Productive Performance of Tomatoes under Fertigation Management

Pedro Henrique Máximo de Souza Carvalho[1], Jamerson Silva e Silva[2], Sérgio Oliveira Pinto de Queiroz[2], João Vitor Máximo de Souza Carvalho[3]

[1]Post-Graduate Program in Agricultural Engineering at the Federal Rural University of Pernambuco – UFRPE, Recife, Pernambuco - Brazil
[2]Department of Technology and Social Sciences - State University of Bahia - UNEB, Juazeiro, Bahia - Brazil
[3]Post-Graduate Program in Medical Physics at the University of São Paulo – USP, São Paulo - Brazil

***Abstract*— *Tomato is an important global commodity, with high socioeconomic expression in Brazil, due to consumer preference and wide availability of varieties. This work aimed to evaluate the use of solution extractors in the management of fertigation and monitoring of soil salinity, in the production of table tomato cultivars, under a protected environment. The experimental design used was in randomized blocks in a factorial scheme, with four fertigation management in the plots, and two table tomato cultivars in the subplots, repeating five times. Fruit length, fruit diameter, average fruit mass, productivity and water use efficiency were evaluated. The management of fertigation based on the replacement of the electrical conductivity of the soil solution, at levels of 10% and 25% provides tomato fruits with qualitative and quantitative characteristics similar to the conventional production system, with reduction in the consumption of fertilizers, having to cultivate nugget superior agronomic performance.*

Keywords— *Solanum lycopersicum; soil solution, salinity.*

I. INTRODUCTION

The consumption of tomatoes has experienced a strong expansion in the world market in recent decades, making it an important global commodity, with a prominent place on the consumer's table, due to its vast availability of varieties (BORGUINI, 2006). According to Squariz (2017), such acceptance and diffusion are related to its nutritional richness, especially regarding the presence of vitamins, combined with its pleasant flavor and color.

Researchers have tried to develop production systems, especially regarding the quality and commercial characteristics of the final product, produced in a protected environment or not, reporting as fundamental factors on the production cycle those of a biotic nature, such as pests and diseases, or abiotic nature, such as water stress and salinity, among others (GINOUX and DAUPLÉ, 1985).

The productive system of table tomatoes requires knowledge of techniques in production processes, such as in the management of irrigation and fertigation, mainly in crops under a protected environment. Production in such environments makes cultivation out of season feasible, reduces costs and increases productivity and, when associated with new technologies such as irrigation and fertigation, provide good results (MEDEIROS et al., 2010).

The inadequate management of irrigation, the addition of fertilizers without technical control and the absence of rainfall in a protected environment can, as a consequence, cause the salinization of soils, impairing the yield of sensitive crops such as tomatoes (DIAS et a., 2005).

According to Medeiros (2010), the high concentrations of fertilizers in the irrigation water, associated with transpiration rates and the disregard of the physiology of the vegetables in such production conditions, increase the levels of salts in the root medium, and promote imbalance in water absorption. and solute for plants. Nery (2009) reports some problems caused by salinization, such as the decreased osmotic potential of the soil solution, decreasing water retention, increasing the dispersion of soil particles, decreasing the infiltration capacity and causing toxicity problems to plants. All of these factors result in decreased productivity.

According to Queiroz (2009) and Oliveira (2011), one of the practices that has been gaining prominence in the control of salinity caused by the excess of fertilizer salts, is the constant monitoring of ions in the soil solution through electrical conductivity, due to the need to maintain the fertilizer stability. Among the equipment used for its speed of response and ease of handling, there is the porous capsule extractor, which promotes the removal of volumes of soil solution in the area occupied by the plant's roots (Silva et al., 2015).

In monitoring the soil solution, Silva (2001) confirms the efficiency of the porous capsule extractor for the management of fertigation, demonstrating accuracy in determining the ionic concentration of the soil solution and enabling the determination of potassium, nitrate, calcium and magnesium ions, with accuracy.

The porous capsule extractor technique is efficient in gauging and monitoring salinity from the soil solution, making it an alternative to manage nutrient distribution via water, effectively and at low cost, especially when related to taking of quick decisions in the field (Medeiros, 2010).

Aiming to increase efficiency, with regard to the management of nutrients in the soil solution, this work aimed to evaluate the use of soil solution extractors to aid in the management of fertigation, under production of tomato cultivars in a protected condition.

