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SOIL SOLUBILITY MONITORING IN RESPONSE TO DIFFERENT FERTILIZATION IN BELL PEPPER CULTIVATION

MONITORAMENTO DA SOLUÇÃO DO SOLO EM FUNÇÃO DE DIFERENTES ADUBAÇÕES NA CULTURA DO PIMENTÃO

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ABSTRACT: Bell peppers (Capsicum annum L.) are one of the most consumed and produced vegetables in Brazil. One of the challenges in their production is their sensitivity to soil salinity, especially in protected cultivation where fertigation is used. The objective of this study was to monitor the development and production of Bell peppers in different saline concentrations by monitoring the soil solution. The experiment was conducted in greenhouse conditions in the city of Bauru, SP, using the Theo variety of seedlings. The design was completely randomized, with three treatments: T1 (control), T2 (recommended fertilization for the crop), and T3 (fertilization with three times the crop's need). At 50 and 78 days after transplanting, the plant's biometric parameters were evaluated. Soil solution management was found to be a viable solution, given the results obtained in the development and production of pepper crops. Furthermore, treatments two and three promoted an increase in the plant's fresh and dry biomass, number of leaves, and stem diameter. However, they also caused the accumulation of salts in the soil, resulting in the loss of productivity, fruit fresh mass, and skin thickness.

Keywords: *Capicum, salinity, electrical conductivity, productivity.*

RESUMO: O pimentão (Capicum annum L.) tem se destacado por ser uma das hortaliças mais consumidas e produzidas no Brasil. Uma das dificuldades encontradas para sua produção é sua sensibilidade à salinidade do solo, principalmente em cultivo protegido onde se emprega a fertirrigação. O objetivo deste estudo foi acompanhar o desenvolvimento e a produção do pimentão em diferentes concentrações salinas, através do monitoramento da solução do solo. O experimento foi conduzido em ambiente protegido na cidade de Bauru-SP, a muda utilizada foi da variedade Theo. O delineamento foi inteiramente casualizado, sendo três tratamentos, onde: T1 (testemunha), T2 (adubação recomendada para cultura), T3 (adubação com tres vezes a necessidade da cultura). Ao fim dos 50 e 78 dias após o transplantio foram avaliados os parâmetros biométricos da planta. O manejo de adução via solução do solo apresentou-se uma solução viável, tendo em vista os resultados obtidos de desenvolvimento e produção da cultura do pimentão. Além disso, os tratamentos dois e três, promoveram aumento da biomassa frescaca e seca da planta, número de folhas e o diâmetro do caule. Também proporcionaram o acúmulo de sais no solo que resultou na perda da produtividade, massa fresca do fruto e espessura de casca.

Palavras-chave: *Capicum, salinidade, condutividade elétrica, produtividade.*

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INTRODUCTION

Bell peppers (Capicum annum L.) have been prominent in Brazil as one of the main vegetables produced in the country. Another positive aspect of this crop is its adaptability to different cultivation systems. Production can take place in the open field or in a protected environment, with the latter being the most popular choice due to several factors (ARAÚJO, 2013). Protected cultivation followed by fertigation, when well-structured, is an effective way to increase productivity in vegetable species. This form of cultivation also reduces pest attacks and avoids nutrient losses through leaching (SILVA, 2014). However, this benefit should not be overestimated when compared to conventional fertilization in a protected environment, due to differences in productivity (BRESLER, 1977).

Silva (2014), reports that the possibility of enhancing soil salinization is common in a protected environment as in a conventional system, due to the excessive use of fertilizers. According to the author, soil salinization is more accelerated in a fertigated system, as soil and irrigation management may be inadequate. These are aspects that must be well managed to avoid soil salinization.

BellPepper is a salinity-sensitive crop, tolerating between 1.3 and 3.0 dS m-1 of electrical conductivity (EC), therefore, at high concentrations the loss of productivity is significant (ANDRADE et al., 2016).

