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INFLUENCE OF FOLIAR TREATMENT WITH SILICON CONTAINED IN THE ACTISIL HYDRO PLUS PREPARATION ON THE GROWTH, FLOWERING AND CHEMICAL COMPOSITION OF *GAZANIA RIGENS* (L.) GAERTN., *SALVIA FARINACEA* BENTH AND *VERBENA HYBRIDA* VOSS

Regina Dębicz, Anna Pawlikowska, Katarzyna Wróblewska, Przemysław Bąbelewski

Chair of Horticulture
Wrocław University of Environmental and Life Sciences

Abstract

Silicon is an element that significantly reduces the vulnerability of plants to biotic and abiotic stress factors, increases their resistance to pathogens and pests, strengthens tissues and cellular membranes, increases biomass and crops, improves the nutrition state of plants and increases the chlorophyll content. It also influences the formation of morphological traits of plants. The aim of our research was to determine the influence of silicon contained in the Actisil preparation on the growth and blooming of *Gazania rigens, Salvia farinacea* and *Verbena hybrida,* which are commonly cultivated in flowerbeds and on balconies. A two-factor experiment consisted of the foliar application of a solution of silicon in the following concentrations: 0 mg dm^{-3}, 120 mg dm^{-3} and 240 mg dm^{-3}. The application was performed 2, 4 and 6 times at one-week intervals. Biometric measurements were carried out at the beginning of the blooming of plants. The laboratory analyses included determinations of P, K, Mg, Ca, Si and the chlorophyll content in leaves. Beneficial influence of silicon on most of the morphological traits of the analysed species was demonstrated. Plants responded the best to two or four treatments with the silicon solution of a concentration of 120 mg dm^{-3}, with an increase in the values of the analysed morphological traits. The application of silicon did not significantly modify the content of mineral elements in the dry weight of leaves. The application of silicon to *Gazania rigens* led to an increase in the content of this element in leaves as well as to an elevated chlorophyll content.

Keywords: Actisil Hydro Plus, orthosilicic acid, biometric properties, macroelements, chlorophyll.

dr hab. inż. Regina Dębicz, Chair of Horticulture, Wroclaw University of Environmental and Life Sciences, pl. Grunwaldzki 24 A, 50-363 Wroclaw, Poland, e-mail: regina.debicz@up.wroc.pl

INTRODUCTION

According to Epstein (1999), silicon (Si) is the second most common element on the Earth (after oxygen). It accounts for approx. 25% of the mass of the Earth's crust. Until recently, it has been considered to be a rather unimportant element in the life of plants. However, research conducted in the last decade has demonstrated that silicon contributes to some improvement in the quality of plants and their resistance to abiotic and biotic stress factors (Sacała 2009, Bockhaven et al. 2013, Jarosz 2013). This has been evidenced, for instance, by the results of experiments showing that silicon reduces the sensitivity of plants to fungal diseases, as the accumulation of silicon under the cuticle layer in leaves limits the degree of pathogen penetration into the underlying tissues (Kamenidou et al. 2010). Cho et al. (2013) demonstrated that the resistance of *Zantedeschia* to *Ervinia carotovora* subsp. increased along with the increase in a silicon dose applied in the form of spray. According to Shetty et al. (2012), silicon in the form of K_2SiO_3 delayed the development of powdery mildew by 1-2 days and noticeably (by 48%) reduced the symptoms of this disease in potted miniature roses cultivated in greenhouses. The active role of silicon in protecting plants against insects has also been proven (Laing et al. 2006, Korndörfer et al. 2010).

In contrast, Moyer et al. (2008) did not observe any significant influence of silicon on the development of powdery mildew in gerbera, suggesting that this might have been caused by an insufficient concentration of silicon in plant tissues, resulting from specific properties of this species.

In recent years, there have been reports that silicon supplementation effectively reduces salt stress and has a beneficial influence on the growth of plants and quality of flowers. This has been demonstrated, for example, by Bayat et al. (2013) in *Calendula officinalis* L., Savvas et al. (2007) in *Rosa* x*hybrida* cultivated on salted hydroponic substrates and Reezi et al. (2009) in *Rosa* cv. Hot Lady cultivated in similar conditions. An addition of silicon to salted media in *in vitro* cultures also minimises salt stress and has a beneficial influence on the pace of shoot regeneration, e.g. in *Ajuga multiflora* Bunge (Sivanesan, Jeong 2014) and *Salvia splendens* Sellow ex Roem. et Schult. (Soundararajan et al. 2013).

