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RESPONSE OF SCARLET SAGE AND COMMON SUNFLOWER PLANTS TO SALINITY CAUSED BY SODIUM SALTS

REAKCJA SZAŁWII BŁYSZCZĄCEJ I SŁONECZNIKA ZWYCZAJNEGO NA ZASOLENIE SOLAMI SODU

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Streszczenie. Zbadano reakcje wybranych roślin ozdobnych na podwyższoną zawartość sodu w podłożu. Do badań wykorzystano dwa gatunki roślin ozdobnych – szałwię błyszczącą (*Salvia splendens* Buc'hoz x Etl.) 'Scarlet Piccolo' oraz słonecznika zwyczajnego *Helianthus annuus* L. 'Teddy Bear'. Rośliny uprawiano w zwapnowanym torfie wysokim wzbogaconym makro- i mikroskładnikami. Zróżnicowanie zawartości sodu uzyskano, stosując dwie sole sodu ($NaCl$ i Na_2SO_4) w dawkach odpowiadających po przeliczeniu 0–500 mg $Na \cdot dm^{-3}$. Zmiany właściwości chemicznych podłoża spowodowały zaburzenia gospodarki mineralnej roślin. Niezależnie od zastosowanej soli sodu wzrastająca zawartość Na miała negatywny wpływ na badane cechy morfologiczne roślin *Salvia speldens*. Badania wykazały, że słonecznik był bardziej tolerancyjny – negatywny wpływ zastosowanych soli sodu w przypadku tego gatunku nie zawsze był statystycznie udowodniony. Wyraźne obniżenie zawartości chlorofilu zaobserwowano jedynie w liściach szałwii. Bardziej niekorzystny wpływ na wartość ozdobną szałwii (wysokość i średnicę roślin mierzoną w połowie pędu głównego) i słonecznika (średnicę kwiatostanu) miał chlorek sodu.

Key words: *Helianthus annuus*, ornamental plants, salt stress, *Salvia splendens.*
Słowa kluczowe: *Helianthus annuus*, rośliny ozdobne, *Salvia splendens,* stres solny.

INTRODUCTION

Due to their specific climatic and soil conditions urban areas are particularly disadvantageous for proper growth and development of vegetation. Soil salinity is one of the factors affecting health condition of plants. Elevated and sometimes even high salt content is caused first of all by the use of sodium chloride in de-icing of roads and sidewalks. In most plants growing in the environment with excessive salt contents as a result of disturbances in the course of physiological and biochemical processes adverse morphological, physiological and anatomical changes occur, affecting plant growth and development (Shannon 1997; Xiong and Zhu 2002). All information on plant response to salinity may prove useful in the selection of species and varieties in terms of their suitability in landscape architecture. Generally, annual ornamental and vegetable plants are more sensitive to salt level than perennial plants (Maas 1984; Sonneveld and van der Burg 1991; Sonneveld et al. 1999). However, threshold salinity levels vary greatly between species.

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The aim of this study was to investigate response of selected ornamental plant species to elevated sodium contents in the substrate, applied as sodium chloride and sodium sulphate.

MATERIAL AND METHODS

The experiment was conducted from March to July 2010 at a greenhouse of the Marcelin Experimental Station in Poznań. Two ornamental plant species were used in the experiment: sage (*Salvia splendens* Buc'hoz x Etl.) 'Scarlet Piccolo' and sunflower (*Helianthus annuus* L.) 'Teddy Bear'. Sage "Scarlet Piccolo" is a dwarf variety of *Salvia splendens*, which grows to a height of only 30 cm with an equal spread. Its leaves are oval, serrulate, pubescent, light to dark green, dense and up to 75 mm long. Flowers are held in terminal spikes of brilliant scarlet and appear even on very young plants. Sunflower Teddy Bear is a popular variety of sunflower, which belongs to the Helianthus genus (*Helianthus annuus*). It produces very dwarf, 15cm ultra-double golden-yellow blooms. Teddy Bear is known for growing to a height less than 0.9 m. This variety tends to bloom in mid-summer.

