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EFFECT OF SILICATE FERTILIZERS ON YIELDING OF GREENHOUSE CUCUMBER (*CUCUMIS SATIVUS* L.) IN CONTAINER CULITIVATION

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Abstract

Silicone (Si), a very abundant element in the Earth's crust, is beneficial for plants, animals and humans. Despite its abundance in nature, it is often unavailable in sufficient quantities. Cucurbits are believed to accumulate elevated quantities of Si and benefit from Si fertilization. It is believed that higher Si content in cucumber plant is connected with increased yields as well as improved resistance to diseases and tolerance to abiotic stresses, for example drought. The beneficial effects of Si have been confirmed by the present study, in which cucumbers were grown in soil and in liquid nutrient solutions. The aim of the experiments has been to evaluate the effect of several silicates supplementing peat-based growing substrates on yield and Si content in growing media and in cucumber plants. For this purpose, pot experiments were carried out in an unheated greenhouse in 2005-2007. Cucumber plants were cultivated in 12-liter containers filled with substrates amended with Na-, K-, Ca- and ammonium silicates at rates of 2 or 4 g per liter. The results indicated that slow-release Ca- and NH_4-silicates contributed to increased yield and elevated Si content in cucumber leaves and fruits. The effect of the other silicates was not certain and, additionally, dependent on their concentrations. Water-soluble Na- and K-silicates caused increased Na or K concentration and raised pH of substrates. The results revealed that increased yields depended on the number of fruits rather than their average weight. The silicates of calcium and ammonium can be valuable, slow-release fertilizers in cucumber cultivation on organic (peat) substrates. Even in quantities as high as 4 g per liter of substrate, they did not cause drastic changes of the pH and salinity of growing media and were a good source of Si available to cucumber plants.

Key words: silicates, fertilization, cucumber, growing medium, yield.

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WPŁYW NAWOZÓW KRZEMOWYCH NA PLON OGÓRKA SZKLARNIOWEGO W UPRAWIE WAZONOWEJ

Abstrakt

Krzem jest zaliczany do pierwiastków dobroczynnych dla roślin, zwierząt i ludzi. Pomimo jego obfitości w przyrodzie pobierany jest jednak niejednokrotnie w zbyt małych ilościach, co zależy również od systematycznej przynależności poszczególnych gatunków. Ogórek należy do gatunków korzystnie reagujących na nawożenie krzemem i kumulujących jego większe ilości. Uważa się, że zwiększenie zawartości krzemu w roślinach przyczynia się również do wzrostu odporności roślin na niektóre choroby oraz stresy abiotyczne. Stwierdzono korzystne działanie krzemu w uprawie glebowej oraz na pożywkach płynnych. Celem badań było określenie wpływu kilku krzemianów na plonowanie ogórka Milenium F_1 i zawartość pierwiastków w substratach torfowych i roślinach. W latach 2005-2007 przeprowadzono badania wazonowe w szklarni nie ogrzewanej. Rośliny ogórka uprawiano w wazonach zawierających po 12 dm^3 substratu torfowego uzupełnianego krzemianami sodu, potasu, wapnia lub amonu w ilości 2 lub 4 g w 1 dm^3 substratu. Stwierdzono korzystne oddziaływanie spowolnionych krzemianów wapnia i amonu na plonowanie roślin oraz wzrost zawartości krzemu w liściach i owocach ogórka. Działanie pozostałych krzemianów nie było jednoznaczne i zależało także od stężeń nawozów. Rozpuszczalne krzemiany sodu i potasu powodowały wzrost zawartości tych pierwiastków oraz odczynu substratu. Wykazano, że zwyżka plonów ogórka wiązała się raczej ze wzrostem liczby owoców, a nie z ich masą. Krzemiany wapnia i amonu mogą w uprawie ogórka na substratach organicznych stanowić cenne nawozy o spowolnionym (długotrwałym) działaniu. Nawet w znacznych ilościach (4 g w 1 dm^3 substratu) nie powodują drastycznych zmian odczynu pH i zasolenia oraz są źródłem krzemu przyswajalnego przez rośliny.

Słowa kluczowe: krzemiany, nawożenie, ogórek, podłoże uprawowe, plon.