By impregnating external cellular walls, silicon improves their mechanical properties and the accumulation of silicon in the covering tissue enhances shoot rigidity (Ma, Yamaji 2006). This was confirmed by Zhao et al. (2012) in their studies on *Paeonia lactiflora* Pall. These authors determined that foliar application of silicon improved the resistance of shoots to loads on flowers in this species, by increasing the thickness of the sclerenchyma layer of the cellular wall and the lignin content. On the other hand, Cho et al. (2013) revealed that the rigidity of the blossom peduncles of *Zantedeschia* improved with an increased amount of silicon deposited in the mechanical tissue cells. Silicon affects early blooming of ornamental plants, which to a certain extent depends on the form of fertiliser. Thus, Kamenidou et al. (2010) concluded that *Gerbera* treated with foliar $NaSiO_3$ blooms 16 days earlier than the control plants, while foliar application of $KSiO_3$, according to the same researchers (2009), delays the flowering of *Helianthus annuus* L. (2008) and *Zinnia elegans* Jacq. in controlled cultivation under covers. Numerous authors have noticed the influence of silicon fertilisers on the weight of both aerial and underground parts of plants. Depending on a plant species and fertiliser dose, a decrease or increase in the fresh or dry plant weight was noted (Mattson, Leatherwood 2010, Lim et al. 2012, Sivanesan et al. 2013).

The aim of our research was to determine the influence of silicon contained in the Actisil Hydro Plus preparation on the growth, flowering and chemical composition of three species of ornamental annual plants, which are often grown in flowerbeds and on balconies.

MATERIAL AND METHODS

In 2012-2013, at the Station of Research on Vegetables and Ornamental Plants, which belongs to the Department of Horticulture at the Wroclaw University of Environmental and Life Sciences, a greenhouse experiment was conducted in order to evaluate the influence of Actisil Hydro Plus by Yara (a preparation containing silicon 0.6% in a form of orthosilicic acid and free silica) on the development of annual ornamental plants. The test objects were: gazania *Gazania rigens* (L.) Gaertn., mealy sage *Salvia farinacea* Benth. and verbena *Verbena hybrida* Voss. Seedlings originating from a licensed horticultural farm were transplanted on the 15 of March 2012 and 2013, from multiplets to pots of 500 cm^3 volume, filled with peat substrate of a pH of 6.47 and containing (in mg dm^{-3}): $N\text{-}NO_3$ – 145, P – 119, K – 263, Mg – 90, Ca – 1120. Pots were placed on cultivating tables at a density of 24 plants per 1 m^2. The temperature in the greenhouse was 16-18°C in the day and 14-16°C at night. Plants were watered with a watering can. A two-factor experiment was set up according to the random blocks method, with three replications, each comprising 9 plants. The first factor was the concentration of Actisil Hydro Plus solution containing silicon (0 mg dm^{-3}, 120 mg dm^{-3}, 240 mg dm^{-3} i.e. concentrations of 0%, 0.2% and 0.4%). The second factor was the number of applications of silicon (2, 4, 6). Plants were foliar sprayed (4 ml per plant) at weekly intervals, from 2 April (in first and second years experiment). Control plants were sprayed (2, 4 or 6 times) with distilled water. During their growth, the plants were supplemented with a 0.5% solution of Florovit, applied to the roots every 10 days (150 cm^3 per pot introducing 30 mg N, 20 mg P, 40 mg K). Measurements of such morphological traits as the height and diameter of plants, diameter of inflorescences, number of inflorescences, number of flowers per one inflorescence and, additionally in *Gazania,* the number of leaves, were taken during the flowering (28-29 May, 10 weeks after planting). Healthy and well-shaped leaves were collected for laboratory analysis from each combination at the end of May 2012 and 2013. Each sample of fresh plant material weighed approx. 20 g. The content of magnesium and phosphorus was determined with use of the colorimetric method, while calcium and potassium were measured with the flame photometric method. The level of silicon was assayed by Inductively Coupled Plasma Optical Emission Spectrometry ICP-OES. The chlorophyll content of leaves was determined after extraction in 80% acetone (ARNON, 1949). Absorbtion was measured using a spectrophotometer (WPA, S106) at 645 and 663 nm and the chlorophyll content (in mg g^{-1} f.w) was calculated from the equation: chlorophyll $a + b = 8.02 (A_{663}) + 20.21 (A_{645})$.

