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**EFFECT OF AN INCREASED CONCENTRATION
OF SODIUM CHLORIDE
ON SOME PHYSIOLOGICAL FEATURES OF LETTUCE
(*Lactuca sativa* var. *capitata*)**

**WPLYW PODWYŻSZONEGO STĘŻENIA CHLORKU SODU
NA NIEKTÓRE CECHY FIZJOLOGICZNE SAŁATY MASŁOWEJ
(*Lactuca sativa* var. *capitata*)**

Abstract: Too high concentration of salt in the environment is one of the most important stressful factors causing serious morphological and physiological changes in plants. The aim of the present studies was to evaluate the effect of an increased concentration of sodium chloride in the medium under the condition of diverse fertilization with potassium on selected physiological features of head lettuce var. 'Justyna'. The content of assimilation dyes in leaves, the dry matter of the plant's aboveground part and root system and parameters of water balance were determined – the indices of relative water content and water saturation deficit of tissues.

Keywords: *Lactuca sativa* var. *capitata*, sodium chloride, water balance, assimilation pigments, dry matter

Excessive salinity of environment, caused mainly by large concentration of NaCl is one of the most important stressogenic factors limiting the growth and productivity of plants [1–3]. Metabolic disturbances of plants under the conditions of salt stress have a complex character and include dysfunctions resulting from both unbalanced water relations in tissues and limited uptake and long-distance transport of many substances indispensable to plants [4, 5]. The knowledge of plant mechanisms of tolerance towards excessive salinity is not satisfactory, which makes it difficult to work out effective methods of softening its influence. The results of some research works show that an increase in the content of mineral components in the medium can prevent negative consequences of environment salinity. Most of the data refer to the use of microelements, mainly potassium and calcium [6–8], and some refer to the effect of chemical elements belonging to other groups [9].

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The present study shows the results of experiments the aim of which was to determine how an increased concentration of NaCl in the medium, at a diversified level of fertilizing plants with potassium, affects the content of assimilation dyes in leaves, the production of biomass and the parameters of water balance of head lettuce var. 'Justyna'.

Material and methods

In 2007 in the laboratory of the Department of Plants Physiology of West Pomeranian University of Technology in Szczecin, a vegetative experiment was carried out using the method of water cultures. A two-factor system of complete randomization in five replications was used. The first experimental factor was concentration of sodium chloride in the medium: the control, 0.068 and 0.136 mol NaCl · dm⁻³, whereas the second factor was the level of fertilization with potassium: + 20 % K, the control (without additional fertilization with potassium). The control was a full Hoagland's medium (pH 5.5). The experiment was carried out in two series (repetitions in time) in June and July.

The biological material of the research was head lettuce var. 'Justyna'. The lettuce seedlings were produced in our greenhouse from seeds. About 16 days after the time of sowing, when the plants reached the height of about 10 cm, they were carried to water cultures (glass flasks of 70 dm³ capacity, filled with a full Hoagland's medium), where they grew for three successive days. Then the composition of the media was diversified in respect of NaCl and potassium concentration. The volume of the medium was systematically completed and it was aerated.

14 days after placing the plants in hydroponics, the content of assimilation pigments (chlorophyll *a*, *b* and total) in leaves, the total dry matter of the aboveground part and root system and the parameters of water balance were determined in three replications. In order to determine the content of assimilation pigments the method of Lichtenthaler and Wellburn [10] was used. The amount of chlorophyll and carotenoids was calculated according to Arnon et al [11]. Indexes of *relative water content* (RWC) and *water saturation deficit* (WSD) were defined according to Barry and Weatherly [12]. The dry matter of the investigated items were determined using the dryer method, after the plants had been dried up to the stable weight at the temperature of 105 °C in a dryer.

The obtained results concerning the content of assimilation dyes and dry matter of lettuce were worked out using the two-factor analysis of variance. The significance of differences between averages were determined by means of the Duncan test at the level of significance of $\alpha = 0.05$. Due to homogeneity of the variance of error the synthesis of results of two series of experiments [13] were carried out.

Results and discussion

Lettuce, like most usable plants, is regarded as the one belonging to typical glycophytes of relatively large sensitivity to too large salinity of environment. In the present studies it was shown that the applied concentration of 0.068 mol NaCl · dm⁻³

did not cause any increase in the content of assimilation pigments in leaves of lettuce. In the case of plants growing in the medium of the $0.136 \text{ mol NaCl} \cdot \text{dm}^{-3}$ concentration, a decrease in concentration of chlorophyll *a*, *b* and total and carotenoids by about 30 % in relation to the control was observed, although the differences were not statistically significant. It proves, then, that the application of higher concentration of salt has a phytotoxic influence on the plants of the studied species. Similar results of studies on the effect of salt stress on the content of photosynthetic pigments in cucumber were reported by Hawrylak [9].

