ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA
VOL. VIII SECTIO EEE 2000

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Reaction of Glasshouse Tomato to Potassium Chloride or Sulphate Fertilization on Various Substrates

Reakcja pomidora szklarniowego na nawożenie chlorkiem lub siarczanem potasu w różnych podłożach

Abstract. The reaction of plants towards KCl or K_2SO_4 fertilization used in sand, mineral wool, peat, and sand-peat mixture was assessed using glasshouse tomato of 'Romatos' cultivar in the experiment carried out in spring and autumn. The results revealed that K_2SO_4 more positively affected the stomata arrangement density, leaf stomata conductivity, photosynthesis intensity and potassium concentration in leaves, than KCl. The relative leaf thickness and transpiration intensity in spring increased more under the influence of KCl than K_2SO_4. The influence of substrate type on tomato leaf traits under analysis was not univocal. In spring, plants growing on peat showed the highest stomata conductivity and transpiration, those cultivated on sand displayed the highest photosynthesis rate. The influence of substrate on gas exchange course in leaves was insignificant in autumn. In both periods, plants growing on sand were characterized by higher stomata arrangement density than those on other substrates. The results showed that substrate type and potassium salt kind did not differentiate the yield of fruits obtained from one plant.

INTRODUCTION

The modern market makes it possibile to apply various substrates for vegetable plants cultivation in glasshouse. However, the natural resources of some of them — peat, for instance — quickly decrease (Haber, 1998); others, such as mineral wool, make great problems with the utilization of by-products. Therefore, the purpose of the research was to assess the usefulness of middle-particle sand in a pure form and in mixture with peat for glasshouse tomato cultivation using fertilization on a background of traditional substrates (wool, peat). A comparison of plants' reaction to elevated contents of Cl^- or SO_4^{2-} ions in the substrates due to potassium chloride or sulphate application in spring and autumn, was another problem to be solved. In the opinion of some authors (Nowosielski, 1978; Satti and Yahyai, 1995), chloride ions presence decreases the tomato yielding, although research by Nurzyński et al. (1980, 1982) did not prove harmful action of chlorine to plants' growth and development.

It was attempted to estimate the plants' reaction to applied substrates and potassium salts among others through an analysis of stomata arrangement density, their conductivity, photosynthesis and transpiration intensity. In many authors' opinion those traits fairly well reflect plants' reaction to environmental factors (Borowski, 1999; Borowski and Michałek, 1998; Buttery et al., 1993; Behboudian and Anderson, 1990; Nerkar et al., 1981; Jones, 1977; Terry and Ulrich, 1973).

MATERIAL AND METHODS

Tomato of 'Romatos' cv. cultivated in glasshouse between March and July as well as August and December in 1999 was the experimental plant. Mineral components were given to the plant as water solution sprayed into the substrates. Substrates consisted of mats made of mineral wool of 100 × 20 × 7.5 cm dimensions, and mats formed by filling the foil pipes of the same dimensions with middle-particle river sand or transient peat. In addition, the mixture of sand and peat (1:1, v/v) was applied as the substrate in the autumn experiment. Both experiments consisted of 8 repetitions, and mean plant density in the entire glasshouse amounted to 3.2 plants $\cdot$ m^{-2}. The frequency of nutrient medium supplementing was controlled by "soltimer" that switched on the dosing device depending on solar radiation intensity. The medium was differentiated only in respect of the type of potassium salt applied; one half of plants used the solution containing KCl, the other half K_2SO_4. The solution contained the following amounts of macronutrients in mg $\cdot$ dm^{-3} tap water; with KCl — 14 N-NH_4, 168 N-$N0_3$, 52 P-$P0_4$, 285 K, 180 Ca, 39 Mg, 89 S-$S0_4$, 80 Cl; with K_2S0_4 — 14 N-NH_4, 158 N-$N0_3$, 56 P-$P0_4$, 290 K, 190 Ca, 41 Mg, 125 S-$S0_4$, 10 Cl. On sunny days, each plant received up to 3 dm^3 of medium in spring, and up to 1.5 dm^3 in autumn. Two plants grew on one mat, and they were led into 7 bunches in spring and 6 bunches in autumn.

