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THE INFLUENCE OF DIVERSIFIED NITROGEN AND LIMING FERTILIZATION ON THE CHEMICAL COMPOSITION OF LETTUCE

Katarzyna Dzida, Zbigniew Jarosz, Zenia Michałojć,
Renata Nurzyńska-Wierdak
University of Life Sciences in Lublin

Abstract. Lettuce needs a properly balanced nutrition base for its proper development. During the greenhouse experiment of 2009 and 2010, the influence of the dose of nitrogen and calcium carbonate on the content of nutrients in edible parts of lettuce was examined. The sowing of the seeds of the Omega variety of lettuce took place on February 24th, on March 7th the plants were bedded out into pallets, and finally planted into pots on March 19th. The vegetables were collected on April 24th, together with leaf samples for micro- and macro-elements analysis. The results of the experiment suggest that the increase in the dose of nitrogen had a significantly positive influence on the accumulation of total N and N-NO_3 in the plant and a significantly negative effect on the content of phosphorus and potassium in lettuce leaves. The microelements uptake of the plant was largely dependent on the dose of nitrogen and calcium carbonate. The largest amount of iron and manganese was found in plants nourished with the lowest dose of nitrogen, and the highest amount of zinc and copper was found in lettuce leaves from plants nourished with the quadruple, compared to the original value, dose of nitrogen, connected with the lower dose of calcium carbonate.

Key words: *Lactuca sativa*, N dose, $CaCO_3$ dose, macroelements, microelements

INTRODUCTION

Within the *Lactuca sativa* species, we can distinguish varieties with green and red leaves. The intensiveness of their colour, degree of leaf pigmentation, mass growth and head formation rate, as well as the ability to accumulate nitrates and other nutrients, are all genetically conditioned characteristics, that can be modified by the conditions in which the plant is cultivated. In order to provide the plants with optimal conditions for

Corresponding author – Adres do korespondencji: Katarzyna Dzida, Department of Cultivation and Fertilization of Horticultural Plants, University of Life Sciences in Lublin, Leszczyńskiego 58, 20-068 Lublin, Poland, phone (+48) 81 524 71 22, e-mail: katarzyna.dzida@up.lublin.pl

growth and development, appropriately proportioned fertilization with different nutrients should be used.

Lettuce is a largely popular plant, both in Poland and in the whole world. Apart from its culinary values, it also possesses nutritional and pharmacological values. It contains vitamins, thyroid stimulating substances, anti-cancer compounds, as well as has some healing properties in cases of high blood pressure and heart diseases. The consumption of this vegetable encourages appetite and improves digestion [Stępkowska 2004].

Following elements are essential for development of highest plants: (nitrogen, phosphorus, potassium, calcium, sulphur, magnesium, chlorine, iron, zinc, manganese, copper, boron and molybdenum).

Nitrogen is the key element, decisive for crop yields of vegetable plants [Paterson and Rahn 1996]. It is used to form many of the organic compounds, like proteins, nucleic acids, chlorophyll [Kopcewicz and Lewak 2002]. In order to achieve the highest crop yields, the fertilization doses of this element are controlled, as it influences on the quality of the crops due to excessive accumulation of nitrates. It is of particular importance in case of leaf vegetables, as the nitrates tend to be accumulated in the usable parts of these plants [Jarosz and Dzida 2006]. Numerous factors influence on the nitrate content of the plant, among them the dose and the form of nitrogen fertilizer. Nitrates are not directly harmful to human beings, but during improper storage or transport they can form harmful nitrites [Skąpski and Dąbrowska 1994, Rożek 2000].

Calcium is another important element for the development of plants. The plants take calcium up in the form of the Ca^{2+} ion and its content in dry mass of the plants should average from 0.1 to 4% Ca. The weak transport of calcium through the older parts of the leaves to the apical meristem requires constant provision of the plants with that element, throughout the whole period of their vegetation. The lack of calcium leads to many physiological diseases in plants, including: the browning of the leaf edges [tip burn] [Hartz et al. 2007], blossom end rot in tomatoes and peppers, and bitter pit in apples, stunting of celery central leaves, or the browning of cabbage heads [Kopcewicz and Lewak 2002].

The aim of the experiment was to ascertain the influence of differentiated nitrogen fertilization and liming doses on the micro- and macro-element content of lettuce leaves.