II. MATERIAL

The work was carried out between January and April 2019 in the experimental field of the State University of Bahia, in the São Francisco Valley, municipality of Juazeiro, Bahia, under geographic coordinates 9 ° 24 'S latitude, 40 ° 30' W longitude and 368 m of altitude, in a protected environment with an area of 10 mx 24 m, a shading structure and a gray shading screen with a 40% shading percentage.

Two cherry tomato cultivars under production in the Northeast region were evaluated and which do not have data on nutrition, cv. Pepita and cv. Gota de Mel, whose sowing was carried out in polystyrene trays, in a greenhouse. Seedlings were transplanted when they reached 0.10 m in height, proceeding with cultivation in pots with a capacity of 5 liters.

The soil in the experimental area is classified as Floss Neossolo (SANTOS., et al 2013). A vertical staking system was used, with the help of strips and smooth wires, and the phytosanitary treatment was carried out weekly in order to keep the area free from pests and diseases.

A randomized block design was adopted, in a split plot scheme, with four fertigation management (Traditional method, based on the nutrient uptake of the crop; Control of the electrical conductivity of the soil solution under 10% variation limit; 25% and 50%) in the plots and two table tomato cultivars (Pepita - hereinafter called CV 1 and Gota de Mel - hereinafter called CV 2) in the subplots, repeated five times.

The elaboration of the artificial soil salinization curve consisted of tests that relate the electrical conductivity as a function of the concentration of fertilizer salts, obtained by regression analysis. The salts used, as well as their proportions, are shown in table 1.

With the relationship between the electrical conductivity of the soil solution (CEss) and the dissolved salts, in the desired proportions of fertilizers, the equation proposed by Richards (1954) was used to transform the electrical conductivity values into concentration (mg L^{-1}).

$$C = CEss * 640$$

Being:

C the concentration of fertilizer salts (mg L^{-1});

CEss electrical conductivity of the soil solution (dS m^{-1}).

Table 1. - Sources of fertilizer salts used in the preparation of the salinization curve and in fertigation management, with respective proportions of application to the soil.

FERTILIZERS	Solubility (g L^{-1})	Saline Index (1,0 g L^{-1})	Proportion (%)
Calcium nitrate	250,00	82,25	42
Potassium nitrate	327,00	99,47	32
Monoamonic Phosphate	361,00	68,06	3
Monopotassium Phosphate	238,00	55,6	11
Potassium Sulfate	123,00	112,94	4
Magnesium Sulfate	500,00	91,45	8

The replacement of fertigation, based on the extraction of the solution from the soil, was only carried out when the electrical conductivity in the solution reached, on average, 10%, 25% and 50% of its initial level. The amount of fertilizer applied was adjusted so that the soil solution recovered the initial electrical conductivity level, based on the equation of the artificial salinization curve (figure 1). The traditional method, on the other hand, was carried out based on the nutrient uptake of the crop, based on Alvarenga (2004).

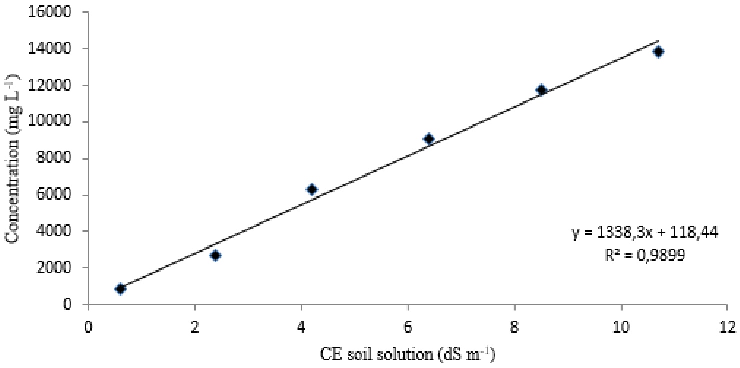

Fig.1: Artificial salinization curve, relating the concentration of fertilizer salts and EC of the soil solution.

The determination of daily water replenishment was based on the tensiometry method, with reference to the characteristic water curve, obtained in the laboratory (figure 2). The irrigation system was composed of three 2000 liter boxes, three 0.5 CV motor pumps, dripper tubes with 0.50 m spacing and 2 L h^{-1} flow, under pressure of kgf cm^{-2}. The fertilizer injection occurred with the aid of a Venturi injector.

