ACTA Acta Sci. Pol., Hortorum Cultus 10(4) 2011, 217-232

RESPONSE OF DIFFERENT BASIL CULTIVARS TO NITROGEN AND POTASSIUM FERTILIZATION: TOTAL AND MINERAL NITROGEN CONTENT IN HERB

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Abstract. Growing herbal plants is aimed at obtaining high yield of raw material with high contents of biologically active substances, as well as other important compounds, also of nutritional character. In the years 2008–2010 (February – May) studies were conducted on the relationship between cultivar, nitrogen dose (NH_4NO_3), potassium dose (K_2SO_4), and some components of chemical composition of basil herb. The study subject were basil plants of two Polish cultivars: Kasia and Wala, as well as the green-leaved form, popular on the domestic fresh herb market. Basil was grown in the greenhouse, in pots of the capacity of 4 dm^3. Four doses of nitrogen and two doses potassium were applied. In the herb collected during full flowering dry matter, $N\text{-}NH_4$ and $N\text{-}NO_3$, nitrogen total, potassium and protein contents were determined. It was demonstrated that average dry matter contents in the herb of examined basil plants was 13.20% and significantly depended on the cultivar and dose of applied nitrogen. The most (15.47%) dry matter was found in the herb of Wala cultivar plants. The increasing nitrogen doses caused the increase of protein contents in basil herb. The most (26.13% d.m.) of protein was found in the herb of plants fed with the highest dose of nitrogen. Plants receiving the most potassium had more (23.24% d.m.) protein in the herb than plants receiving less of that nutrient (22.31% d.m.). Mean content of nitrate nitrogen in the examined herbal material was 0.78% d.m. Plants of Wala cultivar had significantly lower (0.66% d.m.) amount of nitrate nitrogen than the remaining ones. Additionally increased contents were demonstrated of nitrogen (total, ammonium, nitrate) and potassium in basil herb as an effect of increased nitrogen dose.

Key words: *Ocimum basilicum* L., N-total, $N\text{-}NO_3$, $N\text{-}NH_4$, protein

INTRODUCTION

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Common basil (*Ocimum basilicum* L.) is the most frequently grown species of *Ocimum* genus for seasoning and medicinal purposes. The basil herb is used as an aromatic spice, a component of curative herbal mixtures, as well as a source of essential oil and other biologically active substances. It acts as an antioxidant, an anti-microbe [Hussain et al. 2008, Koba et al. 2009], and a fungistatic agent [Dambolena et al. 2010], additionally, Stajković et al. [2007] demonstrated the anti-mutagenic activity of basil oil and pure components of this substance.

Growing basil takes place both in field conditions and under shields, and one of the most important factors limiting plant growth is temperature. Another significant factor affecting the quantity and quality of herb yield is fertilization. Basil has substantial nutritional needs. Nitrogen affects plant growth and yield especially favorably [Sifola and Barbieri 2006, Rao et al. 2007, Zheljazkov et al. 2008, Daneshian et al. 2009], and is defined as the most yield forming of all macro- and microelements. The share of nitrogen in plant dry matter rarely exceeds 4%. In spite of that, it is a nutrient of crucial importance. It is a component of in. a. aminoacids, enzymatic, constitutional and reserve proteins, nucleic acids, nucleotides, or growth regulators [Górecki and Grzesiuk 2002]. Plants take nitrogen up in the mineral ($N\text{-}NO_3$, $N\text{-}NH_4$) and organic form (urea, aminoacids, amids), but the main source is mineral nitrogen. Both ammonium and nitrate nitrogen are equally good and nitrogen taken up in the form of nitrates must be reduced to ammonium nitrogen for further transformations. The response of plants to the above-listed forms of nitrogen is mainly dependent on the concentrations of NH_4^+ and NO_3^- ions in the nutritional environment, as well as on acidity. The excessive uptake of NH_4^+ ions may cause plant metabolism disorders, leading even to poisoning [Barker 1999, Lasa et al. 2001]. Contrary to the response of plants to nutrition with an ammonium form of nitrogen, no irregularities are found with the application of even a substantial dose of nitrogen in nitrate form. The danger of applying large amounts of nitrate nitrogen is, however, related to the possibility of excessive accumulation of nitrates in the yield of cultivable plants, which is harmful to human health [Ikemoto et al. 2002] and, indirectly, also to the growth of plants [Lamattina et al. 2003, Chen et al. 2004].