Measurements of net photosynthesis intensity, transpiration and stomata conductivity of evaporation by leaves were done on a leaf neighboring with apical leave situated under the 4th bunch in spring and under the 3rd bunch in autumn (Tab. 2). The opposite leaf served for measurements of stomata length and the number of stomata per 1 mm^2 of lower and upper epidermis. Chlorophyll (a+b) content was also recorded in the same leaves by means of Arnon's method (Arnon, 1949); their relative thickness (SLW) was calculated on the basis of dry matter and surface area measurements (Tab. 1). During the maturation of the fruits of the 3rd and 4th bunch in a leaf situated under that bunch, the percentage of potassium was analyzed by means of AAS technique (Tab. 3).

Gas exchange of leaves was made in glasshouse using portable gas-analyzer of LCA-4 type (ADC Co. Ltd, England) at noon at radiation intensity of FAR range from 1150 to 1450 μmol (photon) $m^{-2} \cdot s^{-1}$ in spring, and 600-850 μmol (photon) $m^{-2} \cdot s^{-1}$ in autumn. The temperature in a leaf chamber was 30-32°C in spring and 27-29°C in autumn. The yield of fruits gradually collected during their maturation was assessed in both experiments by weighing (Tab. 4).

RESULTS AND DISCUSSION

Results presented in Tab. 1 point out that the type of substrate did not affect the chlorophyll content in tomato leaves and the relative leaf thickness. The influence of potassium chloride or sulphate in the substrate was more evident. Leaf blades of tomato supplemented with KCl addition showed higher relative thickness (SLW) in both experiments, and leaves contained slightly less chlorophyll (a+b) content in autumn than due to K_2SO_4 nutrition. Potassium sulphate positively affected the stomata arrangement density on the leaf surface. The leaves of plants supplemented with medium with K_2SO_4 contained by about 10% more stomata on lower epidermis surface and by about 7% more stomata on upper epidermis surface (on average from both experiments) than using KCl as nutrient. In both cases, plants growing on sand were characterized by higher stomata arrangement density than on other substrates (by 15%, on average). No effects of the analyzed factors on stomata length were found. Probably due to worse light conditions in autumn (Lugg and Sinclair, 1979), tomato leaves showed less chlorophyll content, thinner leaf blades with a smaller number of stomata than in the spring experiment (Tab. 1).

Both experiments revealed that in general, regardless of the substrate type, stomata conductivity of leaves supplemented with K_2SO_4 was higher than those supplemented with KCl (Tab. 2). It can be supposed that it was

Tab.1. Effect of substrate type and potassium salt kind on the content of chlorophyll, specific leaf weight (SLW), length of stomatal slot and number of stomata in tomato leaves Romatos cv. in spring and autumn experiment

Type of substrate	K salt kind	Chlorophyll a+b ($mg \times g^{-1}$)	SLW ($mg \times cm^{-2}$)	Lower epidermis: Slot length µm	Lower epidermis: Number of stomata 1 mm^2	Upper epidermis: Slot length µm	Upper epidermis: Number of stomata 1 mm^2
Spring experiment							
Sand	KCl	2.48	4.74	29	312	33	107
	K_2SO_4	2.26	3.68	26	299	32	93
Wool	KCl	2.34	4.51	33	247	30	98
	K_2SO_4	2.36	3.52	24	272	32	93
Peat	KCl	2.06	4.56	31	244	32	86
	K_2SO_4	2.35	3.50	26	252	28	96
Autumn experiment							
Sand	KCl	1.87	3.96	29	163	22	56
	K_2SO_4	1.92	2.97	33	219	30	93
Wool	KCl	1.80	3.42	36	159	25	59
	K_2SO_4	2.03	2.90	34	179	30	63
Peat	KCl	1.88	3.68	29	148	29	43
	K_2SO_4	2.26	2.77	28	189	24	52
Sand	KCl	2.16	3.24	26	156	29	46
+ Peat	K_2SO_4	2.15	3.73	31	183	29	43

associated with higher potassium content in leaves, because the element has a great influence on stomata conductivity (Terry and Ulrich, 1973; Behboudian and Anderson, 1990), and the data listed in Tab. 3 point that leaves of plants supplemented with K_2SO_4 showed higher K content than those supplemented with KCl. Also, the substrate type significantly affected the leaf stomata conductivity, but only in the spring experiment. The highest conductivity was manifested by leaves of plants growing on peat, the lowest — on sand. It is difficult to explain why plants grown on sand and characterized by the greatest stomata arrangement density on leaves, showed the lowest conductivity. It can only prove that the level of stomata opening was smaller in tomatoes growing on sand than in those growing on other substrates. Literature data also prove that a strict correlation need not be present between those traits. Nerkar et al. (1981) found such dependence in vetch, but Jones (1977) did not find it in barley.