Introduction of potassium to saline environment did not cause any increase in the content of assimilation pigments. Only in the case of lettuce growing in the medium of the $0.068 \text{ mol NaCl} \cdot \text{dm}^{-3}$ concentration, a slight increase in the content of total chlorophyll (by about 5 %) after an additional supply of potassium to plants was observed (Table1).

Table 1

Content of chlorophyll *a*, *b*, *a+b* and carotenoids in leaves of *Lactuca sativa* var. *capitata* [$\text{mg} \cdot \text{g}^{-1}$ f.m.]

Dose of NaCl [$\text{mol} \cdot \text{dm}^{-3}$]	Dose of K		Mean
	Full Hoagland's medium	Full Hoagland's medium + 20 % K	
Chlorophyll <i>a</i>			
Control	0.456 a	0.451 a	0.453 a
0.068	0.443 a	0.460 a	0.451 a
0.136	0.320 a	0.307 a	0.314 a
Mean	0.406 a	0.406 a	
Chlorophyll <i>b</i>			
Control	0.229 a	0.219 a	0.224 a
0.068	0.218 a	0.242 a	0.230 a
0.136	0.167 a	0.160 a	0.164 a
Mean	0.205 a	0.207 a	
Chlorophyll <i>a+b</i>			
Control	0.685 a	0.670 a	0.677 a
0.068	0.662 a	0.701 a	0.681 a
0.136	0.488 a	0.467 a	0.477 a
Mean	0.611 a	0.613 a	
Carotenoids			
Control	0.237 a	0.239 a	0.238 a
0.068	0.237 a	0.253 a	0.245 a
0.136	0.169 a	0.167 a	0.168 a
Mean	0.214 a	0.219 a	

* Averages denoted with the same letters do not differ significantly at the level of significance $\alpha = 0.05$.

Under the conditions of salt stress a distinct limitation of water availability to plants was noticed and this in turn leads to disturbances of almost all vital processes [14]. In the present studies the largest index of the relative content of water was characteristic of the plants growing in the control medium with addition of 20 % K (RWC – 90.6 %) and in the control medium (RWC – 85.9 %) – Fig. 1. The increase in salinity of the environment resulted in the distinct worsening of water balance parameters of lettuce, which was illustrated by an increase in the index of water saturation deficit in tissues (in plants growing in the media of the concentrations of 0.068 and 0.136 mol NaCl · dm⁻³ it was respectively larger by 6.8 and 15.5 % than that of the control) – Fig. 2. The

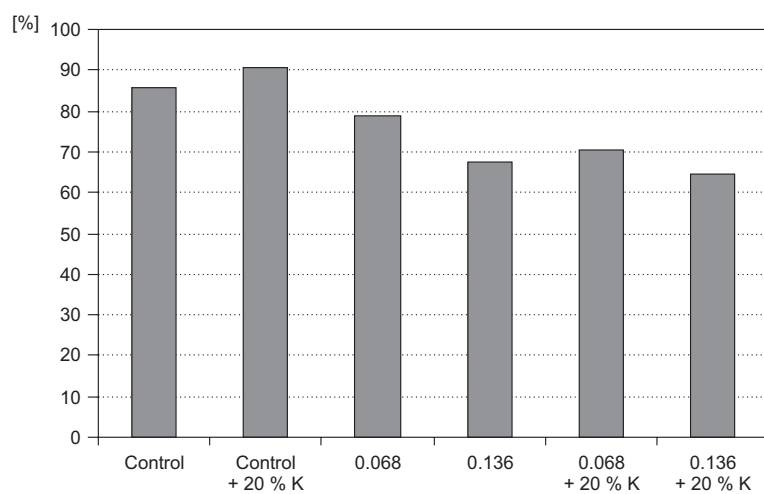


Fig. 1. Index of relative water content (RWC) in leaves of *Lactuca sativa* var. *capitata*

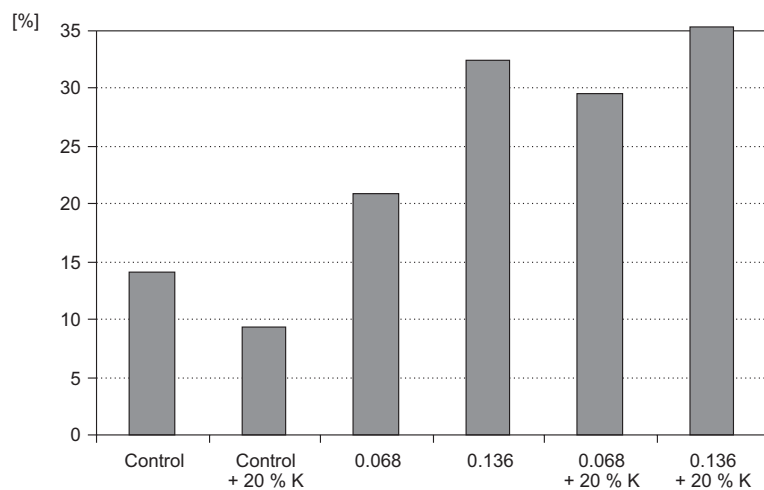


Fig. 2. Index of water saturation deficit (WSD) in leaves of *Lactuca sativa* var. *capitata*

enrichment of water cultures with potassium did not lower the unfavourable influence of the NaCl excess on water relations of the examined plant.

