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THE EFFECT OF FERTILIZATION WITH DIFFERENT RATES OF POTASSIUM AND CALCIUM CARBONATE ON YIELD, VITAMIN C CONTENT, AND SALT CONCENTRATION IN THE MEDIUM OF STALK CELERY

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Abstract. The effect of different rates of potassium: 0.4; 0.8; 1.2; 1.6 g K · dm^{-3}, and calcium carbonate: 5 g and 15 g $CaCO_3$ · dm^{-3}, on stalk celery yield and vitamin C content as well as on salt concentration in the medium was analysed in a greenhouse experiment. Stalk celery weight and vitamin C content were found to be reduced after the application of the potassium rate higher than 1.2 g K · dm^{-3}. The study found that the salt concentration in the medium increased with an increase in the rate of potassium and that there was no effect of the increased rate of calcium carbonate on total salt concentration in the medium of stalk celery. The different rates of calcium carbonate affected the uptake of nitrogen, phosphorus, and magnesium by stalk celery.

Key words: potassium, calcium carbonate, stalk celery, salt concentration, yield, vitamin C

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Introduction

Potassium, alongside nitrogen, is one of the main elements responsible for plant yield (Isidora *et al.* 2008; Lester *et al.* 2010). It is taken up throughout the whole period of plant growth as the K^+ ion, and its tasks include regulating water balance in plants and enhancing plant resistance to drought, frost and diseases. Potassium present in the substrate also affects the salt concentration and, as a consequence, plant yield. The use of too high rates of potassium fertilizer may lead to substrate salinity, which inhibits plant growth (Nurzyński 2008). As shown by the research of Dzida (2004) as well as of Dzida & Jarosz (2010), the addition of calcium carbonate to the medium, apart from a reduction in its salinity, affects the nutrient content in the medium and may lead to a decrease in its salinity.

Horticultural plants have been divided into 3 groups in terms of their sensitivity to salt concentration in the substrate: plants of low and medium sensitivity as well as a group of plants with high sensitivity to salt concentration, which includes stalk celery (Breś *et al.* 2003). The cultivation of stalk celery in Poland covers an area of only several hectares, but due to its dietetic properties its crop area is constantly increasing. The high nutritional value of celery primarily results from its content of mineral salts, mainly calcium (980-1546 mg % DW), potassium (510 mg % DW), phosphorus, magnesium, iron, manganese, and copper. Moreover, stalk celery contains the following vitamins: C (0.3-6.8 mg %), B_1 (0.05 mg %), B_2 (0.07 mg %), and B_3 (0.55 mg %) (Pudelski 2002; Rumpel 2005).

Material and methods

A greenhouse study of stalk celery cv. *'Verde Pascal'* was carried out in 2007. Plants were planted in their permanent place on 5 September and harvested on 5 November. The growth period from seeding to harvest was 83 days. The experiment was set up as a completely randomized design in 8 replications. The experimental unit was one plant growing in one 2 dm^3 pot filled with transitional peat with

Table 1. Content of $N – NH_4$, $N – NO_3$, $P – PO_4$, K, Ca, Mg, $S – SO_4$ ($mg \cdot dm^{-3}$) and pH (H_2O) in substrate of celery.

Dose ($g \cdot dm^{-3}$) K (A)	CaCO$_3$ (B)	$N – NH_4$	$N – NO_3$	$P – PO_4$	K	Ca	Mg	$S – SO_4$	pH
0,4	5,0	82	118	280	31	901	68	353	5,84
0,8	5,0	107	143	160	160	959	67	354	5,62
1,2	5,0	78	120	123	304	1133	79	451	5,56
1,6	5,0	62	126	101	378	819	57	475	5,78
$\overline{X}$		82	127	166	218	953	68	408	5,56-5,84
0,4	15,0	41	150	135	148	3358	138	355	6,28
0,8	15,0	41	154	118	322	3934	114	401	6,42
1,2	15,0	39	161	115	444	2897	92	405	6,52
1,6	15,0	40	163	105	472	2906	81	400	6,60
$\overline{X}$		40	157	118	347	3274	106	390	6,28-6,60
$\overline{X}$ for dose K	0,4	61	134	207	89	2130	103	354	5,84-6,28
	0,8	74	148	139	160	2447	90	377	5,62-6,42
	1,2	58	140	119	304	2015	85	428	5,56-6,52
	1,6	51	144	103	378	1863	69	437	5,78-6,60
$LSD_{0.05}$ for	A	3,60	n.s.	3,18	32,43	n.s.	19,40	2,21	
	B	1,88	7,52	1,66	16,98	347,67	10,16	1,15	
	AB	6,16	24,58	5,44	55,49	n.s.	33,19	3,78	