Tab. 2. Effect of substrate type and potassium salt kind on stomatal conductance, net photosynthesis and transpiration of tomato Romatos cv. in spring and autumn experiment

	Stomatal conductance $\mu mol(H_2O) \cdot m^{-2} \cdot s^{-1}$			Net photosynthesis $\mu mol(CO_2) \cdot m^{-2} \cdot s^{-1}$			Transpiration $mmol(H_2O) \cdot m^{-2} \cdot s^{-1}$		
Type of substrate	KCl	K_2SO_4	$\bar{x}$ for substrate	KCl	K_2SO_4	$\bar{x}$ for substrate	KCl	K_2SO_4	$\bar{x}$ for substrate
Spring experiment									
Sand	0.10	0.12	0.11	11.30	12.37	11.83	3.12	2.82	2.97
Wool	0.10	0.22	0.16	8.47	11.34	9.90	2.34	2.40	2.37
Peat	0.27	0.20	0.23	8.17	8.98	8.57	3.61	2.94	3.27
$\bar{x}$ for K salt	0.16	0.18	-	9.31	10.90	-	3.02	2.72	-
$LSD_{0.05}$:									
substrate			0.06			1.11			0.44
K salt		ns.			0.75			0.29	
substrate × salt		0.10			ns.			ns.	
Autumn experiment									
Sand	0.10	0.13	0.11	7.01	7.28	7.14	2.48	2.85	2.66
Wool	0.07	0.13	0.10	6.34	7.18	6.76	1.83	2.70	2.26
Peat	0.08	0.14	0.11	5.04	6.90	5.97	2.10	2.91	2.50
Sand + Peat	0.08	0.14	0.11	6.33	7.11	6.72	2.10	2.80	2.45
$\bar{x}$ for K salt	0.08	0.13	-	6.18	7.12	-	2.13	2.81	-
$LSD_{0.05}$:									
substrate			ns.			ns.			0.20
K salt		0.02			0.74			0.11	
substrate × salt		ns.			ns.			ns.	

ns. — not significant

The data presented in Tab. 2 point that photosynthesis intensity of plants supplemented with K_2SO_4 was significantly higher than in KCl case, in both vegetation periods. Also, the type of substrate applied for cultivation had an effect on that process. Plants growing on sand were characterized by the highest photosynthesis rate, and those growing on peat — by the lowest. In autumn, the intensity of the process in plants growing on sand-peat mixture was lower than on sand, but higher than only on peat. It is difficult to say why the medium with K_2SO_4 addition and substrate consisting of sand the most positively affected the process, especially that in relation to the sub-

Tab. 3. Effect of substrate type and potassium salt kind on potassium percentage content in dry mass of tomato Romatos cv. leaves in spring and autumn experiment

K salt kind	Type of substrate			
	Sand	Wool	Peat	Sand + Peat
Spring experiment				
KCl	3.68	3.63	3.43	
K_2SO_4	3.99	4.01	4.27	
Autumn experiment				
KCl	2.57	2.35	2.69	2.52
K_2SO_4	2.99	2.79	2.83	2.68

Tab. 4. Effect of substrate type and potassium salt kind on the yield of tomato fruits Romatos cv. ($kg \cdot plant^{-1}$) in spring and autumn experiment

Type of substrate	KCl	K_2SO_4	$\bar{x}$ for substrate
Spring experiment			
Sand	4.04	4.16	4.10
Wool	4.60	4.37	4.48
Peat	4.49	4.36	4.42
$\bar{x}$ for K salt	4.38	4.30	
LSD $_{0.05}$:			
substrate			ns.
K salt	ns.		
substrate × salt		ns.	
Autumn experiment			
Sand	2.93	2.77	2.85
Wool	3.21	2.97	3.09
Peat	2.83	2.89	2.86
Sand + Peat	2.84	2.69	2.76
$\bar{x}$ for K salt	2.95	2.83	-
LSD $_{0.05}$:			
substrate			ns.
K salt	ns.		
substrate × salt		ns.	

