Katarzyna Kowalczyk*, Małgorzata Mirgos, Katarzyna Bączek, Monika Niedzińska, Marek Gajewski

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

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

Effect of different growing media in hydroponic culture on the yield and biological quality of the lettuce (*Lactuca sativa* L. *var. capitata*)

INTRODUCTION

Due to a high content of biologically active compounds, the lettuce should be permanently present in our diet. A desired quality of lettuce crop may be achieved under controlled conditions by engaging different substrates and cultivation methods adjusted to geographic location of the production. Lettuce is traditionally cultivated in soil but recently, alternative soilless cultivation techniques have been considered. Although the cultivation in soil is inexpensive, it brings about some risks. Soilless systems are suited to produce with short culture cycles. Plant nutrition can be better controlled in these systems and soil contamination is avoided. A nowadays market demands for high quality vegetables, therefore the increased interest of lettuce producers' in hydroponics. Lettuce is known to contain phytochemicals, including vitamins, carotenoids and other antioxidants. A number of factors, including plant genotype and environmental growing conditions, can impact the production and quality of lettuce. Lettuce is among the vegetable species most susceptible to nitrate accumulation. Light intensity, nitrogen fertilization, as well as genetic factors and cultivation system are according to many researchers key factors affecting nitrate accumulation in vegetables.

The aim of this study was to determine the effect of different growing media in hydroponic growing systems on the yield and biological quality of the lettuce.

MATERIAL AND METHODS

The experiments were carried out in a greenhouse with the controlled microclimate conditions at Warsaw University of Life Sciences. In the study two butterhead lettuce cultivars 'Omega' and 'Gardia' (Rijk Zwaaan) and one of 'batavia' lettuce cultivar 'Aficion' (Rijk Zwaaan) were included. The plants were cultivated in the spring cycle in tree hydroponic methods on different growing media. Organic medium - coconut fiber (manufacturer: Ceres Intern.) and mineral medium – rockwool (Grodan BV, Master type) were compared to 'nutrient film technique' growing system (NFT). The experiment was established in random design, with three replications and 40 plants in each. The four-week-old lettuce seedlings were replanted on the both rockwool and coconut fiber growing slabs, 5 plants on each. Slabs dimensions in all cases were 100 × 15 × 7.5 cm (length x width x height). The nutrient media were applied to plants via 3 individual droppers for each growing slab. In NFT, the seedlings were planted in net pots which were then placed into a cultivation gutter with a 20 cm distance. Fertigation for plants contained 140 mg×dm$_{-3}$ of nitrogen in the form of ions NO_{3-}. The nutrient solution in 1 dm3 contained the following amounts of elements in mg: P – 50, K – 300, Mg – 40, Ca – 200, Fe – 2, Mn – 0.6, B – 0.3, Cu – 0.15, Zn – 0.3 and Mo – 0.05. pH of the nutrient solution was kept at the level of 6.7 and EC 2.8 mS×cm^{-1}. At about 5 days before harvest, the nutrient solution was replaced to water to reduce nitrate concentration in the leaves of lettuce. During this period plants growing in all combinations were being treated only by water (combination identified in the article as H_2O) to harvest time. Marketable yield of the plants grown in the experiment was compared. The plants were examined for the dry matter content and chemical quality attributes of lettuce. In lettuce leaves the content of total soluble solids (TSS) using the digital refractometer were analyzed and 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. The content of chlorophyll (SPAD index) was estimated by a portable equipment, SPAD-502 (Minolta, Japan). Colour parameters of the leaves were determined with HunterLab XE colorimeter (HunterLab, USA), using CIE L*a*b* system, where L* describes lightness (ranged from 0 to 100 units), a* - colour intensity in red (+) or green (–) and b* – colour intensity in yellow (+) or blue (–). Measurement conditions: D65, Observer = 100, measurement diameter 8 cm. The measurements were done on upper surface of three leaves from each experimental object. Hue angle value (Ho) of the florets was calculated according to the formula: Ho (radians) = atan(b*/a*).

The data were analyzed using the ANOVA analysis of variance procedure and significant differences between treatments were determined using the Tukey's test, at the significance level of α=0.05.