In most plants under the conditions of saline environment the inhibition of growth, the decrease in size and number of leaves and roots are observed, and at the same time the inhibition of growth of aboveground organs is usually larger than the limitation of root growth [15, 16]. Biomass production usually decreases as a result of an unfavourable impact of salt stress on parameters connected with gaseous exchange of plants. In the present studies, the dry matter of the aboveground parts of lettuce decreased significantly under the effect of the growing concentration of NaCl in the medium. In the plants growing in cultures of the concentrations 0.068 and 0.136 mol NaCl · dm⁻³ it was smaller by 40 and 60 %, respectively, in relation to the control. The largest dry matter of the root system was observed in lettuce growing in cultures of the concentration 0.136 mol NaCl · dm⁻³. The increase in salinity of the environment up to the level of 0.136 mol NaCl · dm⁻³ caused a significant decrease in dry matter of roots of the studied plant (Table 2).

Table 2

Dry matter of *Lactuca sativa* var. *capitata* [g · plant⁻¹]

Dose of NaCl [mol · dm ⁻³]	Above-ground part			Roots		
	Full Hoagland's medium	Full Hoagland's medium + 20 % K	Mean	Full Hoagland's medium	Full Hoagland's medium + 20 % K	Mean
0.068	0.062 b	0.045 b	0.054 b	0.015 c	0.011 b	0.013 c
0.136	0.031 a	0.031 a	0.035 a	0.008 ab	0.009 ab	0.008 b
Control	0.110 c	0.070 c	0.090 c	0.005 a	0.006 a	0.0055 a
Mean	0.068 b	0.048 a		0.009 a	0.008 a	

* Averages denoted with the same letters do not differ significantly at the level of significance $\alpha = 0.05$.

Differentiated changes in cumulating the biomass in the response to salinity were also noticed by Khan et al [17] in species *Atriplex griffithii* var. *stocksii*, Ashraf et al [18] in *Brassica* and Wrochna et al [16] in ornamental amaranth. The addition of potassium to saline environment did not significantly influence the size of dry matter of both the aboveground parts and the root system of lettuce.

Conclusions

1. The 0.068 mol NaCl · dm⁻³ concentration did not cause a decrease in the content of assimilation dyes in leaves of lettuce.
2. In plants growing in the medium of the concentration 0.136 mol NaCl · dm⁻³ a decrease in the concentration of both chlorophyll and carotenoids in leaves by about 30 % was observed.
3. The increase in salinity of environment resulted in the distinct worsening of water balance parameters of lettuce, which was illustrated by an increase in the index of water saturation deficit in tissues.

4. The dry matter of the aboveground parts of lettuce decreased significantly under the influence of the growing concentration of sodium chloride in the medium.

5. The effect of a diverse concentration of sodium chloride in the media on the yield of dry matter of root system was equivocal.

6. The introduction of potassium to saline environment was not proved to influence the increase in the content of assimilation pigments, the improvement of water balance parameters and the production of plant dry matter.

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WPLYW PODWYŻSZONEGO STĘŻENIA CHLORKU SODU NA NIEKTÓRE CECHY FIZJOLOGICZNE SAŁATY MASŁOWEJ (*Lactuca sativa* var. *capitata*)

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Abstrakt: Zbyt duże stężenie soli w środowisku to jeden z ważniejszych czynników stresowych wywołujących poważne zmiany morfologiczne i fizjologiczne u roślin. Celem przeprowadzonych badań była ocena wpływu podwyższonego stężenia chlorku sodu w pożywce, w warunkach zróżnicowanego żywienia roślin potasem na wybrane cechy fizjologiczne sałaty głowiastej masłowej odmiany 'Justyna'. Określono zawartość barwników asymilacyjnych w liściach, suchą masę części nadziemnej i systemu korzeniowego oraz parametry bilansu wodnego – wskaźniki względnej zawartości wody oraz deficytu wysycenia tkanek wodą.

Słowa kluczowe: *Lactuca sativa* var. *capitata*, chlorek sodu, bilans wodny, barwniki asymilacyjne, sucha masa