The nitrogen uptake by plants from soil solution is related to mutual influence of other nutrients, among others potassium. Potassium is taken up by plants as cation K^+. Potassium accumulation, reaching a few per cent of dry matter, takes place mainly in the leaves and the contents of this nutrient is usually higher than that of the remaining macroelements [Biesiada and Kuś 2010, Dzida 2010a, Dzida and Jarosz 2010]. Potassium does not form organic compounds in plants and occurs exclusively in ionic form. Thus it is one of the most dynamic (movable) elements in a plant. The share of potassium ions in regulating plant water management, transpiration process and other important metabolic processes is highly specific. The function of potassium in osmoregulation can be partly fulfilled by sodium, but it is potassium that is the key ion determining the size of osmotic potential [Kopcewicz and Lewak 2002]. The correct growth and development of basil plants is determined by the presence of all nutrients in the nutritional environment. Potassium reveals distinct effect upon growth, yield and basil essential oil concentration [Rao et al. 2007], and appropriate proportions between nutrients available to plants are significant [Yamamoto and Takano 1996, Suh et al. 1999, Singh et al.

2004]. Nguyen et al. [2010] demonstrated that changes in the level of potassium significantly affect the composition of phenols and anti-oxidative ability of basil leaves.

Variability within the species *Ocimum basilicum* L. is high and concerns, among others, the earliness, strength of growth, manner of sprout branching, size and shape of leaves, as well as the color of leaves and flowers [Labra et al. 2004, Nurzyńska-Wierdak 2007a, b]. Numerous works also indicate high differentiation of basil chemical composition, first of all as to the quality and quantity of essential oil [Labra et al. 2004, Koba et al. 2009, Carović-Stanko et al. 2010, Dzida 2010b], as well as dyes with the character of biologically active substances [Kopsell et al. 2005], certain macroelements [Dzida 2010a] and vitamin C [Dzida 2010b]. The aim of the studies presented in this paper was to assess the effect of feeding plants with nitrogen and potassium upon the contents of dry matter, protein, total, ammonium and nitrate nitrogen in the herb of basil plants of three cultivars. Nitrogen and potassium were selected for our studies, because these macroelements play a significant role in important physiological processes in plants, including photosynthesis, osmoregulation, nutrient flow and distribution of main metabolytes. The correct course of above-listed processes determines the dynamic growth and high yield of cultivable plants.

MATERIAL AND METHODS

Vegetation experiment was conducted in detached heated glasshouse, situated in northern-southern direction in the period from February to May 2008–2010. the temperature in greenhouse was kept in the interval of 18–25°C during the day and 12–15°C at night. The subject of studies were basil plants of two Polish cultivars: Kasia and Wala, as well as the green-leaved form, popular in the domestic fresh herb market. Dependencies were sought between nitrogen and potassium doses and the quality of basil herb, resulting from the share of dry matter, as well as the contents of nitrogen, protein and nitrates. Basil was grown from seedlings in pots of the capacity of 4 dm^3, filled with sphagnum peat (pH 5.5–6.0). The seedlings had been produced in greenhouse, sowing material came from a grower of Polish cultivars (Institute of Natural Fibers and Medicinal Plants in Poznań – cultivars: Kasia and Wala) and from seed company PNOS Ożarów Mazowiecki (green-leaved form). Basil seeds were sown at the end of February, seedlings were planted into pots in mid March. The experiment was performed using the complete randomization method. In one pot one basil plant grew, which was an experimental unit, each series included 8 repetitions. The following amounts of nutrients in g per 1dm^3 substratum were applied in the experiment: 0.2, 0.4, 0.6, 0.9 N in the form of ammonium saltpeter; 0.4, 0.8 K in the form of potassium sulfate; 0.4 P as superphosphate 20% P; 0.3 Mg in the form of one-water magnesium sulfate and microelements in mg per 1 dm^3 of substratum: 8.0 Fe (chelate), 5.1 Mn ($MnSO_4 \cdot H_2O$), 13.3 Cu ($CuSO_4 \cdot 5H_2O$), 0.74 Zn ($ZnSO_4 \cdot 7H_2O$), 1.6 B (H_3BO_3) and 3.7 Mo $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$). During the experiment plants were watered with the same amount of water every day.

Plant harvest was conducted at the beginning of blooming, cutting off the overground part of the sprout, above its lignified fragments. The herb was dried in thermal drying room in the temperature of 35°C, and a part of it in 70°C, and then it was designed for chemical studies. In the 2% extract of acetic acid the contents of $N\text{-}NH_4$ and $N\text{-}NO_3$ were determined by means of Bremner's distillation method in Starck's modification, nitrogen (total) was determined with the use of Kjeldahl's method on automatic apparatus Kjel-Foss and protein content was calculated as: 6.25 × N-total; after the plant material had been burnt in sulfuric acid the potassium content was determined with the use of atomic absorption method. Immediately after plant harvest samples of substratum were collected for chemical analyses, in which the following was determined: in acetic acid extract 0.03M the contents of $N\text{-}NH_4$ and $N\text{-}NO_3$, as well as potassium, using the method as in the plant material, substratum reaction pH – potentiometrically in H_2O and nutrient concentration (EC) – conductometrically. The obtained results of analyses were statistically elaborated with the use of variance analysis for double cross classification, assessing the significance of differences with the use of Tukey's confidence intervals and by making LSD calculations at the significance level $\alpha = 0.05$.