RESULTS

The results indicate a significant influence of the substrate and the method of cultivation as well as cultivars on the yield and quality of lettuce grown under cover. Batavia lettuce cultivar 'Aficion' was characterized by lower plant mass as compared to the two butterhead lettuce cultivars. Each of the studied cultivars produced heads or rosettes, in the case of 'Aficion', of higher mass comparing to plants cultivated in rockwool or coconut fiber (Fig. 1). Yielding of all the investigated cultivars for rockwool or coconut fiber was similar (Fig. 1). The lettuce from NFT cultivation system accumulated more nitrates, however, the differences appeared statistically insignificant (Tab. 1). The higher rate of nitrate accumulation for NFT than for rockwool or coconut fiber particularly referred to cultivars 'Gardia' and 'Aficion' (Tab. 1). Replacing the nutrient solution with water five days before the harvest, effectively decreased the level of nitrates in lettuce. The reduction was 50% for the plants cultivated in NFT, 30% for the plants cultivated in coconut fiber whereas the effect was the lowest for rockwool (Fig. 2). The studies conducted showed a significant effect of the cultivar on nitrate accumulation rate in lettuce leaves. 'Omega' was the cultivar which plants accumulated highest amounts of nitrates irrespectively the cultivation method (Tab. 1). 'Omega' plants contained similar amounts of dry mass, ranging from 3.0 to 3.2% irrespectively the growing medium. Unlike in the case of 'Gardia' and 'Aficion' observed to produce more dry mass when grown in rockwool or NFT, rather than in coconut fiber. Moreover, 'batavia' lettuce cultivar 'Aficion' showed the highest dry matter content, 4.2% on average, comparing to both butterhead lettuce cultivars. The content of sugar extract was the highest for the plants grown in coconut fiber as compared to rockwool or NFT, with the maximal content noted for 'Aficion' and the minimal for 'Omega' (Tab. 1). Comparative analysis revealed no correlation between media the lettuce was grown in and chlorophyll content (SPAD), while differences were noted between cultivars. The highest chlorophyll index showed 'Gardia'. (Tabs. 2). From colour CIE parameters of the leaves, L* parameter (lightess) was not influenced by kind of substrate, but significantly influenced by a cultivar. 'Omega' showed higher L* value than 'Aficion'. Significate interaction between a cultivar and a substrate on L* parameter was also noted. Plants grown on coconut fiber showed different relations as regards this parameter than plants grown in rockwool or in NFT. Other CIE colour parameters (a* and b*) were not affected by a substrate or a cultivar, but 'Afiction' showed a tendency to the highest b* parameter value (yellowness). This corresponds with the highest content of carotenoids in the leaves of this cultivar. Ho (hue angle) was significantly affected by a cultivar. 'Gardia' showed the highest Ho value, so its leaves were characterized by the most intensive green colour. The plants grown on rockwool or in NFT showed similar contents of chlorophyll a, chlorophyll b, chlorophyll a+b, or carotenoids. The lettuce cultivated in coconut fiber was found to have significantly lower amounts of chlorophyll a and chlorophyll b but higher amounts of carotenoids comparing to plants from other growing media. Considering the cultivars studied, 'Aficion' was the richest in plant pigments (Tab. 2). The study supported no evidence for the effect of cultivation method or the cultivar on the content of potassium in lettuce leaves. There was however a higher calcium content in plants that were grown in NFT than in rockwool or coconut fiber (Tab. 2).

Table 1. Effect of the growing media and cultivar on the selected quality attributes of lettuce plants

Growing media	Cultivar	Dry matter (%)	TSS (%)	Chlorophyll index (SPAM)	NO3	P	K	Ca
					(mg×100 g-1 fr.w.)			
Rockwool	'Omega'	3.1	1.9	19.0	312.9	20.4	370.2	21.0
	'Gardia'	3.9	2.2	27.1	224.4	16.7	332.6	22.8
	'Aficion'	4.7	2.1	19.6	225.8	19.6	359.7	16.4
Mean		**3.9**	**2.1**	**21.9**	**254.3**	**18.9**	**354.2**	**20.0**
Coconut fiber	'Omega'	3.0	2.1	20.5	350.4	18.9	393.0	23.1
	'Gardia'	2.9	2.9	24.1	281.6	17.4	365.7	15.3
	'Aficion'	3.8	3.5	24.2	241.5	22.1	363.0	14.6
Mean		**3.2**	**2.8**	**22.9**	**291.2**	**19.5**	**373.9**	**17.7**
NFT	'Omega'	3.5	2.0	14.9	346.2	17.2	385.7	33.4
	'Gardia'	3.7	2.2	23.7	290.0	16.2	397.2	23.2
	'Aficion'	4.2	2.1	19.6	282.7	20.8	417.3	24.1
Mean		**3.8**	**2.1**	**19.4**	**306.3**	**18.0**	**400.1**	**26.9**
Mean	'Omega'	3.2	2.0	18.1	336.5	18.8	383.0	25.8
	'Gardia'	3.5	2.4	25.0	265.4	16.7	365.2	20.4
	'Aficion'	4.2	2.6	21.1	250.0	20.8	380.0	18.4
LSD 0.05								
Substrate		0.4	0.1	ns	ns	ns	ns	7.7
Cultivar		0.4	0.1	6.0	80.8	3.5	ns	ns
Substrate × Cultivar		0.6	0.2	ns	ns	ns	ns	ns

