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Effect of the dose and form of placement of the potassium on the concentration foliates of macroelements in the tomato (*Lycopersicon esculentum* Mill.)

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Abstract

The effect of three potassium level was studied; 0.220 and 330 kg.ha^{-1}, put in three different ways (central, lateral and at the bottom of the furrow) on the foliar concentration of N, P, K, Ca and Mg, measured by spectrophotometry of atomic absorption and using a Perkin-Elmer equipment, model 2280 and the foliar concentration of P was analyzed by photometry using molybdate of ammonium during flowering, filled and fruiting in the tomato cv. Río Grande plant, of the Guarabal area, Falcon municipality, in a soil classified as Haplocambids. A randomized plot design was used with 7 treatments and 6 replications. N was found between ranks from 5.38% and 5.88% in treatments of 330 kg.ha^{-1}-bottom of the furrow and 330 kg.ha^{-1}-lateral, respectively. A higher concentration of K was determined during flowering. P varied from 0.29%, 0.14%, and 0.23% during flowering, filled and fructification respectively. The treatments that most accumulated K were the one of 330 kg.ha^{-1}-central and the other of 330 kg.ha^{-1}-bottom of the furrow; concentrations of Ca varied from 3.61% to 4.63% in treatments 330 kg.ha^{-1}-lateral and 220 kg.ha^{-1}-bottom of the furrow respectively. Regarding Mg, concentrations varied from 0.83% to 1.06 %for treatments of 330 kg.ha^{-1}-lateral and the witness respectively. The concentration of N, during filling varied from 3.30% to 3.78 % in witness treatments and 220 kg.ha^{-1}-lateral. P varied from ranks of 0.13% to 0.16% in treatments of 220 kg.ha^{-1}-bottom of the furrow and from 330 kg.ha^{-1}-lateral. K was from 2.11% to 2.40% in treatments 220 and 330 kg.ha^{-1}-bottom of the furrow, respectively, during fruiting significant differences were not found among treatments for concentrations of N, P, K, Ca and Mg.

Key words: tomato, flowering, filled, fruiting, potassium, macroelements

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Introduction

Nowadays the crop of tomato demands the knowledge and/or handling of a high technological level, as well as the knowledge of aspects inherent to the growth and development of the plant, especially during the formation of fruits. This phase depends on the adequate application of macro and micro nutrients, which must be based in an estimation of requirements, considering the relation between the absorption of nutrients of the crop, analysis of the soil and analysis of the tissue (1). It also depends on the knowledge of the ecophysiologic behavior based on the agronomic handling, the measurement of the accumulated biomass in the plant (7) and the yield efficiency and production in the conversion of nutrients (8, 11, 19).

The fertilization that is now being used does not obey an established program that agrees to the different phenological development phases of the plant, what makes the practice to be inefficient.

Potassium is a monovalent cation, which absorption is highly selective and widely joined in the metabolic activity; it is characterized by a high mobility in the plant at all levels inside individual cells, inside tissues and the transport to huge distance between xylem and phloem, these functions are related to the enzymatic activation processes, synthesis of proteins, photosynthesis, osmoregulation, cell extension, movements of organs, transport in the phloem, cation-anion balance (16).

Tomato is the best deposit f K, accumulation an average of 60% of the absorbed K^+ (23). K^+ constitutes near 90% of cations present in the fruit of tomato and the pericarp accumulates more K than the locule tissue, for example, 60% and 40% of the total in the fruit respectively (2).

The efficiency in the absorption of K has proved to be higher in young plants, and the ability for concentrating K in the xylem has been related to the growth rate of the steam; likewise, the highest accumulation rate of K in the plant seems to depend on the high rate of transport in the transpiration (24).

Many research have proved the effect of K in combination to other cations as calcium and magnesium, K/Ca and K+Mg/Ca relation is associated to the occurrence of some disorders in the ripening of tomato, which decrease when K/Ca and Ca+Mg/Ca relations increase in leaves and fruits (22).