MATERIALS AND METHODS

The experiment of the influence of nitrogen and liming fertilization on the chemical composition of lettuce was carried out in 2009–2010, in a greenhouse of the Department of Soil Cultivation and Horticultural Plant Fertilization in the University of Life Sciences in Lublin. The seeds of the Omega F_1 variety were sown on February 24th, bedded out to pallets on March 7th and the plantation into the pots took place on March 19th. The plants were grown in pots of the capacity of 2 dm^3 in seven replications. A replication was a pot with one plant. The experiment was established in complete randomization system. The base was transitional peat limed with calcium carbonate – accordingly in doses of 7 and 14 $g \cdot dm^{-3}$ of the medium. The following amounts of nutrients in g per 1 dm^3 substrate were applied: 0.2, 0.4, 0.6, 0.8 N in form of ammonium nitrate (34% N); 0.5 P in form of triple superphosphate (20.2% P), 0.8 K as potassium sulphate (41.5% K) and 0,5 Mg in form of magnesium sulphate (15.6% Mg). The phosphorus was applied in one dose, while nitrogen, potassium and magnesium were divided into three parts – one third before planting (19.03) and the remaining quantity double during vegetative period (01.04, 13.04). The microelements were delivered to the medium in one-off dose, before plantation, in mg per 1 dm^3: 8.0 Fe (chelate); 13.3 Cu ($CuSO_4 \cdot 5H_2O$); 5.1 Mn ($MnSO_4 \cdot H_2O$); 1.6 B (H_3BO_3); 3.7 Mo $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$); 0.74 Zn ($ZnSO_4 \cdot 7H_2O$).

After the harvest (April 24th), the plant material was dried in a temperature of 60°C and its total N content set, with use of Kjeldahl method and with use of a Kjeltec System 2002 Distilling Unit; after that the plants were digested in temperature of 550°C, and after the ashes have been cooled, they were examined with use of diluted hydrochloric acid solution in a ratio of 1:2. This solution allowed to analyse the levels of P, K, Ca, Mg, as well as Zn, Fe, Mn and Cu. Furthermore, the plant material placed in 2% solution of acetic acid was used to determine the levels of N-NH_4, N-NO_3. Both nitrate and ammonium nitrogen levels were measured with use of Starck modified, Bremner micro-distillation method; the phosphorus levels with use of ammonium meta-vanadium with use of colorimetry (Nicolet Evolution 300 Spectrophotometer). The K, Ca, Mg and Zn, Fe, Mn and Cu levels were all measured with use of AAS spectrophotometry method (Analyst 300 Perkin Elmer). The obtained results were subject to a statistical analysis of their variance, by setting the smallest significant difference (LSD), based upon the Tukey's test, at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The analysis of the nutrient content in lettuce leaves shows a number of interesting dependencies (tab. 1 and 2). The total nitrogen content was in the range between 4.05 and 5.67% of dry mass, depending on the kind of fertilization used. Applying the double dose of the calcium carbonate, didn't influence on taking nitrogen by plants; the content of this element in these objects was on the increased level. The concentration of this element was raised with the increasing dose of nitrogen, which is consistent with the results of our previous experiments [Jarosz and Dzida 2006]. Carranca et al. [2001], in their experiments with spinach and Kalisz [2007] experimenting with napa cabbage, also obtained the rise general levels of nitrogen after use of rising doses of nitrogen fertilizer.

The N-NO_3 content changed under the influence of differentiated doses of ammonium nitrate. This dependence is already well known. After the use of the fourth dose of nitrogen, the plants contained the largest amount of nitrates. Nurzyńska-Wierdak [2006], analysing the influence of different kinds of nitrous fertilizers on the quality of rocket crops, obtained the highest concentration of nitrates in plants nourished with calcium nitrate, while lower concentration of these compounds were found in plants nourished with urea and ammonium sulphate. The concentration of this form of nitrogen in the superficial parts of the plants depends not only on the used dose of nitrogen, but

Table 1. Effect of nitrogen and $CaCO_3$ fertilization on macroelements content in lettuce (mean from 2009–2010)
Tabela 1. Wpływ nawożenia azotem i $CaCO_3$ na zawartość makroelementów w sałacie (średnia z 2009–2010)

