

RESPONSE OF *Ornithogalum saundersiae* BAK. TO SALINITY STRESS

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Abstract. Most of the studies on the effects of salinity stress are conducted on ornamental bedding plants and perennials but little is known on flower bulbs response to this stress factor. *Ornithogalum saundersiae* is an attractive bulbous plant recommended for growing in pots, gardens and green areas. The study conducted in the years 2013–2014 investigated the effects of NaCl on the growth, flowering, photosynthetic activity, pigment content, and macro- and micronutrient content in the leaves of *O. saundersiae*. The plants were grown in pots in a plastic tunnel. NaCl was applied once a week for six weeks at concentration of 100 mM or 200 mM. The salt treatment did not cause chlorosis and did not affect flowering rate and number of inflorescences. The plants exposed to salinity stress had lower fresh weight of leaves, inflorescences and bulbs and their flowering began later than in the control plants. Photosynthesis and transpiration intensity decreased as NaCl concentration increased. The content of chlorophyll and carotenoids in NaCl treated plants was significantly higher than in the control plants. Salinity stress increased the leaf content of nitrogen, potassium, sodium and chlorine and reduced the concentration of calcium, zinc and iron.

Key words: Giant Chinchinchee, NaCl, gas exchange, mineral content, photosynthetic pigments

INTRODUCTION

The issue of salinity stress in the cultivation of ornamental plants is receiving global attention [Niu and Cabrera 2010, Cassaniti et al. 2013]. When looking for species and cultivars tolerant to salinity, an important criterion is the effect of salt on the plant ornamental value [Zollinger et al. 2007]. Excessive content of Na⁺ and Cl⁻ causes growth and flowering inhibition, leaf discoloration, and the leaf margins become brown and dry, thus lowering the quality of the ornamental plants [Bernstein et al. 1972]. Apart

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from causing visual symptoms, salinity stress disturbs photosynthesis [Wrochna et al. 2010], water management [Acosta-Motos et al. 2014], enzyme activity [Zhang et al. 2014], nutrient uptake [Valdez-Aguilar et al. 2009, Salachna et al. 2015], and finally can lead to organ and whole plant necrosis [Chaves et al. 2009]. Plant sensitivity to salinity is very diverse and it depends on plant genotype, salt concentration, developmental stage, or growth conditions, in particular moisture conditions [Cassaniti et al. 2013]. Studies on the effects of salinity on plant growth and flowering are conducted mainly in annual and bedding plants and perennials [Niu et al. 2010, Villarino and Matson 2011, Breś et al. 2014], but still little is known of geophyte response to this factor, in particular geophytes not overwintering in the ground beyond natural stands.

Only a few out of 120 species of *Ornithogalum* L. genus (Asparagaceae) have been extensively researched and introduced into cultivation as ornamental plants [Duncan 2013]. A particularly noteworthy plant is Giant Chinchinchee (*Ornithogalum saundersiae* Bak. syn. *Galtonia saundersiae*) from southeast Africa. Its ornamental feature are white flowers with a characteristic ovary similar to a black olive gathered in large inflorescences at the end of long leafless stems [De Hertogh and Le Nard 1993]. It is a valuable species, recommended for cultivation in gardens and green areas, as well as cut and pot plant [Salachna and Zawadzińska 2013, Salachna 2014, Salachna and Zawadzińska 2015]. The bulbs of *O. saundersiae* do not overwinter in the field in the Central European climate and they need to be dug out in the autumn and stored until spring at 25°C. No literature data on the cultivation of this species in the presence of salinity is available. This is why a study aimed at investigating the effects of sodium chloride on the growth, flowering and bulb yield of *O. saundersiae* was undertaken. The plants were also assessed for their gas exchange parameters, chlorophyll fluorescence and leaf content of nutrients and minerals. Our working hypothesis in this study was that salinity stress affect's growth, flowering, photosynthesis, and mineral uptake in *O. saundersiae*.

MATERIALS AND METHODS

The study involved *Ornithogalum saundersiae* Bak. bulbs with a circumference of 14–16 cm, imported from the Netherlands by a horticultural company Ogrodnictwo Wiśniewski Jacek Junior. The bulbs were treated for 30 min in a suspension of 0.7% (w/v) Topsin M 500 SC (Nippon Soda, Tokyo, Japan, active ingredient: thiophanate-methyl) and 1% (w/v) Kaptan 50 WP (Organika-Azot Chemical Company, Jaworzno, Poland, active ingredient: Captan). Single bulbs were planted on 10th May 2013 and 10th May 2014 into black, PVC, 2.5 dm³ pots 15 cm in diameter. The substrate was a mixture of peat (pH 6.5) and Yara Mila Complex fertilizer (5 g·dm⁻³) (Yara International ASA, Norway) containing 12% N, 11% P₂O₅, 18% K₂O, 2.7% MgO, 8% S, 0.015% B, 0.2% Fe, 0.02% Mn and 0.02% Zn. The pots were placed next to each other on 60 cm high tables. The plants were grown under natural photoperiod in unheated plastic tunnel belonging to the Department of Horticulture, West Pomeranian University of Technology in Szczecin (53°25'N, 14°32'E). Air temperature was controlled with vents that opened automatically when the temperature exceeded 25°C. The plants were watered twice a week using tap water in which mean ion concentration (mg·dm⁻³) was as fol-

lows: 1.53 N-NO₃, 1.5 P, 6.2 K, 97.4 Ca, 16.6 Mg, 24.0 Na, 24.0 Cl, 0.62 Cu, 0.42 Zn, 1.3 Fe, 194 HCO₃, and 0.65 mS·cm⁻¹ electrical conductivity (EC).