Seeds of both species were sown singly to pots of 7 cm in diameter – sunflower on 22 March and sage on 8 March. Pots were filled with peat substrate supplemented with Azofoska fertiliser at 2 g · dm^{-3}. Limed highmoor peat at pH 6.0 was used in the cultivation experiment. After liming, based on the results of conducted chemical analysis of peat, macronutrients were added to increase levels of nitrogen, phosphorus and potassium to 100 mg N, 70 mg P and 150 mg K · dm^{-3}. Limestone used to adjust soil reaction was the source of calcium and magnesium. Moreover, micronutrient fertilisation was used applying Polichelat LS-7 at 0.2 g · dm^{-3}. Next sage and sunflower were transplanted to containers filled with 7 dm^3 substrate (30x40x15 cm). Five plants of each species were grown in each container. During the experiment, on 27 May and 10 June, based on the results of chemical analyses, sunflower was supplemented with NH_4NO_3, KH_2PO_4 and K_2SO_4 fertilisers, again increasing nutrient contents in the substrate to the assumed levels. No additional fertilisation was required for sage. Sodium content in the substrate was diversified using two sodium salts (NaCl and Na_2SO_4) at doses corresponding to 0, 100, 300 and 500 mg Na · dm^{-3} substrate. Thus the substrate was supplemented with 0, 154, 462 and 771 mg Cl · dm^{-3} or 0, 70, 209 and 348 mg S-SO_4 · dm^{-3} substrate, respectively.

The experiment was established in three replications, with 15 plants per replication. Throughout the culture period relatively uniform moisture conditions were maintained in the root zone by monitoring substrate moisture content and adequate watering. At anthesis (15 July) lower leaves were collected for chemical analyses (3 samples, with leaves from 15 plants constituting one sample) and morphological characteristics of plants were measured, at which point the experiment was concluded. In sage the following parameters were measured: plant diameter at mid-height of the main shoot, plant height from the substrate level to the tip of the inflorescence, fresh aboveground biomass per plant, the number of branches (over 2 cm in length), the number of inflorescences per plant and weight of inflorescences per plant. In the case of sunflower the following characteristics were measured: inflorescence diameter, plant height from the substrate level to the tip of the head, total aboveground biomass and stem diameter measured at mid-height. In both species the SPAD index was also recorded (30 measurement per treatment), which is correlated with chlorophyll content in leaves. Before chemical analysis samples of leaves were pre dried in an extraction drier at a temperature of 105º. In plant tissue total contents of Na, K, Ca, Mg, Cl and S were determined. (Nowosielski 1974). Results of all measurements were analysed statistically using the Duncan test at the significance level α = 0.05.

RESULTS AND DISCUSSION

Sodium content in urban soils varies greatly, which results from different intensities of sodium chloride application, levels of snowfall and rainfall, distance from the pavement and the mechanical composition of soils (Bach et al. 2006; Breś 2008; Cunningham et al. 2008; Mazur et al. 2011). Studies conducted in the city of Poznań showed that sodium content in soils in the vicinity of transportation routes typically does not exceed 300 mg Na, although contents over 600 mg Na · dm^{-3} soil were also recorded. The levels of Cl^- were markedly lower (< 200 mg Cl · dm^{-3}) (Breś 2010; Wilkaniec et al. 2012). Salinity of urban soils results in the deterioration of decorative value of plants growing in streetside green belts. As a result of inappropriate selection of plant species for such plantings cases of vegetation dying are relatively frequent. The primary cause is related with disturbed mineral metabolism and water relations of plants. Munns (2002) showed that at salinity plants have a limited capacity to absorb water, which results in growth retardation, while metabolic changes in plants are similar to the symptoms caused by water stress.

Mineral metabolism disorders in cultivated plants are confirmed by results of chemical analyses of leaves presented in Tables 1 and 2.