The results of the measurements of biometric traits were statistically analysed with the Anova variance analysis for two-factor experiments in randomized blocks. The significance of differences was determined with the Duncan test at $p = 0.05$. The results of laboratory analyses were processed statistically with ANOVA variance analysis. The significance of differences was determined by the Tukey's test at $p = 0.05$.

RESULTS AND DISCUSSION

Owing to their long periods of flowering, the ornamental plants *Gazania rigens*, *Salvia farinaceae* and *Verbena hybrida* are commonly grown in flowerbeds and on balconies. Their ornamental value depends largely on the size of plants and inflorescences and the number of inflorescence shoots. One of the ways to induce morphological changes in plants is through silicon supplementation, and, according to MA and YAMAJI (2006), the effect depends on a species and cultivar of a given plant. Our results demonstrate a beneficial influence of silicon on the formation of morphological traits in the analysed species of plants.

Regarding *Gazania rigens*, the statistical analysis of results showed that foliar supplementation of silicon at a concentration of 240 mg dm^{-3} had a positive effect on the stem diameter, diameter and number of inflorescences as well as the number of leaves. The largest diameter was observed in plants that were supplemented four times with silicon at a concentration of 240 mg dm^{3} (Table 1). The highest dose of silicon supplied to plants four and six times led to a significant increase in the number of inflorescences (by 15% on average, compared to the control). As SIVANESAN et al. (2013) demonstrated, *Chrysanthemum* cultivars grew more blossoms that were larger in diameter than the control group plants when receiving root supplementation with a nutrient solution containing an addition of K_2SiO_3 at a concentration of 50 or 100 mg dm^{-3}. In our experiment, *Gazania* sprayed with silicon solution grew more flowers and leaves than the control group plants (by 30% and 12%, respectively), regardless of the concentration and the number of applications

Table 1

Morphological traits of *Gazania rigens* depending on silicon concentration and number of application (means from 2012-2013)

Concentration of silicon (mg dm^{-3}) (I)	Number of application (II)	Plant feature				
		diameter of plants (cm)	heigh of plants (cm)	diameter of florescences (cm)	number of florescences	number of leaves
0	2	16.07	12.40	5.97	2.43	12.77
0	4	16.77	12.30	5.93	2.53	13.03
0	6	15.97	14.20	6.13	2.50	13.90
120	2	11.73	12.46	6.57	2.80	15.10
120	4	14.40	13.90	6.63	2.97	20.50
120	6	13.77	11.77	5.93	2.57	21.13
240	2	15.33	11.77	6.77	2.50	18.00
240	4	25.13	13.37	6.40	3.50	17.77
240	6	13.06	12.67	6.80	3.40	18.00
$LSD_{0,05}$		3.12	1.79	0.51	n.s	1.56
Mean for concentration of silicon (I)						
0		16.27	12.97	6.01	2.49	13.24
120		13.30	12.71	6.38	2.78	18.91
240		17.84	12.61	6.66	3.14	17.93
$LSD_{0,05}$		1.80	n.s	0.29	0.36	0.90
Mean for number of application (II)						
2		14.38	12.21	6.44	2.58	15.29
4		18.77	13.19	6.32	3.00	17.10
6		14.27	12.88	6.29	2.83	17.68
$LSD_{0,05}$		1.80	n.s	n.s	n.s	0.90

n.s. – non-significant difference

(Table 1). This is an important characteristic of this species, whose ornamental value is created by both inflorescences and leaves.

The current study shows that the tested combination of two factors (number of sprays and silicon concentration) significantly affected the diameter of plants and the number of blossoms in *Salvia farinaceae* (Table 2). The largest diameter and height were achieved by plants subject in the following variants: the lower and higher silicon concentration and four applications. Plants from these treatments were on average 5-7 cm (27% - 40%) higher. The same dose of silicon had a beneficial effect on the number of inflorescences and thus on the flowering abundance of this species. The most shoots were developed by plants sprayed more than twice with the silicon solution containing the lower amount of silicon (Table 2). SIVANESAN et al. (2013) demonstrated that a nutrient solution containing 50 and 100 mg dm^{-3} of silicon used for growing the following cultivars of *Chrysanthemum:* Gaya Pink,

Table 2

Morphological traits of *Salvia farinacea* depending on silicon concentration and number of application (means for 2012-2013)