Note: n.s. – no significant differences.

an initial pH of 5.6. The study used different rates of potassium fertilizer: 0.4; 0.8; 1.2; 1.6 g $K \cdot dm^{-3}$, and the following rates of calcium carbonate: 5g and 15 g $CaCO_3 \cdot dm^{-3}$. The initial nutrient content in peat (in $mg \cdot dm^{-3}$) was as follows: $N\text{-}NH_4$ – trace amounts; $N\text{-}NO_3$ – 25; P – 25; K – 10; Ca – 40; Mg – 8; whereas in water used for watering plants these values were the following: $N\text{-}NH_4 + N\text{-}NO_3$ – 18; P – 11; K – 4; Ca – 110; Mg – 9; pH – 7.2; and EC – 0.6 $mS \cdot cm^{-1}$.

The following amounts of nutrients were used for all plants, taking into account natural nutrient availability in the substrate ($g \cdot plant^{-1}$): 1.6 N; 0.8 P; 0.9 Mg. Nitrogen was applied in the form of ammonium nitrate (34% N), potassium as K_2SO_4 (42% K), magnesium as $MgSO_4 \times H_2O$ (17.4% Mg), phosphorus – in the form of triple superphosphate (20% P). In all treatments, the following amounts of micronutrients were applied to the medium (in mg · dm-3): Fe – 16; Mn – 10.2; Cu – 26.6; Zn – 1.48; B – 3.2; Mo – 7.4. The above-mentioned micronutrients were supplied in the following form: EDTA – Fe; $MnSO_4 \times H_2O$; $CuSO_4 \times 5\ H_2O$; $ZnSO_4 \times 7\ H_2O$; H_3BO_3; $(NH_4)_6Mo_7O_{24} \times 4\ H_2O$. Phosphorus and micronutrients as well as ¼ of the rates of N, K, and Mg were supplied to the substrate during its preparation for planting. The remaining amounts of N, K, and Mg were applied during plant growth three times at 8-12 day intervals.

The plants were harvested at commercial maturity; subsequently, above-ground weight and vitamin C content in fresh samples, following Tillmans' method (PN-A-04019 1998) were determined. After harvest, the content of the following nutrients in the substrate was determined in 0.03 M acetic acid extract: $N\text{-}NH_4$ and $N\text{-}NO_3$ by Bremner's microdistillation method modified by Starck, K, Ca, and Mg by atomic absorption spectrometry (AAS) (AAnalyst 300 Perkin Elmer) as well as phosphorus colourimetrically with ammonium metavanadate and sulphur with $BaCl_2$. The values of pH and EC were determined in a suspension of the medium and distilled water at a ratio of 2:1.

The obtained results on yield, vitamin C content and the substrate assayed were statistically analysed by analysis of variance. In the experiment, the least significant difference (LSD) was determined based on Tukey's test at the α=0.05 level of significance.

Results and discussion

The applied rates of potassium significantly affected the salt concentration in the medium of stalk celery (Fig. 1). It was shown that the salt concentration in the medium increased with an increase in the rate of potassium. After the application of the lowest potassium rate, 89 mg K · dm^{-3} medium and a salt concentration of 1.2 mS · cm^{-1} were recorded on average, while after the application of the highest potassium rate the average values of these traits were, respectively, 378 mg K · dm^{-3} and 1.64 mS · cm^{-1} (Fig. 1 and Tab. 1). An increase in salt concentration in the medium under the influence of increasing potassium fertilization has been confirmed by Dzida (2004) and Michałojć *et al.* (2006) in their studies. The high content of potassium in the substrate after the application of the higher rates is evidence of its low utilisation by the celery plants. This is reflected in their yield (Fig. 2), since at the highest value of EC the fresh weight of celery plants distinctly decreased. The highest yield (94 g · $plant^{-1}$) was obtained after the application of fertilization at the amount of 0.8 g K · dm^{-3} medium and 15 g $CaCO_3$, which corresponded to the content of 322 mg K · dm^{-3} in the substrate and the value of EC equal to 1.42 mS · cm^{-1}. The different rates of calcium carbonate affected the uptake of nitrogen, phosphorus, potassium, and magnesium by stalk celery. In the medium in which the higher rate of calcium carbonate had been applied, a higher content of potassium and magnesium was recorded, thus a slightly higher salt concentration in the medium. Despite that yield was slightly higher after the application of 15 g $CaCO_3$ than after the application of the lower rate of calcium carbonate, these differences were not confirmed statistically. The study of Pitura *et al.* (2012) showed that increasing rates of calcium had no effect on the weight of kale plants and that there was a significant increase in above-ground weight of stalk celery with an increase in the rate of calcium. On the other hand, the study of Li *et al.* (2010) shows a significant influence of the rate of calcium, phosphorus, potassium, and magnesium on fresh and dry weight yield of stalk celery. The stimulating effect of an increased rate of calcium on greenhouse tomato yield was found in the study of Wińska-Krysiak & Łata (2007). A large amount of potassium in the substrate, thereby a high value of salt concentration, had an adverse effect on vitamin C content in plant fresh weight (Fig. 3). An increase in the amount of potassium supplied to the substrate from 1.2 to 1.6 g K · dm^{-3} caused a decrease in vitamin C content in the plants by half. The above-ground parts of celery grown in the medium to which 1.2 g K · dm^{-3} and 15 g $CaCO_3$ had been supplied were characterized by the highest amount of this compound (54.32 mg 100 g^{-1} FW). As reported by Golcz (1996), the increased rates of potassium had a positive influence on vitamin C content in red pepper fruits. Perucka & Materska (2004) did not find calcium ions to have an effect on vitamin C content in hot pepper, while Kowalska (2004) did not find such effect in spinach.

