concentrações crescentes. *Revista Agro@mbiente On-line* 10: 326-333.

Santos, T.T., Chagas, A.B., Santos, J.K.B., Santos, E., Barros, R.P. 2018. Estudo do desenvolvimento fenológicos de duas gerações de pimentão All Big (*Capsicum annum* L.) plantados em vasos. *Diversitas Journal* 3: 539-548.

Sediyama, M.A.N., Santos, M.R.D., Vidigal, S.M., Pinto, C.L.D.O., Jacob, L.L.2014. Nutrição e produtividade de plantas de pimentão colorido, adubadas com biofertilizante suíno. *Revista Brasília de Engenharia Agrícola e Ambiental* 18: 558-559.

Sharma, N., Acharya, S., Kumar, K., Singh, N., Chaurasia, O. P. 2018. Hydroponics as an advanced technique for vegetable production: An overview. *Journal of Soil and Water Conservation* 17: 364-371.

Shimul, M.A.H., Ito S.I.C., Sadia, S., Roni, M.Z.K., Jamal U ddin, A.F.M. 2014. Response of tomato (*Lycopersicon esculentum*) to salinity in hydroponic study. *Bangladesh Research Publications Journal* 10: 249-254.

Silva, Y.C.P., Oliveira, E.P., Oliveira, E.P., Brito, C.F.B., Fonseca, V.A. 2018. Desempenho de cultivares de pimentão na região semiárida baiana. *Revista Agrotecnológica* 9: 46-53.

Souza, F.I., Dias, N.S., Diniz, A.A., Silva Sá., F.V., Mesquita, F.O., Sousa Neto, O.N. 2018. Produção e qualidade de frutos de pepineiro em diferentes concentrações de solução nutritiva. *Revista Brasileira de Agricultura Irrigada* 12: 3048-3057.

Thuphairo, K., Sornchan, P., Suttisansanee, U. 2019. Bioactive compounds, antioxidant activity and inhibition of key enzymes relevant to alzheimer's disease from sweet pepper (*Capsicum annuum*) extracts. *Preventive Nutrition and Food Science* 24: 327–337.

Trani, P.E., Tivelli, S.W., Carrijo, O.A. 2011. *Fertirrigação em hortaliças*. Instituto Agronômico, Campinas, Brasil, 51p.

Ünlükara, A., Kurunc, A., Cemek, B. 2015. Green long pepper growth under different saline and water regime conditions and usability of water consumption in plant salt tolerance. *Journal of Agricultural Sciences* 21: 167-176.

Zeist, A.R., Zanin, D.S., Camargo, C.K., Resende, J.Tv., Ono, E.O., Rodrigues, J.D. 2018. Fruit yield and gas exchange in bell peppers after foliar application of boron, calcium, and Stimulate. *Horticultura Brasileira* 36: 498-503.

Zhang, P., Senge, P., Dai, Y. 2016. Effects of salinity stress on growth, yield, fruit quality and water use efficiency of tomato under hydroponics system. *Reviews in Agricultural Science* 4: 46-55.

Ziaf, K., Amjad, M., Pervez, M.A., Iqbal, Q., Rajwana, I.A., Ayyub, M. 2009. Evaluation of different growth and physiological traits as indices of salt tolerance in hot pepper (*Capsicum annuum* L.). *Pakistan Journal of Botany* 41: 1797-809.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.