INTRODUCTION

Silicone is one of the most abundant elements on the surface of the Earth (Hou et al. 2006). Although its physiological and nutritional role is still uncertain (Belanger et al. 1995), there is growing interest in silicone, especially with regard to the cultivation of cucumber, a species known to accumulate high quantities of Si. Plants can extract very high quantities of silicone per unit of surface (Carnelli et al. 2001). It is also known that silicone can interact with Al and other toxic elements i.e. Mn, elevating their toxicity to plants (Iwasaki, Matsumura 1999, Badora, Grenda 2002, Grenda, Skowrońska 2004). It was found that Si application had beneficial effects in cucumber cultivation as well in soil as in soilless cultures (Miyake and Takahashi 1983, Lee et al. 2000). The aim of the experiments reported in this paper was to evaluate the effect of several silicates used as amendments to peat-based growing substrates on yield and Si content in growing media and in cucumber plants.

MATERIALS AND METHODS

The experiment was carried out in an unheated greenhouse at the Research Institute of Vegetable Crops in Skierniewice, in 2005-2007. Seeds of cv. Milenium F_1 greenhouse cucumber were planted at the beginning of May, and 4 weeks later transplants were transferred to growing containers. The experiment was terminated at the end of September. Cucumber plants were grown in 12-liter containers filled with peat substrate. The control substrate of pH 6.2 contained per 1 dm^3: $N\text{-}NO_3$ – 140 mg, P – 110 mg, K – 160 mg, Ca – 2250 mg, Mg – 165 mg and micronutrients. The experimental treatments consisted of the control substrate amended with different silicates (sodium, potassium, calcium and ammonium). In 2004, preliminary trials were performed to estimate proper rates of silicates to be used in further experiments. A range of 1.0-6.0 g of silicates per 1 dm^3 of growing medium was tested. Eventually, it was decided that the experimental rates of silicates would be 2.0 and 4.0 g per 1 dm^3. In 2006 and 2007 sodium silicate was not tested because in 2005 at the rate of 4 g per 1 dm^3 it caused an adverse effect on the substrate's pH, Na content and appearance of cucumber plants. Each treatment consisted of 16 plants (4x4 replications). During the growing period plants were watered with tap water and fertilized every second watering with liquid fertilizer according to a current chemical analysis of the growing media. Fruits were usually collected twice a week; their weight and number were recorded. The experiments were arranged in a one-factorial design. The experimental results were evaluated statistically with analysis of variance. Mean values were compared with Newman-Keuls test at p=0.05. For chemical analysis, the substrates and plant material were extracted with acetic acid at concentrations of 0.02% and 2%, respectively. The chemical analyses of the growing media, leaves and fruits were performed using an ICP analyser. Phosphorus was analyzed with the colorimetric method using a Spekol apparatus and $N\text{-}NO_3$ with a colorimetric automatic flow system.

RESULTS AND DISCUSSION

The results are given in Tables 1-3 and Figure 1. During the preliminary experiments performed in 2004 it was found out that silicates added to the substrates at rates over 4 g per 1 dm^3 of media were excessive, particularly in the case of water-soluble Na- and K-silicates. The results obtained in 2005 clearly indicated that supplying the media with the tested silicates, except $(NH_4)_2SiO_3$, caused increased concentration of particular elements at the end of the growing season (Table 1). Also the content of soluble Si was raised in all the treatments. Na-, K- and Ca-containing silicates at both

Table 1

Effect of growing medium amendment with silicone fertilizers on content of elements at the end of the growing season and yield of cucumber fruits, 2005

Treatment ($g\ dm^{-3}$)	pH	Salinity	N-NO_3	P	K	Ca	Mg	Na	Si	Yield
	($g\ dm^{-3}$)		($mg\ dm^{-3}$)							($dag\ plant^{-1}$)
Control	6.5	0.2	<5	86	62	2754	180	55	4.5	186 *b*
Na_2SiO_3 – 2.0	7.2	0.5	<5	100	59	2588	176	261	14.2	177 *b*
Na_2SiO_3 – 4.0	7.7	0.6	<5	90	60	2411	162	336	18.6	177 *b*
K_2SiO_3 – 2.0	7.1	1.0	<5	115	398	2571	158	88	13.6	215 *a*
K_2SiO_3 – 4.0	7.5	1.1	<5	119	675	2455	169	90	22.4	186 *b*
$CaSiO_3$ – 2.0	7.0	1.0	<5	122	61	3112	183	212	14.5	181 *b*
$CaSiO_3$ – 4.0	7.0	1.2	<5	132	67	3390	171	280	15.1	179 *b*
$(NH_4)_2SiO_3$ – 2.0	6.4	0.9	<5	76	54	2623	148	287	6.6	216 *a*
$(NH_4)_2SiO_3$ – 4.0	6.5	1.1	<5	68	50	2373	139	311	8.8	176 *b*

