

**ФИЗИОЛОГИЧЕН ОТГОВОР НА ГЛАВЕСТАТА САЛАТА (*LACTUCA SATIVA* VAR. *CAPITATA*) КЪМ ЗАСОЛЯВАНЕ
A PHYSIOLOGICAL RESPONSE OF THE HEAD LETTUCE (*LACTUCA SATIVA* VAR. *CAPITATA*) ON THE SALINITY**

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Резюме

Експериментите бяха изведени през периода 2008-2009 г. с главеста салата сорт “Nochowska”. Растенията бяха отглеждани като водни култури. Натриевият хлорид беше приложен в следните концентрации: 0, 68, 136 mM NaCl (първи експериментален фактор). В експериментите бяха приложени две нива на хранене с калий: контрола (без допълнително подаване на K), +20% K (втори експериментален фактор). Контролните растения бяха отглеждани върху хранителен разтвор на Hoagland (pH=5,5). Значително намаляване на CO₂ асимилацията беше установено при растенията, отглеждани при 136 mM NaCl, без допълнително хранене с калий. Повишеното засоляване и допълнителното подхранване с 20% K не понижават интензивността на фотосинтезата при хидропонно отглеждани растения. Намаляване на интензивността на транспирацията и нарастване на индекса на ефективността на използване на водата във фотосинтезата бяха установени при нарастващи концентрации на NaCl в растенията, допълнително подхранвани с K. Допълнителното подаване на 20% K, независимо от степента на засоляване с NaCl, води до повишено съдържание на всички форми хлорофил в листата на изследваните растения.

Abstract

The experiment was carried out during 2008-2009, using the method of water cultures. The biological material was head lettuce var. ‘Nochowska’. The first experimental factor was concentration of sodium chloride in the medium: the control, 68 and 136 mM NaCl, 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). A significant decrease in the intensity of CO₂ was observed in plants grown in the medium of 136 mM NaCl concentration, with no additional nutrition with potassium. An increase in salinity, in the hydroponic growing media enriched with 20% of potassium, did not cause a decrease in photosynthesis. A decrease in the intensity of transpiration and an increase in the index of water use effectiveness in photosynthesis were recorded along with an increase in the NaCl concentration in plants additionally nourished with potassium. The addition of 20% of potassium caused, independently of the level of salinity of the media, an increase in the content of all the forms of chlorophyll in the leaves of the studied plant.

Ключови думи: *Lactuca sativa* var. *capitata*, натриев хлорид, листен газообмен, пигменти.

Key words: *Lactuca sativa* var. *capitata*, sodium chloride, gas exchange, pigments.

INTRODUCTION

A too high concentration of salt in the environment is one of more important problems of agriculture, limiting cultivation of plants (Yeo, 1999; Sudhaker et al., 2001; Zhu, 2001). The problem of salinity arises when the concentration of salt in soil exceeds the value of 10 mol^lm⁻³ (Kalaji and Rutkowska, 2004). The influence of salinity on plants can be different depending on the plant species, the kind and

concentration of salt, the duration of stress, the state of environment and the impingement of other factors (Kalaji and Pietkiewicz, 1993; Matuszak and Brzystowicz, 2004). Leaf vegetables, including head lettuce, are sensitive even to relatively small salinity. Under the conditions of an increased concentration of salt in the environment, in the beginning, symptoms of water stress appear in a plant, then symptoms of osmotic stress and finally toxicity of ions of

salt. This leads to the reduction of quantity and quality of crops. In recent years numerous research works on possibilities of soothing the effects of water stress have been carried out. There are publications on the use, for this purpose, of plant nutrition with some macroelements (Bilski, 1990; Elkhatib et al., 2004) and microelements (Hawrylak, 2007).

The aim of the experiment was to determine the effect of an increased concentration of NaCl in the medium on physiological features of head butter lettuce and to answer the question whether the presence of potassium in the nutritive environment of the plant can modify the reaction of this species to salt stress.

MATERIAL AND METHODS

In years 2008-2009 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, 68 and 136 mM NaCl, 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. 'Nochowska'. 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 10cm, 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.

7 days after placing the plants in hydroponics, the content of photosynthetic pigments (chlorophyll *a*, *b* and total) in leaves were determined in three replications. In order to determine the content of photosynthetic pigments the method of Lichtenthaler and Wellburn (1983) was used. The amount of chlorophyll and carotenoids was calculated according to Arnon et al. (1956).

The measurements of gas exchange in leaves of lettuce, e.i. the net intensity of the photosynthesis process (A), transpiration (E), were made 7 days after the salinity, in 8 replications. The measurements were carried out with the use of a TPS-2 gas analyzer with a PLC-4 chamber, manufactured by PP Systems (UK). On the basis of the obtained results of the intensity of assimilation and transpiration, the index of effectiveness of water use in the process of photosynthesis (ω_F), estimated by the ratio A:E, was calculated.

The obtained results 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 from both years were carried out.

RESULTS AND DISCUSSION

The salt and osmotic stress, caused by a too high concentration of salt in the growth environment of a plant, manifests itself by a decrease in the intensity of photosynthesis in rice (Sultana et al., 1999), barley (Cho et al., 1998) and maize (Sage, 2004). In the carried out studies it was observed that addition of NaCl to the medium at the concentration of 68 mmol.dm⁻³ did not cause any changes in the intensity of assimilation in lettuce. Such a relationship was observed both when the hydroponic growing medium was enriched with 20% of potassium and while there was no additional nutrition with this element. Whereas the applied higher concentration of NaCl (136 mM) resulted in a significant decrease in the intensity of photosynthesis in plants growing with no additional nutrition with potassium (Table 1). A similar reaction to the addition of salt at the concentration of 180 mM NaCl was observed, in maize seedlings, by Kalaji and Rutkowska (2004). In the case of lettuce growing in the hydroponic media enriched with 20% of potassium, the increase in the concentration of NaCl did not cause a decrease in the intensity of assimilation. This can prove the fact that potassium increases tolerance of the studied species to the salt stress.

