FRUIT SIZE, MINERAL COMPOSITION AND QUALITY OF TRICKLE-IRRIGATED TOMATOES AS AFFECTED BY POTASSIUM RATES[1]

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ABSTRACT - An experiment was conducted to determine the fruit size, mineral composition and quality of trickle-irrigated tomatoes as affected by potassium fertilizer rates. Six potassium (K) rates were applied as KCl, corresponding to 0, 48.4, 118.6, 188.8, 259.0 and 399.4 kg ha^{-1}, with four replicates, following a randomized block design. Quadratic responses to K rates were observed for double extra large (diameter > 60 mm), extra large (56 to 60 mm) and large (52 to 56 mm) fruit yields. Maximum yields of these classes were achieved with K rates of 116, 190 and 233 kg ha^{-1}, respectively. Fruit dry matter, phosphorus, sulfur and magnesium contents were not affected by K rates, but nitrate and K contents showed significant increments as K rates were increased. Vitamin C, total soluble solids, lycopene and β-carotene contents in the fruits were not affected by K rates. Increments in the K rate lowered the fruit pH and increased total acids content.

Index terms: *Lycopersicon esculentum*, lycopene, soluble solids, acidity.

TAMANHO, COMPOSIÇÃO MINERAL E QUALIDADE DE FRUTOS DE TOMATEIRO IRRIGADO POR GOTEJAMENTO EM RAZÃO DE DOSES DE POTÁSSIO

RESUMO - Para determinar o efeito da fertirrigação com K sobre o tamanho, a composição mineral e a qualidade dos frutos do tomateiro, foi conduzido um experimento com aplicação de seis doses de K, na forma de KCl, correspondendo a 0, 48,4, 118,6, 188,8, 259,0 e 399,4 kg ha^{-1}, com quatro repetições, distribuídas no delineamento experimental em blocos casualizados. Foram observadas respostas quadráticas das produções das classes de frutos graúdo 2 (diâmetro > 60 mm), graúdo 1 (56 a 60 mm) e graúdo (52 a 56 mm) em relação às doses de K aplicadas na adubação. As produções máximas de frutos de cada classe foram obtidas com as doses de K de 116, 190 e 233 kg ha^{-1}, respectivamente. O conteúdo de matéria seca e os teores de P, S e Mg dos frutos não foram influenciados pelas doses de K, mas os teores de nitrato e de potássio aumentaram com o aumento das doses. Os teores de vitamina C, sólidos solúveis, licopeno e β-caroteno não foram influenciados pelas doses de K; porém, os incrementos nas doses reduziram o pH e aumentaram o conteúdo de ácidos nos frutos.

Termos para indexação: *Lycopersicon esculentum*, licopeno, sólidos solúveis, acidez.

INTRODUCTION

Tomato crop has a high commercial value in Brazil (Makishima & Miranda, 1992; Barbosa, 1993), since it is widely appreciated not only in processed forms but also as fresh fruit on the diet, as source of vitamins and minerals. Furthermore, tomato presents a better postharvest conservation and resistance to transport compared to other fruits and vegetables. In order to obtain high tomato yield, it is necessary to add K fertilizer to the soil, when low levels are present. Although it has been attributed to K a controlling effect on tomato fruit production, few studies had been done to verify the influence of different K rates applied by fertirrigation on fruit size, mineral composition and fruit quality.

Potassium plays several important roles in the plant cell, such as enzyme cofactor, synthesis and stability of proteins, and involvement in the carbohydrate synthesis (Marschner, 1995). Moreover, K seems to influence the development of red color in

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the ripe fruit (Amable & Sinnadurai, 1977). Usually, deficiency of K inhibits the biosynthesis of sugars, organic acids and vitamin C, resulting in lower soluble solids content in the fruits (Sobulo & Olorunda, 1977; Matev & Stanchev, 1979).

This study was undertaken to determine the effect of K fertilizer rates applied by drip irrigation water on tomato fruit size, mineral composition and quality.

MATERIAL AND METHODS

The experiment was carried out at the garden field of the Federal University of Viçosa, MG, Brazil, on a Cambic Yellowish Podzolic. The soil chemical characteristics described by Sampaio (1996) are shown (Table 1).

