Journal of Elementology ISSN 1644-2296

Pitura K., Michałojć Z. 2015. *Influence of nitrogen doses on the chemical composition and proportions of nutrients in selected vegetable species*. J. Elem., 20(3): 667-676. DOI: 10.5601/jelem.2015.20.1.760

INFLUENCE OF NITROGEN DOSES ON THE CHEMICAL COMPOSITION AND PROPORTIONS OF NUTRIENTS IN SELECTED VEGETABLE SPECIES

Karolina Pitura, Zenia Michałojć

Chair of Soil Cultivation and Fertilization of Horticultural Plants
University of Life Sciences in Lublin

Abstract

The experiments on celery, curly kale and lettuce reported in this paper were carried out in a greenhouse, with plants grown in 2 dm^3 pots filled with peat substrate. The trials were established in a completely randomized design. The aim was to determine the effect of increasing nitrogen doses (0.3, 0.6, 0.9, 1.2 g N dm^{-3} of substrate) on N-tot., NO_3-N, concentrations of P, K, Ca, Mg, Fe, Zn, Mn and Cu as well as ratios between these elements in three vegetable species such as curly kale, lettuce, and celery, distinguished by different degrees of sensitivity to salinity. An increase in the content of total nitrogen and NO_3-N in lettuce, curly kale and celery appeared to be parallel to the increasing doses of nitrogen, while the average total nitrogen content was similar in all the tested species, and the content of N-NO_3 in kale was about five-fold lower than in lettuce and celery. The level of nitrogen fertilization influenced the content of potassium and magnesium in lettuce as well as the content of phosphorus, potassium, calcium and magnesium in celery. The nitrogen doses significantly differentiated proportions between the nutrients in plants, mostly the K:Mg and Zn:Cu ratios. The increasing doses of nitrogen modified the content of microelements and proportions between various components in the tested plant species.

Keywords: *Lactuca sativa* L. *var. capitata, Apium graveolens* L. var. *dulce* Mill., *Brassica oleracea* L. var. *acephala*, nitrogen dose, chemical composition, nutrient proportions in plants.

Karolina Pitura, PhD, Chair of Soil Cultivation and Fertilization of Horticultural Plants University of Life Sciences in Lublin, Leszczyńskiego 58, 20-068 Lublin, Poland, phone: (81) 524 71 21, e-mail: karolina.pitura@up.pl

INTRODUCTION

The main risks due to unreasonable plant fertilization with nitrogen are the excessive accumulation of nitrates V and III as well as a higher salt concentration in the medium, both of which lead to lower yields and modifications in the chemical composition of plants. The content of nitrates V and III in vegetables depends on genetic traits of plants, soil and climatic conditions, fertilization as well as the cultivation period. Of all these factors, the highest contribution (30%) is attributed to nitrogen fertilization of plants, including the effect of both the form and dose of fertilizer (Premuzic et al. 2004, Jurgiel -Małecka, Suchorska-Orłowska 2008). Plants absorb nitrogen in the form of NH_4^+ and NO_3^-, but the concentration of NH_4^+ ions in the medium is much smaller than NO_3^-. Although NH_4^+ ions are a better nitrogen source in terms of energy, plants prefer to take up nitrate ions. Both forms of nitrogen are equally important in plant nutrition, but their uptake depends on the species and physiological condition of a plant, the form of fertilizer and soil factors. While nitrates V are not toxic to humans, when reduced to nitrates III they have an adverse impact on human health (Kozík 2005). The nitrate content in aerial parts of plants can be lowered by fertilizing plants with the reduced form of nitrogen, which can be directly incorporated into organic compounds (Michałojć 2000, Kozik 2005, Kowalska et al. 2006). Vegetables are the major source of nitrates in a human diet (Biegańska-Marecik et al. 2008, Gajewska et al. 2009). The highest amounts of nitrates are accumulated by plants with a short growing season, especially leafy vegetables (Amr, Hadidi 2001). Celery belongs to vegetables that accumulate moderate amounts of nitrates, while lettuce can absorb their significant quantities (Rożek 2000).

