TOMATO YIELD AND POTASSIUM CONCENTRATIONS IN SOIL AND IN PLANT PETIOLES AS AFFECTED BY POTASSIUM FERTIRRIGATION[1]

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ABSTRACT - Tomato (*Lycopersicon esculentum* Mill.) cv. Santa Clara was grown on a silt clay soil with 46 mg dm^{-3} Mehlich 1 extractable K, to evaluate the effects of trickle-applied K rates on fruit yield and to establish K critical concentrations in soil and in plant petioles. Six potassium rates (0, 48, 119, 189, 259 and 400 kg ha^{-1} K) were applied in a randomized complete block design with four replications. Soil and plant K critical levels were determined at two plant growth stages (at the beginning of the second and fourth cluster flowering). Total, marketable and weighted yields increased with K rates, reaching their maximum of 86.4, 73.4, and 54.9 ton ha^{-1} at 198, 194, and 125 kg ha^{-1} K , respectively. At the first soil sampling date K critical concentrations in the soil associated with K rates for maximum marketable and weighted yields were 92 and 68 mg dm^{-3}, respectively. Potassium critical concentrations in the dry matter of the petioles sampled by the beginning of the second and fourth cluster flowering time, associated with maximum weighted yield, were 10.30 and 7.30 dag kg^{-1}, respectively.

Index terms: *Lycopersicon esculentum*, optimum rate, leaf analysis, soil analysis.

PRODUÇÃO DE TOMATE E CONCENTRAÇÕES DE POTÁSSIO NO SOLO E NA PLANTA INFLUENCIADAS POR FERTIRRIGAÇÃO COM POTÁSSIO

RESUMO - Plantas de tomate (*Lycopersicon esculentum* Mill.) cv. Santa Clara foram cultivadas em solo argiloso contendo 46 mg dm^{-3} de K disponível (Mehlich 1), para avaliar os efeitos de doses de potássio, aplicadas na água de irrigação, por gotejamento, sobre a produção de frutos, e para determinar as concentrações críticas desse nutriente no solo e nos pecíolos. Foram utilizadas seis doses de K (0, 48, 119, 189, 259 e 400 kg ha^{-1}), no desenho experimental de blocos ao acaso, com quatro repetições. As concentrações de K no solo e na planta foram determinadas em dois estádios do desenvolvimento do tomateiro (no início do florescimento do segundo e quarto cachos). As produções total, comercial e ponderada aumentaram com o aumento das doses de K, atingindo os seus máximos de 86,4, 73,4 e 54,9 t ha^{-1} nas doses de K correspondentes a 198, 194 e 125 kg ha^{-1}, respectivamente. Na primeira data de amostragem, as concentrações de K no solo associadas às máximas produções comerciais e ponderada foram 92 e 68 mg dm^{-3}, respectivamente. As concentrações de K nas matérias secas dos pecíolos, nas amostragens realizadas nos florescimentos do segundo e quarto cacho, associadas com a máxima produção ponderada de frutos, foram de 10,30 e 7,30 dag kg^{-1}, respectivamente.

Termos para indexação: *Lycopersicon esculentum*, dose ótima, análise foliar, análise de solo.

INTRODUCTION

Tomato fruits absorb high amounts of K from the soil. With optimum nutrition, nutrient uptake increases rapidly during the fruit growth period. At this time, K is the dominant nutrient (Huett & Dettmann, 1988). Adequate K supply is important to several plant processes among them enzyme

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activation, photosynthesis, osmoregulation, phloem transport (Marschner, 1995), determining the final yield. In low K soil it is not possible to obtain high tomato yields without adding K fertilizer. In these soils, diffusion is an important soil mechanism for supplying nutrients to plant roots, and only potassium within the diffusive soil zone contributes to K supply to the root (Barber, 1984). Potassium diffusion rate depends on several factors, among them soil water in the root zone which is closely associated with the irrigation system. Drip irrigation is an effective way to supply water to tomato plants (Locascio & Myers, 1974; Locascio et al., 1989; Hochmuth, 1994). Usually fertirrigation improves fertilizer use efficiency by the plants (Phene et al., 1989), affecting tomato yields (Locascio et al.,1989; Dangler & Locascio, 1990).

Potassium applied by fertirrigation can provide an efficient means of monitoring the K status of the tomato plant (Besford & Maw, 1974). Published standards of K status of the tomato plant tend to vary for several reasons, including variety, environmental conditions, type and age of tissue sampled.

