academicJournals

Vol. 10(47), pp. 4275-4282, 19 November, 2015
DOI: 10.5897/AJAR2015.9982
Article Number: D1E374F56166
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effect of potassium doses fertirrigated in the nutritional contents of tomato fruit and leaves in their early development

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Received 8 June, 2015; Accepted 21 August, 2015

Tomato is the most commonly consumed and marketed vegetables in the world and one of the plants that respond more to fertilization, and particularly in demanding potassium, which is responsible for stomata opening, sugar translocation, protein synthesis and enzymatic activation. Analysis of nutrients contents made available to the plant and its relationship with what is present in plant tissue is a great alternative for the correct handling of mineral nutrient solutions. The objectives of this study are to evaluate the influence of increased K doses on the growth of tomato and its relationship with other nutrients. For the study, two experiments of fertirigated tomatoes in pots were preformed with sand as substrate, and five different doses of potassium, grown in a greenhouse. Nutritional content in the fruit in early development and leaf immediately above each bunch was evaluated. Data were submitted to polynomial regression analysis to the second degree. Results showed that increased potassium levels significantly influenced K, S and N contents. Increasing potassium doses significantly affect nutritional contents of the plant tissue.

Key words: Plant tissue, nitric, nitric-perchloric perchloric digestion, *Lycopersicon esculentum* Mill.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) originated in South America and is one of the most consumed vegetables in the world; it occupies second place in Brazil in economic importance, second only to potatoes (Paula Júnior and Venzon, 2007). It is consumed fresh or dried in the forms of sauces, pastes, jams and juices.

It is mainly produced in greenhouses by providing production conditions throughout the year, adjusting cropping seasons to market requirements. As an expensive structure that needs an intensive production to have expected financial return, such a system is subject to an increase in the number of pathogens that affect production over time.

In any form of cultivation, the use of technology to reduce costs and increase profit margin is a great alternative to producers. Tomatoes cultivated directly on the ground are often contaminated with pathogens and salinated by intensive fertilization. But, tomato produced

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in a greenhouse using fertirrigated vases are free from such hazard; thus, it is a viable alternative to prevent the proliferation of pests and diseases. In addition, fertigation provides nutrients in adequate quantities for plant growth.

Tomato is among the highest vegetables in nutrients and one of the species that best responds to high doses of chemical fertilizers; nutrient absorption by tomato plants is low until the appearance of the first flowers (Alvarenga, 2000).

All nutrients are fundamental in plant nutrition, but Potassium (K) is the most absorbed nutrient and required by tomato crop. It has an important role in its development and production, acting in the synthesis of carotenoids, particularly lycopene, responsible for red fruit, and also in the biosynthesis, organic acids, sugars and vitamin C (Marschner, 1995).

Knowledge about the nutritional content of plants is important to assess the ability of removal of nutrients for each crop, and the amount that must be provided at every stage of cultivation to ensure high yields. Tracking the nutrient content and especially K in fertirrigated cultivation is of paramount importance for nutritional supplementation according to crops' needs during their cycle.

This study aims to evaluate the influence of increased K doses absorption and nutritional content of tomato fruit and leaves during its development.

MATERIALS AND METHODS

For the analysis, two experiments were conducted in a greenhouse: arch type, with 6 m wide, 30 m long, 3 m high and transparent polyethylene cover. The samples were analyzed in the Laboratory of soils from the State University of Londrina, Londrina, PR, (latitude 23º 23'S, longitude 51º 10'W, at an altitude of 580 m).

These experiments consisted of increased K rate in tests with two varieties of fertirrigated tomato grown in pots with sand. They were done in a randomized block design with five treatments and 10 repetitions, totaling 50 pots side by side and 60 cm between rows, with borders around and fertirrigated drip.