The use of nitrogen fertilizers affects not only the quality of crops, but also the concentration of salt in the soil, ionic balance and proportions of nutrients. In the study by Michałojć (2000) on lettuce, radish, and spinach, as well as by Nurzyńska-Wierdak (2006) on rocket and kohlrabi, regardless of the type of fertilizer, an increase of the EC value in response to increasing nitrogen fertilizer doses was recorded alongside some changes in the ionic equilibrium in the plants' commodity organs.

The aim of the study was to determine the effect of increasing doses of nitrogen on the content of macro- and micronutrients and proportions between these components in three vegetable species, i.e. kale, lettuce, celery, which differ in the sensitivity to salinity.

MATERIAL AND METHODS

The experiments on celery, curly kale and lettuce were carried out in a greenhouse, in the spring of 2006 and 2008. The following cultivars were grown: Verde Pascal, a celery cultivar with upright conformation and medium growing strength, Lerchenzungen, a medium-high curly kale variety with deep-cut leaf blades, and early lettuce cv. Alanis, forming large flat heads with glossy leaves.

The experiments were established in completely randomized blocks. The experimental unit was a single plant growing in a 2 dm^3 pot filled with transition peat of the initial soil reaction of pH 5.6. There were eight replications in a single combinations.

The content of minerals in peat before planting was (mg dm^{-3}): $N\text{-}NH_4$ – traces, $N\text{-}NO_3$ – 25, $P\text{-}PO_4$ – 25, K – 10, Ca – 40, Mg – 8, while watering water contained the following concentrations: $N\text{-}NH_4$ + $N\text{-}NO_3$ – 18, $P\text{-}PO_4$ – 11, K – 4, Ca – 110, Mg – 9, pH – 7.2, and its EC was 0.6 mS cm^{-1}.

The increasing nitrogen doses used in the study were 0.3, 0.6, 0.9 and 1.2 g N dm^{-3} of subsoil, supplied in the form of ammonium nitrate (34% N). Phosphorus, potassium and magnesium doses were uniform for each plant tested and equalled 0.4 P, 0.9 K and 0.45 Mg (g dm^{-3}), Fe 16, Mn 10.2, Cu 26.6, Zn 1.48, B 3.2 and Mo 7.4 (mg dm^{-3}). When calculating the dose, the quantities of nutrients contained in the peat and water were taken into account. Phosphorus, the microelements and a quarter dose of N, K and Mg were added to the substrate prior to vegetable planting. In order to ensure an optimal nutrient content throughout the growing season, the remaining amounts of N, K and Mg were applied, split into three doses, at 8-12 days intervals.

Harvest was performed at the ripeness stage. After harvest, the plant material samples were taken for chemical analyses; dried at 60°C and ground, they were submitted to determination of N-total with the Kjeldahl's method in a Kjeltec System 2002 Distilling Unit.

After incineration at 550°C, phosphorus was colorimetrically determined in samples with the ammonium metavanadate method, while potassium, calcium, magnesium, iron, manganese, zinc and copper were detected by atomic absorption spectrophotometry (ASA) (Analyst 300 Perkin Elmer). Finally, 2% acetic acid extract of plant material was submitted to the determination of $N\text{-}NO_3$ with the Bremner's micro-distillation method modified by Starck.

The results were statistically processed with variance analysis based on the Tukey's tests at the significance level α = 0.05.

RESULTS AND DISCUSSION

The nitrogen doses ranging from 0.3 to 1.2 g N dm^{-3} of substrate significantly modified the chemical composition of lettuce, curly kale and celery, as well as the proportions between nutrients (Tables 1- 4). The content of total

Table 1

Chemical composition of leaves of lettuce, curry kale and celery (g kg^{-1} d.w.)

