Katarzyna Kowalczyk[1]*, Monika Niedzińska[1], Jarosław L. Przybył[1], Agata Metera[1], Magdalena D. Cetner[2]

Warsaw University of Life Sciences – SGGW
Faculty of Horticulture and Landscape Architecture
[1] **Department of Vegetable and Medicinal Plants**
[2] **Department of Plant Physiology**

Nowoursynowska 159, Warsaw, Poland
http://krwil.sggw.pl
* ✉ katarzyna_kowalczyk@sggw.pl

The effect of nutrient solution on yield, its quality and the reaction of photosynthetic apparatus of endive (*Cichorium endivia* L.) grown in hydroponics

INTRODUCTION

In recent years, endive (*Cichorium endivia* L.) which belongs to *Asteraceae* family, has become a valuable leafy vegetable used along with lettuce for various kinds of salads. Endive is valued in dietetics for antioxidant properties of their components. The problem with *Asteraceae* family is a tendency to high nitrogen accumulation in edible part of plants. It is known that the quality of some vegetables may be improved by for example changing the composition of nutrient solution in hydroponic culture or increasing the salinity of substrate. Each plant has a salinity tolerance limit above which yield is reduced in linear fashion, which is called the salinity threshold. Obtaining vegetables with high biological value includes many cultivation factors, such as cultivar, microclimatic conditions, soil and rational fertilization.

The aim of this study was to evaluate the effect of of nutrient solution on yield and its quality and reaction of photosynthetic apparatus of endive growing in hydroponics during spring and autumn cultivating cycle.

MATERIAL AND METHODS

The experiments were carried out in a greenhouse with the controlled microclimate in the years 2012 and 2013 at Warsaw University of Life Sciences. Four endive cultivars obtained from Rijk Zwaan, three crispum leaf cultivars: 'Galanti', 'Perceval' and 'Barundi' and one latifolium leaf cultivar (escarole chicory) – 'Kethel' were cultivated according to the hydroponic system NFT. Plants at the stage of seedlings were transplanted to the NFT growing system under the control fertigation conditions. The control nutrient solution contained the following amounts of macro- and microelements in mg×dm^{-3}: N 140; P 50; K 300; Mg 40; Ca 200; Fe 2; Mn 0.6; B 0.3; Cu 0.15; Zn 0.3; Mo 0.05. pH of the nutrient solution was at the level of 6.7 and EC was 2.8 mS×cm^{-1}. Last week before the harvest, one third part of the plants were being treated only by water (combination identified in the article as H_2O) and the next one third part were feeded with about 8 mS×cm^{-1} of nutrient solution EC which was obtained by adding of 30 mmol NaCl to the control fertigation solution (combination identified in the article as NaCl) and the last part of plants was the control with plants supplied with control nutrient solution. The experiment was conducted in two cultivation cycles – spring and autumn. The experiment was established in random design, with three replications and 15 plants in each. After 7 days of stress conditions the plants were harvested and examined for the dry matter content and chemical quality attributes of endive. Dry matter was determined by drying leaf samples in an oven at 105 °C. In endive leaves the content of ascorbic acid (AA) was determined using the Tillmans' method, the content of total soluble solids (TSS) using the digital refractometer. Nitrate (No3) content was determined spectrophotometrically, the content of P with the colorimetric test and the content of K and Ca with the flame method. Carotenoids and chlorophylls were determined with HPLC. The measurement of chlorophyll fluorescence was performed at light with the fluorimeter FMS-2 (Hansatech Instruments, England). Then, after a 30 min dark adaptation, the plants were checked with PocketPEA for maximal efficiency of photosynthetic apparatus. The content of chlorophyll (SPAD index) was estimated by a portable equipment, SPAD-502 (Minolta, Japan), in the same leaves in which the parameter of fluorescence was measured. Some physiological parameters, such as chlorophyll fluorescence was measured in the middle of leaf, for 3 plants of each combination.

Statistical analysis was performed using two-way and tree-way analysis of variance. Detailed comparison of means was performed by the Tukey's test at the significance level of α=0.05.