Plants were grown in plastic pots with 9 L of capacity (23.5 × 26 × 19.5 cm), using sand as coarse substrate. The sand test results were obtained: H^+ +Al^{+3} = 1.89 cmolc dm^{-3}; organic matter = 0 g dm^3; K^+ = 0 cmolc dm^{-3}; Mehlich P = 0.02 cmolc dm^{-3}; Mg^{+2} = 1.44 cmolc dm^{-3}; Ca^{+2} = 0.29 cmolc dm^{-3} and Al^{+3} = 0.08 cmolc dm^{-3}.
Tomato seedlings used for the first experiment were Pizzadoro type (E1) and for the second experiment, Carina (E2) from commercial vivarium certificates that were transplanted to pots with 25 to 30 cm on March, 23rd 2013 and terminated on July 29th 2013.

The pest control was performed with preventive measures and the following insecticides were applied from the start of cultivation: Cypermethrin (pyrethroid), one ml^{-1}, every 15 days; large fruit borer (Helicoverpa zea) and Dipel® (biological), one ml^{-1} once a week for tomato leafminer (Tuta absoluta). The fungicides applied from the reproductive stage were: Chlorothalonil, five mL L^{-1} once a week for early blight, septoria and powdery mildew; and Amistar Top®, one ml^{-1} once every 15 days also to early blight.

The experiments were conducted with five treatments consisting of five concentrations of K in the nutrient solution (60, 120, 180, 240 and 300 mg dm^{-3} K). It was applied after the opening of the first flowers, at 29 days after transplanting. Up to this stage of development, the nutrient solution was standard for all treatments.

These doses were established from prior knowledge of the mean dose of K which is recommended for tomato (180 mg $dm^{-3)}$. From this information, it was decided to test doses, starting from 60 to 300 mg dm^{-3}.

The doses were of essential nutrients (mg dm^{-3}): N: 198, P: 43.6, C: 152.4, Ca 233, Mg: 27 S: 39; the followings were used as fertilizers: MAP (200 g 1000L^{-1}); Ca (NO3) 2 (800 g 1000 L^{-1}); $CaCl_2$ (300 g 1000 L^{-1}); $MgSO_4$ (300 g 1000 L^{-1}) and KNO_3 (400 g 1000 L^{-1}). Micronutrients were supplied through REXOLIN BRA® (11.6% K_2O, 1.28% S, 0.86% Mg, 2.1% B, 0.36% Cu, 2.66% Fe, 2.48% Mn, 0.036% Mo and 3.38% Zn) and REXOLIN M48® (65% to chelated Fe EDDHMA); both at a concentration of 25 g.1000 L^{-1} (Table 1).

The concentration of each nutrient present was monitored by periodically measuring the electrical conductivity of the solution in water tanks and the resulting eluviation. The nutrient solution was passed through the pot and retained on the plate below it, leaving the system conductivity to exceed three dS m^{-1} which could adversely affect plant development. When the conductivity exceeded three dS m^{-1} , fertigation was ceased and the system was irrigated for one day only with water to prevent salinization of the system.

The fertigation system consisted of submersible pumps; it has an operating pressure of up to 1.9 mca and power of 38 watts, model AT 203 Atman® in water tank with 80 L capacity for each treatment. The pumps were connected to a timer, driven by a contactor to avoid damage due to oscillation of the amperage.

The fertilizer applications were made through irrigation water with variable frequency so that the losses did not exceed 10% by irrigation interval. Each dripper was set for maximum flow of 300 ml min^{-1}. The irrigation interval was defined based on climatic conditions - temperature, relative humidity, which were measured inside the greenhouse during the experiment, with datalogger Instrutherm® ht-500 model. The characteristics of culture range from 1 to 5 times a day shift.

Average monthly temperatures were 33.6°C on 27 to 31 March; 26°C in April; 27.5°C in May; 23.8°C in June and 27.9°C in July 29. The relative humidity was 42% in 27 to 31 March; 64.4% in April; 57% in May, 72.6% in June and 54.1% in July 29.

Plants were conducted with three tomato bunches, and after the third bunch, five leaves were counted and plants were pruned to cut the apical dominance. After the onset of fruiting, a green fruit in each repetition, the basal part of the bunch, with a diameter between four and five centimeters were collected.

The leaf immediately above the same cluster was also collected for analysis and both suitably packaged in kraft paper bags and labeled. They were kept under air forced circulation stove at 65°C for three days and then ground in mill type Willey.