Table 1. Effect of dose and kind of applied salt on the content of selected elements in scarlet sage leaves
Tabela 1. Wpływ dawki oraz soli sodu na zawartość wybranych pierwiastków w liściach szałwii błyszczącej

Salt Sól	Dose of – Dawka Na · dm^{-3}				$\bar{x}$
	0	100	300	500	
		Na [% d.m. – s.m.]			
NaCl	1.66 a	2.26 c	2.75 d	3.13 e	2.45 a
Na_2SO_4	1.73 a	2.17 b	2.77 d	3.11 e	2.44 a
$\bar{x}$	1.70 a	2.22 b	2.76 c	3.12 d	
		Cl [% d.m. – s.m.]			
NaCl	0.51 b	0.83 c	2.18 d	3.05 e	2.14 b
Na_2SO_4	0.42 a	0.43 a	0.41 a	0.42 a	0.42 a
$\bar{x}$	0.97 a	1.13 b	1.29 c	1.74 d	
		S [% d.m. – s.m.]			
NaCl	0.36 a	0.33 a	0.37 a	0.34 a	0.35 a
Na_2SO_4	0.33 a	0.42 b	0.56 c	0.73 d	0.51 b
$\bar{x}$	0.34 a	0.37 b	0.47 c	0.54 d	
		K [% d.m. – s.m.]			
NaCl	3.93 g	3.13 e	2.58 d	2.21 b	2.96 a
Na_2SO_4	3.77 f	3.74 f	2.43 c	1.61 a	2.89 a
$\bar{x}$	3.85 d	3.44 c	2.50 b	1.91 a	
		Ca [% d.m. – s.m.]			
NaCl	4.63 e	3.88 d	2.63 c	2.24 b	3.35 a
Na_2SO_4	4.65 e	3.91 d	2.71 c	1.63 a	3.23 a
$\bar{x}$	4.64 d	3.89 c	2.67 b	1.94 a	
		Mg [% d.m. – s.m.]			
NaCl	0.79 e	0.72 d	0.47 b	0.41 a	0.59 a
Na_2SO_4	0.75 de	0.68 d	0.54 c	0.43 a	0.60 a
$\bar{x}$	0.77 d	0.70 c	0.50 b	0.42 a	

Values marked with the same letters do not differ significantly at p = 0.05 – Wartości oznaczone tymi samymi literami nie różnią sie istotnie przy p = 0.05.
d.m. – dry matter – s.m. – sucha masa.

Table 2. Effect of dose and kind of applied salt on the content of selected elements in common sunflower leaves
Tabela 2. Wpływ dawki sodu oraz soli sodu na zawartość wybranych pierwiastków w liściach słonecznika zwyczajnego

Salt Sól	Dose of – Dawka Na · dm^{-3}				$\bar{x}$
	0	100	300	500	
		Na [% d.m. – s.m.]			
NaCl	0.10 a	0.14 ab	0.17 bc	0.34 e	0.19 a
Na_2SO_4	0.11 a	0.13 a	0.19 c	0.22 d	0.16 a
$\bar{x}$	0.11 a	0.14b	0.18 c	0.28 d	
		Cl [% d.m. – s.m.]			
NaCl	2.25 b	2.45 c	2.67 d	3.28 e	2.67 b
Na_2SO_4	0.27 a	0.27 a	0.25 a	0.26 a	0.26 a
$\bar{x}$	1.26 a	1.36 b	1.46 c	1.77 d	
		S [% d.m. – s.m.]			
NaCl	0.69 a	0.67 a	0.64 a	0.65 a	0.67 a
Na_2SO_4	0.76 b	0.76 b	0.77 b	0.84 c	0.78 b
$\bar{x}$	0.73 a	0.72 a	0.71 a	0.75 a	
		K [% d.m. – s.m.]			
NaCl	5.30 f	4.97 e	3.25 d	2.91 b	4.11 a
Na_2SO_4	5.40 f	4.94 e	3.07 c	2.70 a	4.03 a
$\bar{x}$	5.35 d	4.95 c	3.16 b	2.81 a	
		Ca [% d.m. – s.m.]			
NaCl	4.23 f	4.02 e	2.85 b	2.54 a	3.41 a
Na_2SO_4	4.99 h	4.62 g	3.87 d	3.59 c	4.27 b
$\bar{x}$	4.61 d	4.32 c	3.36 b	3.07 a	
		Mg [% d.m. – s.m.]			
NaCl	1.00 bc	1.02 bc	0.98 a	1.07 c	1.02 a
Na_2SO_4	0.96 a	1.03 bc	1.04 bc	1.00 bc	1.00 a
$\bar{x}$	0.98 a	1.02 a	1.01 a	1.04 a	