Each year, watering with NaCl solution (100 mM or 200 mM NaCl dissolved in distilled water) was started 30 days after planting. NaCl solution (100 mL per plant) was applied once a week for six weeks. Control plants were treated with distilled water. The dates of opening of the first flower in each inflorescence were recorded in order to estimate the beginning of flowering from the time of planting the bulbs. At the beginning of flowering, 10 plants were randomly selected from each treatment and the following parameters were evaluated: length of the longest leaf, number of leaves per plant, number of inflorescences, length of inflorescence stem, fresh weight (FW) of all leaves on plant and inflorescence stems. Visual quality inspection was performed by 3 independent researches using 1–5 score scale, where 5 points were given to the plants with the highest ornamental value. Net photosynthesis intensity (CO₂ assimilation rate) and leaf transpiration rate were measured with infrared gas analyzer (TPS-2 Portable-Photosynthesis System, USA) and chlorophyll a fluorescence was measured with HandyPEA analyzer (Hansatech Instruments Ltd., England) after dark-adapting the leaves for 30 min using a leaf clip. The measurements were conducted on well-developed leaves from the central part of the plants. Based on chlorophyll *a* fluorescence measurements the maximum quantum efficiency of photosystem II (Fv/Fm) was calculated according to Lichtenthaler and Rinderle [1988]. Then, the leaves were sampled for pigment content analysis. To determine the content of chlorophyll a and b and carotenoids, leaf discs 7 mm in diameter were collected from the centre of a leaf blade. The pigments were extracted with N-N-dimethylformamide for 24 hours. Solution absorbance was determined with SPEKOL 11 spectrophotometer (Carl Zeiss Jena, Germany). Absorbance was measured at 440 nm, 645 nm, and 663 nm. Chlorophyll content was calculated using a method described by Arnon et al. [1956] with the following formulae:

Chlorophyll a (mg·kg⁻¹ FW) : [12.7 (E663) – 2.69 (E645)] · V/W;

Chlorophyll b (mg·kg⁻¹ FW) : [22.9 (E645) – 4.68 (E663)] · V/W;

Carotenoid content was calculated according to Hager and Mayer-Berthenrath [1966]:

Carotenoids (mg·kg⁻¹ FW) : [4.16 (E440) – 0.89 (E663)] · V/W, where:

E – extinction at specific wavelength,

V – amount of used extraction solution,

W – sample weight in grams.

At the end of the cultivation period, on 6th November 2013 and 20th November 2014, the whole plants were removed from the pots and leaves and inflorescence stems were cut off the parent bulbs. The parent bulbs were cleaned by removing roots and their weight and circumference were determined. The leaves were washed with water and dried in a hot air oven at 80°C for 48 h. Dried and ground leaves were sent to an accredited laboratory at the Chemical and Agricultural Station in Szczecin for determination of macro- and micronutrient content according to standard methods [Ostrowska et al. 1991]. After plant dry matter mineralization the following assess were performed: total nitrogen by the Kjeldahl method; potassium and sodium by flame photometry AFP-100; phosphorus and boron by spectrophotometry UV-VIS Genensys 6; magnesium, calcium, copper, zinc, manganese and iron by atomic absorption spectrophotometry ASS 30; chlorine by the Mohr method.

Each year a total of 120 bulbs were planted, 40 plants per each treatment. The results, presented as a mean from two years of the study, were statistically analyzed by means of one-way analysis of variance in fully randomized design. The calculations were performed using Statistica 10 software (Statsoft, Poland).

RESULTS AND DISCUSSION

There is an ongoing search for salinity and drought resistant ornamental plants that can be grown in urbanized areas. Our study focused on *Ornithogalum saundersiae* that produces very decorative and long lasting inflorescences [Salachna and Zawadzińska 2015]. Rosette forming leaves of the plant are decorative over the entire vegetative period and they do not dry out as the species experiences no visible dormancy period [Kariuki and Kako 1999]. In this study *O. saundersiae* was exposed to salinity stress triggered by watering the plants with NaCl solution at a concentration of 100 mM or 200 mM. No chlorosis, leaf drying or other damage impairing plant quality were observed during their growth and flowering. Bonitation score (1–5) of salt-treated plants was significantly lower than of the control plants but this difference was small (Table 1). No chlorosis under salinity stress was also reported in narcissi treated with 50–300 mM NaCl [Veatch-Blohm et al. 2014] and colored calla lily [Veatch-Blohm et al. 2012].