RESULTS

Mean dry matter contents in the herb of examined basil plants equaled 13.20% and significantly depended on the cultivar and dose of applied nitrogen (tab. 1). The plants of Wala cultivar accumulated more (15.47%) dry matter in their herb than the remaining ones. The mean share of dry matter in the herb of plants of Kasia cultivar and of the green-leaved form did not significantly differ between each other. The plants fed with an average dose of nitrogen (0.4 g N · dm^{-3}) had the lowest (12.12%) content of dry matter in the herb, compared to the remaining ones. No significant effect of potassium dose was found, nor of the cooperation of examined factors upon the share of dry matter in the basil herb. The examined basil plants contained on average 22.78% of protein in dry herb matter. The protein concentration did not depend on the cultivar, but it remained under a significant influence of the applied fertilization (tab. 1). The increasing nitrogen doses caused the increase of protein content in basil herb. The plants that received the least nitrogen contained the least (18.64% d.m.) protein, compared to the remaining ones. The most (26.13% d.m.) was in the herb of plants fed with the highest dose of nitrogen. Similarly, the increased amount of potassium contributed to the increase of protein content in basil herb. The plants receiving more potassium had higher (23.24% d.m.) content of protein in herb than the plants receiving less of that nutrient (22.31% d.m.) (tab. 1). No significant cooperation was found between the cultivar, nitrogen dose and potassium dose upon mean protein content in basil herb.

The content of potassium in basil herb was on average 2.93% d.m. and did not significantly depend upon the cultivar (tab. 1). The applied nitrogen doses significantly affected the concentration of potassium in basil herb. Plants fed with the lowest nitrogen dose contained less (2.26% d.m.) potassium in herb than plants fed with increased doses of that element. Lack of effect of potassium dose was demonstrated upon the mean content of this component in herb, as well as of the joint effect of cultivar, nitrogen dose and potassium dose upon the mean potassium content in basil herb (tab. 1).

Table 1. Effect of cultivar, nitrogen and potassium fertilization on dry matter, protein and potassium content in basil herb (mean for 2008–2010)
Tabela 1. Wpływ odmiany, nawożenia azotem i potasem na zawartość suchej masy, białka i potasu w zielu bazylii (średnio z 2008–2010)

Cultivar Odmiana	Dose – dawka $g \cdot dm^{-3}$ N	K	Dry matter Sucha masa %	Protein Białko % d.m. – % s.m.	K % d.m. – % s.m.
Kasia	0.2	0.4	13.52	17.93	2.26
		0.8	11.09	19.85	2.62
	0.4	0.4	11.35	21.80	2.78
		0.8	10.50	24.15	2.94
	0.6	0.4	12.09	24.31	3.39
		0.8	10.64	24.50	3.54
	0.9	0.4	12.63	26.20	3.69
		0.8	13.56	26.75	4.18
Wala	0.2	0.4	14.84	17.70	1.66
		0.8	15.51	19.56	1.97
	0.4	0.4	12.95	22.10	2.45
		0.8	15.73	21.68	2.59
	0.6	0.4	17.48	23.30	2.73
		0.8	16.31	23.28	2.92
	0.9	0.4	16.03	24.96	3.07
		0.8	14.89	25.71	3.19
Green leaved form Forma zielonolistna	0.2	0.4	13.43	17.96	2.43
		0.8	13.24	18.86	2.66
	0.4	0.4	11.36	21.92	2.75
		0.8	10.85	22.44	3.00
	0.6	0.4	11.81	23.71	3.25
		0.8	11.95	24.84	3.28
	0.9	0.4	12.06	25.86	3.45
		0.8	13.12	27.31	3.65
Mean Średnio	Kasia		11.92	23.18	3.17
	Wala		15.47	22.28	2.57
	Green leaved form		12.23	22.86	3.06
Mean N dose Średnio dawka N	0.2		13.60	18.64	2.26
	0.4		12.12	22.35	2.75
	0.6		13.38	23.99	3.18
	0.9		13.71	26.13	3.53
Mean K dose Średnio dawka K		0.4	13.29	22.31	2.82
		0.8	13.11	23.24	3.04
Mean – Średnio			13.20	22.78	2.93
$LSD_{0.05}$ $NIR_{0,05}$	A – cultivar – odmiana		1.11	n. s.	n. s.
	B – N dose – dawka		1.41	0.15	0.95
	C – K dose – dawka		n. s.	0.80	n. s.
	A × B		n. s.	n. s.	n. s.
	A × C		n. s.	n. s.	n. s.
	B × C		n. s.	n. s.	n. s.
	A × B × C		n. s.	n. s.	n. s.