Seeds of cultivar Santa Clara were sown in paper bags in May 25, and then transplanted to plots after 25 days. Plots consisted of four 3.5 m rows, 1.0 m apart. Yield data were collected from the two central rows and the outer rows served as guard rows. Six treatments of K rates, expressed as kg ha^{-1}, were added to increase the soil cation exchange capacity to 2% (48.4 kg ha^{-1}), 3% (118.6), 4% (188.8), 5% (259.0) and 7% (399.4). The K rates, as KCl, were applied 40% in the furrows at the transplanting time and 60% at the second, fourth and sixth cluster set, through the trickle irrigation system. The experiment was arranged in a complete randomized block design with four replications. The production system was managed following conventional procedures for staked fresh-market tomatoes production in the field conditions, except for the irrigation system.

Fruits were harvested periodically, from September 20 up to November 16, at full red stage and classified by the size of transversal diameter as follow: double extra large, ≥ 60 mm; extra large, ≥ 56 mm < 60 mm; large, ≥ 52 mm < 56 mm; medium, ≥ 47 mm < 52 mm and small, ≤ 47 mm. Samples of whole fruit were used to determine the pH and titratable acidity as described by Gould (1974). Total soluble solids was measured in a refractometer Abbe and vitamin C was determined as described by Instituto Adolfo Lutz (1985). Lycopene and total carotenoids were analyzed using the method described by Zscheile & Porter (1947). Whole fruits were oven-dried at 70°C to constant weight and dry matter samples were used for the determination of nitrate (Cataldo et al., 1975), phosphorus (Braga & Defelipo, 1974), sulfur, potassium, calcium and magnesium (Malavolta et al., 1989) contents.

All data were subjected to analysis of variance, and when appropriated, adjusted by regression analysis.

RESULTS AND DISCUSSION

Significant responses to K rates were observed for total, double extra large, extra large and large fruits (Table 2), reaching their maximum of 86.4, 40.7, 20.6 and 16.0 t ha^{-1} at rates of 198, 116, 190 and 233 kg ha^{-1}, respectively. The K rates associated to the optimum profit yield for double extra large, extra large and large fruits were 116, 185 and 217 kg ha^{-1}, respectively.

Fruit dry matter, P, S and Mg concentrations were not influenced by K rates. Fruit dry matter values were lower than reported in the literature for other tomato cultivars (De Bruyn et al., 1971; Panagiotopoulos & Fordham, 1995). Nitrate ($N\text{-}NO_3^-$), K, and K/Ca, K/Mg and K/(Ca+Mg) ratios in the fruits increased with the increment of K rates (Table 3). At the K rate equal to 198 kg ha^{-1}, which led to the maximum tomato fruit yield, $N\text{-}NO_3$, K and Ca contents in the fruit dry matter were 0.24, 2.12 and 0.10 dag kg^{-1}, respectively. These values were similar to those found by Sanchez Conde (1983, 1986). At this same K rate, the K/Ca ratio was 21.48, K/Mg equal to 13.90 and K/(Ca+Mg) of 8.33 (Table 3).

It has been reported that the vitamin C content in the fruit is influenced by soil K level (Sobulo & Olorunda, 1977). However, in this experiment, the K rates supplied to the plant did not influence the vitamin C concentration in the fruits, 16.91 mg 100^{-1} g of

TABLE 1. Soil chemical and physical characteristics[1].

C	pH-H_2O 1:2.5	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	Argila	Silte	Areia
(dag kg^{-1})		-- (mg dm^{-3}) --		-------------- ($cmol_c$ dm^{-3}) --------------				---------- (dag kg^{-1}) ----------		
2.38	5.5	2.6	46	3.6	0.5	0.1	4.8	40	9	51

[1] P and K^+: Mehlich-1 extractor; Al^{3+}, Ca^{2+} and Mg^{2+}: KCl 1 mol L^{-1} extractor; H+Al: $Ca(OAc)_2$ 0,5 mol L^{-1} with pH 7,0 extractor.

fresh weight (Table 3). Similar results were observed for total soluble solids, lycopene and total carotenoid concentrations in the fruits (Table 3). These data are in contrast to those where K fertilizer rate affected the lycopene and carotenoid contents in tomato (Trudel & Ozbun, 1970, 1971; Amable & Sinnadurai, 1977). The results reported here may reflect adequate original K disponibility and cultivar differences in absorption and response to K fertilization.

TABLE 2. Relationship between potassium fertilizer rates (X = kg ha^{-1}) and total (T), double extra large (D), extra large (E) and large (L) fruit yields (t ha^{-1}).

Regression equations	R^2
$Y_T = 69.12 + 0.1746^{**}X - 0.000441^{**}X^2$	0.92
$Y_D = 24.60 + 0.3099^{*}X - 0.00178^{*}X^2 + 0.0000026^{+}X^3$	0.96
$Y_E = 15.04 + 0.058094^{**}X - 0.000153^{**}X^2$	0.93
$Y_L = 11.57 + 0.03803^{*}X - 0.00008155^{+}X^2$	0.77

+, * e ** Significant at 0.10, 0.05 and 0.01 probability level, respectively.