RESULTS

Endive plants cultivated during a spring cycle gained higher mass of rosettes (Fig.1). Plants from vernal cultivation cycle contained less dry mass, sugar extract and phosphorus but higher amounts of ascorbic acid, nitrates and calcium comparing to the plants cultivated in autumn (Tab. 1). Changing the nutrient seven days before the harvest contributed to the reduction of yield and with effect was particularly noticeable in spring. For H_2O combination, the mass of plants decreased by average 30% for spring cultivation cycle and the decrease reached ca 11% when NaCl was added to the nutrient solution. In plants cultivated during autumn the values were 11% and 14% respectively (Fig. 1). The use of water instead of nutrient significantly (by 50%) reduced the accumulation of nitrates in endive leaves (Fig. 2). Supplementing the nutrient solution with NaCl did not result in the decrease in nitrates content of endive leaves. A substituting nutrient solution with water was also responsible for the reduction of SPAD index and decreased content of carotenoids (Fig. 3). Plants treated before the harvest with water showed also lower amounts of phosphorus and potassium but higher amounts of calcium compared to control plants (Tab. 1). Adding of 30 mmol×l^{-1} NaCl to the control fertigation solution resulted in the increase in the content of dry mass and the decrease in contents of calcium and carotenoids for plants from autumnal cultivation cycle. An additive of NaCl was responsible for the increased SPAD index of endive leaves and higher amounts of sugar extract and phosphorus irrespectively the term of cultivation (Tab. 1, Fig. 3). Despite the observed differences in the plant growth rate and biological value of endive upon the use of water instead of nutrient solution or its supplementation with NaCl at the 7th day prior the harvest, there were no substantial changes observed for the performance of endive's photosystem II (Tab. 2). All the presented parameters of photosynthetic apparatus efficiency in endive had lower values for plants cultivated in spring than in autumn (Tab. 2). No significant differences were found in nitrates accumulation between the studied cultivars, under NFT cultivation conditions (Tab. 2). Differences between cultivars referred to the average mass of endive rosette, contents of dry mass, ascorbic acid, sugar extract and chlorophyll. The obtained results corroborate the high quality of the plants showing high contents of carotenoids and chlorophylls and endive as such a plant seems worth the promotion of in a daily diet.

Table 1. Effect of the endive treatment on the selected quality attributes of plants grown in spring and autumn cycle

Treatment	Dry matter (%)	AA (mg·100 g^{-1} fr.w.)	TSS (%)	P	K	Ca
				(mg·100 g^{-1} fr.w.)		
Spring						
Control	6.1 ns	31.0 b*	2.9 b	7.1 b	502.6 a	38.3 b
H_2O	6.4 ns	34.4 a	3.0 b	3.6 c	386.9 b	48.1 a
NaCl	6.6 ns	34.3 a	3.2 a	12.3 a	507.2 a	38.1 b
Mean	**6.4**	**33.2**	**3.0**	**7.7**	**465.6**	**41.5**
Autumn						
Control	7.1 b*	30.3 b	4.4 b	16.5 b	512.4 a	22.6 b
H_2O	6.9 b	32.4 a	4.5 b	9.3 c	487.5 b	26.8 a
NaCl	7.5 a	31.9 ab	5.0 a	22.5 a	512.2 a	13.3 c
Mean	**7.2**	**31.5**	**4.6**	**16.1**	**504.0**	**20.9**

* Note: Mean values for factors which do not differ according to Tukey's HSD test at P=0.05 are marked with the same letters; ns, non-significant

Table 2. Effect of the cultivar on the selected quality attributes of endive plants grown in NFT system