Dose – Dawka g·dm^{-3}		% d.m. – s.m.					
N	$CaCO_3$	N-og N-total	$N\text{-}NO_3$	P	K	Ca	Mg
0.2	7.0	4.05	0.42	0.80	6.38	0.94	0.49
0.4	7.0	5.01	1.11	0.76	5.95	0.89	0.48
0.6	7.0	5.23	1.29	0.63	5.54	0.89	0.48
0.8	7.0	5.61	1.39	0.68	5.26	0.86	0.46
$\bar{x}$		4.98	1.05	0.71	5.78	0.89	0.48
0.2	14.0	4.17	0.37	0.73	6.14	0.72	0.38
0.4	14.0	4.93	0.83	0.63	5.53	0.79	0.41
0.6	14.0	5.22	1.15	0.65	5.19	0.91	0.44
0.8	14.0	5.67	1.36	0.65	4.47	0.80	0.40
$\bar{x}$		5.00	0.93	0.67	5.33	0.81	0.41
$\bar{x}$	0.2	4.11	0.40	0.76	6.25	0.83	0.43
	0.4	4.97	0.97	0.70	5.74	0.84	0.45
	0.6	5.23	1.22	0.64	5.36	0.90	0.46
	0.8	5.64	1.37	0.66	4.86	0.83	0.43
$LSD_{\alpha = 0,05}$ – $NIR_{\alpha = 0,05}$							
N Dose – Dawka		0.39	0.09	0.11	0.55	n.s. – r.n.	n.s. – r.n.
$CaCO_3$ Dose – Dawka		n.s. – r.n.	0.05	n.s. – r.n.	0.29	0.07	0.03
N Dose – Dawka × $CaCO_3$ Dose – Dawka		n.s. – r.n.	n.s. – r.n.	n.s. – r.n.	n.s. –r .n.	n.s. – r.n.	n.s. – r.n.

also on the form in which the nitrogen was provided. Sady et al. [1995] and Kozik [2006] indicated the more beneficial reduced forms of nitrous fertilizer. The degree of accumulation of nitrates in vegetables is also influenced by the type of soil, its pH value, humidity and insolation [Parks et al. 2008, Rutkowska 1996]. Wojciechowska et al. [2000] also underlined the fact, that the nitrate content of the plants also depends on their usable part. Rożek [2000] and Wojciechowska [2005], based on the experiments they have conducted, proved that the ability to accumulate (V) nitrates in cultivated plants, can be genetically determined and forms a one of the characteristics of a given species or variety of vegetable. Fontes et al. [1997], in tests with lettuce, reported that maximum yields were achieved at the content of 6361 mg $N\text{-}NO_3$ kg DM.

The concentration of nitrates during our experiment was also dependent on the dose of calcium carbonate. The use of higher dose of $CaCO_3$ resulted in smaller amount of nitrates in the lettuce. Kowalska [2004], while analysing the influence of the calcium carbonate dose on the nitrate content of spinach leaves, came to a completely different result, in that the rise of the dose of this fertilizer caused the accumulation of nitrates to rise.

The amount of nitrogen provided to the plants influences not only on the level of nitrates, but also the content of phosphorus and potassium.

No significant differences were found in phosphorus levels, after use of different levels of calcium carbonate. A tendency of reducing the concentration of phosphorus in plants was prominent under the influence of the increased dose of nitrogen.

Table 2. Effect of nitrogen and $CaCO_3$ fertilization on microelements content in lettuce (mean from 2009–2010)
Tabela 2. Wpływ nawożenia azotem i $CaCO_3$ na zawartość mikroelementów w sałacie (średnia z 2009–2010)

Dose – Dawka $g \cdot dm^{-3}$		mg·kg^{-1} d.m. – s.m.			
N	$CaCO_3$	Zn	Fe	Mn	Cu
0.2	7.0	136.75	148.05	123.90	9.55
0.4	7.0	122.15	120.95	74.25	7.90
0.6	7.0	122.95	131.05	80.75	7.49
0.8	7.0	144.05	137.45	88.75	10.98
$\bar{x}$		131.48	134.38	91.91	8.97
0.2	14.0	117.15	122.05	94.55	6.63
0.4	14.0	108.35	110.45	76.05	9.25
0.6	14.0	104.35	96.95	76.80	8.45
0.8	14.0	121.90	97.20	98.15	5.58
$\bar{x}$		112.94	106.66	86.39	7.48
$\bar{x}$	0.2	126.95	135.05	109.23	8.09
	0.4	115.25	115.70	75.15	8.57
	0.6	113.65	114.00	78.78	7.97
	0.8	132.98	117.33	93.45	8.28
LSD $_{\alpha = 0,05}$ – NIR$_{\alpha = 0,05}$					
N Dose – Dawka		8.49	7.46	2.07	n.s. – r.n.
$CaCO_3$ Dose – Dawka		4.32	3.79	1.05	0.47
N Dose – Dawka × $CaCO_3$ Dose – Dawka		n.s. – r.n.	13.05	3.63	1.63

The potassium content of lettuce leaves averaged 5.56% of dry mass, and was significantly dependent on the doses of nitrogen and calcium carbonate used. Lettuce from the objects with lower $CaCO_3$ dose was characterized by higher concentration of this element, when compared to objects where the higher dose of this fertilizer was used. The increasing doses of nitrogen also caused the decreasing of potassium concentration in plants. After the examinations of the influence of differentiated methods of nitrous-potassium fertilization, Jarosz and Dzida [2006] observed a similar dependency in leaves of lettuce, consisting in the negative influence of larger nitrogen doses on the potassium content of the plants.