Concentration of silicon, (mg dm^{-3}) (I)	Number of application (II)	Plant feature			
		diameter of plants (cm)	heigh of plant (cm)	shoot number	number of inflorescences
0	2	9.73	13.10	14.17	1.37
0	4	9.93	13.57	14.43	1.30
0	6	9.37	11.67	15.80	1.47
120	2	9.30	13.43	15.10	1.80
120	4	11.10	18.10	20.50	3.30
120	6	9.63	13.60	21.13	1.70
240	2	7.63	11.03	18.00	0.43
240	4	11.87	18.77	17.77	2.73
240	6	10.67	11.60	18.00	0.77
$LSD_{0,05}$		1.64	2.85	1.97	0.69
Mean for concentration of silicon (I)					
0		9.68	12.78	14.80	1.38
120		10.01	15.05	18.91	2.27
240		10.06	13.80	17.93	1.31
$LSD_{0,05}$		n.s	1.64	1.14	0.40
Mean for number of application (II)					
2		8.89	12.52	15.76	1.20
4		10.97	16.82	17.57	2.45
6		9.89	12.29	18.31	1.32
$LSD_{0,05}$		0.95	1.64	1.14	0.40

n.s. – non-significant difference

Lemon Tree, White Angel, allowed the plants to grow higher and produce more shoots and blossoms. Bayat et al. (2013) also proved that - regardless of a silicon dose - the height of *Calendula officinalis* plants was increased in comparison to plants not supplemented with silicon, which is quite important in the cultivation of this species for fresh cut flowers. On the other hand, Kamenidou et al. (2010) demonstrated that a similar content of silicon in the supplementing medium strongly inhibited the growth of blossom peduncles in *Gerbera* and, additionally, caused deformation of blossoms in this plant.

Based on the mean results, it was proven that an application of the silicon solution in a concentration of 120 mg dm^3 improved all the morphological traits of *Verbena hybrida* (Table 3). Bayat et al. (2013) demonstrated that a similar concentration (100 mg dm^{-3}) of silicon had a positive influence on the

Table 3

Morphological traits of *Verbena hybrida* depending on silicon concentration and number of application (means for 2012-2013)

Concentration of silicon, (mg dm^{-3}) (I)	Number of application (II)	Plant feature				
		diameter of plants (cm)	heigh of plants (cm)	diameter of lorescences (cm)	number of lorescences	number of flowers
0	2	21.47	10.40	4.03	2.57	9.83
0	4	22.70	10.30	4.20	3.03	9.73
0	6	19.67	10.13	4.43	2.77	11.17
120	2	26.40	11.00	5.97	5.03	18.57
120	4	25.63	11.10	6.20	5.23	22.07
120	6	18.47	9.60	4.50	1.93	12.37
240	2	16.97	9.83	6.37	4.10	19.03
240	4	18.30	7.60	5.30	2.93	14.60
240	6	13.30	7.00	2.93	1.07	6.73
$LSD_{0.05}$		n.s	1.27	0.67	0.76	3.60
Mean for concentration of silicon (I)						
0		21.28	10.28	4.22	2.79	10.25
120		23.50	10.57	5.56	4.06	17.67
240		16.19	8.15	4.87	2.70	13.46
$LSD_{0.05}$		2.15	0.73	0.39	0.44	2.08
Mean for number of application (II)						
2		21.62	10.41	5.46	3.90	15.81
4		22.21	9.67	5.23	3.73	15.47
6		17.15	8.91	3.95	1.92	10.09
$LSD_{0.05}$		2.15	0.73	0.39	0.44	2.08

n.s. – non- significant difference

diameter and number of inflorescences and the height of *Calendula officinalis* L. plants, while MATTSON and LEATHERWOOD (2010) concluded that popular flowerbed ornamental plants differed in the response to silicon applied in the same concentration. Silicon contained in potassium-silicon fertiliser positively affected the height of *Impantiens hawkerii* W. Bull, *Lobelia erinus* L. and *Portulaca grandiflora* Hoock. In comparison to control, silicon-treated plants were higher by 10%, 13% and 9%, respectively. Reversely, *Bracteantha bracteata* (Vent.) Anderb. & Heagi was 9% lower. *Fuchsia hybrida* hort. ex Siebold & Voss, *Portulaca grandiflora* Hoock. *Petunia* x *hybrida* Vilm. and *Torenia fournieri* Linden ex E. Fourn., which had received silicon supplementation (100 mg dm^{-3}), grew flowers or inflorescences with a larger diameter. MATTSON and LEATHERWOOD (2013) noted a significant decrease in the value of this trait versus the control group in *Lobelia erinus* L., *Sutera* (Galpin) Hilliard and *Argyranthemum frutescens* (L.) Sch. Bip. Our experiment showed that two and four applications of Si had the most beneficial influence on the growth and blooming of *Verbena hybrida*. The interaction of both factors significantly raised the values of all the analysed parameters of this species except the diameter. Particularly promising effects in terms of the number of blossoms and the number of flowers per blossom were noted when two and four sprays with a solution containing silicon in a concentration of 120 mg dm^{-3} had been applied. These traits were 51% and 48% higher, respectively (Table 3).