Content of		Cultivar			
		'Galanti'	'Perceval'	'Kethel'	'Barundi'
FreshWeight of plant (FW) (g)		204.2 c*	282.2 b	351.4 a	294.2 b
Dry matter (DM) (%)		7.3 a	6.8 b	6.3 c	6.7 c
TSS (%)		4.3 a	3.8 b	3.3 c	4.0 b
AA	mg·100 g^{-1} FW	34.3 a	32.3 ab	31.9 b	31.1 b
NO_3		264.8 ns	298.3 ns	261.2 ns	240.9 ns
P		13.5 ns	11.8 ns	9.9 ns	12.4 ns
K		510.2 ns	471.6 ns	475.7 ns	481.7 ns
Ca		26.3 b	36.1 a	35.0 a	27.4 b
Chlorophyll (SPAM)		32.7 a	31.7 a	27.6 b	32.5 a
Neoxanthin	mg·100 g^{-1} DM	30.9 ns	49.9 ns	41.6 ns	43.8 ns
Violaxanthin		0.4 b	0.6 ab	0.8 a	0.6 ab
Lutein		44.7 ns	77.5 ns	61.2 ns	64.3 ns
Zeaxanthin		18.0 ns	25.0 ns	24.4 ns	20.8 ns
Chlorophyll a		29.4 b	62.6 a	45.9 ab	49.7 ab
Chlorophyll b		15.3 b	27.7 a	20.5 ab	21.9 ab
β-carotene		0.4 ns	0.4 ns	0.4 ns	0.6 ns
α-carotene		nd	nd	nd	nd

* Note: Mean values for factor which do not differ according to Tukey's HSD test at p=0.05 are marked with the same letters; ns, non-significant, nd, below the level of detection

Table 3. Effect of endive plants treatment with H2O and NaCl, on the chlorophyll fluorescence of plants grown in spring and autumn cycle. Measurement conditions: at light (Fs, FM', FV'/FM'), after a 30 min dark adaptation, (FV/FM and PI)

Treatment	Fs	Fm'	Fv'/Fm'	Fv/Fm	PI
Spring					
Control	203.7 a*	596.3 b	0.638 ns	0.82 ns	2.18 ns
H_2O	170.4 b	596.4 b	0.710 ns	0.82 ns	2.53 ns
NaCl	200.8 ab	708.5 a	0.716 ns	0.82 ns	2.53 ns
Autumn					
Control	560.0 ns	2364.1 ab	0.763 b	0.83 ns	2.81 ns
H_2O	542.1 ns	2264.1 b	0.761 b	0.83 ns	2.91 ns
NaCl	546.3 ns	2448.2 a	0.777 a	0.82 ns	2.96 ns

* See Table 1

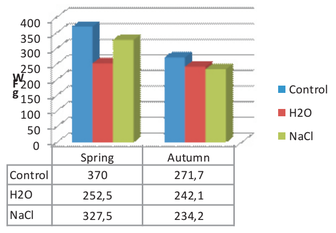

Figure 1. Effect of the endive treatment on the marketable fresh weight (FW) of plant

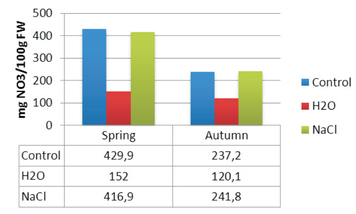

Figure 2. Effect of the endive treatment on the accumulation of nitrates in endive leaves

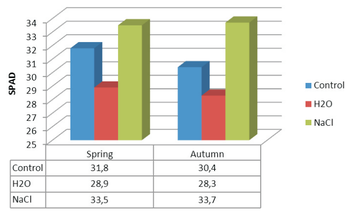

Figure 3. Effect of the endive treatment on the SPAD index of endive leaves

CONCLUSIONS

1. Endive plants cultivated in NFT system were characterized by high biological value dependent on the cultivar and cultivation conditions.
2. The highest amounts of carotenoids in the cultivars of endive investigated were found for lutein (30%), chlorophyll a (24 %), chlorophyll b (11%), neoxanthine (22%), zeoxanthine (10%) and the remaining carotenoids were β-caroten, violaxanthine and α-carotene in trace amounts.
3. Endive plants cultivated during a spring cycle gained higher mass of rosettes. Plants from vernal cultivation cycle contained less dry mass, sugar extract and phosphorus but higher amounts of ascorbic acid, nitrates and calcium comparing to the plants cultivated in autumn.
4. The use of water instead of nutrient solution seven days before the harvest significantly (by over 50%) reduced the accumulation of nitrates in endive leaves
5. Adding of 30 mmol×l^{-1} NaCl to the control fertigation solution, seven days before the harvest, resulted in the increased dry mass, SPAD index of leaves the content of sugar extract and phosphorus.
6. The endive was found to tolerate the saline solution applied during the experiment.

The participation in the Conference is financed from EU "FP7 - Capacities" REGPOT project 2011-1-286093-WULS Plant Health

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