Table 1. Effect of salinity on growth, flowering and bulb yield of *Ornithogalum saundersiae*

Features	Treatment		
	control	100 mM NaCl	200 mM NaCl
Number of leaves per plant	7.33 ±0.02 ^b	8.00 ±0.00 ^a	8.33 ±0.37 ^a
Leaf length (cm)	57.3 ±1.52 ^b	62.3 ±1.15 ^a	58.3 ±1.53 ^b
Weight of leaves per plant (g)	245 ±16.9 ^a	196 ±6.92 ^b	143 ±15.1 ^c
Days to flowering	104 ±4.81 ^c	118 ±5.00 ^b	134 ±7.19 ^a
Flowering (%)	100 ±0.00 ^a	100 ±0.00 ^a	100 ±0.00 ^a
Number of inflorescences	1.00 ±0.00 ^a	1.00 ±0.00 ^a	1.00 ±0.00 ^a
Inflorescence length (cm)	137 ±8.50 ^a	134 ±11.1 ^a	86.0 ±2.90 ^b
Inflorescence weight (g)	153 ±16.5 ^a	118 ±22.3 ^b	40.9 ±13.8 ^c
Visual score (1-5)	5.00 ±0.00 ^a	4.50 ±0.25 ^b	4.25 ±0.29 ^b
Bulb circumference (cm)	20.7 ±0.76 ^a	18.6 ±0.90 ^a	17.0 ±0.50 ^b
Bulb weight (g)	158 ±14.4 ^a	124 ±11.1 ^b	92.0 ±7.60 ^c

All data are means ±SE (n = 10–40). Values in the same row followed by the same lower-case letter do not differ significantly at $P \leq 0.05$ by Duncan's multiple range test

The plants treated with 100 mM and 200 mM NaCl had more leaves than the control ones (tab. 1). Moreover, the plants watered with 100 mM NaCl had longer leaves than the control plants and those treated with NaCl at the concentration of 200 mM, by respectively 5.0 cm and 4.0 cm. Moderate salinity was reported to stimulate plant growth in lisianthus [Shillo et al. 2002] and sunflower [Grieve and Poss 2010], but high NaCl concentration was found to negatively affect morphological features [Koksal et al. 2014].

O. saundersiae plants grown under salinity stress were characterized by significantly reduced fresh weight of flowers and inflorescences, and this effect was more pro-

nounced at higher NaCl concentration (tab. 1). At 100 mM NaCl fresh weight of the leaves and inflorescences was by 20 and 23% lower than in control, and at 200 mM NaCl it was reduced by 42 and 73%, respectively. Adverse effect of salinity on leaf weight in geophytes was also reported by Shillo et al. [2002] who watered *Hippeastrum hybridum* and *Ornithogalum arabicum* with salt water with EC ranging from 1.8 to 11.5 dSm⁻¹.

In our study all *O. saundersiae* plants flowered, both control and treated with NaCl (tab. 1). Shillo et al. [2002] claimed that *H. hybridum* and *O. arabicum* plants watered with salt water did not flower but it might have been due to planting too small bulbs in which flower buds had not been formed. In this study, *O. saundersiae* bulbs with a circumference of 14–16 cm were used to secure production of inflorescences.

Salinity did not significantly affect the number of *O. saundersiae* inflorescences derived from a single bulb (tab. 1). Similar results were described by Veatch-Blohm et al. [2013], who showed no effect of salinity on the number of flowers in three early narcissus cultivars. The course of *O. saundersiae* flowering depended on NaCl concentration (tab. 1). The plants treated with 100 mM or 200 mM of NaCl started to bloom 14 and 30 days later than the control plants. Delayed flowering under salinity stress was also reported in such geophytes as *Iris hexagona* [Van Zandt and Mopper 2002] and *Crocus sativus* L. [Torbaghan et al. 2011] and in narcissus cultivars ‘Dutch Master’ and ‘Ice Follies’ [Veatch-Blohm et al. 2014]. Contrary to that, the presence of salt did not change the time of *Zantedeschia aethiopica* flowering [Veatch-Blohm and Morningstar 2011].

O. saundersiae plants treated with higher NaCl concentration produced shorter inflorescence stems – by 48 cm shorter than those treated with 100 mM NaCl and by 51 cm shorter than the control plants (tab. 1). Strong growth of *O. saundersiae* is not desired in pot cultivation, and therefore using growth retardants is recommended [Salachna and Zawadzińska 2013]. Ornamental plants grown under salinity stress are usually smaller and more compact, which may in fact improve their decorative value and thus salt may be an alternative for growth retardants that negatively affect the environment [Carter and Grieve 2006].

In none experimental treatment the parent bulbs of *O. saundersiae* produced daughter bulbs. Salt stress negatively affected fresh weight of the parent bulbs at the end of the cultivation period (tab. 1). Fresh weight of the parent bulbs in the plants treated with 100 mM and 200 mM NaCl was by 22 and 42% lower than in control. Moreover, circumference of the parent bulbs in the plants watered with 200 mM NaCl was significantly smaller than in the control plants and those watered with 100 mM NaCl (tab. 1). Our results seem to corroborate the observations of Shillo et al. [2002], who noticed a reduction in fresh weight of *H. hybridum* and *O. arabicum* bulbs watered during their growth period with salt water. Lowered fresh weight of new corms was also reported in greenhouse-grown gladiolus exposed to salt at a concentration of 150 mM [Haouala and Sahli 2011].

Figures 1 and 2 present the effects of NaCl on photosynthesis intensity and leaf transpiration rate in *O. saundersiae*. The values of both parameters significantly decreased with increasing concentration of NaCl. In the plants treated with 100 mM NaCl net photosynthesis intensity and transpiration rate were by 37 and 28% lower and in the plants treated with 200 mM NaCl by 66 and 72% lower than in the control. Significant reduction in carbon assimilation rate under salt stress was also reported in narcissi [Veatch-Blohm et al. 2013]. In calla lily treated with 25 mM or 50 mM NaCl, carbon assimilation rate was in the beginning the same as in control plants but decreased significantly along the cultivation time [Veatch-Blohm et al. 2012].