Species	Dose (g N dm^{-3})	N total	$N-NO_3$	P	K	Ca	Mg
Lettuce	0.3	35.70	7.401	4.001	61.50	12.63	2.701
	0.6	37.09	11.00	5.020	57.80	13.60	3.223
	0.9	43.40	10.40	5.810	47.80	13.51	3.301
	1.2	46.60	11.50	5.013	44.60	14.60	4.101
	$\overline{x}$	40.70	10.08	4.961	52.90	13.58	3.332
Curly kale	0.3	34.70	0.101	1.001	17.30	23.80	2.612
	0.6	39.42	2.503	1.702	23.40	22.09	3.302
	0.9	43.50	3.601	1.001	27.71	20.90	3.520
	1.2	45.60	4.804	2.002	31.80	21.00	3.820
	$\overline{x}$	40.81	2.752	1.426	25.00	21.90	3.311
Celery	0.3	33.00	5.501	1.001	35.52	9.40	1.800
	0.6	36.60	11.50	1.502	40.80	10.80	2.800
	0.9	42.01	12.20	1.501	37.30	11.30	2.800
	1.2	45.60	14.30	1.615	36.10	14.30	2.100
	$\overline{x}$	39.30	10.88	1.405	37.40	11.40	2.380
$LSD_{0.05}$ for	lettuce	2.201	3.405	n.s.*	14.10	n.s.*	0.902
	curly kale	1.603	1.202	n.s.*	11.05	n.s.*	n.s.*
	celery	1.601	2.801	0.500	1.401	2.106	0.503

n.s.* – not significant

nitrogen in plants was significantly differentiated by the applied nitrogen dose. In lettuce, it ranged from 35.7 to 46.6 g of N-tot. kg^{-1}, in curly kale from 34.7 to 45.6 of N-tot. kg^{-1} and in celery from 33.0 to 45.6 g of N-tot. kg^{-1}. The difference in the content of N-tot. between the lowest and the highest dose of nitrogen applied in lettuce and curly kale cultivation was 10.9 g of N-tot. kg^{-1} , while in celery it reached 12.6 g of N-tot. kg^{-1} (Table 1). In contrast, nitrate nitrogen was more differentiated by the nitrogen dose and the difference in lettuce was 4.10 g $N-NO_3$ kg^{-1}, in kale 4.70 g $N-NO_3$ kg^{-1}, and in celery 8.80 g $N-NO_3$ kg^{-1}. Particular attention should be paid to an average content of total nitrogen in various species, for example in our study the nitrate nitrogen content in kale was about five times smaller than in lettuce or celery (Table 1). This finding indicates that plants with nitrogen in the root zone collect it in amounts directly proportional to its concentration, while the conversion of nitrogen in a plant depends on the nutritional requirements of a particular species and the analyzed part of the plant. Modifications in the chemical composition of celery under the influence of different nitrogen doses are confirmed by Biczak et al. (2011). In numerous studies involving vegeta-

Table 2

Content of microelements (mg kg^{-1} d.w.) in lettuce, curly kale and celery leaves

Species	Dose (g N dm^{-3})	Fe	Mn	Cu	Zn
Lettuce	0.3	51.00	26.37	6.749	60.97
	0.6	62.00	34.21	7.060	71.47
	0.9	63.00	38.25	7.731	88.08
	1.2	54.50	37.06	8.010	66.51
	$\bar{x}$	57.63	38.97	7.387	71.76
Curly kale	0.3	117.3	194.6	8.711	146.9
	0.6	87.51	220.8	8.279	111.4
	0.9	88.03	185.3	10.41	103.1
	1.2	87.49	140.4	11.11	87.70
	$\bar{x}$	95.08	185.3	9.627	112.3
Celery	0.3	58.00	86.76	9.182	79.44
	0.6	66.57	76.03	7.869	74.04
	0.9	61.23	73.55	7.951	71.74
	1.2	72.15	68.54	7.352	62.46
	$\bar{x}$	64.49	76.22	8.088	71.92
$LSD_{0.05}$ for	lettuce	n.s.*	10,04	n.s.*	n.s.*
	curly kale	19.03	68.30	2.310	52.02
	celery	10.02	15.12	n.s.*	10.04