No significant influence of the amount of used nitrogen on the contents of calcium and magnesium in the plants was found. The use of doubled dose of $CaCO_3$ did not bring about distinct changes in the accumulation of calcium in the plants, the lettuce from objects treated with the single dose contained 0.89% in dry mass and the lettuce from objects treated with the double dose – 0.81%. Li et al. [2010], using three levels of Ca and Mg fertilization, achieved the highest concentration of calcium in celery plants from objects where the lowest dose was used. The calcium concentration ranged from 0.72 to 0.94% of dry mass. These results can be considered as optimal for lettuce, as there was no evidence of tipburn in the plants subject to our experiment. Lettuce is highly sensitive to calcium deficiency. Nurzyński et al. [2009] also found no evidence of this plant disease in lettuce plants, although the calcium concentration in some of the objects was lower, ranging from 0.62 to 1.48 of dry mass. Brumm and Schenk [1993] claim, that other factors, such as the rate of vegetative growth and underground to aboveground parts ratio of the plants, are the cause for this disorder.

The microelement content of lettuce leaves is shown in table 2. Microelements play specific roles in metabolic processes. The microelement content of the vegetables is shaped by numerous factors, including the pH value of the soil, fertilization methods and the species and growth stage of the plants [Rogóż 2003]. Based upon our analysis we ascertained a significant influence of the used doses of nitrogen and calcium carbonate on the zinc, iron and manganese contents of lettuce leaves. The copper concentration was largely dependent on the used dose of calcium carbonate (tab. 2). The content of Zn and Cu in the tested lettuce is consistent with the content specified by Tyksińskiego [1992], while the amount of Fe and Mn in lettuce leaves is less than that reported by the author. Baran and Kołton [2009] examining influence of increasing fertilizing with nitrogen on corn salad, were able to confirm, that rising doses of nitrogen fertilizer caused the drop in copper, manganese and iron concentration in corn salad, in comparison to control plants.

CONCLUSIONS

1. The use of rising doses of nitrogen caused the increase of total nitrogen and nitrates contents in the superficial parts of lettuce, and the fall in concentrations of potassium.
2. Leaves of lettuce fertilized with double dose of calcium carbonate accumulated less nitrates, phosphorus, potassium, calcium and magnesium, when compared with the plants fertilized with a single dose.
3. Significantly lower amounts of zinc, iron, manganese and copper were found in lettuce after use of the higher dose of calcium carbonate.
4. No univocal effect of different nitrogen doses on the content of Zn, Fe, Mn, Cu in lettuce leaves was observed.

REFERENCES

Baran A., Kołton A., 2009. Wpływ zróżnicowanego nawożenia azotem na zawartość mikroelementów w roszponce warzywnej (*Valerianella locusta* (L.) Latter.). Zesz. Probl. Post. Nauk Roln. 541, 15–22.

Brumm I., Schenk M., 1993. Influence of nitrogen supply on the occurrence of calcium deficiency in field grown lettuce. Acta Hort. 339, 125–136.

Carranca C., Soares da Silva A., Fernandes M., Varela J., 2001. ^{15}N Fertilizer Use Efficiency by Spinach Grown under Portuguese Field Conditions. Acta Hort. 563, 67–72.

Fontes P.C.R., Pereira P.R.G., Conde R.M., 1997. Critical chlorophyll, total nitrogen, and nitrate&nitrogen in leaves associated to maximum lettuce yield. J. Plant Nutr. 20 (9), 1061–1068.

Hartz T.K., Johnstone P.R., Smith R.F., Cahn M.D., 2007. Soil calcium status unrelated to tipburn of romaine lettuce. Hort. Science 42 (7), 1681–1684.

Jarosz Z., Dzida K., 2006. Wpływ zróżnicowanego nawożenia azotowo-potasowego na plonowanie i skład chemiczny sałaty. Acta Agrophysica, 7(3), 591–597.

Kalisz A., 2007. Wpływ zróżnicowanych dawek azotu na plonowanie i wartość odżywczą kapusty pekińskiej. Roczniki AR w Poznaniu 383, 511–515.

Kopcewicz J., Lewak S., 2002. Fizjologia roślin. Wyd. Nauk. PWN. Warszawa.

Kowalska I., 2004. Zawartość wybranych składników w szpinaku (*Spinacia oleraceae* L.) uprawianym przy zróżnicowanej zawartości wapnia. Roczniki AR w Poznaniu 360, 105–110.