Lettuce growing under the conditions of a differentiated concentration of NaCl, without addition of potassium, was characterized by transpiration at the level approximate to transpiration of the control plants (Table 1). Whereas in plants additionally provided with potassium, a decrease in the intensity of transpiration along with an increase in the concentration of salt in the hydroponic media was observed. In the studies carried out by Leidi (1991) and Kalaji and Rutkowska (2004) it was stated that a low concentration of NaCl (25-136 mM NaCl) did not cause, among other things, any changes in transpiration. According to Toker et. al. (1999), under the conditions of stress, a limitation of transpiration appears.

In lettuce growing under the conditions of the largest salinity, without addition of potassium, a slightly lower index of water use effectiveness (ω_F) than in the control plants and the plants growing in the medium of a 68 mM concentration was observed. In the case of plants additionally nourished with potassium, addition of differentiated doses of NaCl resulted in an increase in the ω_F index as compared to the control plants (Table 1).

The drop in the level of assimilation dyes was classified as the cause of a decrease in photosynthesis under the conditions of salinity by Kolchevskii et al. (1995)



Таблица 1. Интензивност на CO₂ асимилацията и транспирацията в листата на *Lactuca sativa var. capitata*
Table 1. The intensity of assimilation of CO₂ and transpiration in the leaves of *Lactuca sativa var. capitata*

Dose of NaCl [mM]	Dose of K		Mean
	Full Hoagland's medium	Full Hoagland's medium + 20%K	
Assimilation of CO ₂ [$\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$]			
Control	2.05a	2.15a	2.10b
68	2.12a	2.58a	2.35b
136	1.21b	2.60a	1.90a
Mean	1.79a	2.44b	
Transpiration [$\text{mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$]			
Control	0.37a	0.51b	0.44a
68	0.38a	0.38ab	0.38a
136	0.34a	0.30a	0.36a
Mean	0.36a	0.39a	
Index of water use in the photosynthesis (ωF) [$\text{mmol}\cdot\text{mol}^{-1}$]			
Control	5.54b	4.21a	4.77a
68	5.58b	6.79b	6.18a
136	3.56a	8.67b	5.28a
Mean	4.97a	6.26a	

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

Таблица 2. Съдържание на хлорофил a, b, a+b и каротиноиди в листата на *Lactuca sativa var. capitata* [$\text{mg}\cdot\text{g}^{-1}$ FW]
Table 2. Content of chlorophyll a, b, a+b and carotenoids in leaves of *Lactuca sativa var. capitata* [$\text{mg}\cdot\text{g}^{-1}$ FW]

Dose of NaCl [mM]	Dose of K		Mean
	Full Hoagland's medium	Full Hoagland's medium + 20%K	
Chlorophyll a			
Control	0.586a	0.597a	0.591a
68	0.582a	0.618ab	0.600ab
136	0.634ab	0.698b	0.666b
Mean	0.600a	0.638a	
Chlorophyll b			
Control	0.228a	0.229a	0.228a
68	0.246a	0.238a	0.242a
136	0.224a	0.268a	0.246a
Mean	0.233a	0.245a	
Chlorophyll a+b			
Control	0.814a	0.826a	0.820a
68	0.828a	0.856a	0.842ab
136	0.878a	0.966a	0.922b
Mean	0.840a	0.883a	
Carotenoids			
Control	0.309a	0.400a	0.354a
68	0.318a	0.339a	0.328a
136	0.343a	0.367a	0.346a
Mean	0.323a	0.369a	

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

and Sultana et al. (1999). In the carried out studies it was observed that the content of chlorophyll a, b and total in leaves of lettuce was growing along with the increase in the concentration of NaCl in the hydroponic growing media. This relationship was the most distinct in the case of chlorophyll a+b. The statistical analysis showed significant differences between the content of these dyes in leaves of the control plants and the plants growing in the cultures of the concentration of 136 mM NaCl (Table 2).

The additional nutrition of plants with potassium caused, independently of the salinity level of the media, an increase in the content of all the forms of chlorophyll in the leaves of lettuce. The largest growth was recorded in the case of the content of chlorophyll a in leaves of the plants growing in hydroponic media of the concentration of 68 mM NaCl and in the case of total chlorophyll in leaves of the plants from the cultures of the largest salinity. In the research conducted by Kalaji and Rutkowska (2004) no distinct changes in the absolute content of chlorophyll were noticed in seedlings of maize treated with NaCl of the concentration of 60 mM NaCl as compared to the control. Whereas, NaCl at the concentrations of 120 and 180 mM caused a significant decrease in chlorophyll in leaves.

The content of carotenoids in leaves of lettuce growing under differentiated conditions of salinity was approximate. No significant effect of additional nourishment of plants with potassium on the content of these dyes was observed.

CONCLUSIONS

1. The addition of NaCl at the concentration of 68 mM did not cause any changes in the intensity of photosynthesis in lettuce.
2. A significant decrease in the intensity of CO₂ was observed in plants growing in the medium of the concentration of 136 mmol.dm⁻³, with no additional nutrition with potassium.
3. An increase in salinity, in the hydroponic growing media enriched with 20% of potassium, did not cause a decrease in photosynthesis.
4. A decrease in the intensity of transpiration and an increase in the index of water use effectiveness in photosynthesis were recorded along with an increase in the concentration of NaCl in plants additionally nourished with potassium.
5. The addition of 20% of potassium caused, independently of the level of salinity of the media, an increase in the content of all the forms of chlorophyll in leaves of the studied plant.

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