Table 2. Effect of cultivar, nitrogen and potassium fertilization on nitrogen content in basil herb (mean for 2008–2010)
Tabela 2. Wpływ odmiany, nawożenia azotem i potasem na zawartość azotu w zielu bazylii (średnio z 2008–2010)

Cultivar Odmiana	Dose – dawka, $g \cdot dm^{-3}$		N-total	$N\text{-}NH_4$	$N\text{-}NO_3$
	N	K	% d.m. – % s.m.		
Kasia	0.2	0.4	2.82	0.05	0.56
		0.8	3.20	0.03	0.27
	0.4	0.4	3.50	0.06	0.87
		0.8	3.82	0.06	0.68
	0.6	0.4	3.88	0.10	1.00
		0.8	3.95	0.07	0.91
	0.9	0.4	4.12	0.12	1.59
		0.8	4.34	0.10	1.12
Wala	0.2	0.4	2.83	0.06	0.38
		0.8	3.12	0.06	0.26
	0.4	0.4	3.41	0.08	0.64
		0.8	3.58	0.07	0.53
	0.6	0.4	3.62	0.11	0.81
		0.8	3.80	0.09	0.72
	0.9	0.4	4.01	0.17	1.09
		0.8	4.11	0.12	0.86
Green leaved form Forma zielonolistna	0.2	0.4	2.82	0.05	0.58
		0.8	3.06	0.03	0.43
	0.4	0.4	3.50	0.08	0.71
		0.8	3.58	0.06	0.68
	0.6	0.4	3.79	0.10	0.84
		0.8	3.92	0.09	0.80
	0.9	0.4	4.18	0.21	1.38
		0.8	4.36	0.09	0.92
Mean Średnio	Kasia		3.70	0.07	0.87
	Wala		3.56	0.09	0.66
	Green leaved form		3.65	0.09	0.81
Mean N dose Średnio dawka N	0.2		2.97	0.04	0.41
	0.4		3.57	0.06	0.68
	0.6		3.83	0.09	0.84
	0.9		4.19	0.13	1.15
Mean K dose Średnio dawka K		0.4	3.54	0.10	0.87
		0.8	3.74	0.07	0.68
Mean – Średnio			3.63	0.08	0.78
$LSD_{0.05}$ $NIR_{0,05}$	A – cultivar – odmiana		n.s.	n.s.	0.17
	B – N dose – dawka		0.224	0.02	0.22
	C – K dose – dawka		0.119	0.01	0.12
	A × B		n.s.	n.s.	n.s.
	A × C		n.s.	n.s.	n.s.
	B × C		n.s.	n.s.	n.s.
	A × B × C		n.s.	n.s.	n.s.

Table 3. The chemical composition (mg · dm^{-3}) of substratum from basil cultivation (mean for 2008–2010)
Table 3. Skład chemiczny podłoża (mg · dm^{-3}) z uprawy bazylii (średnio z 2008–2010)

Cultivar Odmiana	Dose – dawka, g · dm^{-3} N	K	$N-NH_4$	$N-NO_3$	K
Kasia	0.2	0.4	8.89	39.00	155.66
		0.8	11.34	25.11	456.66
	0.4	0.4	15.12	80.23	171.50
		0.8	19.17	101.05	516.00
	0.6	0.4	30.29	138.36	187.16
		0.8	36.17	143.63	389.66
	0.9	0.4	53.57	217.43	179.00
		0.8	50.53	222.13	468.16
Wala	0.2	0.4	5.53	21.11	161.83
		0.8	6.56	23.56	642.00
	0.4	0.4	16.58	65.90	120.50
		0.8	22.70	97.80	408.16
	0.6	0.4	39.21	129.68	195.66
		0.8	45.80	177.18	564.50
	0.9	0.4	55.84	221.21	261.33
		0.8	57.84	218.06	397.66
Green leaved form Forma zielonolistna	0.2	0.4	6.39	36.05	94.16
		0.8	9.68	24.83	532.33
	0.4	0.4	13.33	49.35	114.83
		0.8	15.10	72.95	345.16
	0.6	0.4	29.99	127.46	173.16
		0.8	42.63	129.21	351.33
	0.9	0.4	50.79	197.2	138.00
		0.8	52.91	239.2	436.66
Mean Średnio	Kasia		28.14	120.87	315.47
	Wala		31.25	119.31	343.95
	Green leaved form		27.60	109.47	273.20
Mean N dose Średnio dawka N	0.2		8.06	28.20	340.44
	0.4		17.00	77.87	279.36
	0.6		37.35	140.92	310.25
	0.9		53.58	219.20	313.47
Mean K dose Średnio dawka K		0.4	27.13	110.24	162.73
		0.8	53.58	122.85	459.02
Mean – Średnio			29.00	116.54	310.88
$LSD_{0.05}$ $NIR_{0,05}$	A – cultivar – odmiana		n. s.	n. s.	n. s.
	B – N dose – dawka		23.94	104.87	n. s.
	C – K dose – dawka		n. s.	n. s.	56.51
	A × B		n. s.	n. s.	n. s.
	A × C		n. s.	n. s.	n. s.
	B × C		n. s.	n. s.	n. s.
	A × B × C		n. s.	n. s.	n. s.