Conclusions

1. Stalk celery weight and vitamin C content were found to be reduced after the application of the potassium rate higher than 1.2 g K · dm^{-3}.

2. The study found that the salt concentration in the medium increased with an increase in the rate of potassium and that there was no effect of the increased rate of calcium carbonate on the salt concentration in the medium of stalk celery.

3. The different rates of calcium carbonate affected the uptake of nitrogen, phosphorus and magnesium by stalk celery.

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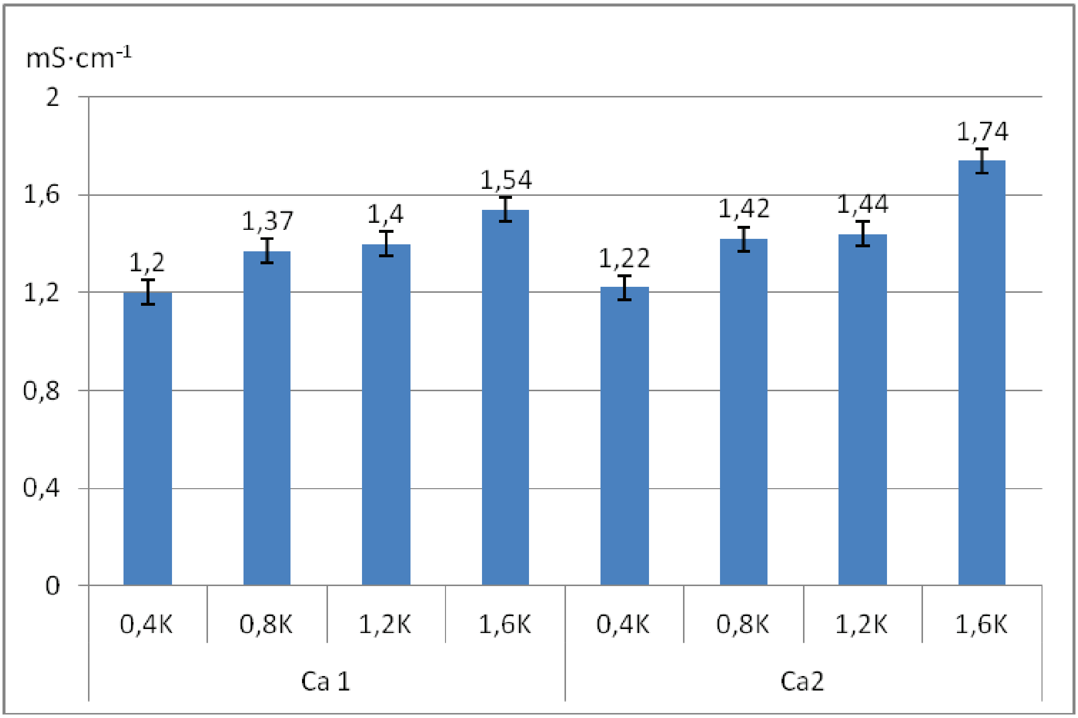

Fig. 1. Effect of potassium and $CaCO_3$ fertilization on salt concentration in substrate.