In our study, the response of *O. saundersiae* PS II to salinity was assessed based on F_v/F_m ratio, i.e. maximum photochemical efficiency of photosystem II. F_v/F_m ratio ranged from 0.81 to 0.84 and did not significantly depend on salinity level. Similar findings were published by Bănón et al. [2011] who investigated the effects of different salt concentrations in the irrigation water on gas exchange and chlorophyll fluorescence in *Polygala myrtifolia*. These authors revealed no influence of salinity on maximum photochemical efficiency of photosystem II, quantum yield of photosystem II and non-photochemical quenching, and showed significantly decreased net photosynthesis with increasing water salinity.

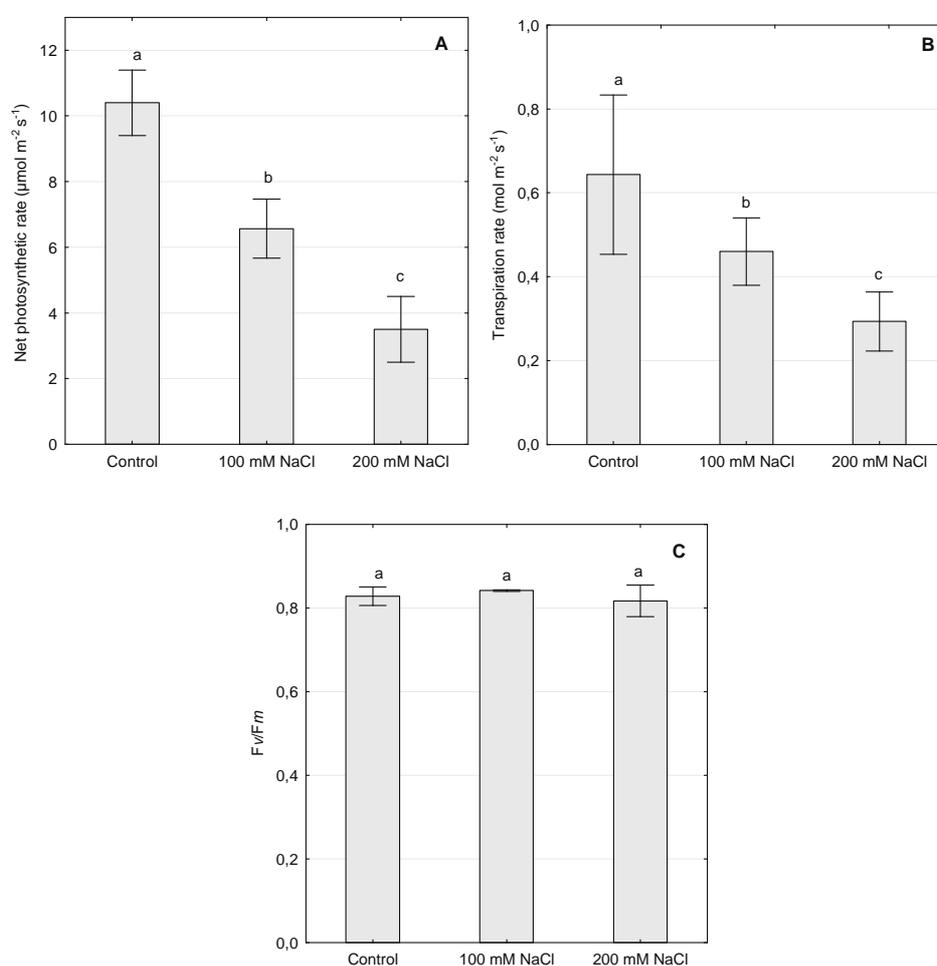


Fig. 1. Effects of salinity on net photosynthetic rate (A), transpiration rate (B) and F_v/F_m – maximum photochemical efficiency of photosystem II (C) of *Ornithogalum saundersiae*. Data are means ($n = 10$) \pm SE (vertical bars). The columns with the same lower-case letters were not significantly different by Duncan's multiple range test at $P \leq 0.05$