All collected plant materials were prepared for determination of nutrients. They were obtained by sulfuric acid digestion N content using Kjeldahl microdestilador method (Bremner and Keeney, 1965). Certain nutrients and P content underwent nitroperclórica digestion. Phosphomolybdate was reduced by ascorbic acid (Braga and Defelipo, 1974; Blanchar et al., 1965), S turbidimetrically sulfate, K photometrically flame and Ca, Mg and micronutrients were reduced by atomic absorption spectrophotometry.

The results of nutritional contents of leaves and fruits of the crop were submitted to polynomial regression analysis to the second degree to verify the influence of increased K doses on them.

RESULTS AND DISCUSSION

Results show that the behavior of nutrients in the two varieties of tomato was noticed at the beginning of fruit development (Tables 2 and 3). There was significant increase in K levels and reduction in N, P, Fe and Zn in

Table 1. Nutrient concentration (mg dm^{-3}) of the nutrient solutions and electrical conductivity (EC) (dS m^{-1}) of the nutrient solutions used in the treatments.

Nutrient	Complete solution (100%)*	Treatments containing K (mg dm^{-3}) and of the nutritive solution Conductivities ***					
		Solution * (70%)**	60 (2.07)***	120 (2.14)***	180 (2.15)***	240 (2.26)***	300 (2.42)***
N	198	138.6	198.0	198.0	198.0	198.0	198.0
P	43.6	30.52	43.6	43.6	43.6	43.6	43.6
K	152.4	106.68	60.0	120.0	180.0	240.0	300.0
Ca	233	163.1	233.0	233.0	233.0	233.0	233.0
Mg	27	18.9	27	27	27	27	27
S	39	27.3	39	39	39	39	39
B	0.5	0.35	0.5	0.5	0.5	0.5	0.5
Fe	5	3.5	5	5	5	5	5
Cu	0.07	0.049	0.07	0.07	0.07	0.07	0.07
Mn	0.1	0.07	1	1	1	1	1
Mo	0.075	0.0525	0.075	0.075	0.075	0.075	0.075
Zn	0.4	0.28	0.4	0.4	0.4	0.4	0.4

* Sarruge (1975) modified and used in the UEL Soils Laboratory. ** Nutrient solution used for 15 days for adaptation of seedlings. *** Means of electrical conductivity (EC) measured in the nutrient solution water tanks (dS m^{-1}).

Table 2. Levels of nutrients in g kg^{-1} and micronutrients mg kg^{-1} in early fruit development of the first, second and third bunch of Experiment 1 with Pizzadoro tomato.

		N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
	mg.dm^{-3}	g.kg^{-1}						mg.kg^{-1}			
	60	39.22	11.74	54.84	3.58	2.88	5.48	21.38	396.41	115.32	54.27
	120	40.16	16.77	83.50	3.37	2.79	6.09	24.76	233.40	127.32	46.38
	180	38.96	12.72	78.21	3.39	2.85	6.15	21.44	213.75	89.75	31.36
	240	36.39	13.43	71.54	3.10	2.74	6.43	24.57	255.94	168.35	42.89
1st bunch	300	36.55	11.60	75.66	3.34	2.65	5.90	29.60	159.71	88.33	46.43
	CV(%)	6.49	18.97	19.48	38.38	16.80	22.19	27.62	62.05	82.77	20.94
	p>F*	*	*	*	ns	ns	ns	ns	*	ns	*
	60	32.95	7.91	65.88	3.17	1.92	4.01	11.53	140.29	128.80	29.08
	120	32.34	10.57	69.17	3.47	2.07	4.08	15.93	185.76	98.36	38.80
	180	29.44	9.58	70.64	4.36	2.01	5.06	16.52	178.72	113.28	75.78
2sd bunch	240	30.39	10.45	72.64	4.02	2.23	5.42	16.94	118.53	167.14	69.50
	300	29.50	9.60	74.39	4.50	2.01	5.79	18.69	144.66	129.24	77.28

Table 2. Contd.