Fruit pH declined linearly with the increment in the K rate (Fig. 1). With K at 198 kg ha^{-1}, the fruit pH was 4.25, just bellow the 4.50 threshold considered as non acid fruit (Gould, 1974). The presence of low pH in tomato fruit is an important feature for its processing, since pH bellow 4.3 reduces the risk of bacterial growth. In addition, it is well known that higher acid content is related to a superior fruit flavor in tomato (Panagiotopoulos & Fordham, 1995). Grierson & Kader (1986) emphasized that the fruit flavor is particularly determined by the concentration of soluble sugars and acids. Fruit titratable acidity was significantly increased with the increment in the K rates, reaching 0.24% of citric acid with K at 198 kg ha^{-1} (Fig. 1). Comparing data from Fig. 1, it can be established a negative linear correlation (r = -0.91) between pH and acids content in tomato fruit. Mahakun et al. (1979) analyzing acidic constituents of various tomato types and fruit tissues, also observed similar relationship between pH and total acidity.

TABLE 3. Relationship between potassium fertilizer rates (X = kg ha^{-1} K) and fruit dry matter, nutrient contents, cation ratios, vitamin C, total soluble solids, lycopene and total carotenoid in tomato fruits.

Characteristics	Regression equation[1]	R^2
Dry matter (dag kg^{-1})	$Y_e = Y_a = 3.31$	
$N\text{-}NO_3^-$ (dag kg^{-1})	$Y_e = 0.19 + 0.000234^{+}X$	0.60
P (dag kg^{-1})	$Y_e = Y_a = 0.23$	
S (dag kg^{-1})	$Y_e = Y_a = 0.09$	
K (dag kg^{-1})	$Y_e = 1.62 + 0.00251^{**}X$	0.95
Ca (dag kg^{-1})	$Y_e = 0.09 + 0.00321^{*}X^{0.5} - 0.000159^{*}X$	0.53
Mg (dag kg^{-1})	$Y_e = Y_a = 0.16$	
K/Ca	$Y_e = 15.46 + 0.0304^{**}X$	0.83
K/Mg	$Y_e = 10.24 + 0.0185^{**}X$	0.83
K/(Ca+Mg)	$Y_e = 6.05 + 0.0115^{**}X$	0.93
Vitamin C (mg 100 g^{-1} FW)	$Y_e = Y_a = 16.91$	
Total soluble solids (%)	$Y_e = Y_a = 4.43$	
Lycopene (μg g^{-1} FW)	$Y_e = Y_a = 56.57$	
Carotenoid (μg g^{-1} FW)	$Y_e = Y_a = 65.76$	

[1] Y_e and Y_a are the estimated and average values, respectively.
+, * e ** Significant at 0.10, 0.05 and 0.01 probability level, respectively.

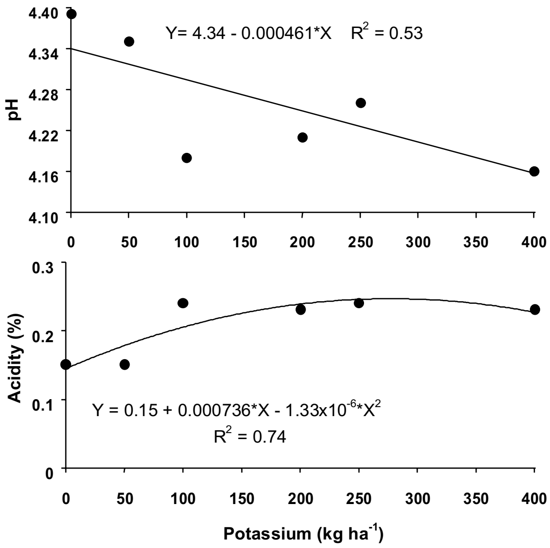

FIG. 1. Influence of potassium fertilizer rates on tomato fruit pH and acidity (* significant at 0.05 probability level).

CONCLUSIONS

1. Maximum yields of larger fruit sizes are obtained with lower potassium rates.

2. Dry matter, phosphorus, sulfur, magnesium, vitamin C, total soluble solids, lycopene and β-carotene concentrations in the fruits are not affected by K rates.

3. Nitrate, potassium, K/Ca, K/Mg and K/(Ca + Mg) concentration ratios in the fruits increase with the increase in the potassium rates.

4. Fruit pH decreases with the decrease in the potassium rates.

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