Explanations: see Table 1 – Obaśnienia zob. tab. 1.

Sodium contents in leaves of sage and sunflower were increasing with an increase of salt doses. Depending on the used salt the contents of chlorine (substrate with NaCl) and sulphur (substrate with Na_2SO_4) were also growing. At the same time, as a result of ionic antagonism contents of potassium and calcium were decreasing. In the case of magnesium a similar trend was found only in leaves of sage, while in sunflower leaves levels of this nutrient, despite an increase in substrate salinity, may be considered stable. A reduction of cations content in plant leaves under the influence of sodium has been confirmed in many publications. However, a lack of the effect of increasing NaCl doses on Ca content has also been occasionally reported (Chiroma et al. 2007).

Apart from contents of S and Cl, no marked effect was found of the type of salt on the accumulation of nutrients in plants. Similar effects of salts were observed in an experiment on basil (*Ocimum basilicum)* (Tarchoune et al. 2012). An ambiguous effect of salt was only found for calcium – Ca content in leaves of plants grown in the substrate supplemented with Na_2SO_4 is usually greater, although not always statistically significant, in comparison to that in plants grown in the substrate with an addition of NaCl. Such a trend was not observed only in leaves of sage plants from the combination with 500 mg Na · dm^{-3}. Disturbance of ionic balance and thus also disorders in physiological processes in plants led to marked changes in plant morphology (Tables 3 and 4).

Table 3. Effect of dose and kind of applied salt on morphological traits and SPAD index of scarlet sage
Tabela 3. Wpływ dawki sodu oraz soli sodu na cechy morfologiczne i indeks SPAD szałwii błyszczącej

Salt Sól	Dose of – Dawka Na · dm^{-3}				$\bar{x}$
	0	100	300	500	
		Plants height Wysokość roślin [cm]			
NaCl	28.25 d	26.55 c	22.30 b	18.85 a	23.99 a
Na_2SO_4	28.45 d	27.85 d	25.55 c	22.60 b	26.11 b
$\bar{x}$	28.35 d	27.20 c	23.93 b	20.73 a	
		Plant diameter Średnica rośliny [cm]			
NaCl	24.30 d	23.40 d	21.05 bc	17.25 a	21.50 a
Na_2SO_4	23.70 d	24.05 d	22.45 cd	19.60 b	22.45 b
$\bar{x}$	24.00 c	23.73 c	21.75 b	18.43 a	
		Plant fresh weight [g/plant] Świeża masa części nadziemnej [g na roślinę]			
NaCl	40.85 c	37.30 bc	26.30 a	24.50 a	32.21 a
Na_2SO_4	37.75 bc	36.90 bc	34.30 b	26.45 a	33.85 a
$\bar{x}$	39.30 c	37.10 c	30.25 b	25.48 a	
		Number of lateral shoot Liczba pędów bocznych			
NaCl	2.55 bc	1.85 a	1.80 a	1.75 a	1.99 a
Na_2SO_4	2.70 c	2.55 bc	2.10 ab	1.85 a	2.30 b
$\bar{x}$	2.63 c	2.20 b	1.95 ab	1.80 a	
		Number of inflorescences Liczba kwiatostanów			
NaCl	4.10 ab	4.25 ab	3.95 ab	3.50 a	3.95 a
Na_2SO_4	4.70 b	4.35 b	4.15 ab	3.90 ab	4.28 a
$\bar{x}$	4.40 b	4.30 b	4.05 ab	3.70 a	
		Weight of inflorescence [g/plant] Masa kwiatostanu [g na roślinę]			
NaCl	15.55 c	14.40 bc	10.20 a	9.65 a	12.45 a
Na_2SO_4	14.60 bc	13.80 bc	13.35 b	9.75 a	12.88 a
$\bar{x}$	15.08 c	14.10 c	11.78 b	9.70 a	
		SPAD index Indeks zazielenienia liści (SPAD)			
NaCl	54.71 d	53.62 cd	48.32 b	42.98 a	49.91 a
Na_2SO_4	53.29 cd	54.08 cd	51.46 c	44.92 a	50.94 a
$\bar{x}$	54.00 c	53.85 c	49.89 b	43.95 a	