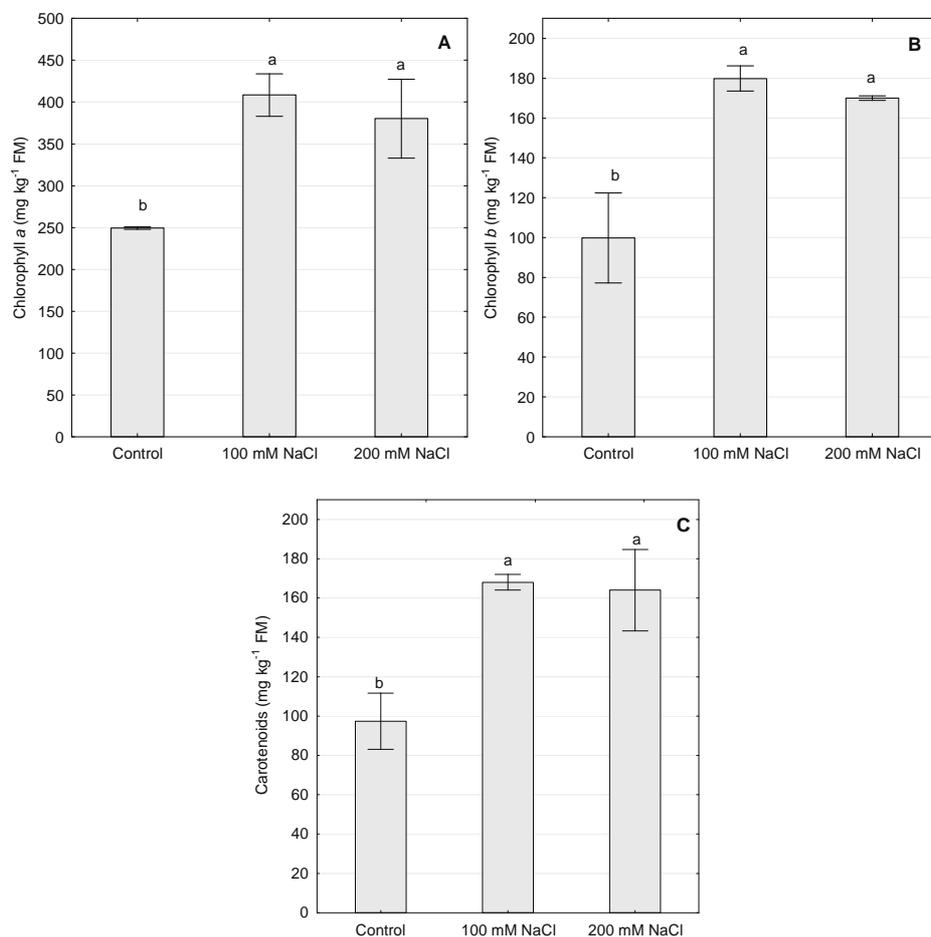


Fig. 2. Effects of salinity on chlorophyll a (A), chlorophyll b (B) and carotenoids (C) concentrations in leaves of *Ornithogalum saundersiae*. Data are means ($n = 6$) \pm SE (vertical bars). The columns with the same lower-case letters were not significantly different by Duncan's multiple range test at $P \leq 0.05$.

O. saundersiae cultivated under salt stress was characterized by altered content of chlorophyll a, chlorophyll b and carotenoids. At 100 mM NaCl chlorophyll a and b content in the leaves was respectively 380.4 and 179.9 mg·kg⁻¹ FW and was significantly higher than in the control plants (249.5 and 99.8 mg·kg⁻¹ FW, respectively). At 200 mM NaCl chlorophyll a and b content in the leaves was respectively 408.4 and 170.0 mg·kg⁻¹ FM and was also higher than that in the control plants. Carotenoids content in the leaves of the plants treated with 100 or 200 mM NaCl was 168.0 and 164.0 mg·kg⁻¹ FW, respectively, and was significantly higher than in non-treated plants (97.4 mg·kg⁻¹ FW). Salt concentration did not significantly affect photosynthetic pigment content. The research literature contains inconsistent data on the effect of salinity

on pigment content in the leaves. In broad bean treated with moderate concentrations of NaCl (40 and 80 mM), chlorophyll a and carotenoid content in the leaves increased significantly, and higher salt concentration caused a reduction in photosynthetic pigment level [Hamada and El-Enany 1994]. In wheat grains (*Triticum aestivum* L.) salinity caused a significant increase in the chlorophyll a and b contents during the flag leaf growth [Aidesuquy 1992]. According to this author the stimulative effect of salinity on the pigment content of the wheat flag leaf might be due to the fact that salinity lead to an increase in a number of chloroplasts per a mesophyll cell. However, both epidermal and mesophyll thickness and intercellular spaces decrease in *Bru-guiera parviflora* under salinity stress [Parida et al. 2004]. Veatch-Blohm and Morrningstar [2011] claimed that in calla lily the salinity level (up to 6 dS·m⁻¹) did not affect chlorophyll and carotenoid contents. In salt-treated hyacinth the leaf content of chlorophyll a, chlorophyll b and carotenoids decreased along with rising NaCl concentration (25–600 mM) [Türkoglu et al. 2011].

Table 2. Effect of salinity on nutrients concentrations in the leaves of *Ornithogalum saundersiae*

Nutrients	Treatment		
	control	100 mM NaCl	200 mM NaCl
N (g·kg DW*)	21.2 ±1.00 ^b	23.1 ±0.93 ^{ab}	26.6 ±2.53 ^a
P (g·kg DW)	3.41 ±0.20 ^a	3.10 ±0.33 ^a	3.80 ±0.20 ^a
K (g·kg DW)	30.7 ±0.75 ^c	37.4 ±0.85 ^b	44.0 ±0.70 ^a
Ca (g·kg DW)	14.6 ±0.60 ^a	9.80 ±0.43 ^b	11.5 ±0.43 ^b
Mg (g·kg DW)	2.90 ±0.30 ^a	3.00 ±0.25 ^a	2.90 ±0.20 ^a
Na (g·kg DW)	2.50 ±0.35 ^c	5.50 ±0.70 ^b	7.90 ±0.95 ^a
Cl (g·kg DW)	7.50 ±1.93 ^c	25.2 ±9.55 ^b	41.9 ±10.4 ^a
B (mg·kg DW)	21.4 ±0.95 ^a	19.5 ±1.20 ^a	21.3 ±2.25 ^a
Cu (mg·kg DW)	1.70 ±0.13 ^a	1.79 ±0.15 ^a	1.98 ±0.09 ^a
Zn (mg·kg DW)	31.4 ±3.36 ^a	23.1 ±2.47 ^b	24.2 ±1.21 ^b
Mn (mg·kg DW)	15.6 ±1.25 ^a	13.9 ±2.10 ^a	15.2 ±1.97 ^a
Fe (mg·kg DW)	58.8 ±3.22 ^a	43.6 ±5.25 ^b	42.4 ±6.71 ^b