n.s.* – not significant

ble plants, an increase in the level of nitrates in plants with increasing nitrogen doses has been demonstrated (MICHAŁOJĆ 2000), BABIK and ELKNER (2002), KOTSIRAS et al. (2002), KALISZ (2007), NURZYŃSKI et al. (2007), DZIDA and PITURA (2008). In another study on lettuce, curly kale and celery, incremental doses of nitrogen significantly modified the yield and its biological value, and the highest level of nitrogen (1.2 g N dm^{-3}) significantly reduced the yield volume in addition to having a significant positive effect on the concentration of salts in soil (PITURA, MICHAŁOJĆ 2012). The phosphorus content in commercially usable parts of lettuce ranged from 4.001 to 5.810 g P kg^{-1}, in curly kale – from 1.001 to 2.002 g P kg^{-1}, and in celery – from 1.001 to 1.615 g P kg^{-1}. Lettuce leaves were found to contain about 75% more of this element than curly kale and celery, but the phosphorus content was significantly differentiated by a nitrogen dose only in celery, where an increase in phosphorus occurred in response to the growing doses of nitrogen (Table 1).

The nitrogen doses applied in our research significantly modified the content of potassium in all the plants, for example potassium in lettuce fell from 61.50 to 44.60 g K kg^{-1} and the K:Ca ratio improved from 3.3 to 4.9 as

Table 3

Ratios of macroelements in lettuce, curly kale and celery

Species	Dose (g N dm^{-3})	K:Ca	K:Mg	K: [Ca+Mg]	Ca:Mg	Ca:P
Lettuce	0.3	4.869	22.78	4.020	4.676	3.157
	0.6	4.250	17.95	3.440	4.221	2.709
	0.9	3.538	14.48	2.845	4.090	2.325
	1.2	3.055	10.88	2.385	3.558	2.912
Curly kale	0.3	0.727	6.628	0.638	9.110	23.78
	0.6	1.059	7.090	1.121	6.693	12.98
	0.9	1.326	7.870	0.959	5.932	20.88
	1.2	1.514	8.324	1.282	5.496	10.49
Celery	0.3	3.779	19.78	2.910	3.356	9.392
	0.6	3.778	14.57	3.238	5.220	7.190
	0.9	3.301	13.32	2.645	4.034	7.528
	1.2	2.524	17.19	2.201	6.800	8.854
LSD $_{0,05}$ for	lettuce	1.501	7.913	1.023	n.s.*	n.s.*
	curly kale	0.687	n.s.*	0.527	3.012	8.024
	celery	1.002	6.025	0.506	2.314	n.s.*

n.s.* – not significant

the doses of nitrogen increased (Tables 1 and 3), unlike in curly kale, in which the higher doses of nitrogen raised the potassium content from 17.30 to 31.80 g and the K:Ca ratio from 0.7 to 1.5; the influence of nitrogen doses on potassium in celery was not explicit, while the K:Ca ratio in this plant rose was from 2.3 to 3.8. These results indicate that the three plants have different requirements with respect to potassium. A high potassium content in lettuce leaves (52.9 g K kg^{-1}) as compared to kale (25.0 g K kg^{-1}) is worth emphasizing. A decrease in phosphorus and potassium in lettuce leaves after administration of elevated doses of nitrogen was reported by Jarosz and Dzida (2006); similar effects were achieved in research on several varieties of rapeseed (Tunctürk et al. 2011*a*) and leafy beet (Dzida et al. 2012). According to Biesiada and Kołota (2008), increased accumulation of potassium in aerial parts of plants is promoted by intensive nitrogen fertilization. Balanced proportions between the mineral components is important for ensuring proper plant development and yield quality. The optimal proportions of nutrients in plants should be: K:Ca 2-4, K:Mg 2-6, K:[Ca+Mg] 1.62-2.2, Ca:P 2 and Fe:Mn 1.5-2.5, cf. Krzywy and Krzywy (2001), Tariq and Mott (2006), Jarnuszewski and Meller (2013). In the present study, the K:Ca ratio as suggested above was observed only in celery, while being too wide in lettuce and too narrow in kale.