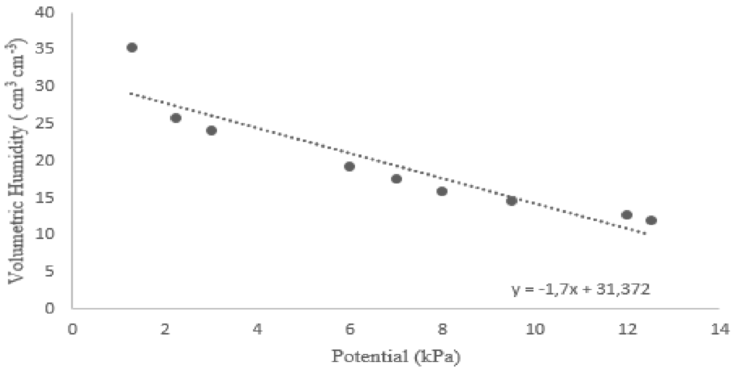

Fig.2: Water characteristic curve of the soil used in the experiment

Table 2. - Chemical analysis of soil in the experimental area

pH	C.E	Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	SB	Al^{+3}	$H+Al^{+3}$	T	V	PST	P	Org. Mat.
H_2O	(dS cm^{-1})				(cmolc dm^{-3})					(%)	(%)	(mg dm^{-3})	(g kg^{-1})
5,7	0,02	2,62	1,81	0,16	0,04	4,63	0	0,15	4,78	96,9	0,83	58	5,82

Note: C.E - electrical conductivity, T - cation exchange capacity, V - percentage of base saturation, PST - percentage of exchangeable sodium, Org. Mat. - organic matter.

The variables analyzed were: fruit length (mm), fruit diameter (mm), average fruit mass (g), productivity (t ha-1) and water use efficiency (kg ha^{-1} mm^{-1}).

For the evaluations, three harvests were carried out, at 50 days after transplanting (DAT), at 65 DAT, and at 77 DAT, with the harvested fruits having the same maturation stage.

The results obtained were subjected to analysis of variance, using the F test, and comparison of treatment averages with each other, adopting Tukey at 5%

probability, using the ASSISTAT version 7.6 software. (SILVA 2012)

III. RESULTS AND DISCUSSION

In addition to variables related to tomato crop production, during the experiment meteorological parameters obtained from an agrometeorological station installed in the area were monitored during the study period. The climatic data referring to the maximum, average and minimum temperatures (ºC) and relative humidity of the air (%) are shown in figure 3

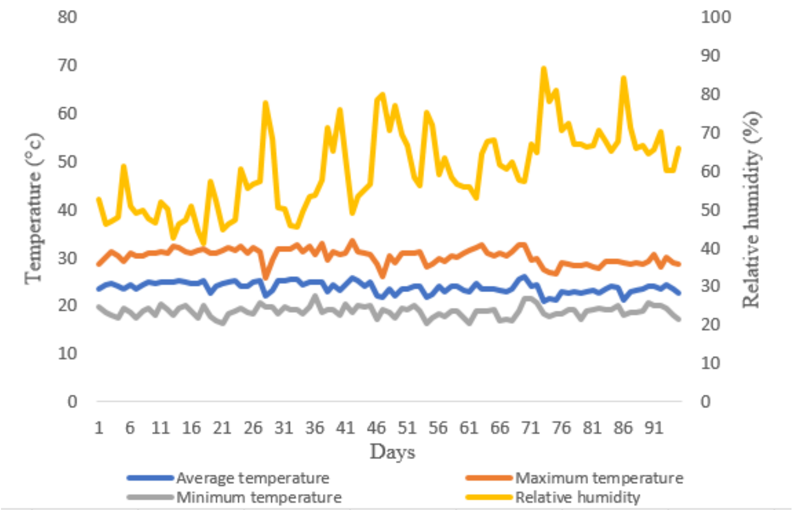

Fig.3: Climatic data obtained over the experimental time

During the tomato production cycle, the maximum, average and minimum air temperatures ranged between 26.4 and 34.3, 22.1 and 28.2 and 17.8 and 22.1 ºC, respectively.

The lowest values of relative humidity were observed shortly after transplanting until the beginning of flowering and, subsequently, the values increased until the end of the experiment. During the experimental period, there were no precipitations.