* – DW – dry weight. All data are means ±SE (n = 6). Values in the same row followed by the same lower-case letter do not differ significantly at $P \leq 0.05$ by Duncan's multiple range test

Chemical analyses indicated a stimulating effect of NaCl addition on the content of nitrogen, potassium, sodium and chlorine in the leaves of *O. saundersiae*, and this effect was more pronounced in the plants treated with 200 mM NaCl (tab. 2). Increased content of these ions may indicate their role in the process of adaptation to salt stress conditions. Increased content of sodium and chlorine in the plants exposed to salt stress most likely resulted from using NaCl solution. The most frequently observed consequences of salinity stress on plants is a reduction content of nutrient ions, particularly potassium [Helal and Mengel 1979]. On the contrary, K⁺ content has been increased in ornamental plants such as *Chrysanthemum × morifolium* 'Yellow Blush' [Lee and van Iersel 2008], *Amaranthus paniculatus* 'Cooper Mountain', *Amaranthus caudatus* 'Pony Tails', *Atriplex hortensis* 'Green Spire' [Wrochna et al. 2006]. Brugnoli and Björkman [1992] suggest that K⁺ maintenance may be a common mechanism of protection against salt damage in glycophytes. The high K⁺ content in leaves may act as the key monovalent cationic osmoticum in the presence of external salt and might be a regulatory mecha-

nism to maintain osmotic balance under increasing salinity condition [Grieve and Walker 1983]. Our study also showed that, in comparison to control, the NaCl treated plants had lower content of calcium, zinc and iron and similar content of phosphorus, magnesium, boron, copper and manganese (tab. 2). It has been reported that excessive concentration of ions, especially Na^+ and Cl^- may limit the uptake of other ions [Marschner 1995]. Differences in the uptake and accumulation of nutrients observed in this study were also reported in other geophytes grown under salt stress conditions. In *Ranunculus asiaticus* 'Yellow ASD' NaCl treatment resulted in increased content of chlorine and sodium and lowered content of potassium, phosphorus, calcium, sulfur and zinc in the shoots [Valdez-Aguilar et al. 2009]. An analysis of minerals in the leaves of calla lily treated with 25 and 50 mM NaCl revealed increased concentration of magnesium, calcium and sodium [Veatch-Blohm et al. 2012] and unchanged level of potassium. In narcissi, the level of potassium was also independent of salinity. Hyacinths treated with NaCl at the concentrations ranging from 0 to 600 mM were characterized by higher content of sodium and calcium but the level of potassium remained unaffected [Koksal et al. 2014]. Türkoglu et al. [2011] investigated the growth of hyacinth exposed to salt stress (0–400 mM NaCl) and found salinity-triggered reduction in the content of potassium, magnesium and zinc and higher concentration of iron and manganese in the substrate. Better understanding of salinity effects on the accumulation of minerals in *O. saundersiae* could be achieved by further analyses comparing the content of macro- and micronutrients in the leaves, inflorescence stems and bulbs, as ion concentration is different in different plant organs.

CONCLUSIONS

1. *O. saundersiae* plants, grown under salt stress triggered by watering with solutions containing 100 or 200 mM NaCl, retained their ornamental value, produced inflorescences and bloomed, and their leaves were not chlorotic.

2. Increasing concentration of NaCl was accompanied by a reduction in leaf, inflorescence and bulb weight, delayed flowering and lowered photosynthesis and transpiration intensity.

3. The leaves of NaCl treated plants had higher content of chlorophylls and carotenoids and nitrogen, potassium, sodium and chlorine, and lower content of calcium, zinc and iron.

REFERENCES

- Acosta-Motos, J.R., Alvarez, S., Barba-Espin, G., Hernandez, J.A., Sanchez-Blanco, M.J. (2014). Salts and nutrients present in regenerated waters induce changes in water relations, antioxidative metabolism, ion accumulation and restricted ion uptake in *Myrtus communis* L. plants. *Plant Physiol. Biochem.*, 85, 41–50.
- Aidesuquy, H.S. (1992). Growth and pigment content of wheat as influenced by the combined effects of salinity and growth regulators. *Biol. Plant.*, 34(3–4), 275–283.
- Amon, D.J., Allen, M.B., Whatley, F. (1956). Photosynthesis by isolated chloroplast. *Bioch. Biophys. Acta*, 20, 449–461.