According to MA and YAMAJI (2006), plants differ in their capacity to accumulate silicon, depending on a species and cultivar. This observation was supported by HOGENDORP et al. (2012), who conducted experiments on ten species of ornamental plants. Their research proved that *Zinnia elegans* Jacq. and *Symphyotrichum novae-angliae* L. (*Aster novaee-angliae* L.) accumulated the highest amount of silicon in flower, leaf and shoot tissues. The silicon content in tissues of *Phlox paniculata* L. and *Coreopsis verticillata* L. was lower by half, and the lowest content of this element was noted in tissues of *Tagetes patula* L. and *Heuchera hybrida*.

Our research demonstrates that the content of silicon in leaves of *Gazania rigens* sprayed with a silicon-containing solution was significantly higher than in control plants, which means that plants of this species are good at absorbing and accumulating silicon in leaf tissues (Table 4). *Verbena* also accumulates silicon in leaves (Table 5). The more silicon was supplied to

Table 4

Nutrient content and chlorophyll in leaves *Gazania rigens* depending on the use of silicon (means for 2012-2013)

Concentration of silicon (I) (mg dm^{-3})	Number of application (II)	P	K	Mg	Ca	Si	Chlorophyll content (mg g^{-1} f.w)
		(g kg^{-1})					
0	2	1.8 *a*	37.7 *a*	4.2 *a*	13.4 *a*	2.7 *a*	0.95 *a*
0	4	2.4 *a*	35.5 *a*	4.3 *a*	14.5 *a*	2.1 *a*	0.85 *a*
0	6	2.3 *a*	27.8 *a*	5.3 *a*	15.6 *a*	2.1 *a*	0.66 *a*
120	2	2.4 *a*	25.0 *a*	3.1 *a*	14.2 *a*	3.8 *a*	0.93 *a*
120	4	2.8 *a*	29.5 *a*	3.5 *a*	15.2 *a*	3.6 *a*	1.06 *a*
120	6	2.1 *a*	22.9 *a*	3.4 *a*	15.1 *a*	8.0 *b*	1.17 *a*
240	2	1.9 *a*	19.8 *a*	3.1 *a*	10.6 *a*	8.5 *b*	1.22 *a*
240	4	2.1 *a*	25.3 *a*	8.0 *a*	10.0 *a*	5.2 *a*	1.21 *a*
240	6	2.4 *a*	23.0 *a*	3.6 *a*	10.7 *a*	2.2 *a*	1.22 *a*
Mean for concentration of silicon							
0		2.1 *a*	33.7 *a*	4.6 *a*	14.5 *a*	2.3 *b*	0,82 *a*
120		2.4 *a*	25.8 *a*	3.3 *a*	14.8 *a*	5.1 *a*	1.06 *ab*
240		2.1 *a*	22.7 *a*	4.9 *a*	10.4 *a*	5.2 *a*	1.30 *b*
Mean for number of application							
2		2.0 *a*	27.5 *a*	3.4 *a*	12.7 *a*	5.0 *b*	1.03 *a*
4		2.4 *a*	30.1 *a*	5.2 *a*	13.2 *a*	3.6 *a*	1.04 *a*
6		2.2 *a*	24.6 *a*	4.1 *a*	13.8 *a*	4.1 *ab*	1.02 *a*

Means followed by the same letter do not differ significantly at $p = 0.05$.

Table 5

Nutrient content and chlorophyll in leaves *Verbena hybrida* depending on the use of silicon (means for 2012-2013)