	CV(%)	7.63	17.99	12.48	41.82	20.06	16.41	27.23	50.43	44.01	28.66
	p>F*	*	*	ns	ns	ns	*	*	ns	ns	*
	60	52.39	9.89	54.88	3.53	1.82	4.69	11.23	175.96	86.53	48.50
	120	44.03	9.50	66.00	3.29	1.96	5.59	8.50	220.81	59.68	29.07
	180	29.11	10.00	67.62	3.27	2.30	5.45	6.72	186.62	69.13	25.20
	240	34.15	9.60	70.20	2.97	2.04	5.82	6.55	256.02	84.20	24.58
3th bunch	300	34.42	9.29	73.32	3.16	1.79	6.01	2.34	280.20	69.58	20.86
	CV(%)	5.79	20.70	7.77	38.74	22.73	11.01	17.44	75.35	30.60	29.42
	p>F*	*	ns	*	ns	ns	*	*	ns	ns	*

*: Significant data to 5% by regression testing. ns: not significant data for 5% by regression testing.

Table 3. Levels of nutrients in g kg^{-1} and micronutrients in mg kg^{-1} in early fruit development of the first, second and third bunch of Experiment 2, tomato Carina.

	$mg.dm^{-3}$	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
		$g.kg^{-1}$						$mg.kg^{-1}$			
	60	33.49	12.25	67.16	2.95	2.84	6.84	23.46	168.14	82.08	48.84
	120	30.83	11.31	80.88	3.73	3.01	7.14	22.26	240.55	76.46	48.73
	180	44.71	11.11	78.64	2.65	2.95	8.11	22.75	179.65	34.62	45.90
	240	36.38	10.59	82.17	5.03	2.79	8.21	22.77	149.85	20.28	41.51
1st bunch	300	33.28	10.98	88.59	5.14	2.93	8.79	27.57	280.54	41.29	40.50
	CV(%)	6.52	18.27	16.59	41.04	13.74	18.52	33.30	50.86	44.34	18.27
	p>F*	*	ns	*	*	ns	*	ns	*	*	ns
	60	33.37	8.96	50.46	1.66	1.92	3.90	10.09	161.73	93.49	34.64
	120	41.93	10.57	69.62	2.09	2.53	4.29	8.63	185.76	109.77	39.19
	180	36.68	9.74	74.29	5.90	2.49	4.98	15.20	176.24	110.72	76.67
	240	35.54	10.40	81.39	1.86	2.17	3.83	13.72	118.53	101.80	70.20
	300	38.79	9.44	84.22	1.35	2.13	4.48	12.84	132.29	118.88	76.14
2sd bunch	CV(%)	11.40	20.57	14.48	152.52	16.14	15.34	47.85	61.59	24.48	28.74
	p>F*	*	ns	*	ns	*	*	ns	ns	ns	*
	60	36.42	9.60	59.51	3.51	1.61	5.43	7.27	158.51	93.53	20.60
	120	32.38	7.62	65.09	3.25	1.71	5.58	10.76	224.71	78.65	21.54
3th bunch	180	29.66	10.29	69.32	3.24	2.19	5.85	11.65	207.44	83.14	30.30

Table 3. Contd.

240	30.83	8.80	76.00	2.94	2.11	5.85	12.15	111.68	64.24	19.40
300	30.50	7.69	80.53	3.13	1.56	6.34	14.24	130.97	67.22	20.64
CV(%)	8.35	13.92	7.39	37.77	11.93	9.20	15.05	53.29	25.68	21.34
p>F*	*	*	*	ns	*	*	*	*	*	*

*: Significant data to 5% by regression testing. ns: not significant data for 5% by regression testing.

the fruits of the first bunch in line with an increase of K levels in the nutrient solution in E1 (Table 2). For the second bunch, there are increases in the levels of P, S, Cu and Zn and reduced levels of N. In the third bunch, there was an increase in the levels of K and S and reduced N, Cu and Zn (Table 2).

E2 consisted of the fruits of the first bunch; there was significant increase in K, Ca, S and Fe and decrease in Mn content and quadratic fit for the contents of N. In the second bunch, there was an increase in levels of N, K, Mg, and Zn.