Explanations: see Table 1 – Obaśnienia zob. tab. 1.

Sage plants under the influence of increasing doses of sodium showed not only growth retardation, but they also had smaller diameters of whole plants, lower fresh aboveground biomass of plants, lower numbers of lateral shoots and inflorescences, and a markedly lower mass of inflorescences. Application of increasing sodium doses had a significant negative effect also on sunflower, particularly by reducing both its height and fresh aboveground biomass. The effect on the diameter of the stem and the inflorescence was manifested only after the application of the highest sodium doses. An even greater diversification of plant response was observed when measuring the SPAD index. In sage SPAD values decreased considerably under the influence of the increasing sodium doses, whereas no such dependence was found in sunflower. Such a trend may be explained by the changes in Mg contents in leaves of cultivated plants, described above. Anions from the applied sodium salts had a limited effect on plants. Chlorides had an adverse effect on plant height and diameter as well as the number of lateral shoots in sage, while in sunflower a negative influence was observed on the diameter of inflorescences and the SPAD index of leaves.

Table 4. Effect of dose and kind of applied salt on morphological traits and SPAD index of sunflower
Tabela 4. Wpływ dawki sodu oraz soli sodu na cechy morfologiczne i indeks SPAD słonecznika zwyczajnego

Salt Sól	Dose of – Dawka Na · dm^{-3} 0	100	300	500	$\bar{x}$
			Plants height Wysokość roślin [cm]		
NaCl	48.45 c	47.05 bc	43.00 ab	41.40 a	44.98 a
Na_2SO_4	47.15 b	48.15 b	44.75 a	44.35 a	46.10 a
$\bar{x}$	47.80 b	47.60 b	43.88 a	42.88 a	
			Stem diameter Średnica pędu [cm]		
NaCl	0.95b	0.94 b	0.89 ab	0.84 a	0.91 a
Na_2SO_4	0.95 b	0.94 b	0.92 ab	0.90 ab	0.93 a
$\bar{x}$	0.95 b	0.94 b	0.91 ab	0.87 a	
			Plant fresh weight [g/plant] Świeża masa części nadziemnej [g na roślinę]		
NaCl	133.00 bc	123.60 abc	121.20 abc	108.00 a	121.45 a
Na_2SO_4	134.80 c	119.50 abc	115.20 abc	112.20 ab	120.43 a
$\bar{x}$	133.90 b	121.55 ab	118.20 a	110.10 a	
			Inflorescence diameter Średnica kwiatostanu [cm]		
NaCl	9.85 bc	9.55 ab	9.60 ab	9.15 a	9.54 a
Na_2SO_4	10.05 bc	10.20 c	10.25 c	9.85 bc	10.09 b
$\bar{x}$	9.95 b	9.88 b	9.93 b	9.50 a	
			SPAD index Indeks zazielenienia liści (SPAD)		
NaCl	29.02 a	29.86 ab	28.82 a	28.84 a	29.14 a
Na_2SO_4	32.35 c	31.74 bc	30.40 abc	30.72 abc	31.30 b
$\bar{x}$	30.69 a	30.80 a	29.61 a	29.78 a	

Explanations: see Table 1 – Obaśnienia zob. tab. 1.