Table 4

Ratios of microelements in lettuce, curly kale and celery

Species	Dose (g N dm^{-3})	Fe:Mn	Fe:Cu	Zn:Cu	Mn:Zn	Mn:Fe
Lettuce	0.3	1.934	7.557	9.034	0.433	0.517
	0.6	1.812	8.782	10.12	0.479	0.552
	0.9	1.647	8.149	11.39	0.434	0.607
	1.2	1.471	6.804	8.303	0.557	0.680
Curly kale	0.3	0.603	13.47	16.86	1.325	1.659
	0.6	0.396	10.57	13.46	1.982	2.523
	0.9	0.475	8.456	9.904	1.797	2.105
	1.2	0.623	7.875	7.894	1.601	1.605
Celery	0.3	0.669	6.316	8.651	1.092	1.496
	0.6	0.876	8.459	9.409	1.027	1.142
	0.9	0.832	7.701	9.023	1.025	1.201
	1.2	1053	9.814	8.495	1.097	0.950
$LSD_{0,05}$ for	lettuce	0.180	0.702	2.113	n.s.*	n.s.*
	curly kale	0.102	5.751	6.002	0.508	0.755
	celery	0.143	1.099	0.404	n.s.*	0.179

n.s.* – not significant

There has been no clear influence of the applied nitrogen fertilization on the content of calcium in the three plants. Its lowest content was found after the application of the lowest nitrogen dose in celery (9.40 g Ca kg^{-1}) and lettuce (12.63 g Ca kg^{-1}). Both in lettuce and celery, the calcium content increased with the increasing dose of nitrogen. However, the highest calcium level in kale (23.80 g Ca kg^{-1}) was recorded after the application of 0.3 g of N dm^{-3}. Any further increase of the nitrogen dose negatively affected the calcium content in kale (Table 1). The Ca:Mg ratio in all the examined plants was above the recommended values (the Ca:Mg ratio is 3). NURZYŃSKA-WIERDAK (2006) in her experiment on rocket showed an increase of calcium in plants due to the increasing doses of nitrogen, while TUNCTÜRK et al. (2011*b*) demonstrated a decrease of calcium in oilseed rape, which was caused by the increased soil salinity.

The nitrogen fertilization significantly affected the magnesium content in lettuce and celery, but it did not diversify the magnesium content in curly kale. Most of magnesium (4.1 g Mg kg^{-1}) was found in lettuce after the administration of 0.9 g N dm^{-3}. Such large differention in the content of calcium and magnesium in lettuce and celery resulted from some imbalance between potassium, calcium and magnesium, which was confirmed by an excessively wide ratio of K:Mg (22.78 - 13.31), while the normal value is 2-6. However, the K:Mg ratio in curly kale was similar to the correct level (Table 3).

The study showed no univocal effect of the nitrogen doses on changes in the microelement composition of the tested plants (Table 2). The highest iron content (117.3 mg Fe kg^{-1}) was recorded in curly kale after the application of the lowest nitrogen dose, with further increments of nitrogen fertilization from 0.3 to 1.2 g N dm^{-3} having no significant effect on the content of this component (Table 3). Lettuce had the highest iron content after the use of nitrogen doses from 0.6 to 0.9 g of N dm^{-3}, while the iron content in celery increased only between the lowest and the highest dose of nitrogen (Table 2).

The average manganese content in lettuce was 38.97 mg Mn kg^{-1}, which was less than in curly kale (185.3 mg Mn kg^{-1}) or in celery (76.22 mg Mn kg^{-1}). Significantly more manganese was found in lettuce after applying nitrogen doses higher than 0.6 g N dm^{-3}, while a significantly lower Mn content was noted in kale and celery at the highest nitrogen dose.

The smallest variations were noted between the tested plants with respect to copper, whose content ranged from 6.75 mg Cu kg^{-1} (lettuce) to 11.11 mg Cu kg^{-1} (curly kale). There was no significant effect of nitrogen fertilization on the copper content in lettuce and celery, while in kale a significant increase occurred at a dose higher than 0.6 g N dm^{-3} (Table 2).

The zinc content in the tested plants ranged from 60.97 mg Zn kg^{-1} (lettuce) to 146.90 mg Zn kg^{-1} (curly kale). There was no effect of nitrogen doses on the zinc content in lettuce and celery, while in kale it gradually decreased as the nitrogen doses went up. The largest differences in the content of micronutrients were found in kale. According to Jurgiel-Małecka and Suchorska-Orłowska (2008), Dzida et al. (2012), increasing the dose of nitrogen favourably affected the uptake of iron and copper by leafy beet and onion, while Shelkhi and Ronaghi (2012) discovered that a higher nitrogen content in soil resulted in a decreased accumulation of iron and manganese in spinach plants. The present study reveals a similar trend.