The objective of this study was to evaluate the effects of trickle-applied K rates on tomato fruit yield and to determine K concentrations in soil and in tomato petioles associated with maximum yield.

MATERIAL AND METHODS

A field study was conducted on a silt clay soil at Universidade Federal de Viçosa, Minas Gerais State, Brazil, with 46 mg dm^{-3} Mehlich 1 extractable K (median) and 9.02 cmol$_c$ dm^{-3} cation exchange capacity. The experiment was a randomized complete block design with four replications. Potassium chloride was applied at the rates of 0, 48, 119, 189, 259 and 400 kg ha^{-1} K. The K rates were divided into four split applications with 40% placed in the furrows at transplanting time; 20% applied through the trickle irrigation when the plant set the second cluster; 20% at the fourth, and 20% at the sixth cluster stage.

One month before transplanting tomato seedlings to the field, the soil was limed to raise the pH to 6.5. Preplant N (80 kg ha^{-1} N) as urea, micronutrients and P fertilizer, together with the 40% K rate were placed in the furrows at transplanting time. Plots were fertirrigated with urea at 120 kg ha^{-1} N at the time of each K application.

Santa Clara tomato cultivar was transplanted to the field on June 29. Spacing was 0.5 m between plants and 1.0 m between rows (20,000 plants ha^{-1}). Plots were 4.0 x 3.5 m with the middle two of four rows being sampled and harvested. Plants were staked and trained as commercial crops. Each plant was thinned weekly, allowing only two stems to grow.

Trickle irrigation tubing with emitters 0.5 m apart was placed on the soil surface 10 cm from the plant shoots. The volume of irrigation water applied daily was calculated using the mean daily class A pan evaporation. During the whole crop season, irrigation and rainfall totaled 85 and 478 mm, respectively. Pest and disease control practices were applied as necessary.

Plant and soil were sampled at the beginning of the 2nd, 4th, and 6th cluster flowering stage. In each plant, petioles from a basal fully expanded (PBE) but not senescent leaf and from the leaf adjacent to each cluster were sampled. Petioles were dried in a forced-air drier at 75ºC and ground through a 1-mm screen. After HNO_3/H_2O_2 digestion Ca and Mg were analysed by atomic absorption spectrometry and K by flame emission spectrophotometry. Soil samples were taken to a depth of 20 cm in the rows between the plants one day after sampling of petioles. Soil was dried, ground and passed through a 2-mm sieve. Soil pH was determined using a 2:1 water:soil volume ratio; soil electrical conductivity was determined in a saturated extract, at 25ºC. Soil was extracted with Mehlich 1 and analysed for K; it was also extracted with 1 M KCl and analysed for Ca and Mg.

Fruits were harvested weekly at the breaker stage for 9 weeks beginning on September 20. Fruit, free of blemishes, blossom-end rot and cracks, and exceeding 33 mm in diameter, were graded into extra large, > 60 mm in diameter; large, 56-60 mm; medium, 52-56 mm and small, 52-33 mm. Total yield was the sum of all graded classes, marketable yield was the sum of the three largest classes. As fruit price depends on its size, weighted yields were taken as the sum of extra large, large, and medium fruit class multiplied by 1.0, 0.5, and 0.3, respectively. These factors were obtained from the market prices attained by each fruit class (Boletim..., 1994).

Total, marketable, and weighted fruit yields, and K concentrations in the tomato petioles and in the soil samples were statistically evaluated by analysis of variance. Models were fitted to statistically significant data using K fertilizer rates as the independent variable. The best fitting model was used to estimate maximum yields. To estimate critical K concentrations in petiole dry matter and soil, K rates associated to either maximum total, marketable and weighted fruit yields were introduced into the best fit model previously calculated, which correlates petiole K concentrations or the soil K level with K fertilizer rate.

RESULTS AND DISCUSSION

Significant responses to K fertilizer were observed for total, marketable (Fig. 1) and weighted yields ($Y = 35.62 + 0.350317X - 0.001882X^2 + 0.00000256\,X^3$, $R^2 = 0.962$), reaching their maxima of 86.4, 73.4, and 54.9 ton ha^{-1} at 198, 194 and 125 kg ha^{-1} K, respectively. Those are higher than 43.4 and 47.4 ton ha^{-1}, Brazilian and Minas Gerais State average tomato yields (Anuário..., 1996). As pointed out by Fontes (1997), the weighted yield expresses the tomato production performance better than does total yield. High K rates, as KCl, decrease yield by increasing K competition with other cations and between Cl^- and NO_3^- (Cadahia et al., 1993; Daliparthy et al., 1994) and also by eventually increasing soil solution salinity.