The efficiency in the use of fertilizers has been well documented (4, 12, 15, 26), likewise, the efficiency has also been widely related to the different positioning ways; for the case of tomato, it has been said that the average response regarding the central position is of 43.45 $Tm.ha^{-1}$ with and efficiency of 296 kg per kg of phosphorus fertilizer applied, while for the potassium fertilizer the average response was of 36.46 $Tm.ha^{-1}$ of the lateral position with an efficiency of 233 kg (18, 19).

Therefore, considering all these aspects the objective of this research was to evaluate the effect of three potassium levels and their ways of application on the foliar concentration of N, P, K, Ca, Mg during flowering, filled and fruiting of tomato (*Lycopersicon esculentum* Mill.).

Materials and methods

The experiment was carried out at Santa Bárbara farm, located at el Guarabal, Independencia parish, 13 Km west from Churuguara, capital of Falcon municipality, at 10º 47' of North latitude, 69º 32' West longitude and altitude of 685 meters on sea level.

According to the life zone classification of Ewel *et al*, (9), this area is located inside the description of Very Dry Tropical Forest. The annual average precipitation varies from 550 to 1100 mm and the annual mean temperature is 28ºC, which absolute maxima is 18ºC. Evapotranspiration surpasses 2000 mm.year^{-1} (5).

The vegetal material used was the Río Grade hybrid, which was sowed in seed beds and transplanted 35 days after, at a distance of 1.20 m between the furrow and 0.30 m between plants, for a density of 27.000 plants.ha^{-1}. 150 kg.ha^{-1} of ammonium nitrate were applied, fractioned in three parts; 80 kg^{-1} of P (fosfopoder) at the moment of the transplant, and potassium in the indicated doses (treatments). Irrigation per furrows was used, applying it in the morning daily for the first 8 days after the transplant and then every three days.

Potassium chloride (KCI) was used as a source of potassium, being treatments:

Number	Doses (kg.ha^{-1})	Positioning
1	220	Central
2	220	Lateral
3	220	Bottom of the furrow
4	330	Central
5	330	Lateral
6	330	Bottom of the furrow
7	0	Witness

The fertilizer was put manually, so it was necessary to open on the ridge a band of 10 cm of width x 15 of depth (stakes were put in both extremes), the fertilizer was applied later and the ridge was formed again. Subsequently, the transplant was done considering as a guide the stakes that indicated where the fertilizer was located. Potassium was put similarly, in a lateral way or next to the plant. While, for the other positioning 70% of the KCl doses was put at the moment of the transplant at the bottom of the furrow, applying the rest in the water used for irrigating.

For foliar samplings 15 leaves were selected that were under and opposite to the most apical floral branch. The first sampling carried out 58 to 70 days after the transplant (DDT) which agreed to flowering; the second from 70 to 82 DDT (filled) and

the third from 80 to 120 DDT (fruiting).

Samples were dried in a stove at 75ºC for 72 hours. Then were grinded and sifted; a sub sample of 1 g was taken, which was taken to a stove and was incinerated at 500ºC for 5 hours. To the obtained ash was added nitric acid at 20% for 24 hours, then, in a tube of 50 ml the correspondent dilutions were obtained in order to measure N, K, Ca and Mg per atomic absorption spectrophotometry, using a Perkin-Elmer equipment, model 2280, and the foliar concentration of P was analyzed by photometry using the ammonium molybdate reactive.

A randomized plot design was used with seven (7) treatments and six (6) replications, for a total of 42 experimental units, each one formed by tour (4) furrows of 4 m length, divided in 1.20 m among them for a surface of 14.40 m^2.plot-^{1} and an effective total area of 604.80 m^2.

Results and discusión

A. Absorption of macro elements during flowering, filled and fruiting

In table 1 are shown the means obtained from macro elements N, P, K, Ca and Mg in the main phenology events, significant differences were observed ($P<0.05$) in the results in relation to the three phases of reproductive development of the crop.