The other traits were not modified by the type of the applied salt. Differences between plants grown in the substrate with an addition of NaCl and Na_2SO_4, although confirmed statistically, are of no major importance in horticultural practice. The limit of tolerance to sodium in plants, defined based on their overall decorative value, proved to be more significant. Results of measurements and observations taken during plant culture indicate that irrespective of the type of salt both species may be grown in the substrate containing 100 mg Na · dm^{-3} with no loss of their decorative value. Exceeding the level of 300 mg Na · dm^{-3} had a marked negative effect on plants.

According to Kozłowska et al. (2007), the deterioration of quality parameters in plants may be caused by the accumulation of sodium and chlorine in chloroplasts, thus blocking the process of photosynthesis, transport of electrolytes and photosynthetic phosphorylation. Reduction of plant growth may be explained by the effect of sodium on an increased intensity of biosynthesis of abscisic acid (ABA) in these organs. It is one of the first compounds acting as a signalling molecule, indicating water deficit in plants (Wilkinson and Davies 2002). Its amount increases both in roots and leaves, where it induces several changes leading to closure of stomata and reduced transpiration (Sakhabutdinova et al. 2003; Zhang et al. 2006; Wang et al. 2008).

There is an extensive body of publications discussing salinity, but they do not concern the species discussed in this paper. Niu and Rodriguez (2006), when investigating tolerance of flowerbed plants to salinity showed that an increasing amount of NaCl in the nutrient solution used in fertigation of plants grown in peat substrate caused a reduction of biomass in plumbago (*Ceratostigma plumbaginoides* Bunge*),* treasure flower *(Gazania rigens* Gaertn*.)* and wall germander *(Teucrium chamaedrys* L*.).* Nowak and Kunka (2009) investigated the effect of salinity on growth and flowering of mealy sage (*Salvia farinacea* 'Blue Victory'). Those authors found that higher doses of sodium chloride reduced the number of inflorescences, plant height and dry biomass of plants in comparison to specimens grown in substrate containing no NaCl. Valdez-Aquilar et al. (2009) reported a deterioration of quality parameters in marigolds (*Tagetes patula* 'French Vanilla', *Tagetes erecta* 'Flagstaff' and 'Yellow Climax'). However, the negative effect on individual morphological characteristics was manifested at different EC values of the nutrient solution, e.g. on plant height it was at EC 4 mS · cm^{-1}, and the number of flowering shoots, the number and diameter of flowers at EC 8 mS · cm^{-1}. Wrochna et al. (2007) showed that species from the Amaranth family exhibit a relatively high tolerance to substrate salinity; however, those authors proved it to be a variety-dependent trait. The above mentioned studies were conducted applying very different research methods. For this reason it is difficult to interpret their results concerning tolerance of plants to salinity. Still we need to mention here the findings reported by Weinhold et al. (1997), who proposed boundary sodium contents for begonia (*Begonia elatior* 'Netja') at 550 mg Na, petunia (*Petunia x hybr.* 'Blue Flash') at 540 mg Na, and for poison primrose (*Primula obconica* 'Juno Deeprose') at 140 mg Na · dm^{-3} substrate.

Soil salinity in urban areas poses a considerable problem for management of urban green, as it affects both herbaceous plants, shrubs and trees. Nevertheless, areas located along transportation routes need to be planted with ornamental plants. It is advisable to search for methods to limit salinity stress or to use species and varieties less sensitive to stress factors. Unfortunately, neither sage 'Scarlet Piccolo' nor sunflower 'Teddy Bear' are such plants. However, moderate salinity is not always definitely an adverse condition. In the presented investigations an example in this respect may be provided by dwarfing of sage caused by salinity stress – this fact does not eliminate this species as an element of urban green, since it may be suitable for very low plantings, e.g. borders of summer flower beds.