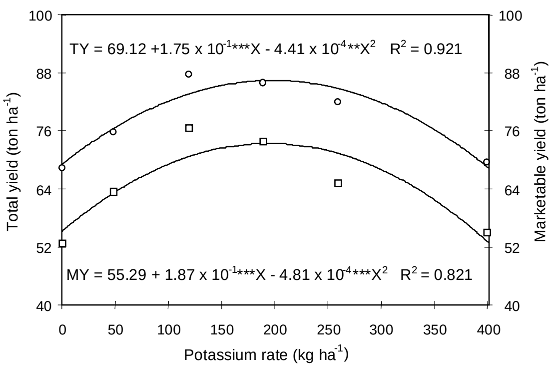

FIG. 1. Relationships between potassium fertilizer rates and total (TY) and marketable tomato yields (MY) (and *** = significant at 0.01 and 0.001 probability level).**

Fruit blossom-end rot incidence reached only 2.2% of the total fruit yield and it was not affected by high K probably due to low variety susceptibility, to adequate soil Ca and root growth adequacy, and to the irrigation system allowing good water and nutrient utilization by the tomato plants, as discussed by Phene et al. (1989).

Potassium fertilizer rates increased K content and decreased (Ca+Mg)/K ratio in the soil and had no practical effects on the soil pH or soil solution electrical conductivity (EC) at the two sampling dates (Table 1). At the first soil sampling date, when the tomato plants set the second cluster, potassium critical concentrations in the soil associated with maximum total and weighted yields were 92 and 68 mg dm^{-3}, respectively; (Ca+Mg)/K ratios were 49 and 62; soil pH 6.64 and 6.61; and EC was 2.22 dS m^{-1} for both. Soil K concentrations were also related to calculated maximum weighted tomato yield proportions. The highest weighted yield was found at 68 mg dm^{-3} K. In Minas Gerais State, Brazil, soil K content higher than 80 mg dm^{-3} is classified as high K level. In Florida, for example, K fertilization is not recommended when soil K content is higher than 60 mg dm^{-3} (Kidder et al., 1989). Higher soil K critical concentration, 120 mg dm^{-3}, is cited by Sobulo et al. (1977). In Australia, in soil with 117 mg kg^{-1} K, the total fruit yield from plants growing on beds covered with polyethylene mulch and trickle irrigated was not affected by K fertilizer rate but the addition of 90 kg ha^{-1} K increased the yield of large fruit (Huett,

TABLE 1. Relationship between potassium fertilizer rates and electric soil solution conductivity and soil pH, K, and K/(Ca+Mg) ratio sampled at the beginning of the 2nd and 4th cluster flowering time (and *** = significant at 0.01 and 0.001 probability level).**

Soil characteristics	Regression equations[2]	R^2
	Second cluster	
EC[1] (dS m^{-1})	$Y = Y_m = 2.22$	
pH	$Y = Y_m = 6.76$	
K^+ (mg dm^{-3})	$Y = 27.74 + 3.23 \times 10^{-1}{***}X$	0.937
(Ca+Mg)/K	$Y = 83.53 - 1.75 \times 10^{-1}{***}X$	0.959
	Fourth cluster	
EC (dS m^{-1})	$Y = Y_m = 1.06 + 8.14 \times 10^{-3}{**}X - 2.01 \times 10^{-5}{**}X^2$	0.742
pH	$Y = Y_m = 6.59$	
K^+ (mg dm^{-3})	$Y = 35.05 + 9.46 \times 10^{-2}{***}X$	0.751
(Ca+Mg)/K	$Y = 91.88 - 1.51 \times 10^{-1}{***}X$	0.849

[1] Saturated extract electrical conductivity at 25°C.
[2] Y_m : mean values; X : potassium rates as kg ha^{-1}.

1993). Also, K had no effect on total tomato yield but marketable yield increased linearly up to 112 kg ha^{-1} K in soil high in plant available K (Martin & Liebhardt, 1994).