ns. — not significant

strate it was not associated with leaf stomata conductivity. However, it is worth of mention that in both cases plants showed the number of stomata higher by 10-15% on average, which perhaps compensated for their lower conductivity, favoured CO_2 diffusion into the mesophyll, causing the photosynthesis rate increase. Buttery et al. (1993) observed such dependence in two soybean cultivars differing with the stomata arrangement density. The mean assimilation rate was lower by about 35% in autumn than in spring, which was probably associated with lower light intensity, less stomata conductivity and their number on lower and upper epidermis surface (Tabs. 1, 2).

The same factors were also the reason for a higher rate of water loss from leaves in spring than in autumn. However, differences in transpiration were much lower than in photosynthesis rate and they reached only 14%. The substrate type and KCl or K_2SO_4 content in the medium influenced that process rate in spring and autumn in a different way. Plants supplemented with KCl and growing on peat transpired the most intensively in spring, then came those which grew on sand. In autumn, plants growing on sand transpired slightly more intensively than those on peat. Plants supplemented with K_2SO_4 were characterized by a higher water evaporation rate than those supplemented with KCl, on every substrate. In both experiments, it was not found out that differences of transpiration amount between the substrates were statistically significant. However, plants growing on mineral wool were characterized by statistically lower transpiration in both experiments.

The rate of water evaporation, as research proved, depended on stomata conductivity more than on the number of stomata in lower and upper epidermis of leaves. In the spring experiment, plants growing on peat transpired the most intensively in spite of the fact that the number of stomata in lower epidermis was by 57 lower (on average) than in plants growing on sand, and at the same time, their stomata conductivity for water vapor was by 12 μmol (photon) $m^{-2} \cdot s^{-1}$ higher than in plants growing on sandy substrate (Tab. 2). Borowski (1999) and Borowski and Michałek (1998) found strict interdependence between leaf stomata conductivity and transpiration in earlier investigations carried out on pot cultures using tomato and lettuce.

The fruit yield from plants supplemented with KCl or K_2SO_4 addition was almost identical in both experiments (Tab. 4). Thus, the results did not show that higher chloride ions content in leaves of tomato supplemented with KCl in opposite to those supplemented with K_2SO_4, decreased plant yielding (Nowosielski, 1978; Satti and Yahyai, 1995), but they confirmed the results of earlier studies carried out by Nurzyński et al. (1980, 1982). Significant differences in respect of the yielding of tomatoes cultivated on substrates applied were not found, either. Thus, the obtained data pointed out that middle-particle river sand used in a comparable way as other horticultural substrates commonly accepted in glasshouse tomato production, can be successfully applied for that plant cultivation using fertilization system.

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STRESZCZENIE

W doświadczeniu z pomidorem szklarniowym odm. 'Romatos', prowadzonym w okresie wiosennym i jesiennym z zastosowaniem systemu fertygacji, określono reakcję roślin na nawożenie KCl lub K_2SO_4 zastosowane w piasku, wełnie mineralnej, torfie i mieszaninie piasku z torfem. Uzyskane wyniki wykazały, że K_2SO_4 wpływał korzystniej niż KCl na gęstość rozmieszczenia szparek, przewodność szparkową liści, intensywność fotosyntezy i zawartość potasu w liściach. Pod wpływem KCl wzrastała bardziej niż pod wpływem K_2SO_4 względna grubość liści i intensywność transpiracji w okresie wiosennym. Wpływ podłoży na analizowane cechy liści pomidorów był niejednoznaczny. W okresie wiosennym najwyższą przewodność szparkową i transpirację wykazywały rośliny uprawiane w torfie, zaś fotosyntezę — uprawiane w piasku. W okresie jesiennym wpływ podłoży na przebieg wymiany gazowej liści był nieistotny. W obu analizowanych okresach rośliny wyrosłe w piasku charakteryzowały się większą gęstością rozmieszczenia szparek niż w pozostałych podłożach. Uzyskane wyniki wykazały, że typ podłoża i rodzaj soli potasu nie różnicował wielkości plonu owoców.