Data marked with the same letters within columns did not differ statistically, according to Newman-Keuls test at $p = 0.05$.

Table 2

Effect of medium amendment with potassium-, calcium- and ammonium-silicates at rates of 2 and 4 $g\ dm^{-3}$ on yield and growth of cucumber. Data per plant, 2006

Treatment	Yield of fruits		Fruits number		Weight of 1 fruit		Fresh wt of 1 plant	
	(dag)	(%)	(no)	(%)	(dag)	(%)	(dag)	(%)
Control	190 *b*	100	12.7 *ab*	100	15.0	100	36 *b*	100
K_2SiO_3 2 $g\ dm^{-3}$	162 *c*	85	10.4 *b*	82	15.7	105	34 *b*	94
K_2SiO_3 4 $g\ dm^{-3}$	159 *c*	84	10.3 *b*	81	15.4	103	38 *b*	106
$CaSiO_3$ 2 $g\ dm^{-3}$	152 *c*	80	12.8 *ab*	101	11.9	79	49 *a*	136
$CaSiO_3$ 4 $g\ dm^{-3}$	163 *c*	80	10.8 *ab*	85	15.1	100	38 *b*	106
$(NH_4)_2SiO_3$ 2 $g\ dm^{-3}$	230 *a*	121	15.3 *a*	120	15.0	100	51 *a*	142
$(NH_4)_2SiO_3$ 4 $g\ dm^{-3}$	220 *a*	116	14.0 *a*	110	15.7	100	53 *a*	147

Data marked with the same letters within columns did not differ statistically, according to Newman-Keuls test at $p = 0.05$.

tested rates caused increase of pH. K- and NH_4 – silicates at lower rates caused statistically proven yield increase of cucumber fruits. In 2006 the highest yield and fruit number were obtained with $(NH_4)_2SiO_3$ at the lower rate of 2 g per liter. The fresh weight of whole plants also increased under the influence of $(NH_4)_2SiO_3$ and $CaSiO_3$ at the rate of 2 g per 1 dm^3 of substrate (Table 2). The chemical analysis of the growing substrates as well

Table 3

Effect of growing medium amendment with 2 g dm^{-3} of calcium silicate (Ca Si) and 2 g dm^{-3} ammonium silicate (N Si) on the content of elements in the substrate, leaves and fruits, analyzed twice in 2007

Material date	Treat-ment	pH H_2O	Sali-nity	$N-NO_3$	P	K	Mg	Ca	Si
			(g NaCl dm^{-3})						
Substrate Aug. 07	control	7.8	0.46	10	79	234	224	2294	10.5
	Ca Si	7.8	0.62	10	133	187	208	2236	9.73
	N Si	7.7	0.89	58	93	130	219	2454	10.4
				(mg kg^{-1} d.m.)					
Leaves Jul. 20	control			1160	4500	28 019	4595	43820	263.7
	Ca Si			3770	2900	35 683	4168	50460	381.7
	N Si			12120	4100	35 512	4518	48200	308.9
Fruits Jul. 20	control			113	6610	32 348	2839	3940	3.9
	Ca Si			199	4240	39 614	2860	5290	2.38
	N Si			1050	7310	39 965	2529	4220	0.98
Leaves Aug. 07	control			1500	4700	26 454	7897	52300	454.8
	Ca Si			1620	3100	27 092	6194	53830	517.6
	N Si			3280	3800	25 339	6386	60420	620.8
Fruits Aug. 07	control			964	6700	42 312	3038	3840	< 0.1
	Ca Si			500	4300	38 752	2849	4060	8.74
	N Si			796	5800	41 193	2853	3630	4.96