Potassium concentrations in tomato petioles from basal fully expanded (PBE) but not senescent leaves and from the leaf adjacent to the second cluster (PAC) increased with increasing K rates added to the soil (Fig. 2); similar results were found for K concentrations in tomato petioles sampled at the fourth cluster stage (Sampaio, 1996). Locascio et al. (1997) also found increasing K concentrations in tomato leaves due to K fertirrigation. Potassium critical concentrations in the PBE and in the PAC associated with maximum total weighted tomato yields decreased with the plant age and also decreased from the young to the old petiole, that is from PBE to PAC, mainly at the first and the second sampling dates. At the first sampling date, K critical concentrations in the PBE for maximum total and weighted yields were 7.16 and 6.02 dag kg^{-1} dry weight, respectively; in the PAC the values were 10.77 and 10.30, respectively. The corresponding K concentrations at the second sampling date for the PBE were 6.08 and 5.02 and for the PAC were 8.82 and 7.30 dag kg^{-1} dry weight, respectively. For the whole tomato season, K concentration values higher than 3.0 dag kg^{-1} of dry matter are cited as normal (Mills & Jones Junior, 1996).

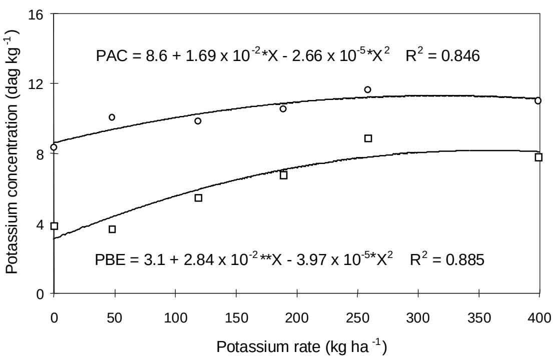

FIG. 2. Relationship between potassium fertilizer rate and potassium concentrations in tomato petioles from basal fully expanded but not senescent leaves (PBE) and from the leaf adjacent to the second cluster (PAC) sampled by its flowering time (* and ** = significant at 0.05 and 0.01 probability level).

An interpretation table of K concentrations in tomato petioles from the leaves adjacent (PAC) to the second and the fourth clusters is shown in Table 2. Interpretation of K concentrations in tomato petioles from a basal fully expanded but not senescent leaves (PBE) are also presented. Potassium concentration of 3.3 dag kg^{-1} in fully-expanded leaves, sampled when most tomato fruits were small and green, was related to maximum fruit yield (Martin &

TABLE 2. Potassium concentrations in tomato petioles from a basal fully expanded but not senescent leaves and from leaves adjacent to the second and fourth cluster sampled by their flowering times related to maximum weighted tomato yield proportions.

Flowering time	Class	Petioles from adjacent cluster	Petioles from expanded leaves	Maximum weighted yield proportions
		----------------------(dag kg^{-1} of DM)	---------------------	(%)
2nd Cluster	Very low	< 9.44	< 4.52	< 90
	Low	9.44 to < 9.70	4.52 to < 4.98	90 to < 95
	Medium	9.70 to < 10.04	4.98 to < 5.56	95 to < 99
	Sufficient	10.04 to 10.30	5.56 to 6.02	99 to 100
	High	> 10.30	> 6.02	< 100
4th Cluster	Very low	< 5.66	< 3.99	< 90
	Low	5.66 to < 6.12	3.99 to < 4.28	90 to < 95
	Medium	6.12 to < 6.75	4.28 to < 4.68	95 to < 99
	Sufficient	6.75 to 7.30	4.68 to 5.02	99 to 100
	High	> 7.30	> 5.02	< 100

Liebhardt, 1994). Sufficient K concentrations in dry matter of petioles at 2nd cluster mid bloom ranged from 5.0 to 10.0 dag kg^{-1} (Jones Junior et al., 1991). At the 4th cluster, the values were 4.0 to 8.0. The sufficient K concentrations found in the present experiment are also very close to the values cited by Lingle & Lorenz (1969) and by Reuter & Robinson (1986).

CONCLUSIONS

1. Total and marketable tomato yields increase with the K rates, reaching their maxima of 86.4 and 73.4 ton ha^{-1} at 198 and 194 kg ha^{-1} K, respectively.
2. Potassium concentrations in soil and petioles increase with the increase in the K rates.
3. At the time the tomato plants set the second cluster, K critical concentrations for maximum marketable tomato fruit yield are 92 mg dm^{-3} in the soil and 10.30 dag kg^{-1} in the petioles from the leaf adjacent to the second cluster.

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