For the third bunch, there was an increase in content K, S and Cu quadratic fit for P and Mg and Zn, and reduction in content of N, Fe and Mn (Table 3). As they are immature fruits, in the beginning of development; they still transpire and fully absorb nutrients; also, as there are some immovable or slightly mobile nutrients in the plant, there is an initial fructification period when the greatest increase of concentration in the fruits occurs.

The slightly mobile nutrients are transported by the xylem and this type of transport only occurs while these fruits still have the permeable membrane, which enables the transpiration. This fact can result in the increased concentration of immobile or slightly mobile nutrients, as the Ca is absorbed in large quantities in this period; consequently it can inhibit the absorption of other nutrients, such as Mg, Zn, and Cu, as they compete for the same absorption sites. But as soon as the membrane becomes impermeable, the Ca concentration is diluted in the fruit and the concentration of other nutrients increases, becoming balanced again. It is important to emphasize that the dosages of K in the experiments did not harm the nutritional concentration of the fruits.

Prado et al. (2011), in the research work on mineral absorption in growing “Raissa” tomato plants in a hydroponic culture, also uncovered a decreased concentration of Cu and B in fruits as time went on, a quadratic adjustment for Ca, Mn, and Zn and increased concentrations of N, P, K Mg, and S.

The accumulation of P by the organs that compose the fruit branch began to increase after the twelfth week while sprouting. This was accompanied by the increase of the dry mass by the fruits and this was also observed in the studies by Clark and Smith (1990). Miller et al. (1979) reported that in field conditions phosphorus absorption rate was higher in the time interval from 84 to 98 days after transplantation.

K constituted the increased quantity of absorbed macro-nutrient. A proportional growth in the increase of the dosages of nutritive solution was observed when analyzing the accumulation curve of this nutrient, throughout the development cycle in the fruits. For the Ca in our experiments, there was an increase in the beginning of the development and afterwards a decrease. Clark and Smith (1990) verified in the persimmon fruit that there was a significant accumulation during the initial development and 12 weeks after pollination; approximately 88% of the final contents had been acquired, while only 35% of the dry mass had accumulated during the same period.

For the nutritional concentrations of the leaves above each cluster in E1, for “Pizzadoro” tomato, there was an increase in K dosages, a decrease in the concentrations of N and Ca and a quadratic increase for the concentrations of P (Table 4).

There was an increase in the concentrations of S and Mn. The values found in the leaves above the first cluster coincide with those found by Fernandes et al. (2002). In the leaves collected above the second cluster, there was an increase in the concentrations of N, K, Cu, and Mn, as well as a decrease in the concentrations of Ca. This coincides with Fernandes et al. (2002) for N, P, and S and also with Raij et al. (1996) for the other analyzed nutrients.

The leaves above the third cluster displayed a decrease in the concentrations of N, P, Ca, and Mn and an increase in the concentrations of K, S, and Cu. This is in line with Fontes et al. (2000) in the concentrations of K and Ca, and also with Ribeiro et al. (1999), who worked on the analyses of the leaf and petiole opposed to the third cluster, in N and Mg and Fernandes et al. (2002) for the other nutrients (Table 4).

In E2 consisting of “Carina” tomato, when the nutritional concentrations were analyzed for the

Table 4. Levels of macronutrients in g kg^{-1} and micronutrients in mg kg^{-1} of the leaves just above the first, second and third cluster at the beginning of fruit development of Experiment 1, tomato Pizzadoro along with reference levels (Londrina, 2014).