Table 2. Effect of the growing media and cultivar on chlorophyll and carotenoids content and CIE colour

Growing media	Cultivar	Chlorophyll a	Chlorophyll b	Chlorophyll a+b	Carote-noids	CIE Lab L	CIE Lab a*	CIE Lab b*	CIE Lab H
		(mg×g^{-1} fr.w.)							
Rockwool	'Omega'	0.20	0.08	0.28	0.46	60.0	-14.2	39.2	-1.22
	'Gardia'	0.29	0.14	0.42	0.66	53.9	-14.9	37.6	-1.19
	'Aficion'	0.54	0.36	0.89	0.60	55.4	-14.8	39.1	-1.21
Mean		**0.34**	**0.19**	**0.53**	**0.57**	**56.4**	**-14.7**	**38.6**	**-1.21**
Coconut fiber	'Omega'	0.11	0.07	0.18	0.47	58.5	-14.7	37.8	-1.20
	'Gardia'	0.07	0.06	0.13	1.26	56.5	-14.5	37.5	-1.20
	'Aficion'	0.26	0.13	0.39	1.48	63.2	-15.1	36.0	-1.25
Mean		**0.15**	**0.09**	**0.23**	**1.07**	**59.4**	**-14.7**	**40.4**	**-1.22**
NFT	'Omega'	0.24	0.15	0.39	0.45	61.6	-15.0	42.9	-1.23
	'Gardia'	0.26	0.14	0.41	0.47	54.1	-15.2	37.2	-1.18
	'Aficion'	0.45	0.25	0.71	0.78	57.2	-13.7	37.6	-1.22
Mean		**0.32**	**0.18**	**0.50**	**0.57**	**57.6**	**-14.6**	**39.2**	**-1.21**
Mean	'Omega'	0.18	0.10	0.28	0.46	60.0	-14.6	40.0	-1.22
	'Gardia'	0.21	0.11	0.32	0.80	54.8	-14.9	37.4	-1.19
	'Aficion'	0.42	0.25	0.66	0.95	58.6	-14.5	40.9	-1.23
LSD $_{0.05}$									
Substrate		0.14	0.10	0.23	0.43	ns	ns	ns	ns
Cultivar		0.14	0.10	0.23	0.43	3.0	ns	ns	0.02
Substrate x Cultivar		ns	ns	ns	ns	5.1	ns	ns	0.03

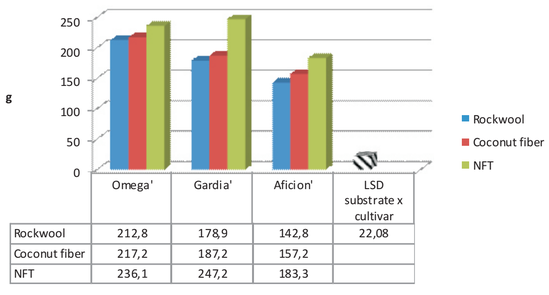

Figure 1. Effect of growing medium on the marketable fresh weight (FW) of plant depending on lettuce cultivar

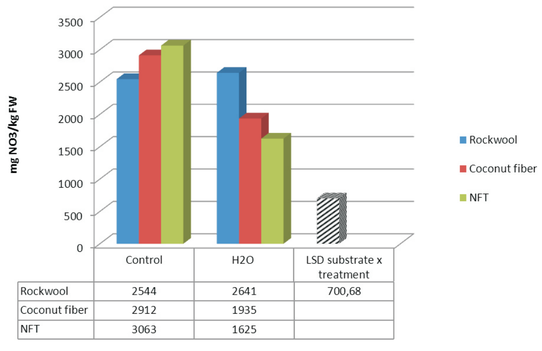

Figure 2. Effect of the growing media and the treatment plant by water on the accumulation of nitrates in lettuce leaves

CONCLUSIONS

1. The effect of growing medium and cultivar on the yield and biological quality of the lettuce in hydroponic culture was significant.
2. Lettuce plants were growing faster in NFT growing system as compared to those cultivated in rockwool or coconut fiber
3. Replacing nutrient solution with water five days before the harvest decreased the content of nitrates most effectively (by 50%) for the lettuce cultivated in NFT system.
4. Nitrate accumulation rate was the highest for the cultivar 'Omega', irrespectively the cultivation method.
5. Batavia' lettuce cultivar 'Aficion', was characterized by a lower harvest, but the highest contents of dry mass, sugar extract, chlorophylls and carotenoids in relation to the two butterhead lettuce cultivars studied.
6. 'Gardia' was characterized by the most intensive green colour of leaves.

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