It was obtained, from the equation generated in the artificial soil salinization curve (Figure 1), a high correlation (R = 0.989) between the concentration of salts and the electrical conductivity of the soil solution, thus allowing to estimate the quantity of salts to be applied to the soil in order to obtain the desired electrical conductivity in the saturation extract and, with the aid of the curve and the use of soil solution extractors, it was possible to control the electrical conductivity of the soil solution.

Table 3 shows the amounts of fertilizer used throughout the experiment for each cultivar, depending on fertigation management.

Table 3. - Quantity of fertilizers applied to the cultivars of tomato Pepita and Gomo de mel, under different limits of replacement of fertilizers based on the electrical conductivity of the soil solution.

Fertilizers	Absorption march		10% replacement		25% replacement		50% replacement	
	t ha^{-1}							
	CV 1	CV 2	CV 1	CV 2	CV 1	CV 2	CV 1	CV 2
Monoamonic Phosphate	2,925	2,925	0,772	0,172	0,328	0,286	0,140	0,330
Monopotassium Phosphate	7,800	7,800	2,035	0,447	0,936	0,754	0,368	0,872
Potassium Sulfate	2,044	2,044	0,350	0,086	0,140	0,130	0,063	0,165
Magnesium Sulfate	11,700	11,700	3,088	0,688	1,408	1,144	0,560	1,320
Calcium nitrate	4,000	4,000	1,241	0,388	0,720	0,594	0,196	0,872
TOTAL	28,469	28,469	7,486	1,781	3,532	2,908	1,327	3,559

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Cultivar 1 demanded a greater quantity of fertilizers, when compared to cultivar 2, in the replacement limits of 10 and 25% of the initial electrical conductivity. This effect resulted in a superior performance of cultivar 1, regarding the physical variables analyzed in the present work.

Regarding productivity, treatments with conductivity replacement in 10% and 25% did not differ from the treatment with nutrition based on the absorption gait (table 4).However, such treatments reduced the amount of fertilizers applied by 73.7% and 87.5%, respectively, when compared to the treatment with nutrition based on the absorption rate (table 3). Under a replacement limit of 50% of the electrical conductivity of the soil solution, there was a reduction in productivity compared to other treatments. This fact, related to the longer time for replacement of nutrients, in which the treatment with replacement limits of 50% was submitted. According to Andrade et al (2017) and Fayad et al. (2002), the nutritional deficit in stages of the tomato production cycle, such as in pre-flowering, flowering and fruiting, results in low productivity and lower quality fruits.

For the variable water use efficiency, the results obtained showed the same trend observed for productivity, related to the volume of water applied in irrigation and quantified by the tensiometry method.

Table 4. - Analysis of variance and test of means of the variables productivity and efficiency in the use of water

SourceofVariation	Productivity	Efficiency in water use
Fertigation Management	2.324 *	2.324 *
Cultivars	67.863 **	67.863 **
M. fertirrigation x Cultivars interaction	1.937 ns	1.937 ns
CV (%)	28.45	28.45
AVERAGES		
Fertigation Management	t ha^{-1}	kg ha^{-1} mm^{-1}
Absorption march	3,048 a	7,399 a
10% replacement	3,06 a	7,429 a
25% replacement	2,866 a	6,956 a
50% replacement	1,096 b	4,604 b
Cultivars		
Cultivate 1	4,216 a	10,234 a
Cultivate 2	1,219 b	2,960 b

Note: (**) and (*) at 1% and 5% probability respectively; (s) not significant; averages followed by different letters in the column, differ by 5% probability by the Tukey test.

In tomato, the length, diameter and average fruit mass are important production characteristics for the farmer, defining the choice of cultivar and the subsequent commercialization of the fruits. (ANDRADE et al., 2017)

The physical variables of length, diameter and average fruit mass were influenced by the management of fertigation, resulting in larger fruits up to treatments with a limit of replacement of the electrical conductivity of the soil solution at 25% of the initial EC. It was found that cultivar 1 showed superior performance for all physical characteristics and in all limits established for replacement of fertigation, with significant interaction in treatments with nutrition based on the culture absorption gait and replacement of electrical conductivity at 10% and 25 % (table 5).

The average mass of tomato fruits was influenced by the different fertigation management studied. It can be seen, through Table 5, that the treatments with nutrition based on the absorption gait and with replacement at 10% and 25%, did not differ and reached the highest values 7.58, 7.03 and 7.18, respectively, with cultivar 1.