CONCLUSIONS

1. An addition of sodium salts to substrate disturbs mineral metabolism in sage and sunflower, particularly reducing the accumulation of potassium and calcium.
2. At an identical sodium content in the substrate plants used in this experiment showed a greater tolerance to sodium sulphate than to sodium chloride.
3. Sodium content in substrate over 100 mg · dm^{-3} has a negative effect on most measured morphological traits in sage 'Scarlet Piccolo' and sunflower 'Teddy Bear'. However, a dose as high as 500 mg Na · dm^{-3} was not lethal to cultivated plants.

REFERENCES

Bach A., Bartyńska M., Kraus D., Malinowska Z., Pawłowska B., Pniak M. 2006. Reakcja roślinności drzewiastej pasów przydrożnych Krakowa na zasolenie i pH gleby [Effect of sodium chloride salinity and pH of soil on ornamental urban trees in Krakow]. Zesz. Probl. Post. Nauk Rol. 510, 39–48. [in Polish]

Breś W. 2008. Czynniki antropopresji powodujące zamieranie drzew w krajobrazie miejskim [Anthropopressure factors causing trees to die off on urban landscape]. Nauka Przyr. Technol. 2(4), 31. [in Polish]

Breś W. 2010. Abiotyczne czynniki stresowe jako przyczyna zaburzeń wzrostu i zamierania drzew na terenach zurbanizowanych (w: Problemy ochrony roślin na terenach zurbanizowanych. T. 1. Miejskie tereny zielone – zagrożenia). Red. E. Pląskowska. Wrocław, Wydaw. UP we Wrocławiu. [in Polish]

Chiroma A.M., Abubakar A., Saddiq A.M. 2007. Concentration of NaCl as it affects emergence, early growth, and nutrient composition of *Amaranthus*. Int. J. Veg. Sci. 13, 65–74.

Cunningham M.A., Snyder E., Yonkin D., Ross M., Elsen T. 2008. Accumulation of deicing salts in soils in an urban environment. Urban Ecosyst. 11, 17–31.

Kozłowska M., Bandurska H., Floryszak-Wieczorek J., Politycka B. 2007. Fizjologia roślin. Warszawa, PWRiL, 544. [in Polish]

Maas E.V. 1984. Salt tolerance of plants (in: The handbook of plant science in agriculture). Ed. B.R. Christie. Boca Raton, FL, CRC Press.

Mazur Z., Radziemska M., Deptuła D. 2011. Wpływ środków zwalczania śliskości jezdni na zawartość chlorków glebach wzdłuż ulic Olsztyna [Impact of salinity working against after-snowing slippery on the content of chlorides in the soil around of roads in Olsztyn]. Ochr. Środ. Zasob. Natural. 50, 212–217. [in Polish]

Munns R. 2002. Comparative physiology of salt and water stress. Plant Cell Environ. 25, 239–25.

Niu G., Rodriguez D.S. 2006. Relative salt tolerance of selected herbaceous perennials and groungovers. Sci. Hortic. 110, 352–358.

Nowak J., Kunka M. 2009. The effect of salinity, mycorrhizal inoculation and compost supply on growth and flowering of mealycup sage 'Blue Victory' (*Salvia farinacea* BENTH). Zesz. Probl. Post. Nauk. Rol. 539, 551–559.

Nowosielski O. 1974. Metody oznaczania potrzeb nawożenia. Warszawa, PWRiL. [in Polish]

Sakhabutdinova A.R., Fatkhutdinova D.R., Bezrukova M.V., Shakirova F.M. 2003. Salicylic acid prevents the damaging action of stress factors on wheat plants. Bulg. J. Plant Physiol., special issue, 314–319.