as leaves and fruits, which was performed twice in 2007 (Table 3), indicated that enrichment of peat substrate with Ca- and NH_4 – silicates caucused increased salinity and P content as well as decreased K content. The content of elements in cucumber leaves and fruits depended strongly on the time when plant parts were sampled. The results showed that leaves accumulated several-fold more Si than fruits and that silicates-amended growing media caused higher Si accumulation in leaves and fruits (Table 3). It was also demonstrated the lower rate of silicates usually evoked the response of cucumber plants, expressed as increased yields (Figures 1a, b). These figures clearly show that higher yields (Figure 1a) were connected with the number of fruits per plant (Figure 1b)

MIYAKE and TAKAHASHI (1983) reported beneficial effect of soil fertilization with silicates on the growth and yield of cucumber plants and reduced damage caused by wilt disease. Excessive silicate fertilization resulted in increased soil pH and inferior growth of cucumber. Application of organic mat-

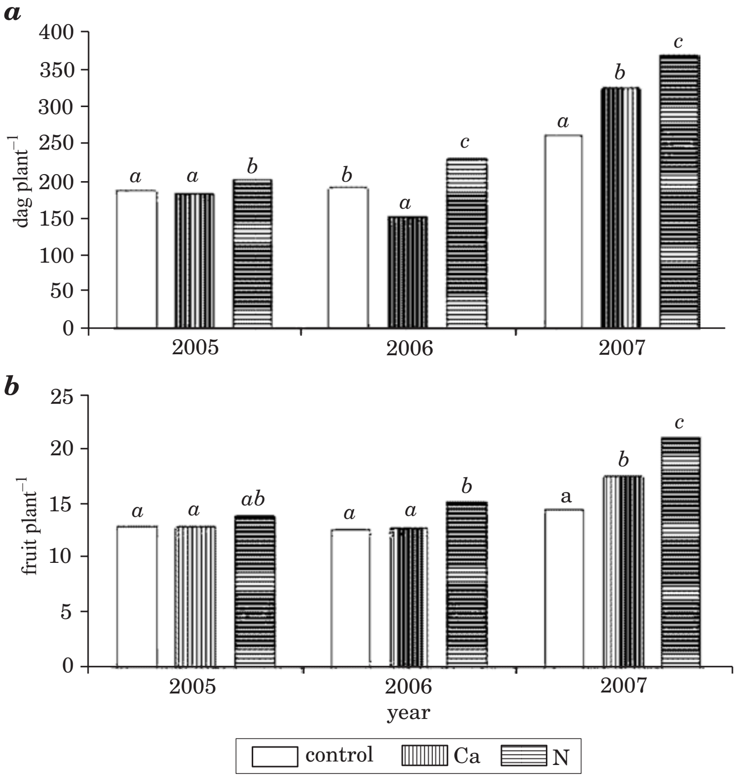

Fig. 1. The effect of substrate amendment with 2 g dm^{-3} calcium silicate (Ca) or ammonium silicate (N) on the yield (*a*) and fruit number (*b*) in 2005-2007. Data marked with the same letters did not differ significantly within years, according to Newman-Keuls test at p=0.05

ter helped to improve soil pH. RODGRES-GRAY and SHAW (2004) also stated that organic matter amendment to soil altered plants' tolerance to foliar and stem diseases in winter wheat. It is of interest that the yield increase in our experiments was connected with the number of fruits. In our previous work (GÓRECKI et al. 2004) on eggplant, we reported that Si-fertilizers caused more numerous seed set. Distribution of silicone in cucumber plants has been described by ABD ELMONIEM et al. (1997) and SAMUELS et al. (1991). FAWE et al. (1998) and DRAGISIĆ MAKSIMOVIĆ et al. (2007) discussed the physiological role of silicone in modulation and metabolism of different compounds in cucumber plants.

CONCLUSIONS

1. Insoluble, slow-release calcium- and ammonium-silicate fertilizers proved to be valuable amendments of peat-based organic growing media for cucumber cultivation.

2. At doses of 2 g per 1 dm^3 of growing media, they contributed to increased cucumber yield and Si contents in leaves and fruits of cucumber plants.

3. Increased fruit yields were more strongly connected with the fruit number per plant rather than the average fruit weight.

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