According to Krzywy and Krzywy (2001), a proper Fe:Mn ratio is 1.5-2.5. In the present study, only lettuce was determined to have correct proportions between these micronutrients, while the said ratio was too narrow in curly kale and celery (Table 4). Studies by Tariq and Mott (2006) on radish implicated the following proportions as the correct ones: Fe:Cu 14-19, Zn:Cu 4.9-7.2, Mn:Zn 3.2-5.8, and Mn:Fe 1.2-2. In all the plants tested in the present study, the ratios of Fe:Cu and Mn:Zn were too narrow, the Zn:Cu ratio was too broad and the Fe:Mn ratio was correct only in kale. The above indicates the significant influence of nitrogen fertilization on microelements in these plants, as well as significant changes in the proportions between different nutrients.

CONCLUSIONS

1. The greatest variation in the content of macronutrients due to the applied nitrogen doses was found in celery, slightly smaller in lettuce, and the smallest in curly kale. With respect to microelements: the highest variation was detected in kale, lower in celery, and the lowest in lettuce.

2. An increase was found in the content of total nitrogen and $N\text{-}NO_3$ in the three plants as the doses of nitrogen increased, while the average content of total nitrogen remained similar in all the three vegetavles and the $N\text{-}NO_3$ content was approximately five times lower in curly kale than in lettuce and celery.

3. The level of nitrogen fertilization significantly affected the phosphorus content only in celery, potassium in lettuce and curly kale, calcium in celery, magnesium in lettuce and celery.

4. The applied nitrogen doses significantly differentiated proportions between the analyzed nutrients in the plants. The K:Mg and Zn:Cu ratios were differentiated to the largest extent.

5. The increasing doses of nitrogen fertilizers modified the content of microelements in the three plant species. Nitrogen fertilization significantly affected the content of manganese in lettuce, iron, manganese, copper, and zinc in kale, as well as iron, manganese and zinc in celery.

REFERENCES

Amr A., Hadidi N. 2001. *Effect of cultivar and harvest date on nitrate and nitrite content of selected vegetable grown under open field and greenhouse conditions in Jordan*. J. Food Compos. Anal., 14: 59-67-67.

Babik, I., Elkner K. 2002. *The effect of nitrogen fertilization and irrigation on yield and quality of braccoli*. Acta Hort. (ISHS), 571: 33-43.

Biczak R., Herman B., Rychter P. 2011. *Effects of nitrogen, phosphorus and potassium fertilization on yield and biological value of leaf celery.* Part I. *Vegetables yield and mineral composition.* Proc. of EC Opole, 5(1): 161-171. (in Polish)

Biegańska-Marecik R., Walkowiak-Tomczak D., Radziejewska-Kubzdela E. 2008. *Changes in the content of nitrates (III) and (V) in the minimally processed spinach packed and stored in modified atmosphere*. Żywność. Nauka. Technologia. Jakość., 4(59): 247-256. (in Polish)

Biesiada A., Kołota E. 2008. *The effect of nitrogen fertilization on yielding and quality of radicchio*. J. Elementol., 13(2): 175-180.

Dzida K., Jarosz Z., Michałojć Z. 2012. *Effect of nitrogen fertilization on the yield and nutritive value of Beta vulgaris* L. J. Elem., 17(1): 19-29. DOI: 10.5601/jelem.2012.17.1.02

Dzida K., Pitura K. 2008. *The influence of varied nitrogen fertilization on yield and chemical composition of Swiss chard* (*Beta vulgaris* L. var. *cicla* L.). Acta Sci. Pol. Hort. Cult., 7(3), 15-24.