Nitrogen concentration was in 5.60% in flowering phase, which is appropriate according to Bennett (6), who reported adequate concentrations from 4 to 6% while 3% was considered as deficient levels in young plants. On the contrary, this percentage was high if it is considered that Jones *et al*. (14) reported that an accumulation higher of 3.5% of this element was high. N concentration reduced during filled and then increased in fruiting, which agrees to what Jones *et al*. (14) reported.

On the particular case of phosphorus for flowering, a higher concentration of this element was observed with 0.30%, then it reduced during the filled to 0.15% and finally increased during fruiting to 0.24%, these values World be low if are compared to those reported by Jones *et al*. (14). Likewise, Bennett (6) reported that concentrations under 0.4% were deficient in young plants, 0.98% was an adequate level 28 days after the transplant, as well as 0.78% 56 days after the transplant.

The percentage of potassium started reducing during flowering, filled and fruiting phases, with averages of 2.41; 2.23 and 1.22, respectively, which were considered low compare to those reported by Jones *et al.* (14) and Wilcox (25), who found the highest concentration of K in the foliar tissue within 45 days of emergency; while the lowest was found within 91 days with 2.57% agreeing with fruiting. However, potassium constitutes at least 90% of cations present in the fruit (29, which might explain this behavior since the fruit is the best "drain" of this element, that is the reason that it was

Table 1. Concentration of macro elements N, P, K, Ca and Mg in the foliar tissue of tomato cv. Río Grande, treated with potassium chloride and evaluated in flowering, filling and fruiting.

Phase of the crop	Macro elements (%)				
	N	P	K	Ca	Mg
Flowering	5.60a[1]	0.30a	2.41a	4.16b	0.98b
Filling	3.53c	0.15c	2.23b	2.39c	0.70b
Fruiting	4.13b	0.24b	1.22c	5.12a	1.04a
P<0.05	*	*	*	*	*
C.V. (%)	16.02	44.77	18.58	23.24	14.09

Average of three evaluations

[1] Values in columns followed by different letters are statistical different (P<0.05) according to Duncan multiple rank test.

observed this reduction in leafs, because an excess is required to obtain a good ripening and firmness of fruits (17).

Calcium reached the highest concentration during fruiting, reducing in flowering and finally was the lowest level during filling; this element is related to the formation of the cellular wall, which is an important role in the consistency of fruits (18), likewise, it is also related to the ripening and softness process of fruits (8). According to Jones *et al.* (14), during flowering Ca concentration was high, meanwhile in the filling and fruiting was normal, with values from 1.5% to 2.5% respectively.

The absorption of Ca might be particularly reduced by high concentrations of potassium, and in this essay K was found in low levels. Likewise, Greenwood and Stone (13) mentioned an increment in the absorption of Ca as a consequence of the restriction of K. The movement of Ca in the plant is through the transpiratory torrent, irrigation was applied in the morning and in this are the evapotranspiration is very high, which might explained the high concentration of this element and the lowest absorption of K.

Magnesium reached values from 0.98% to 0.70% and 1.04% in flowering, filling and fruiting, respectively. On the other hand, Jones *et al.* (14) found the highest levels in flowering > 8.0% filling > 1.0% and fruiting > 0.9% while Wilcox (25) found the highest value in leafs, 77 days after the emergency with 1.15%. Potassium is directly related to the absorption of some macro nutrients and its application in high quantities might cause some nutritional problems product of the fixation and/or displacement of cations (1).

B. Absorption of macro elements in relation to treatments

N, P, K, Ca and Mg concentrations during flowering can be observed

in table 2, significant differences were found (P<0.05) among treatments for concentrations of N, Ca and Mg. In relation to nitrogen, it was found from 5.38% and 5.88% in treatments of 330 kg.ha^{-1}-bottom of the furrow and 330 kg.ha^{-1}-lateral, respectively, being these values high compare to those reported by Wilcox (25) who reported concentrations lower of 2.5% as deficient and values higher of 3.5% as an adequate level.