Lima et al. (2017), highlight that electrical conductivity is directly proportional to the concentration of salts. Therefore, monitoring the EC to obtain the saline solution index is important, considering that the higher the concentration of salts, the higher the EC value (SOUZA et al., 2013). Pedrotti et al. (2015) demonstrated that the chemical and physical aspects of soils with high salinity inhibit the uptake of nutrients by plants. Therefore, the proper ionic balance and physical-chemical aspect, as well as the maintenance of fertilizers in soluble form, are necessary conditions for plants to absorb nutrients properly (MARFÁ, 1987).

Silva et al. (2013) stated that the correct way for plants to absorb nutrients is through the constant application of them to the root area at levels equal to those absorbed by plants. This intensifies the effectiveness of the use of these nutrients and minimizes their loss through leaching and salinity.

Therefore, it is important to increase the use of new tools such as soil solution extractors and soil fertility management, aiming to reduce the impacts generated by the excessive use of fertilizers. Thus, monitoring the soil solution would be an alternative to adjust fertilizer management and provide greater productive gains (SOUZA et al., 2013). Based on the above, the objective of this work was to evaluate the development and production of bell peppers at three different levels of soil fertility, in addition to monitoring the soil solution.

MATERIAL AND METHODS

The experiment was conducted in a protected cultivation area at the experimental site of the Integrated Colleges of Bauru (FIB) in the city of Bauru, São Paulo, with coordinates 22°20'41.1"S and 49°06'24.7"W at an elevation of 530 meters above sea level. The soil used in the experiment was collected from 9 points at a depth of 0 to 40 cm, forming a composite sample, which was then sent to the laboratory for chemical and physical analysis (Table 1).

Table 1. Values of the chemical and physical analysis of the soil used in the bell pepper experiment.

pH	**M.O.**	**P**	**Al^{3+}**	**H**	**$H+Al^{3+}$**	**K**	**Ca**	**Mg**	**V**	**SB**	**CTC**
Ca Cl_2	g dm^{-3}	mg dm^{-3}	-------------mmolc dm^{-3}--------------						%	mmolc dm^{-3}	
4,4	7,3	170,4	2,64	18,88	21,52	5,03	32,6	18,6	72	56,23	77,75

B	**Cu**	**Mn**	**Zn**	**Fe**
------------------------------------ mg dm^{-3} ---------------------------------				
0,29	0,7	1,2	0,3	86

Corse Sand	**Fine sand**	**Total sand**	**Clay**	**Silt**	**Texture**
		g kg^{-1}			
668	199	867	100	33	Sandy

For the experiment, 60 plastic pots with a capacity of 14 liters were used. They were filled with 13 liters of soil and 2 liters of commercial Carolina Soil substrate. Soil correction was based on the methodology of Raij et al. (1997) in order to raise the V% to 80 (4.5 grams of limestone were added). After the pots were incubated for 15 days, the seedlings were transplanted. This interval was respected to allow the limestone to be incorporated into the soil.

The transplanting was carried out on October 3, 2020, using pepper seedlings of the Theo variety. One day before transplanting the seedlings, the soil was saturated to standardize the soil water content. The experimental design used was completely randomized (CRD), consisting of 3 treatments with 20 replications: T1: no fertilization (control); T2: fertilization according to the crop's needs; T3: fertilization with 3 times the crop's needs.

Fertilization was done through fertigation, as recommended by Raij et al. (1997), with an application frequency of every 10 days starting from the date of transplanting the seedlings (table 2).

Table 2. Fertilization should be applied every 10 days starting from the transplant date.

	Fertilization					
DAT	TRATAMENT 1 g pot^{-1}			TRATAMENT 2 g pot^{-1}		
	UREA	MAP	KCl	UREA	MAP	KCl
10	0,222	0,000	0,167	0,667	0,000	0,500
20	0,222	0,000	0,167	0,667	0,000	0,500
30	0,222	0,167	0,167	0,667	0,500	0,500
40	0,556	0,167	0,750	1,667	0,500	2,250
50	0,889	0,250	0,833	2,667	0,750	2,250
60	1,111	0,250	1,500	3,333	0,750	4,500

The values of urea and potassium chloride (KCl) shown in Table 2 were multiplied by 20 (the number of pots per treatment). The amount of both fertilizers was then diluted in a 2-liter solution and 100 mL was distributed to each pot. The same procedure was followed for MAP, but it was diluted in a 1-liter solution and 50 mL was applied per pot. Small doses of a calcium source were also applied during the experiment to meet the plant's calcium needs and prevent injuries caused by calcium deficiency. According to the methodology of Gomes et al. (2015), irrigation was managed according to the soil water retention curve, using four tensiometers installed and distributed throughout the experiment at a depth of 12 cm, to monitor the soil water tension (Figure 1) and maintain the soil water content at field capacity (FC).