Table 4. The value pH and EC of substratum from basil cultivation (mean for 2008–2010)
Tabela 4. Wartość pH i EC podłoża z uprawy bazylii (średnio z 2008–2010)

Cultivar Odmiana	Dose – dawka, $g \cdot dm^{-3}$ N	K	pHH_2O	EC $mS \cdot cm^{-1}$
Kasia	0.2	0.4	5.46 – 6.10	1.06
		0.8	5.44 – 5.80	1.36
	0.4	0.4	5.30 – 5.55	1.46
		0.8	4.90 – 5.55	1.65
	0.6	0.4	4.90 – 5.40	1.71
		0.8	4.85 – 5.35	1.83
	0.9	0.4	4.85 – 5.35	2.08
		0.8	4.80 – 5.30	2.20
Wala	0.2	0.4	5.60 – 5.95	1.38
		0.8	5.50 – 5.74	1.56
	0.4	0.4	5.25 – 5.45	1.65
		0.8	4.95 – 5.45	1.90
	0.6	0.4	4.90 – 5.20	2.11
		0.8	4.80 – 5.20	2.33
	0.9	0.4	4.75 – 5.10	2.46
		0.8	4.70 – 5.00	2.63
Green leaved form Forma zielonolistna	0.2	0.4	5.45 – 6.05	0.95
		0.8	5.20 – 6.05	1.36
	0.4	0.4	4.80 – 5.75	1.66
		0.8	4.70 – 5.70	1.78
	0.6	0.4	4.65 – 5.60	1.86
		0.8	4.60 – 5.50	2.05
	0.9	0.4	4.60 – 5.45	2.06
		0.8	4.50 – 5.35	2.40
Mean Średnio	Kasia		4.80 – 6.10	1.67
	Wala		4.70 – 5.95	2.00
	Green leaved form		4.50 – 6.05	1.76
Mean N dose Średnio dawka N	0.2		5.20 – 6.10	1.28
	0.4		4.70 – 5.75	1.68
	0.6		4.60 – 5.60	1.98
	0.9		4.50 – 5.45	2.30
Mean K dose Średnio dawka K		0.4	4.60 – 6.10	1.70
		0.8	4.50 – 6.05	1.92
Mean – Średnio			4.50 – 6.10	1.81
$LSD_{0.05}$ $NIR_{0,05}$	A – cultivar – odmiana			0.22
	B – N dose – dawka			0.28
	C – K dose – dawka			0.15
	A × B			n. s.
	A × C			n. s.
	B × C			n. s.
	A × B × C			n. s.

The examined basil cultivars did not significantly differ between themselves as to the amounts of accumulated total and ammonium nitrogen (tab. 2). However, significant differentiation was found of mean nitrate nitrogen concentration in basil herb of the examined cultivars. The plants of Wala cultivar were distinguished by a smaller (0.66% d.m.) aptitude to accumulating nitrate nitrogen than the remaining ones. The increased contents of total and mineral nitrogen as well as protein were demonstrated in basil herb, as the effect of the applied nitrogen dose. Plants fed with the highest nitrogen dose accumulated more (respectively: 0.13, 1.15 and 4.19% d.m.) of total and mineral nitrogen than plants receiving less of this component (tab. 2). It was also found that with the increase of potassium dose mean concentration of ammonium and nitrate nitrogen decreased, whereas mean total nitrogen content increased. Mean content of nitrate nitrogen in the examined herbal material was 0.78% d.m.

The substratum reaction after plant harvest ranged from 4.50–6.10 and, as the data analysis shows, the pH value of the examined substratum was slightly modified by the applied fertilization (tab. 4). The substrates fertilized with a smaller dose of nitrogen and with a smaller dose of potassium were characterized by reaction ranging from 4.60–6.10, whereas the reaction of the remaining ones ranged from pH 4.50–6.05. Besides, the highest pH value (4.80–6.10) was demonstrated in the substratum after harvesting the plants of Kasia cultivar, compared to the remaining ones (respectively: 4.70–5.95 and 4.50–6.05). On the basis of substratum analysis after plant harvest a significant effect was demonstrated of cultivar and nitrogen, as well as potassium dose upon ion concentration after basil harvest. The substratum after harvest of Wala cultivar plants was characterized by the highest (2.00 mS · cm^{-1}) concentration of ions, compared to the remaining one. An increase of EC value was demonstrated together with the increase of nitrogen and potassium doses (tab. 4). The highest (2.30 mS · cm^{-1}) value of EC was found in the substratum fertilized with the highest nitrogen dose. Mean ion concentration in the examined substratum was 1.81 mS · cm^{-1}.