Concentration of silicon (I) (mg dm^{-3})	Number of application (II)	P	K	Mg	Ca	Si	Chlorophyll content (mg g^{-1} f.w)
		(g kg^{-1})					
0	2	1.7 *a*	16.0 *a*	4.7 *a*	21.5 *a*	11.3 *a*	1.32 *a*
0	4	1.5 *a*	14.8 *a*	4.5 *a*	24.2 *a*	6.8 *a*	1.12 *a*
0	6	1.9 *a*	16.1 *a*	4.2 *a*	19.8 *a*	6.2 *a*	1.53 *a*
120	2	1.7 *a*	14.2 *a*	4.1 *a*	25.4 *a*	7.8 *a*	1.56 *a*
120	4	1.7 *a*	14.3 *a*	4.6 *a*	25.3 *a*	5.8 *a*	1.79 *a*
120	6	5.2 *a*	16.2 *a*	4.4 *a*	22.2 *a*	5.6 *a*	1.43 *a*
240	2	1.8 *a*	14.0 *a*	5.4 *a*	25.9 *a*	6.3 *a*	1.52 *a*
240	4	1.9 *a*	14.1 *a*	5.5 *a*	24.8 *a*	3.9 *a*	1.90 *a*
240	6	1.9 *a*	15.3 *a*	4.6 *a*	26.7 *a*	4.0 *a*	1.54 *a*
Mean for concentration of silicon							
0		1.7 *a*	15.6 *a*	4.4 *a*	21.8 *a*	4.7 *a*	1.32 *a*
120		2.9 *a*	14.9 *a*	4.4 *a*	24.3 *a*	6.4*ab*	1.59 *a*
240		1.9 *a*	14.5 *a*	5.2 *a*	25.8 *a*	8.1 *b*	1.65 *a*
Mean for number of application							
2		1.7 *a*	14.7 *a*	4.7 *a*	24.3 *a*	5.3 *a*	1.46 *a*
4		1.7 *a*	14.4 *a*	4.8 *a*	24.7 *a*	5.5 *ab*	1.60 *a*
6		3.0 *a*	15.8 *a*	4.4 *a*	22.9 *a*	8.4 *b*	1.50 *a*

Means followed by the same letter do not differ significantly for $p = 0.05$.

plants (240 mg Si dm^{-3} and 6 sprays), the higher the Si content in *Verbena* plants was. In *Salvia farinacea* Benth. no significant influence of silicon supplementation on the content of this element in leaves was noted (Table 6). Górecki and Danielski-Bush (2009) and Soundararajan et al. (2013) claim that the ability to accumulate silicon in plant tissues depends not only on a species and variety, but also on the form and concentration of silicon and the method of application. Results of their tests on *Salvia splendens* cv. Vista Red and Sizzler Red proved that the highest amount of silicon accumulated in the tissues of these varieties when silicon had been applied to roots in the form of K_2SiO_3 and at a dose of 100 mg dm^{-3}. On the other hand, Kamenidou et al. (2008, 2010) reported that the content of silicon in leaves of *Helinthus annus* and *Gerbera* cv. Acapella increased under the influence of a higher dose of silicon applied as $KSiO_3$ to roots. In our experiment, silicon was sprayed over leaves in the form of a solution containing H_4SiO_4.

In our experiment, the nutrient content (P, K, Mg, and Ca) in leaves of the analysed species did not differ significantly between the experimental variants. According to Sivanesan et al. (2013), fertilisation with silicon leads to an increase in the content of P, S, Ca, Mg, Zn and a decrease in the content of K, B, Cu, Fe and Mn in leaves of *Chrysanthemum* cv. Gaya Pink, Lemon Tree, White Angel parallel to the increase in the silicon concentration in the medium. Tesfagiorgis and Laing (2013) demonstrated that a high sili-

Table 6

Nutrient content and chlorophyll in leaves *Salvia farinacea* depending on the use silicon (means for 2012-2013)

Concentration of silicon (I) (mg dm^{-3})	Number of application (II)	P	K	Mg	Ca	Si	Chlorophyll content (mg g^{-1} f.w)
		(g kg^{-1})					
0	2	1.9 *a*	26.2 *a*	2.0 *a*	7.9 *a*	1.1 *a*	1.35 *a*
0	4	1.8 *a*	28.8 *a*	3.3 *a*	8.6 *a*	2.0 *a*	1.39 *a*
0	6	2.3 *a*	26.2 *a*	3.2 *a*	13.9 *a*	1.1 *a*	1.49 *a*
120	2	2.1 *a*	28.0 *a*	3.7 *a*	9.6 *a*	2.5 *a*	1.29 *a*
120	4	2.3 *a*	29.8 *a*	4.8 *a*	10.1 *a*	2.0 *a*	1.42 *a*
120	6	2.3 *a*	27.0 *a*	3.6 *a*	7.4 *a*	0.8 *a*	1.40 *a*
240	2	2.6 *a*	25.8 *a*	5.1 *a*	14.6 *a*	2.1 *a*	1.37 *a*
240	4	2.0 *a*	25.5 *a*	3.2 *a*	15.1 *a*	1.2 *a*	1.46 *a*
240	6	1.9 *a*	23.5 *a*	4.0 *a*	16.7 *a*	2.6 *a*	1.36 *a*
Mean for concentration of silicon							
0		2.0 *a*	27.0 *a*	2.8 *a*	10.1 *a*	1.3 *a*	1.41 *a*
120		2.2 *a*	28.3 *a*	4.0 *a*	9.0 *a*	1.7 *a*	1.37 *a*
240		2.2 *a*	24.9 *a*	4.1 *a*	15.5 *a*	2.0 *a*	1.39 *a*
Mean for number of application							
2		2.2 *a*	26.6 *a*	3.6 *a*	10.7 *a*	1.9 *a*	1.34 *a*
4		2.0 *a*	28.0 *a*	3.8 *a*	11.3 *a*	1.7 *a*	1.42 *a*
6		2.2 *a*	25.6 *a*	3.6 *a*	12.7 *a*	1.5 *a*	1.41 *a*