Lower performances were observed by establishing replacement management at 50% of the initial

EC, which, when imposed on cultivar 2, did not result in production. (table 5). Fact attributed to low ionic concentrations, which reflect on the decline of nutrient availability, in the soil solution, providing responses inferior to the productive potential of the crop (ANDRIOLO et al., 2015 and ROCHA et al., 2010), as observed in plants submitted to replacement management at 50% of the initial EC.

It was observed that a smaller volume of fertilizers applied until the replacement of 25% CEss, (Table 1), resulted in fruits with physical qualities similar to the conventional nutrition system, with a reduction of up to 87.5% in the application of fertilizers.

Such results are similar to those found by Kawakami et al. (2007), evaluating the physical characteristics of post harvest of tomato fruits, submitted to the replacement of the electrical conductivity of the soil solution with levels of 25%, 50% and 75%. Such authors report that it is possible, in a fertigation management program, to use as a reference limit a reduction of up to 25% of the initial electrical conductivity of the soil solution to effect a new application of fertilizers, without prejudice to productivity and physical characteristics post-harvest, thus rationalizing the use of fertilizers and reducing the production costs of cherry tomatoes.

Table 5. - Breakdown of the interaction between fertigation management factors vs. cultivars for the variables fruit length (C.F), fruit diameter (D.F) and average fruit mass (M.M.F)

Fertigation management	C.F		D.F		M.M.F	
	mm		mm		gramas	
	CV 1	CV 2	CV 1	CV 2	CV 1	CV 2
Absorption march	24,616 aA	20,689 aB	23,072 Aa	19,334 aB	7,584 aA	4,818 aB
10% replacement	23,985 aA	18,688 aB	22,456 aA	18,190 aB	7,038 aA	3,920 aB
25% replacement	24,006 aA	18,752 aB	22,711 aA	17,403 aB	7,182 aA	3,829 aB
50% replacement	23,295 bA	0,000 bB	22,140 bA	0,000 bB	6,667 bA	0,000 bB

Note: Averages followed by the same lowercase letter in the column and the same uppercase letter in the row do not differ statistically from each other, at 5% probability, by the Tukey test.

IV. CONCLUSIONS

Fertigation management based on the replacement of the electrical conductivity of the soil solution, at levels of 10% and 25%, provides tomato fruits with qualitative and quantitative characteristics similar to the conventional production system, with less consumption of fertilizers.

The nugget cultivar showed superior productive performance for all the evaluated productive variables.

REFERENCES

[1] ALVARENGA, M. A. R. Tomate: produção em campo, em casa de vegetação e em hidroponia. Lavras: Editora UFLA, 2004. 400p.

[2] ANDRADE, A. R.; NORONHA, S. P.; AZEVEDO, P. R.; SILVA, P. R. A.; SANTOS, R. C.; Fertirrigação no cultivo de quatro cultivares de tomate (Lycopersicum sculentum) irrigado por gotejamento. Revista Brasileira de Tecnologia Aplicada nas Ciências Agrárias, Guarapuava, v.10, n.2, may/aug. (2017). Available in: https://revistas.unicentro.br/index.php/repaa/article/view/4706

[3] ANDRIOLO. J, L; WITTER. M; DAL.; ROSS, T; GODÓI R. S. Crescimento e desenvolvimento do tomateiro cultivado em substrato com reutilização da solução nutritiva drenada. Horticultura Brasileira. Brasília, v. 21, n. 3, jul.-set. 2003. Available in: https://www.scielo.br/scielo.php?pid=S0102-05362003000300015&script=sci_arttext

[4] BORGUINI, R. G. Avaliação do potencial antioxidante e algumas características do tomate (Lycopersicon esculentum) orgânico em comparação ao convencional. 2006. 178 p. (Doutorado em Saúde Pública) Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, 2006. (Tese)

[5] DIAS, N. S.; DUARTE, S. N.; GHEYI, H. R.; MEDEIROS, J. F.; SOARES, T. M. Manejo da fertirrigação e controle da salinidade do solo sob ambiente protegido, utilizando-se de extratores de solução do solo. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande, v.9, n.4, p.496-504, 2005. Available in: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662005000400009

[6] FAYAD, J. A; FONTES, P. C. R.; CARDOSO, A. A.; FINGER, F. L.; FERREIRA, F. A. Absorção de nutrientes pelo tomateiro cultivado sob condições de campo e de ambiente protegido. Horticultura brasileira Brasília, v. 20,

n.1, p. 90-94, 2002. Available in: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S0102-05362002000100017