A significant differentiation of ammonium and nitrate nitrogen contents in the examined substratum after plant harvest, resulting from the applied fertilization (tab. 4). The concentration of the above mentioned forms of nitrogen in the substratum was not, however, differentiated by cultivar and amount of the contributed potassium. It was found that together with the increased nitrogen dose the ammonium and nitrate nitrogen contents increased in the substratum. Mean ammonium nitrogen content in the examined substratum after harvest was 116.00 mg · dm^{-3}, whereas that of nitrate nitrogen was 116.54 mg · dm^{-3}. The examined substrata, analyzed after harvest, were not significantly differentiated by the cultivar and dose of the applied nitrogen as to mean potassium content (tab. 4). The concentration of this nutrient, however, increased from 162.73 mg · dm^{-3} to 459.02 mg · dm^{-3} as an effect of increasing potassium dose.

DISCUSSION

The chemical composition of basil plants assessed in this experiment was differentiated depending upon the examined cultivar and nitrogen fertilization. The highest (15.47%) dry matter contents was that of Wala cultivar, and the lowest (11.92%) – that of Kasia cultivar. The opposite relationships were demonstrated by Dzida [2010b]. Besides, this author found that mean dry matter content was much higher in the examined cultivars, which may be explained by different nutrition state of the examined plants. In this paper the most (13.71%) dry matter was found in the herb of plants grown in the substratum with the application of the highest nitrogen dose. Similar relationships in glasshouse lettuce growing were demonstrated by Dzida and Jarosz [2006], as well as in the previous studies with kohlrabi and rocket [Nurzyńska-Wierdak 2006a, b]. However, opposite dependencies were found in the experiments with red cabbage [Biesiada et al. 2010], strawberry [Jarosz and Konopińska 2010], as well as with leaf beetroot [Dzida and Jarosz 2010]. The results presented above indicate the close connection between the amount of nutrients in the nourishing environment and the accumulation of dry matter by certain plant species, including basil.

The protein concentration in the examined herb was high and was on average 22.78% d.m. This value can even be comparable to mean share of this component in cabbage vegetable leaves: rocket (26.8% d.m.) and kohlrabi (31.8% d.m.) [Nurzyńska-Wierdak 2006a]. This indicates high nutritional value of basil herb, whose indicator is, among others, protein concentration. In this experiment no effect of cultivar on mean protein content in basil herb was found, which confirmed the study by Dzida [2010b]. It was demonstrated, however, that protein concentration in basil herb increases together with the increase of the amount of applied nitrogen. This remains in consistence with the results of studies concerning other species [Nurzyńska-Wierdak 2006a, 2006b, Dzida and Jarosz 2010], confirming the relationship between yield quality and fertilizing nitrogen dose. Potassium, applied in an increased dose, contributed to the increase of protein concentration. This dependence may be explained by the fact that potassium works as an activator for enzymes participating in the process of photosynthesis and in the biosynthesis of starch and protein [Amtmann et al. 2008]. The effect of potassium dose upon protein content in basil herb demonstrated in the paper indicates an important connection between yield quality and the amount of the contributed potassium. It confirms the results obtained with other cultivable plants: kohlrabi [Fisher 1992], melon [Lin et al. 2004], tea [Venkatesan et al. 2005], onions [El-Bassiony 2006], rocket [Nurzyńska-Wierdak 2006a], sunflower and safflower [Abbadi et al. 2008].

The highest amount of potassium was demonstrated in plants of Kasia cultivar (3.17%), which confirms the results presented by Dzida [2010a]. The potassium content in the examined basil herb was not determined by the cultivar and dose of applied potassium, but it depended on the amount of contributed nitrogen. The ascertained increase of potassium content in basil herb as an effect of increasing nitrogen dose remains in consistence with the results obtained by other authors [Nurzyńska-Wierdak 2006a, 2009, Dzida and Pitura 2008, Abel-Motagally et al. 2009, Biesiada and Kołota 2010, Biesiada and Kuś 2010]. Rao et al. [2007] demonstrated that the application of a large nitrogen dose increases the accumulation of potassium by basil plants, when nitrogen was not applied, the intrasoil potassium application did not increase the effectiveness of potassium uptake by basil. The authors did not also find the increased potassium accumulation in the overground part of basil because of applying the increased dose of fertilizing potassium.