- Bánón, S., Miralles, J., Ochoa, J., Franco, J.A., Sánchez-Blanco, M.J. (2011). Effects of diluted and undiluted treated wastewater on the growth, physiological aspects and visual quality of potted lantana and polygala plants. *Sci. Hortic.*, 129, 869–876.
- Bernstein, L., Francois, L.E., Clark, R.A. (1972). Salt tolerance of ornamental shrubs and ground covers. *J. Amer. Soc. Hort. Sci.*, 97, 550–556.
- Breś, W., Kupska, A., Trelka, T. (2014). Response of scarlet sage and common sunflower plants to salinity caused by sodium salts. *Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech.*, 315(32), 5–14.
- Brugnoli, E., Björkman, O. (1992). Growth of cotton under continuous salinity stress: influence on allocation pattern, stomatal and non-stomatal components of photosynthesis and dissipation of excess light energy. *Planta*, 187(3), 335–47.
- Carter, C.T., Grieve, C.M. (2006). Salt tolerance of floriculture crops. In: *Ecophysiology of high salinity tolerant plants*, Khan, M.A., Weber, D.J. (ed.). Springer, Netherlands, 279–287.
- Cassaniti, C., Romano, D., Hop, M.E.C.M., Flowers, T.J. (2013). Growing floricultural crops with brackish water. *Environ. Exp. Bot.*, 92, 165–175.
- Chaves, M.M., Flexas, J., Pinheiro, C. (2009). Photosynthesis under drought and salt stress: regulation mechanisms from whole plant to cell. *Ann. Bot.*, 103, 551–56.
- De Hertogh, A.A., Le Nard, M. (1993). *Ornithogalum*. In: *The physiology of flower bulbs*. Elsevier, Amsterdam, 761–764.
- Duncan, G.D. (2013). Geophyte research and production in South Africa. In: *Ornamental geophytes: From basic science to sustainable production*, Kamenetsky, R., Okubo, H. (eds). Taylor and Francis Group LLC, Boca Raton, p. 487.
- Grieve, A.M., Walker, R.R. (1983). Uptake and distribution of chloride, sodium and potassium ions in salt-treated citrus plants. *Aust. J. Agric. Res.*, 34, 133–143.
- Grieve, C.M., Poss, J.A. (2010). Response of ornamental sunflower cultivars ‘Sunbeam’ and ‘Moonbright’ to irrigation with saline wastewaters. *J. Plant Nutr.*, 33, 1579–1592.
- Hager, A., Mayer-Berthenrath, T. (1966). Die Isolierung und quantitative Bestimmung der Carotenoide und Chlorophyll von Blättern, Algen und isolierten Chloroplasten mit Hilfe dunn-schichtchromatographischer Methoden. *Planta*, 69, 198–217.
- Hamada, A. M., El-Enany, A.E. (1994). Effect of NaCl salinity on growth, pigment and mineral element contents, and gas exchange of broad bean and pea plants. *Biol. Plant.*, 36(1), 75–81.
- Haouala, F., Sahli, I. (2011). NaCl effects on growth, flowering and bulbing of gladiolus (*Gladiolus grandiflorus* Hort.). *Rev. Suisse Vitic. Arboric. Hortic.*, 43(6), 378–383.
- Helal, H.M., Mengel, K. (1979). Nitrogen metabolism of young barley plants as affected by NaCl-salinity and potassium. *Plant Soil*, 51, 457–462.
- Kariuki, W., Kako, S. (1999). Growth and flowering of *Ornithogalum saundersiae* Bak. *Sci. Hortic.*, 81(1), 57–70.
- Koksal, N., Kulahlioglu, I., Ertargin, E., Torun, A.A. (2014). Relationship between salinity stress and ion uptake of hyacinth (*Hyacinthus orientalis*). *Turk. J. Agr. Nat. Sci.*, 1, 578–583.
- Lee M.K., van Iersel, M.W. (2008). Sodium chloride effects on growth, morphology, and physiology of chrysanthemum (*Chrysanthemum × morifolium*). *HortScience*, 43(6), 1888–1891.
- Lichtenthaler, H.K., Rinderle, U. (1988). The role of chlorophyll fluorescence in the detection of stress conditions in plants. *Critic. Rev. Anal. Chem.*, 19(1), 29–85.
- Marschner, H. (1995). *Mineral nutrition of higher plants* (2nd ed.). Academic Press, New York.
- Niu, G., Cabrera R.I. (2010). Growth and physiological responses of landscape plants to saline water irrigation: A review. *HortScience*, 45(11), 1605–1609.
- Ostrowska, A., Gawliński, S., Szczubiałka, Z. (1991). *Procedures for soil and plants analysis*. Inst. Environ. Prot. Warsaw [in Polish]