[7] KAWAKAMI, F. P. C.; ARAUJO, J. A. C.; IUNCK, A. V.; FACTOR, T. L.; CORTEZ, G. E. Manejo da fertirrigação em função da condutividade elétrica da solução nutritiva drenada no cultivo de tomate cereja sob ambiente protegido. Horticultura Brasileira 2007. v. 25: Suplemento-resumo.Available in:http://www.abhorticultura.com.br/eventosx/trabalhos/ev_1/a116_t1201_comp.pdf

[8] MEDEIROS, P. R. F. Manejo da fertirrigação em ambiente protegido visando o controle da salinidade para a cultura do tomate em solo franco-argiloso. 2010 85 p. (Doutorado em Irrigação e Drenagem) Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 2010. (Tese) Available in: https://www.teses.usp.br/teses/disponiveis/11/11143/tde-11022011-100428/publico/Pedro_Fernandes_de_Medeiros.pdf

[9] NERY, A. R.; RODRIGUES, L. N.; SILVA, M. B. R.; FERNANDES, P. D.; CHAVES, L. H. G.; DANTAS NETO, J.; GHEYI, H. R. Crescimento do pinhão-manso irrigado com águas salinas em ambiente protegido. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande, v.13, p.551-558, 2009. Available in: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662009000500007

[10] OLIVEIRA, F. A.; MEDEIROS, J. F.; DUARTE, S. N.; SILVA JÚNIOR, M. J.; CAMPELO, C. M. Calibração de extratores providos de cápsula porosa para monitoramento da salinidade e da concentração de íons. Eng. Agríc., Jaboticabal, v.31, p.520-528, 2011. Available in: https://www.scielo.br/scielo.php?pid=S0100-69162011000300012&script=sci_arttext

[11] QUEIROZ, S. O. P.; TESTEZLAF, R.; MATSURA, E. E. Metodologia para avaliação da salinidade do solo em ambiente protegido. Irriga, Botucatu, v.14, n.3, p.383-397, 2009.Available in: http://revistas.fca.unesp.br/index.php/irriga/article/view/3426

[12] ROCHA. M, Q; PEIL. R, M, N; COGO. C, M. Rendimento do tomate cereja em função do cacho foral e da concentração de nutrientes em hidroponia. Horticultura Brasileira, Brasília, v. 28, n. 4, out.- dez. 2010. Available in: https://www.scielo.br/scielo.php?pid=S0102-05362010000400015&script=sci_arttext.

[13] SANTOS, H. G. DOS; JACOMINE, P. K. T.; ANJOS, L. H. C. DOS; OLIVEIRA, V. A. DE; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; CUNHA, T. J. F.; OLIVEIRA, J. B. de. Sistema brasileiro de classificação de solos. 3.ed. rev. ampl. Brasília: Embrapa, 2013. 353p.

[14] SILVA, A. O.; KLAR, A. E.; SILVA, E. F. F. Manejo da fertirrigação e salinidade do solo no crescimento da cultura da beterraba. Eng. Agríc., Jaboticabal, v.35, n.2, p.230-241, mar./abr. 2015. Available in: https://www.scielo.br/pdf/eagri/v35n2/1809-4430-eagri-35-2-0230.pdf

[15] SILVA, F. A. S. ASSISTAT versão 7.6 beta. Campina Grande: Assistência Estatística, Departamento de Engenharia Agrícola do CTRN - Universidade Federal de Campina Grande, Campus de Campina. 2012.

[16] SILVA, M.A.G.; BOARETTO, A.E.; MURAOKA, T.; FERNANDES, H. G.; GRANJA, F.A.; SCIVITTARO, W.B. Efeito do nitrogênio e potássio na nutrição do pimentão cultivado em ambiente protegido. Revista Brasileira de Ciência do Solo, Campinas, v. 25, p. 913–922, 2001. Available in: https://www.scielo.br/pdf/rbcs/v25n4/14.pdf

[17] SQUARIZ. J, C, DE O.; RESENDE. J, T, V, DE.; TOLOMEOTTI. K, R, B. Avaliação da microsporogênese em acessos de Mini Tomate. Ambiência. Ambiência Guarapuava (PR) v.13 n.2 p. 342 - 355 Maio/Ago. 2017. Available in: https://revistas.unicentro.br/index.php/ambiencia/article/view/3663