The ascertained higher (3.70% d.m.) total nitrogen content in the herb of plants of Kasia cultivar than in Wala (3.56% d.m.) cultivar plants remains consistent with the relationship demonstrated by Dzida [2010a]. The applied nitrogen fertilization significantly modified the total nitrogen concentration in basil herb of examined cultivars. The highest (respectively: 4.19 and 3.74% d.m.) total nitrogen content in basil herb was found in objects with the greatest doses of nitrogen and potassium. Similarly Golcz et al. [2006] demonstrated that total nitrogen content in basil herb increased with the increase of fertilizing nitrogen dose and in Wala cultivar it ranged from 1.24 to 3.96% d.m. The demonstrated dependencies confirm the results obtained in other cultivable plant species: leaf chicory [Custic et al. 2002], rocket and kohlrabi [Nurzyńska-Wierdak 2006a], as well as leaf spinach beet [Dzida and Pitura 2008, Kołota and Czerniak 2010]. The examined basil plants accumulated more total nitrogen as an effect of the increased potassium quantity. Similar dependencies in the case of sugar beet were demonstrated by Abel-Motagally and Attia [2009], as well as Abd El-Razek et al. [2011] in the experiment with grape-vine.

In the studies presented in this paper the plants of green leaved form and Wala cultivar accumulated larger (0.09% d.m.) amounts of ammonium nitrogen compared to Kasia cultivar, whereas the largest (0.87% d.m.) nitrate nitrogen content was found in the herb of Kasia cultivar, compared to the remaining ones. These results remain in consistence with these obtained by Dzida [2010a]. The author demonstrated that the plants of Kasia cultivar accumulated more (0.48% d.m.) of nitrate nitrogen than the plants of Wala cultivar (0.43% d.m.). However, these results have not been statistically proven. What is worth noting, is nearly two times higher concentration of nitrate nitrogen in the herb of plants, demonstrated in this paper with reference to the studies by Dzida [2010a].

The nitrogen doses applied in the foregoing studies modified nitrate nitrogen concentration in basil herb. With the increase of nitrogen dose there occurred an increase of nitrate nitrogen concentration in the basil herb. The studies by Chen et al. [2004] reveal that the increase of nitrogen dose in growing rape, Chinese cabbage and spinach caused the increase of nitrate concentrations, especially in the overground parts of plants. Roots constituted an exception, where with the application of the highest nitrogen dose the concentration of nitrates was lower than in plants receiving less of this component. The increase of nitrogen dose also caused the increased content of nitrates (V) in rocket and kohlrabi leaves [Santamaria et al. 2002, Nurzyńska-Wierdak 2006a]. The results presented in this paper confirm the significant effect of increased nitrogen dose upon the increase of nitrate nitrogen concentration in the overground parts of cultivable plants.

In the presented studies a tendency was presented to the decrease of nitrate amounts in basil herb under the influence of increased potassium dose. The basil plants fed with higher potassium dose accumulated less (0.68% d.m.) of nitrate nitrogen than plants receiving twice less of this nutrient (0.87% d.m.). Hanafy Ahmed et al. [2000] demonstrated that the increase of potassium dose caused the decrease of nitrate accumulation in rocket leaves. Similar dependencies were found in previous studies [Nurzyńska-Wierdak 2006a, 2006b, 2009]. This phenomenon can be explained by the effect of potassium upon the nitrate reduction process. The increased amount of this component in the nutritive environment of plants enhances the process of these compounds' reduction and thus their accumulation in tissues is reduced.

From among many factors affecting plant growth and yielding an important role is played by the substratum reaction. The optimum pH range for most horticultural plants is 5.5 to 6.5 [Nurzyński 2005]. In the experiments presented in this paper the substratum reaction after basil harvesting was contained in the range from 4.50 to 6.10, depending on the examined factors. Changes of substratum pH values can be explained by acidifying properties of ammonium saltpeter, which was applied as a source of nitrogen for the examined plants. Besides, as it is revealed by the works of other authors [Nurzyńska-Wierdak 2006a, 2006b, Dzida 2010a, Dzida and Jarosz 2010], the substratum reaction results from the different nutritional requirements of cultivated plants and the applied fertilization. Besides the substratum reaction, one of the factors determining normal plant development is ion concentration in substratum (EC). The EC value is determined by all cations and anions contained in the substratum, but to the high extent these are potassium, magnesium and nitrates [Nurzyński 2005]. In this paper the highest EC value was demonstrated in objects with the highest nitrogen and potassium doses. Similar relationships were demonstrated in experiments with rocket and kohlrabi [Nurzyńska-Wierdak 2006a, 2006b, 2009, Nurzyński et al. 2007]. The confirmation of the above interdependence is also the positive correlation (r = 0.73) between the sum of mineral nitrogen ($N\text{-}NH_4$ $+N\text{-}NO_3$) and the EC value in the peat substrate, demonstrated by Krzebietke and Benedycka [2006].