Phosphorus concentration varied from 0.27% to 0.33%, which meant normal values according to Jones *et al.* (14), who reported as normal values those from 0.25 and 10%, while Wilcox (25) registered lower concentrations at 0.12% as deficient and lower at 0.2% as adequate.

Potassium was found in ranks 2.22% and 2.52%, being these averages in insufficiency conditions or under the normal values (14). Normal concentrations have been found from 4.00 and 8.00 according to Jones *et al.* (15). However, Wilcox (25) found that concentrations under 2.3% were deficient levels and 3.5% were adequate levels. There have also been cited adequate levels from 56 and 70 days after the transplant values of 3.93% and 3.85%, respectively (6). The treatments that most accumulated potassium were 330 kg.ha^{-1}-central and 330 kg^{-1}-bottom of the furrow, the witness accumulated the lowest quantity of K (2.22 %).

Mulholand *et al.* (17), studying the individual and interactive effect of the temperature in the radical area, nutrition with potassium and the

Table 2. Effect of the doses of potassium chloride and the way of positioning in the soil on the concentration of macro elements N, P, K, Ca and Mg in the foliar tissue of Tomato cv. Río Grande, evaluated in flowering.

Way of positioning	KCl (kg.ha^{-1})	Macro elements (%)				
		N	P	K	Ca	Mg
Witness	0	5.55^{b1}	0.31^{a}	2.22^{a}	4.39^{ab}	1.07^{a}
Central	220	5.63^{ab}	0.27^{a}	2.32^{a}	4.20^{ab}	0.98^{a}
	330	5.70^{ab}	0.33^{a}	2.52^{a}	3.92^{ab}	1.00^{a}
Lateral	220	5.53^{b}	0.29^{a}	2.34^{a}	4.01^{ab}	0.95^{ab}
	330	5.88^{a}	0.29^{a}	2.28^{a}	3.61^{b}	0.83^{b}
Bottom of	220	5.55^{b}	0.29^{a}	2.45^{a}	4.64^{a}	1.00^{a}
the furrow	330	5.38^{b}	0.32^{a}	2.46^{a}	4.36^{ab}	1.00^{a}
P<0.05		*	n.s.	n.s.	*	*
C.V. (%)		4.53	16.31	16.98	18.13	11.57

Average of three evaluations.
[1]Values in columns followed by different letters are statistical different (P<0.05) according to Duncan multiple rank test.

deficit of vapor pressure on the accumulation of Ca and K in tomato, found that the accumulation of K was low in all leafs and fruits in the lowest portion of the plants that grew in the highest humidity. It is known that the regulation of the osmotic potential and the cellular turgor is the primary function of K in the plant, and also that high levels of K in the cell are associate to high turgor, Mengel and Kirkby 1980, cited by Mulholand *et al*. (17). In this matter Mulholand *et al*., (17) proponed that on high humidity the inhibition of the absorption of K from the root might be occurring, due to the steady and high turgor in the leaf, causing the lowest accumulation in the sprout.

The concentrations of calcium varied from 3.61% to 4.64% in treatments 330 kg.ha^{-1}-lateral and 220 kg.ha^{-1}-bottom of the furrow respectively, which is a high level compare to the reported by Jones et al. (14) who mentioned as normal levels those from 1.50 to 2.50%. On the contrary, Wilcox (25) reported as adequate levels those higher of 3.0% and as deficient those lower of 1.0%.

In relation to Magnesium, concentrations varied from 0.83% to 1.07% for treatments of 330 kg.ha^{-1}-lateral and the witness respectively. Jones *et al*. (14) reported that normal values were from 0.32 to 0.8%, while Wilcox (25) found the highest level within 77 days after the emergency with 1.15% and reported the highest value at 0.42% as adequate.

The concentration of N, P, K, Ca and Mg during the filling is shown in table 3; significant differences were found among treatments for the concentration of P. For the case of nitrogen, the concentration varied from 3.30% and 3.78% in the witness treatments and of 220 kg.ha^{-1}-lateral, respectively.