Gajewska M., Czajkowska A., Bartodziejska B. 2009. *The content of nitrates (III) and (V) in selected vegetables on detail sale in Łódź region*. Ochr. Środ. Zas. Natur., 40, 388-395. (in Polish)

Jarnuszewski G., Meller E. 2013. *Mineral element ratios in plants grown on post-bog soil fer-*

tilised with zinc and copper. Fol. Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech., 304 (26): 25-32.

Jarosz Z., Dzida K. 2006. *Effect of different nitrogen-potassium fertilization on the yielding and chemical composition of lettuce*. Acta Agroph., 7(3): 591-597. (in Polish)

Jurgiel-Małecka G., Suchorska-Orłowska J. 2008. *The effect of nitrogen fertilization on the content of microelements in selected onions*. J. Elementol., 13(2): 227-234.

Kalisz A. 2007. *The effect of different nitrogen doses on yielding and nutritive value of chinese cabbage*. Rocz. AR Pozn. CCCLXXXIII, Ogrod., 41: 511-515.

Kotsiras A, Olympios Cm, Drosopoulos J, Passa HC. 2002. *Effects of nitrogen form and concentration on the distribution of ions within cucumber fruits*. Sci. Hort., 95:175–183.

Kowalska I., Sady W., Szura A. 2006. *Effects of nitrogen form, foliar nutrition and growing place on yield and quality of lettuce*. Acta Agroph., 7(3): 619-631. (in Polish)

Kozik E. 2005. *The reaction of lettuce (Lactuca sativa* L. var. *capitata) grown in a greenhouse on selected agronomic factors influencing the nitrate content*. Rozp. Nauk. Rocz. AR w Poznaniu, 307.

Krzywy E., Krzywy J. 2001. *The N:S and Fe: Mn ion ratios as factors indicative of the quality of crop plants obtained under the Waste 7 · sulfate hydrate (VI) iron (II)*. Fol. Univ. Stetin., 221 Agric. 88, 133-140. (in Polish)

Michałojć Z. 2000. *Effect of nitrogen and potassium fertilization, and the term of cultivation on the yield and chemical composition of lettuce, radishes and spinach*. Rozpr. Nauk. 238, AR Lublin.

Nurzyńska-Wierdak R. 2006. *Growth and yield of garden rocket and kohlrabi affected by nitrogen and potassium fertilization*. Rozpr. Nauk. 307, AR Lublin. (in Polish)

Nurzyński J. Dzida K., Nowak L. 2007. *The effect of different nitrogen fertilization on yielding of kohlrabi and chemical composition of leaves and stems*. Rocz. AR Pozn., Ogrod., 41(383): 583-587. (in Polish)

Pitura K. Michałojć Z. 2012. *Influence of salts concentration on yielding, biological value and chemical composition of selected vegetable species*. Part. I. *Yielding and biological value*. Acta Sci. Pol. Hort. Cult., 11(6): 145-153.

Premuzic Z. Villela F. Garate A. Bonnila I. 2004. *Light supply and nitrogen fertilization for the production and quality of butterhead lettuce*. Acta Hort., 659: 671-678

Rożek S. 2000. *Factors affecting nitrate accumulation in vegetable yield*. Zesz. Nauk. AR w Krakowie, 71: 19-31. (in Polish)

Sheikhi J. Ronaghi A. 2012. *Growth and macro- and micronutrients concentration in spinach* (*Spinacia oleracea* L.) *as influenced by salinity and nitrogen rates* Intl. Res. J. Appl. Basic. Sci., 3(4): 770-777.

Tariq M., Mott C.J. B. 2006. *Effect of boron supply on the uptake micronutrients by radish* (*Raphanus sativus* L.). J. Agric. Biol. Sci., 1(2): 1-8.

Tunçtürk M., Tunçtürk R., Yildirim B., Çiftçi V. 2011*a*. *Effect of salinity stress on plant fresh weight and nutrient composition of some Canola* (*Brassica napus* L.) *cultivars*. Afr. J. Biotechnol., 10(10): 1827-1832.

Tunçtürk M., Tunçtürk R., Yildirim B., Çiftçi V. 2011*b*. *Changes of micronutrients, dry weight and plant development in canola* (*Brassica napus* L.) *cultivars under salt stress*. Afr. J. Biotechnol., 10(19): 3726-3730.