Means followed by the same letter do not differ significantly at $p = 0.05$.

con concentration in the medium solution decreased the accumulation of Ca in the roots, flowers and fruit of *Zinnia elegans* and *Cucurbita pepo*. On the other hand, the level of P in the fruit of *Cucurbita pepo* and in the flowers of *Zinnia elegans* increased significantly in response to a higher silicon dose. According to these authors, 50 mg dm^{-3} is an optimum Si dose that can ensure proper nutrition of the analysed plants.

Proper supply of mineral elements to plants affects also the efficiency of photosynthesis. According to literature, silicon supplementation may cause an increase in the chlorophyll content in leaves and enhance the synthesis of sugars (Mikiciuk, Mikiciuk 2008). Our own research shows that only *Gazania splendens* responded to silicon supplementation, regardless of its concentration, with a significantly higher accumulation of this chlorophyll in leaves (Table 4). Similar observations were reported by Sivanesan et al. (2013). According to these authors, the chlorophyll content in the leaves of *Chrysantemum* cultivars increased along with the increase of Si concentration in the nutrient solution supplemented to plants.

CONCLUSIONS

1. Foliar application of silicon contained in the Actisil Hydro Plus preparation has a beneficial influence on most of the analysed morphological traits in the tested species of annual plants.

2. The best response of plants was noted for two and four treatments with the silicon solution of a concentration of 120 mg dm^{-3}, which is when the values of all the analysed morphological traits improved.

3. The application of silicon did not significantly influence the content of mineral elements in the dry weight of leaves.

4. The application of silicon to *Gazania rigens* led to an increase in the content of this element in leaves as well as to an increased chlorophyll content.

RERERENCES

Arnon D.I. 1949. *Copper enzymes in isolated chloroplasts. Poly-phenoloxidase in Beta vulgaris*. Plant. Physiol., 24: 1-15.

Bayat H., Alirezaie M., Neamati H., Saadabad A. 2013. *Effect of silicon on growth and ornamental traits of salt-stressed calendula* (*Calendula officinalis* L.). J. Ornamen. Plants, 3(4): 207-2014. DOI: 10.1093/jxb/ers329

Bockhaven J., De Vleesschauwer D., Hofte M. 2013: *Towards establishing broad-spectrum disease resistance in plants: Silicon leads the way*. J. Exp. Bot., 64: 1281-1293.

Cho R.H., Joung H.Y., Lim K., Kim L. 2013. *Effect of calcium and silicate application on pathogenicity of Erwinia carotovora subsp. carotovora in Zantedeschia spp*. Hort. Environ. Biotechnol., 54(4): 364-371. DOI: 10.1007/s13580-013-0059-1

Epstein E. 1999. *Silicon*. Annu. Rev. Plant. Physiol. Plant. Mol. Biol., 50: 641-664.

Górecki R.S., Danielski-Busch W. 2009. *Effect of silicate fertilizers on yielding of greenhouse cucumber (Cucumis sativus* L.*) in container cultivation*. J. Elem., 14(1): 71-78.

Hogendorp B.K., Cloyd R.A., Swiader J.M. 2012. *Determination of silicon concentration in some horticultural plants*. Hort. Sci., 47(11): 1593-1595.

Jarosz Z. 2013. *The effect of silicon application and type of substrate on yield and chemical composition of leaves and fruit of cucumber*. J. Elem., 3: 403-414. DOI: 10.5601/jelem.2013.18.3.05

Kamenidou S., Cavins T.J., Marek S. 2008. *Silicon supplements affect horticultural traits of greenhouse- produced ornamental sunflowers*. Sci. Hort., 43(1): 236-239.