Kozik E., 2006. Wpływ terminu zbioru oraz nawożenia azotem i potasem na zawartość azotanów w sałacie uprawianej w szklarni. Acta Agrophysica, 7(3), 633–642.

Li Y., Wang T., Li J., Ao Y. „2010. Effect of phosphorus on celery growth and nutrient uptake under different calcium and magnesium levels in substrate culture. Hort Sci.(Prague) 37, 99–108.

Nurzyńska-Wierdak R., 2006. The effect of nitrogen fertilization on field and chemical composition of garden rocket (*Eruca sativa* Mill.) in autumn cultivation. Acta Sci. Pol., Hortorum Cultus 5(1), 53–63.

Nurzyński J., Dzida K., Nowak L. 2009. Plonowanie i skład chemiczny sałaty w zależności od nawożenia azotowego i wapnowania. Acta Agrophysica 14(3), 683–689.

Parks S.E., Huett D.O., Campbell L.C., Spohr L.J., 2008. Nitrate and nitrite in Australian leafy vegetables. J. Agric. Res., 59 (7), 632–638.

Paterson C.D., Rahn C.R., 1996. The nitrogen contribution of lettuce crop residues in intensive vegetable rotations. Acta Hort. 428, 105–114.

Rogóż A., 2003. Właściwości fizykochemiczne gleb i zawartość pierwiastków śladowych w uprawianych warzywach. Cz. II Zawartość miedzi, cynku oraz manganu w warzywach. Zesz. Probl. Post. Nauk Roln. 471, 29–34

Rożek S., 2000. Czynniki wpływające na akumulację azotanów w plonie warzyw. Zesz. Nauk. AR w Krakowie, 364, 19–31.

Rutkowska G., 1996. Jeszcze o azotanach. Chłodnictwo 31 (12), 38–40.

Sady W., Rożek S., Myczkowski J., 1995. Effect of different forms of nitrogen on the quality of lettuce yield. Acta Hort., 401, 409–416.

Skąpski H., Dąbrowska B., 1994. Uprawa warzyw w polu. Wyd. SGGW Warszawa.

Stępkowska I., 2004. Porównanie działania leczniczego *Lactuca* sp. (L) (*Asteraceae*) na podstawie medycyny dawnej, ludowej i współczesnej. Post Fitoter 4: 173–177.

Tyksinski W., 1992. Reakcja salaty szklarniowej na zróżnicowane nawożenie mikroelementami. Roczn. AR Poznan, Rozpr. Nauk. 233.

Wojciechowska R., 2005. Akumulacja azotanów a jakość produktów ogrodniczych. Wyd. Coperite, Kraków, 21–27.

Wojciechowska R., Smoleń S., Przybyło J., 2000. Zawartość azotanów w różnych częściach użytkowych wybranych gatunków warzyw. Zesz. Nauk. AR. w Krakowie, ser. Sesja Naukowa, 71, 205–208.

WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA AZOTOWEGO ORAZ WAPNOWANIA NA SKŁAD MINERALNY SAŁATY

Streszczenie. Do prawidłowego wzrostu i rozwoju sałata potrzebuje odpowiednio zbilansowanego nawożenia. W doświadczeniu szklarniowym w 2009 i 2010 roku oceniano wpływ dawki azotu i węglanu wapnia na zawartość składników pokarmowych w częściach jadalnych sałaty. Siew nasion sałaty odmiany Omega wykonano 24 lutego, pikowanie do palet przeprowadzono 7 marca, a wysadzenie na miejsce stałe do doniczek nastąpiło 19 marca. Jednorazowy zbiór wykonano 24 kwietnia, pobierając próbki liści do oceny zawartości makro- i mikroelementów. Wyniki przeprowadzonych badań wskazują, że wzrost dawki azotu miał istotnie dodatni wpływ na akumulację N-ogółem i $N\text{-}NO_3$ w roślinie oraz istotnie ujemny wpływ na zawartość fosforu i potasu w częściach nadziemnych badanej rośliny. Pobieranie mikroelementów przez rośliny w istotny sposób uzależnione było od dawki azotu i węglanu wapnia. Największą ilością żelaza i manganu charakteryzowały się rośliny żywione najniższą dawką azotu. Największą ilość cynku i miedzi stwierdzono w liściach sałaty dokarmianej czterokrotnie większą dawką azotu w stosunku do dawki wyjściowej w obiektach z mniejszą dawką węglanu wapnia.

Słowa kluczowe: *Lactuca sativa*, dawka N, dawka $CaCO_3$, makroelementy, mikroelementy

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