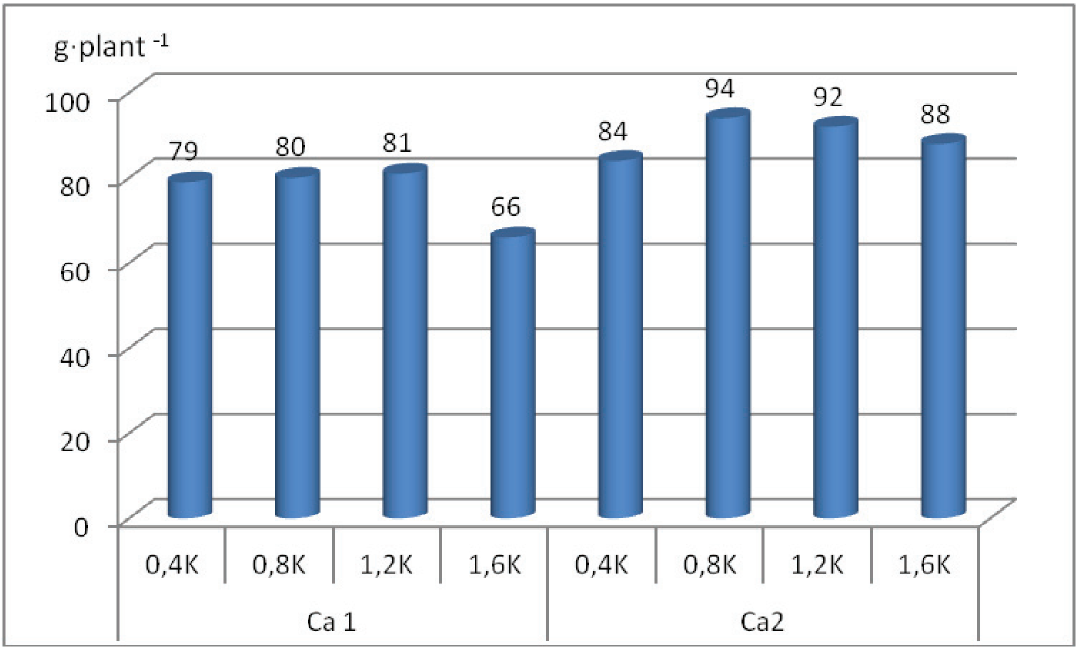

Fig. 2. Effect of potassium and $CaCO_3$ fertilization on yield of celery.

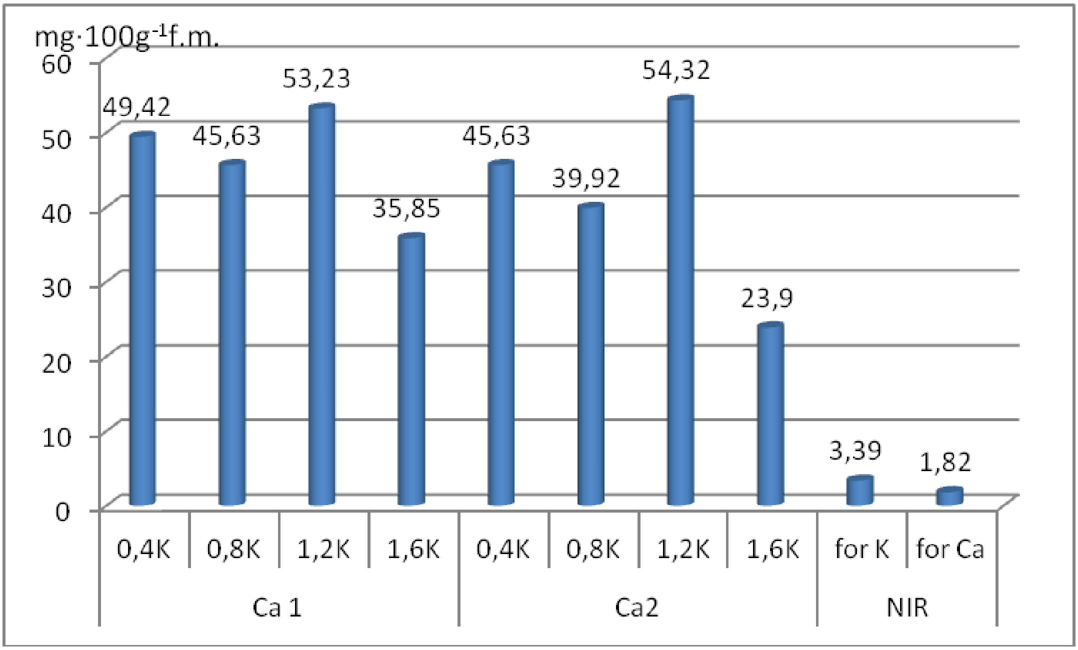

Fig. 3. Effect of potassium and $CaCO_3$ fertilization on content of vitamin C in celery.

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