Plants of the examined basil cultivars were taking nutrients up during vegetation period with different intensity. A higher EC value was found in the substratum after harvesting plants of Wala cultivar than in the substratum after harvesting plants of Kasia cultivar. This phenomenon may be justified by morphological differences in the plants of examined cultivars and the course of physiological processes conditioned by the presence of nutrients that have been taken up. The conducted studies revealed a relationship between nitrogen-potassium fertilization and the chemical composition of substratum, which resulted from differences in basil plant nutrient uptake under the influence of examined factors. The increased contents of ammonium and nitrate nitrogen as an effect of increasing fertilizer nitrogen dose is a normal phenomenon and confirms the dependencies demonstrated in experiments with other plants [Nurzyńska-Wierdak 2006a, 2006b, 2009, Nurzyński et al. 2007]. The demonstrated larger amounts of potassium remaining in the substratum, related to the increasing dose of this component, also do not raise any reservations and were found by Dzida [2004] and in earlier works [Nurzyńska-Wierdak 2006a, 2006b, 2009]. What is striking, however, are different amounts of mineral nitrogen and potassium remaining in the substratum after harvest of the examined plants. The plants of Wala cultivar took up less ammonium nitrogen and potassium and those of Kasia cultivar – less nitrate nitrogen than the remaining ones, which might have resulted from different nutritional needs. This tendency, not confirmed statistically, is, however, difficult to explain in the aspect of accumulating nutrients by plants, because it is in Wala cultivar the most dry matter was found, and in Kasia- the most nitrate nitrogen. On the other hand, however, Wala cultivar was characterized by the lowest accumulation of nitrate nitrogen and potassium with respect to the remaining studied plants.

CONCLUSIONS

Our studies demonstrated that the herb of *Ocimum basilicum* L. can be significantly differentiated as to its chemical composition, depending on cultivar and fertilization with nitrogen and potassium. The most dry matter was found in Wala cultivar: it was also distinguished by significantly the lowest contents of nitrate nitrogen in the herb with regard to the remaining ones. The herb of examined basil plants had a significant content of protein. The increasing nitrogen doses caused the increase of dry matter, total, ammonium and nitrate nitrogen, potassium and protein contents in the examined herb. The increased potassium amount significantly contributed to increased protein and total nitrogen concentration, as well as to the decrease of ammonium and nitrate nitrogen contents in basil herb. Nitrogen-potassium fertilization distinctly modified the chemical composition of the substratum after plant harvesting. Increasing the dose of nitrogen caused the increase of EC values, as well as $N\text{-}NH_4$ and $N\text{-}NO_3$ contents. Significant increase of EC values was also found, as well as of potassium concentration in the substratum, as the effect of increasing fertilizer potassium dose.

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REAKCJA ODMIAN BAZYLII NA NAWOŻENIE AZOTEM I POTASEM: ZAWARTOŚĆ AZOTU OGÓŁEM I AZOTU MINERALNEGO W ZIELU

Streszczenie. Uprawa roślin zielarskich ma na celu uzyskanie wysokiego plonu surowca o dużej zawartości substancji biologicznie czynnych oraz innych ważnych związków, także o charakterze odżywczym. W latach 2008–2010 (luty – maj) przeprowadzono badania nad zależnością pomiędzy odmianą, dawką azotu (NH_4NO_3), dawką potasu (K_2SO_4) a składem chemicznym ziela bazylii. Przedmiotem badań były rośliny bazylii dwóch polskich odmian: Kasia i Wala oraz formy zielonolistnej, popularnej na krajowym rynku świeżych ziół. Bazylię uprawiano w szklarni, w doniczkach o pojemności 4 dm^3. Zastosowano cztery dawki azotu oraz dwie dawki potasu. W zebranym w okresie pełni kwitnienia zielu oznaczono zawartość suchej masy, N-NH_4 i N-NO_3, azotu ogółem, potasu oraz białka. Wykazano, że średnia zawartość suchej masy w zielu badanych roślin bazylii wynosiła 13,20% i była istotnie uzależniona od odmiany oraz dawki stosowanego azotu. Najwięcej (15,47%) suchej masy stwierdzono w zielu roślin odmiany Wala. Wzrastające dawki azotu powodowały zwiększenie zawartości białka w zielu bazylii. Najwięcej (26,13% s.m.) białka stwierdzono w zielu roślin żywionych najwyższą dawką azotu. Rośliny otrzymujące więcej potasu charakteryzowały się większą (23,24% s.m.) ilością białka w zielu niż rośliny otrzymujące mniej tego składnika (22,31% s.m.). Średnia zawartość azotu azotanowego w badanym materiale zielarskim wynosiła 0,78% s.m. Rośliny odmiany Wala odznaczały się istotnie mniejszą (0,66% s.m.) ilością azotu azotanowego niż pozostałe. Wykazano ponadto zwiększenie zawartości azotu ogółem, azotu amonowego i azotanowego oraz potasu w zielu bazylii, pod wpływem zwiększonej dawki azotu.

Słowa kluczowe: *Ocimum basilicum* L., N-og., N-NO_3, N-NH_4, białko

Accepted for print – Zaakceptowano do druku: 12.09.2011