- Parida, A.K., Das, A.B., Mitra, B. (2004). Effects of salt on growth, ion accumulation photosynthesis and leaf anatomy of the mangrove, *Bruguiera parviflora*. *Trees-Struct. Funct.*, 18, 167–174.
- Salachna, P. (2014). Effect of size of on the inflorescences and bulb yield of *Ornithogalum saundersiae* Bak. grown in an unheated plastic tunnel. *Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech.*, 312(31), 153–158.
- Salachna, P., Piechocki, R., Zawadzińska, A., Woškowiak, A. (2015). Response of speckled spurflower to salinity stress and salicylic acid treatment. *J. Ecol. Eng.*, 16(5), 68–75.
- Salachna, P., Zawadzińska, A. (2013). The effects of flurprimidol concentrations and application methods on *Ornithogalum saundersiae* Bak. grown as a pot plant. *Afr. J. Agric. Res.*, 8(49), 6625–6628.
- Salachna, P., Zawadzińska, A. (2015). Comparison of growth, flowering and bulbs yield of four *Ornithogalum* L. species grown in the ground. *Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech.* 318(34), 57–64.
- Shillo, R., Ding, M., Pasternak, D., Zaccai, M. (2002). Cultivation of cut flower and bulb species with saline water. *Sci. Hortic.*, 92(1), 41–54.
- Torbaghan, M.E., Torbaghan, M.E. Ahmadi, M.M. (2011). The effect of salt stress on flower yield and growth parameters of saffron (*Crocus sativus* L.) in greenhouse condition. *Int. Res. J. Agric. Sci. Soil Sci.*, 1(10), 421–427.
- Türkoglu, N., Erez, M.E., Battal, P. (2011). Determination of physiological responses on hyacinth (*Hyacinthus orientalis*) plant exposed to different salt concentrations. *Afr. J. Biotechnol.*, 10(32), 6045–6051.
- Valdez-Aguilar, L.A., Grieve, C.M., Poss, J., Mellano, M.A. (2009). Hypersensitivity of *Ranunculus asiaticus* to salinity and alkaline pH in irrigation water in sand cultures *HortScience*, 44(1), 138–144.
- Van Zandt, P.A., Mopper, S. (2002). Delayed and carryover effects of salinity on flowering in *Iris hexagona* (Iridaceae) *Am. J. Bot.*, 89(11), 1847–1851.
- Veatch-Blohm, M.E., Chen, D., Hassett, M. (2013). Narcissus cultivar differences in response to saline irrigation when application began either pre- or postemergence. *HortScience*, 48(3), 322–329.
- Veatch-Blohm, M.E., Malinowski, M., Keefer, D. (2012). Leaf water status, osmotic adjustment and carbon assimilation in colored calla lilies in response to saline irrigation. *Sci. Hortic.*, 144, 65–73.
- Veatch-Blohm, M.E., Morningstar, L. (2011). Calla lily growth and development under saline irrigation. *HortScience*, 46(2), 222–227.
- Veatch-Blohm, M.E., Sawch, D., Elia, N., Pinciotti, D. (2014). Salinity tolerance of three commonly planted *Narcissus* cultivars. *HortScience*, 49(9), 1158–1164.
- Villarino, G.H., Mattson, N.S. (2011). Assessing tolerance to sodium chloride salinity in fourteen floriculture species. *HortTechnology*, 21(5), 539–545.
- Wrochna, M., Gawrońska, H., Gawroński, S.W. (2006). Effect of salt stress on fresh and dry matter production and accumulation of Na⁺, K⁺, Ca²⁺, Mg²⁺, Cl⁻ ions in selected species of ornamental plants. *Acta Agrophys.* 7(3), 775–785. [in Polish]
- Wrochna, M., Małeczka-Przybysz, M., Gawrońska, H. (2010). Effect of road de-icing salts with anti corrosion agents on selected plant species. *Acta Sci. Pol. Hortorum Cultus*, 9(4), 171–182.
- Zhang, L., Ma, H., Chen, T., Pen, J., Yu, S., Zhao, X. (2014). Morphological and physiological responses of cotton (*Gossypium hirsutum* L.) plants to salinity. *PLoS ONE* 9(11): e112807. doi: 10.1371/journal.pone.0112807.
- Zollinger, N., Koenig, R., Cerny-Koenig, T., Kjelgren, R. (2007). Relative salinity tolerance of intermountain western United States native herbaceous perennials. *HortScience*, 42, 529–534.

REAKCJA *Ornithogalum saundersiae* BAK. NA STRES SOLNY

Streszczenie. Większość badań nad wpływem warunków stresowych wynikających z zasolenia prowadzi się na ozdobnych roślinach rabatowych i bylinach, natomiast wciąż niewiele jest informacji dotyczących reakcji geofitów na ten czynnik. *Ornithogalum saundersiae* to atrakcyjna roślina cebulowa polecana do uprawy w pojemnikach, w ogrodach i na terenach zieleni. Przeprowadzone w latach 2013–2014 badania dotyczyły oceny wpływu NaCl na wzrost, kwitnienie, funkcjonowanie aparatu fotosyntetycznego, zawartość barwników oraz makro- i mikroskładników w liściach *O. saundersiae*. Rośliny uprawiano w doniczkach w tunelu foliowym. Zasolenie prowadzono raz w tygodniu, przez okres 6 tygodni, stosując roztwór NaCl w stężeniu 100 i 200 mM. Stwierdzono, że traktowanie roślin NaCl nie spowodowało chloroz, nie miało wpływu na procent kwitnących roślin oraz na liczbę kwiatostanów. Pod wpływem stresu solnego rośliny miały zmniejszoną świeżą masę liści, kwiatostanów i cebul oraz rozpoczynały później kwitnienie. Intensywność fotosyntezy i natężenie transpiracji zmniejszyło się wraz ze wzrostem stężenia NaCl. Zawartość chlorofilu i karotenoidów w liściach roślin traktowanych NaCl była istotnie wyższa w porównaniu z roślinami kontrolnymi. W wyniku zasolenia wzrosła zawartość w liściach azotu, potasu, sodu i chloru, natomiast spadła zawartość wapnia, cynku i żelaza.

Słowa kluczowe: śniedek Saundersa, barwniki fotosyntetyczne, NaCl, składniki mineralne, wymiana gazowa

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