Tension measurements (kPa) were taken daily around 6 pm using a digital tensiometer to determine the irrigation depth based on the available water content (AWC).

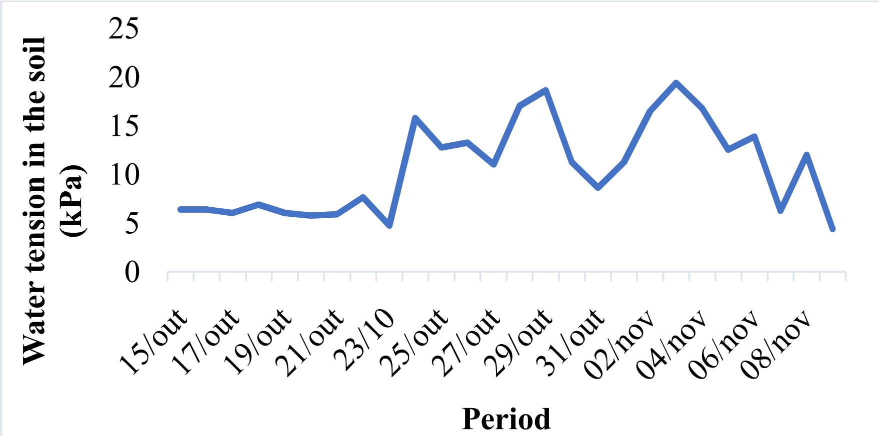

Figure 1. Average soil water tension

To maintain the soil all treatments at field capacity for, the irrigation volumes ranged from 300 mL to 500 mL as needed, with the determining factors being between 5 kPa (lower limit of soil water content) and 20 kPa (upper limit of soil water content).

During the experiment, soil solution was also collected weekly using a porous capsule soil extractor. Six extractors were installed per treatment at a depth of 12 cm. One day before collecting the soil solution, a vacuum was applied using a syringe, and after 24 hours, extraction was performed to monitor pH and electrical conductivity. Measurements were taken using a pH meter and a conductivity meter. After 50 days of transplantation (DAT), 10 plants per treatment were randomly selected for the first evaluation (totaling 30 plants in the first evaluation). The following characteristics were evaluated: plant height (cm), stem diameter (cm), aboveground plant fresh weight (g) and dry weight (g), plant roots fresh weight (g) and dry weight (g), and the number of leaves, branches, and fruits per plant.

At the end of 78 days after DAT, the same parameters were evaluated for the remaining 30 plants, including the fresh weight of each fruit per plant (g) and skin thickness (cm). The data obtained in the experiment were subjected to analysis of variance and mean comparison using the Tukey test at a 5% significance level in the SISVAR program (FERREIRA, 2008).

RESULTS AND DISCUSSION

In Figures 2A and 2B, the development of the bell pepper is observed during the experiment as a function of various saline concentrations.

Figure 2. Phenological stages of bell pepper at 50 days after transplanting (DAT) - Figure A and 78 days after transplanting (DAT) - Figure B.

In Tables 3 and 4, the values obtained at 50 and 78 days after transplanting the seedlings (DAT) are represented, respectively. It can be observed that there was no significant difference between the treatments at $p<0.05$ for the parameters of plant height and number of branches at 50 and 78 DAT. The evaluated characteristics, as well as the fresh mass of the shoot, dry mass of the shoot, and number of leaves, showed statistical differences at $p<0.05$ between the three treatments for the two evaluation phases.

It is noted that the values for T2 and T3 are high due to fertilization when compared to T1 (control). As explained by Silva (2019), the nitrogen sources used in the cultivation of bell pepper favor the concentration of nutrients, leading to increased biomass production and consequently better commercial productivity. This explanation also applies to the stem diameter parameter. In the first evaluation (Table 3), there was no statistical difference between them. However, at 78 (DAT), the difference is noticeable due to the increasing values of fertilization (Table 4). In the first evaluation at 50 days after transplanting (DAT), only the number of fruits was considered for the productivity parameters (Table 3). It was observed that there was no significant difference between the treatments. However, T2 and T3 showed higher productivity values compared to T1, due to the conditions of protected cultivation combined with fertigation when managed correctly.