Kamenidou S., Cavins T.J., Marek S. 2009. *Evoluation of silicon as a nutrional supplement for greenhouse zinnia production*. Sci. Hort., 119: 297-301.

Kamenidou S., Cavins T.J., Marek S. 2010. *Silicon supplements affects floricultural quality traits and elemental nutrient concentration of greenhouse produced gerbera*. Sci. Hort., 123: 390-394.

Korndörfer A.P., Grisoto E., Vendramin D. 2010. *Introduction of insects plant resistance to the spittlebug (Hemiptera: Cercopidae) in sugarcane by silicon application*. Neotrop. Entomol., 40(3): 387-392.

Laing M.D., Gataryiha M.C., Adandonon A. 2006. *Silicon use for pest control in agriculture*. Proc. S. Afr. Sug. Technol. Ass., 80: 280-286.

Lim M.Y., Lee E.J., Jana S., Sivanesan I., Jeong B.R. 2012. *Effect of potassium silicate on growth ad leaf epidermal characteristics of begonia and pansy grown in vitro*. Kor. J. Hort. Sci. Technol., 30: 579-585.

Ma F.J., Yamaji N. 2006. *Silicon uptake and accumulation in higher plants*. Trends Plant Sci., 11(8): 392-397.

Mattson N.S., Leatherwood W.R. 2010. *Potassium silicate drenches increase leaf silicon content and affect morphological traits of several floriculture crops grown in a peat-based substrate*. Hort. Sci., 45(1): 43-47.

Mikiciuk G., Mikiciuk M. 2008. *Physiological reaction of strawberry (Fragaria ananassa* Duch.*) cultivar Senga Sengana on foliar fertilization potassium-silicate*. Ann. UMCS, Agric., 63(2): 81-85. (in Polish)

Moyer C., Peres N.A., Datnoff L.E., Simonne E.H., Deng Z. 2008. *Evaluation of silicon for managing powdery mildew on Gerbera daisy*. J. Plant Nutr., 31: 2131-2144.

Reezi S., Babalar M., Kalantari S. 2009. *Silicon alleviates salt stress, decreases malondialdehyde content and affects petal color of saltstressed cut rose* (*Rosa* x *hybrida* L.) *'Hot Lady'*. Afr. J. Biotechnol., 8(8): 1502-1508.

Sacała E. 2009. *Role of silicon in plant resistance to water stress*. J. Elem., 14(3): 619-630.

Savvas D., Gizas G., Karras G., Lydakis-Simantiris N., Salahas G., Papadimitriou M., Tsouka. 2007. *Interactions between silicon and NaCl-salinity in a soiless culture of roses in greenhouse*. Europ. J. Hort. Sci., 72(2): 73-79.

Shetty R., Jensen B., Shetty N.P., Hansen M., Hansen C.W., Starkey K.R., Jørgensen H.J.L. 2012. *Silicon induced resistance against powdery mildew of roses caused by Podosphaera pannosa*. Plant Pathol., 61: 120-131.

Sivanesan I., Jeong B.R. 2014. *Silicon promotes adventitious shoot regeneration and enhances salinity tolerance of Ajuga multiflora* Bunge *by altering activity of antioxidant enzyme*. Sci. World. J. DOI: 10.1155/2014/521703

Sivanesan I., Son S.M., Song Y.J., Jeong R.B. 2013. *Silicon supply through the subirrigation system affects growth of three chrysanthemum cultivars*. Hort. Environ. Biotechnol., 54(1): 14-19. DOI 10.1007/s13580-013-0120-0

Soundararajan P., Sivanesan I., Jo E.H., Jeong B.R. 2013. *Silicon promotes shoot proliferation and shoot growth of Salvia splendens under salt stress invitro*. Hort. Environ. Biotechnol., 54: 311-318. DOI 10.1007/s13580-014-0023-8

Tesfagiorgis H.B., Laing M.D. 2013. *The effects of silicon level in nutrient solution on the uptake and distribution of silicon in zucchini and zinnia, and its interaction with the uptake of selected elements*. Afr. J. Biotechnol., 12(14): 1617-1623. DOI: 10.5897/AJB2012.3038

Zhao D., Hao Z., Tao J., Han Ch. 2012. *Silicon application enhances the mechanical strength of inflorescence stem in herbaceous peony* (*Paeonia lactiflora* Pall.). Sci. Hort., 151: 165-172.