According to Jones et al. (14), normal values for this phase was found from 2.0% and 3.96%, while Bennet (6), registered values over 4.70% as adequate levels.

Phosphorus varied from 0.13% to 0.17% in treatments of 220 kg.ha^{-1}-bottom of the furrow and of 330 kg.ha^{-1}-lateral, respectively. Wilcox (25) found that phosphorus reduced 21 days after the emergency until the end of the plant's cycle, reporting averages from 0.20% to 0.54%, so it can be said that in this essay levels were low. Potassium was from 2.12% and 2.40% in treatments of 220 kg.ha^{-1}-bottom of the furrow and of 330 kg.ha^{-1}-bottom of the furrow, respectively. Low levels of K even with high applications have been associated to a specific competition of cations or cationic antagonism (16).

The concentration of calcium varied from 1.89% to 2.91% in the witness treatments and 220 kg.ha^{-1}-lateral, respectively. Likewise, Jones *et al*. (14) reported as normal values those from 1.50% to 2.50%, contrary to Wilcox (25), who reported values from 3.06% to 4.31% and fixed 3.0 as the most adequate level. It must be mentioned that Ca concentrations were lower in flowering and fruiting. Magnesium content varied from 0.68% to 0.70% in treatments of 220 kg.ha^{-1}-central and 220 kg.ha^{-1}-lateral, respectively. These concentrations reduced during

Table 3. Effect of the doses of potassium chloride and the way of positioning in the soil on the concentration of macro elements N, P, K, Ca and Mg in the foliar tissue of tomato cv. Río Grande, evaluated during the filling of fruits.

Way of positioning	KCl (kg.ha^{-1})	Macro elements (%)				
		N	P	K	Ca	Mg
Witness	0	3,30^{a1}	0,14^{ab}	2,19^{a}	1,89^{a}	0,70^{a}
Central	220	3,32^{a}	0,14^{ab}	2,14^{a}	2,34^{a}	0,69^{a}
	330	3,60^{a}	0,15^{ab}	2,27^{a}	2,38^{a}	0,71^{a}
Lateral	220	3,78^{a}	0,14^{ab}	2,31^{a}	2,91^{a}	0,71^{a}
	330	3,50^{a}	0,17^{a}	2,18^{a}	1,93^{a}	0,69^{a}
Bottom of	220	3,38^{a}	0,13^{b}	2,12^{a}	2,29^{a}	0,71^{a}
the furrow	330	3,72^{a}	0,16^{a}	2,40^{a}	2,28^{a}	0,70^{a}
P<0,05		n.s.	*	n.s.	n.s.	n.s.
C.V. (%)		4,53	16,72	14,20	45,15	15,45

Average of three evaluations.
[1]Values in columns followed by different letters are statistical different (P<0.05) according to Duncan multiple rank test.

flowering. Jones *et al*. (14) found normal values from 0.33% and 0.90%, averages that agree to the ones found in this research.

During fruiting (non shown information), potassium was found in low values, which was expected since the analysis was done in the leaf and in that moment the fruit is the highest drain, as is mentioned by Mulholand *et al*. (17). Phosphorus was found in normal levels and Ca was high. Magnesium registered a reduction during filling and the increased during fruiting. Rezende *et al*. (20) found that the concentrations of P, S and Mg in the fruit are not affected by the doses of potassium, while nitrate, potassium and K/Ca and K/Mg relations increased when the doses of potassium increment.

Conclusions

Generally, all elements reduced during filling, being this reduction in the following order: Ca > N > Mg > K > P because this element is the most demanded during fruiting and Ca was in high levels restringing the absorption of K.

On the other hand, the way of positioning did not influence the absorption of K by the plant in any of

the evaluated phases. Nevertheless, in the position bottom of the furrow, was slightly higher in all cases, so it would be convenient to continue investigating with different doses, relating them to the humidity content of the soil.

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