In the second evaluation, in addition to the number of fruits, the values of fresh fruit mass and peel thickness were also obtained, with significant differences observed for these characteristics. However, the fresh fruit mass, although not statistically different, had higher values for T1 and T2 compared to T3. Rocha et al. (2015) observed that the cultivation of bell peppers with high doses of KCl (Potassium Chloride) hinders productivity and growth, reducing the weight and size of the fruit, as indicated by the values obtained for peel thickness (Table 4). This is generally caused by the increase in ionic strength in the nutrient solution.

This also explains why the quantity of fruits in T1 and T2 was higher compared to T3. Therefore, the results for T1 and T2 were better, as T3 had a high concentration of K source, causing a saline effect determined by the electrical conductivity present in the soil solution.

Table 3. Plant height (PH), stem diameter (ST), fresh shoot mass (FSM), dry shoot mass (DSM), number of leaves (NL), number of fruits (NF), and number of branches (NB) values as a function of the following treatments: T1 (control), T2 (recommended fertilization for the crop), T3 (recommended fertilization, tripled amount) at 50 days after transplanting.

TRAT.	AP (cm)	ST (cm)	FSM (g)	DMS (g)	NF (unid)	NFR (unid)	NR (unid)
1	23,40 a	0,69 a	31,53 b	5,45 b	32,00 b	1,40 a	6,40 a
2	24,20 a	0,76 a	52,22 a	8,93 a	45,70 ab	2,80 a	7,80 a
3	24,00 a	0,78 a	56,15 a	9,17 a	39,90 ab	2,60 a	7,00 a
CV (%)	**9,53**	**12,79**	**18,50**	**21,06**	**20,95**	**64,55**	**24,24**

Media followed by the same letter in the column do not differ from each other at the Tukey test at a 5% significance level.

Table 4. Values obtained for plant height (PH), stem diameter (SD), fresh shoot mass (FSM), dry shoot mass (DSM), number of leaves (NL), fresh fruit mass (FFM), peel thickness (PT), number of fruits (NF), number of branches (NB) as a function of the following treatments: T1 (control), T2 (recommended fertilization for the crop), T3 (recommended fertilization with tripled amount) at 78 days after transplanting.

TRAT.	AP (cm)	SD (cm)	FSM (g)	MS (g)	MFF (g)	ESP (g)	NF (unid)	NFR (unid)	NR (unid)
1	22,90 a	0,79 b	37,31 c	7,00 c	59,17 a	0,48 a	25,30 b	4,00 a	5,60 a
2	23,40 a	0,90 ab	67,11 b	14,10 b	60,10 a	0,41 ab	44,20 a	2,70 ab	7,20 a
3	23,00 a	0,94 a	108,22 a	19,87 a	26,37 a	0,27 b	50,00 a	2,00 b	8,00 a
CV (%)	**8,18**	**5,47**	**12,95**	**18,31**	**36,06**	**15,66**	**18,18**	**22,64**	**29,31**

Media followed by the same letter in the column do not differ from each other at the Tukey test at a 5% significance level.

For parameters such as dry root mass and root volume at both evaluation times, there were no differences between the treatments. However, for the parameter of fresh root mass, there were significant differences between the treatments for both evaluations, especially for the last evaluation, where the values were higher compared to the first evaluation. According to Garcia et al. (2009), the phosphorus source applied in the form of MAP had a positive effect on the cultivation of pepper plants, as it stimulated root development, consequently leading to better nutrient utilization and improving crop efficiency (Tables 5 and 6).

Table 5. Values obtained for fresh root mass (MFR), dry root mass (MSR), and root volume (VOL) as a function of the following treatments: T1 (control), T2 (recommended fertilization for the crop), T3 (recommended fertilization with tripled amount) at 50 days after transplanting.