Shannon M.C. 1997. Adaptation of plants to salinity. Adv. Agron. 60, 75–120.

Sonneveld C., Burg A.M.M. van der. 1991. Chloride salinity in fruit vegetable crops in soilless culture. J. Agr. Sci. 39, 115–112.

Sonneveld C., Baas R., Nijssen H.M.C., De Hoog J. 1999. Salt tolerance of flower crops grown in soilless culture. J. Plant Nutr. 22, 1033–1048.

Tarchoune I., Degl'Innocenti E., Kaddour R., Guidi L., Lachaâl M., Navari-Izzo F., Ouerghi Z. 2012. Effects of NaCl or Na_2SO_4 salinity on plant growth, ion content and photosynthetic activity in *Ocimum basilicum* L. Acta Physiol. Plant. 34(2), 607–615.

Wang C., Yang A., Yin H., Zhang J. 2008. Influence of water stress on endogenous hormone contents and cell damage of maize seedlings. J. Inter. Plant Biol. 50(4), 427–434.

Weinhold F., Scharpf H.C., Roeber R.U. 1997. Tolerance of ornamental plants to salt, sodium and chloride in potting substrates containing compost made of separately collected organic residues. Acta Hortic. 450, 221–228.

Wilkaniec B., Breś W., Frużyńska-Jóźwiak D., Borowiak-Sobkowiak B., Wilkaniec A., 2012. The assessment of chemical properties of soil, the chemical composition of leaves and the occurrence of diseases on acer platanoides and tilia cordata in selectet sites of urban greenery in Poznań. Phytopathologia 65, 19–28.

Wilkinson S., Davies W.J. 2002. ABA-based chemical signalling: the co-ordination of responses to stress in plants. Plant Cell Environ. 25, 195–210.

Wrochna M., Gawrońska H., Borkowska B.,Gawroński S.W. 2007. Wpływ zasolenia na akumulacje biomasy i fluorescencją chlorofilu u roślin trzech odmian szarłatu ozdobnego [The effect of salinity on biomass accumulation and chlorophyll fluorescence in plants of three cultivars of ornamental amaranth]. Rocz. AR Pozn., Ser. Ogrod. 383(41), 235–239. [in Polish]

Valdez-Aguilar L.A., Grieve C.M., Poss J. 2009. Salinity and alkaline pH in irrigation water affect marigold plants. I. Growth and shoot dry weight partitioning. Hortscience 44(6), 1719–1725.

Xiong L., Zhu J.K. 2002. Molecular and genetic aspects of plant responses to osmotic stress. Plant Cell Environ. 25, 131–139.

Zhang Z.J., Li H.Z., Zhou W.J., Takeuchi Y., Yoneyama K. 2006. Efect of 5-aminolevulinic acid on development and salt tolerance of potato (*Solanum tuberosum* L.) microtubers in vitro. Plant Growth Regul. 49, 27–34.

Abstract. The aim of the presented study was to evaluate the response of scarlet sage and common sunflower to an increasing sodium content in the substrate. The experiment was conducted on plants of *Salvia splendens* Buc'hoz x Etl. 'Scarlet Piccolo' and *Helianthus annuus* L. 'Teddy Bear'. Plants were planted in pots filled with limed high-moor peat substrate with the necessary nutritional components. The content of sodium was diversified by adding two different sodium salts (NaCl and Na_2SO_4) to the substrate at 0 to 500 mg · dm^{-3}. The change of substrate chemical properties caused disturbance in mineral nutrition of plants. Irrespective of the applied salt, increasing concentrations of sodium affected negatively the analysed morphological features of *Salvia splendens*. The study showed that sunflower was more tolerant – in case of this plant the negative influence of applied sodium salts was not always statistically proven. A marked decrease of chlorophyll content was recorded only in sage leaves. A more adverse effect on the ornamental value of sage (plant height and plant diameter at mid-height of the main shoot) and sunflower (inflorescence diameter) was observed for sodium chloride.