	mg.dm^{-3}	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
				kg.ha^{-1} *2					mg.kg^{-1}		
1st bunch	60	32.81	13.34	27.64	40.49	5.04	16.24	21.65	474.37	568.32	78.85
	120	35.87	15.97	50.25	38.69	5.25	18.96	19.08	500.87	578.26	56.83
	180	34.59	12.24	52.05	32.70	5.17	19.38	18.83	403.76	578.00	37.81
	240	33.16	14.23	63.12	20.71	5.37	23.38	20.58	445.69	726.49	75.02
	300	32.03	12.62	65.08	19.96	5.05	23.99	19.02	395.54	786.93	76.62
	CV(%)	5.07	20.30	17.48	30.79	25.20	6.51	22.25	24.54	12.04	12.85
	p>F*	*	*	*	*	ns	*	ns	ns	*	*
2sd bunch	60	33.83	9.77	30.97	34.67	3.00	11.87	21.11	480.89	655.78	38.76
	120	32.17	10.63	35.01	36.54	3.05	14.95	24.75	511.55	693.80	40.50
	180	29.82	10.68	37.69	30.12	2.71	14.41	28.55	556.70	697.06	35.70
	240	32.28	10.55	48.84	19.27	2.93	16.43	41.33	542.06	900.83	49.94
	300	34.30	9.57	48.41	18.76	2.73	14.65	40.39	608.33	839.39	48.56
	CV(%)	14.32	13.76	25.17	32.66	21.21	23.42	28.83	16.91	22.43	32.76
	p>F*	ns	ns	*	*	ns	ns	*	ns	*	ns
3th bunch	60	34.59	16.71	27.73	33.83	3.22	19.48	8.63	368.31	796.51	48.80
	120	36.39	15.32	49.69	36.10	3.13	17.05	10.52	417.39	619.11	38.60
	180	32.71	11.13	56.04	28.83	3.09	18.78	12.05	419.81	599.08	30.32
	240	31.81	11.62	61.09	18.26	2.90	21.07	14.38	279.48	775.85	61.73
	300	31.35	11.33	83.50	17.59	2.78	22.89	15.77	295.88	731.96	46.48
	CV(%)	5.49	24.53	11.93	32.49	13.91	10.99	13.41	41.03	20.72	23.65
	p>F*	*	*	*	*	ns	*	*	ns	*	*
Fontes (2000)		56	3.1	47-70	31.6	8.4	9.8	798	183	258	25
Ribeiro (1999)		26-40	5.9	91-80	27.4	4.9	-	41	66	103	134
Raij et al. (1996)		40-60	4-8	30-50	14-40	4-8	3-10	5-15	100-300	50-250	30-100
Fernandes (2002)		32	13	51	45	9	18	10	209	665	96

*: Significant data to 5% by regression testing. ns: not significant data for 5% by regression testing.

first leaf above the first cluster, a quadratic relationship was observed based on the increase of the dosages of K for N and P (Table 5).

There was an increase in the concentration of K and S and a decrease in the concentrations of Ca, based on the increase in the dosages of K, coinciding with Fernandes et al. (2002). There was a reduction in the concentrations of N, Ca, and Fe, an increase in the concentrations of K, S, and Mn and a quadratic response for the Cu in the leaves of the second cluster. The results coincide with Fernandes et al. (2002) for N, P, and S and

Table 5. Levels of macronutrients in g kg^{-1} and micronutrients in mg kg^{-1} of the leaves just above the first, second and third cluster at the beginning of fruit development of the Experiment 2, tomato Carina, with reference levels (Londrina, 2014).