TRAT.	MFR (g)	MSR (g)	VOL (mL)
1	12,59 ab	2,82 a	10,00 a
2	10,25 b	3,02 a	12,00 a
3	16,46 a	2,82 a	14,00 a
CV (%)	**39,25**	**28,66**	**31,26**

Media followed by the same letter in the column do not differ from each other at the 5% Tukey test.

Table 6. Values obtained for fresh root mass (MFR), dry root mass (MSR), and root volume (VOL) as a function of the following treatments: T1 (control), T2 (recommended fertilization for the crop), T3 (recommended fertilization with tripled amount) at 78 days after transplanting.

TRAT.	MFR (g)	MSR (g)	VOL (mL)
1	16,73 b	3,06 a	13,50 a
2	21,41 a	4,68 a	17,00 a
3	40,27 a	5,92 a	20,00 a
CV (%)	**22,53**	**31,60**	**33,81**

*Media followed by the same letter in the column do not differ from each other at the 5% Tukey test.

In Table 7, the pH values obtained in the soil solution showed statistical differences at p<0.5. However, in general, the numbers varied between 6.5 and 7.9 in the three treatments, so we did not have considerable values that could interfere with the cultivation of bell peppers. It is noted in Table 8 that the values obtained for EC are high. According to Neto et al. (2013), high salt concentration results in a considerable loss of productivity. While T1 and T2 remained at acceptable levels for EC.

Table 7. pH values obtained from soil solutions collected at different saline concentrations.

TRAT.	Date 1	Date 2	Date 3	Date 4	Date 5	Date 6	Date 7	Date 8	Date 9
1	7,70 ab	6,95 a	6,66 a	7,28 ab	7,46 a	7,75 a	7,73 ab	7,89 a	7,83 a
2	7,41 a	6,81 ab	6,75 a	7,48 a	7,66 a	7,88 a	7,88 ab	7,80 a	7,90 a
3	6,70 b	6,53 b	6,63 a	6,96 b	7,10 b	7,56 a	7,43 b	7,68 a	7,65 a
CV (%)	**5,48**	**3,38**	**2,80**	**3,97**	**1,89**	**3,01**	**2,68**	**2,13**	**2,77**

Means followed by the same letter in the column do not differ from each other at the 5% Tukey test probability. Date 1: 17/10/2020; Date 2: 24/10/2020; Date 3: 31/10/2020; Date 4: 15/11/2020; Date 5: 21/11/2020; Date 6: 28/11/2020; Date 7: 05/12/2020; Date 8: 12/12/2020; and Date 9: 19/12/2020.

Table 8. Values obtained for electrical conductivity (EC, dS m-1) of the soil solution collected at different salinity concentrations.

TRAT.	Date 1	Date2	Date 3	Date 4	Date5	Date 6	Date 7	Date 8	Date 9
1	1,18 a	1,70 a	1,20 b	0,98 c	0,88 c	0,79 c	0,74 b	0,70 b	0,52 c
2	1,99 a	1,69 a	1,52 b	1,80 b	1,43 b	1,78 b	1,69 b	1,64 b	1,62 b
3	1,99 a	2,12 a	2,58 a	2,54 a	2,74 a	2,30 a	3,23 a	3,29 a	3,26 a
CV (%)	**28,46**	**21,64**	**31,15**	**19,60**	**20,67**	**15,85**	**36,48**	**32,05**	**36,95**

*Media followed by the same letter in the column do not differ from each other at the 5% Tukey test. Date 1: 10/17/2020; Date 2: 10/24/2020; Date 3: 10/31/2020; Date 4: 11/15/2020; Date 5: 11/21/2020; Date 6: 11/28/2020; Date 7: 12/05/2020; Date 8: 12/12/2020; and Date 9: 12/19/2020.

CONCLUSION

The management of soil solution advection proved to be a viable solution, considering the results obtained in the development and production of bell pepper crops. Additionally, treatments 2 and 3 promoted an increase in plant fresh and dry biomass, number of leaves, and stem diameter. However, treatments 2 and 3 led to the accumulation of salts in the soil, resulting in a loss of productivity, fresh fruit weight, and skin thickness.

Therefore, the high concentration of phosphorus influenced the development of roots and, consequently, the values of fresh weight.

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