	mg.dm^{-3}	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
		kg.ha^{-1} *2						mg.kg^{-1}			
1st bunch	60	34.47	11.27	46.39	40.45	4.51	11.62	20.59	503.35	505.46	82.54
	120	29.69	18.11	50.66	38.66	5.40	21.13	19.16	527.44	512.44	62.03
	180	36.70	11.95	62.53	34.86	5.12	20.42	18.71	420.51	530.13	53.85
	240	34.99	14.15	63.06	24.73	5.33	23.29	19.05	416.23	733.52	75.09
	300	34.22	12.83	64.92	19.94	5.01	21.33	17.22	303.04	683.60	76.81
	CV (%)	7.71	25.06	18.52	34.28	24.67	13.24	24.83	28.51	20.04	13.53
	p>F*	*	*	*	*	ns	*	ns	*	*	*
2sd bunch	60	43.00	12.44	43.52	33.51	2.71	6.66	6.08	363.29	637.95	79.26
	120	37.49	10.02	65.55	36.50	3.01	12.42	10.00	359.91	564.44	83.66
	180	27.20	11.27	71.35	31.90	2.35	12.26	11.24	253.71	603.37	93.08
	240	32.34	10.21	73.39	20.41	2.77	17.70	11.56	167.69	785.45	58.81
	300	31.89	9.68	75.50	18.74	2.88	18.57	7.86	153.07	874.04	58.02
	CV (%)	10.70	27.78	16.50	32.88	26.38	24.06	41.50	38.83	27.30	28.06
	p>F*	*	ns	*	*	ns	*	*	*	*	*
3th bunch	60	36.53	11.37	25.87	33.79	2.39	12.59	10.21	273.88	745.53	30.21
	120	31.75	10.97	51.21	36.06	2.85	17.27	11.92	388.09	626.03	38.79
	180	31.24	11.60	63.81	27.64	2.77	23.28	16.64	332.18	696.26	47.74
	240	30.23	9.78	69.17	18.21	2.97	20.41	15.14	310.74	585.10	35.67
	300	34.82	11.20	72.15	17.57	2.96	23.05	13.67	181.29	605.54	47.32
	CV (%)	6.65	14.23	14.62	30.21	18.82	13.46	19.20	30.76	27.13	23.73
	p>F*	*	ns	*	*	ns	*	*	*	*	*
Fontes (2000)		56	3.1	47-70	31.6	8.4	9.8	798	183	258	25
Ribeiro (1999)		26-40	5.9	91-80	27.4	4.9	-	41	66	103	134
Raij et al. (1996)		40-60	4-8	30-50	14-40	4-8	3-10	5-15	100-300	50-250	30-100
Fernandes (2002)		32	13	51	45	9	18	10	209	665	96

*: Significant data to 5% by regression testing. ns: not significant data for 5% by regression testing.

with Raij et al. (1996) for all the other analyzed nutrients (Table 5).

When the leaves were analyzed right above the third cluster, there was a decrease in the concentration of N and Mn and an increase in the concentration of K, S, and Zn. There was a quadratic response for Ca and Fe. The results coincide with Fontes et al. (2000) and the concentrations of K and Ca, and with Ribeiro et al. (1999), who worked on the leaf and petiole opposite to the third cluster, in N and Mg and Fernandes et al. (2002) for all the other nutrients.

When analyzed jointly, the behavior of the nutrients above the three clusters, with increased dosages of K, an increased concentration of Mn was verified in the leaves of the first and second cluster in both experiments and a decrease in the leaves of the third cluster. This behavior was mainly attributed to the excess of K that caused Mn deficiency, as confirmed by Silva et al. (1995) and Carvalho et al. (2001) in the study onh the increase of the dosages of K in passion fruit plant. It was also verified the reduction in the concentrations of Ca based on the increase of the dosages of K in the leaves above all the clusters in both experiments. This is another case of competition among cations, verified since the beginning of the development of the plant. It coincides with the reports of Mascarenhas et al. (2000) and Oliveira et al. (2001).

According to Malavolta (2006), based on the increase in the concentrations of K in the nutritive solution, there is competition in the absorption of Ca and Mg as during the absorption process, thesenutrients use the same loading sites.

There was a quadratic response in the leaves of the first cluster and the concentration of Cu increased in the leaves of the second and third cluster of E1 in both experiments on the concentration of P. There was quadratic behavior in the leaves of the same clusters in E2, based on the increase in the dosages of K. This fact is related to the decrease in the concentrations of Ca whose increase leads to a decrease in the concentrations of Cu.

A decrease in the concentrations of N was alsoobserved in the leaves above the third cluster in both experiments. This is attributed to the increase in the dosages of K that caused an increase in the synthesis of proteins in the plant, consuming the N for the synthesis of proteins. Due to the increase in the synthesis of proteins, an increase in the concentration of S in the leaves was also observed, above the three clusters, in both experiments. This led to a high demand for this macro-nutrient because of the increase of the dosages of K.

The increase in the dosages of potassium significantly influenced the nutritional concentration in the vegetable tissue, as there were increases in the concentrations of K and S in the fruits and K, Mn, and Cu in the leaves, with decreased concentrations of Ca, in both experiments.

Conflict of Interests

The authors have not declared any conflict of interests.

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