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Influence of nitrogen nutrition and cultivar on quality of sweet basil herbs

Oddziaływanie nawożenia azotowego i odmiany na jakość surowca bazylii pospolitej

INTRODUCTION

Basil is a plant species with diverse applications: in pharmaceutical, food-producing industries, as well as ornamental and component plant that improves the scent in aromatherapeutic gardens. The sweet basil herb (*herba basilici*) is the main material for processing. It is warm-climate plant and requires a lot of warmth, insolation, soil fertility, and moisture.

The basil herb contains from 0.5 to 1.5% essential oils, including the most appreciated compounds such as linalol and eugenol. Furthermore, basil contains saponins, tannins, flavonoids, glycosides, and minerals, namely potassium, phosphorus, magnesium, and calcium [20].

The basil oil is one of the components for perfumery and is used in aromatherapy. Basil herb is also widely applied in medicine and foodstuff production [9].

A rational herbs cultivation allows to improve their quality and to achieve uniform material. In Poland, cultivation of herbal plant species still develops. Trade with increasing quantities of spices and medicinal plants in containers makes a necessity to work out some detailed nutritional recommendations for such plants. Therefore, the study aimed at evaluating the changes in the content and qualitative composition of essential oils, yields, and biological value of basil due to varied nitrogen nutrition and cultivar grown, was undertaken.

MATERIAL AND METHODS

The experiments involving basil were carried out in a greenhouse in 2010 in 2-liter pots filled with tall peat limed up to pH 6.5. The experiment was established by means of complete randomization method in 10 replicates. Every replicate consisted of a single plant. Nutrients were applied at following quantities ($g \cdot dm^{-3}$ of subsoil): N-0.6, P-0.5, K-1.0, Mg-0.4, as well as ($mg \cdot dm^{-3}$ of subsoil) Fe-8.0, Cu-13.3, Mn-5.1, B-1.6, Mo-3.7, and Zn-0.74. Particular nutrients were used in forms of: N – calcium nitrate, ammonium nitrate, and urea, P - superphosphate 20.2% P, K – potassium sulfate, Mg – magnesium sulfate monohydrate, Fe – chelate, Cu, Mn, Zn – sulfates, B – boric acid, Mo – ammonium molybdate.

After the harvest, plants were weighed, then fresh matter yields and plant height was determined. Plant material was collected at the moment of the experiment complete. Fresh material was subject to determinations of: vitamin C by means of Tillman method (PN-A-04019 1998), phosphorus (colorimetry with ammonium vanado-molybdate) after combustion at 550 ^{o}C, as well as potassium, calcium, magnesium, zinc, copper, iron, and manganese applying AAS technique (Perkin-Elmer, Analyst 300) [12].

The essential oil content in air-dried herbs was determined in accordance with Polish Pharmacopoeia VI. The qualitative and quantitative composition of basil essential oil was analyzed by means of gas chromatography coupled with mass spectrometry technique (GC/FID). For the examinations we applied Varian Chrompack CP-3800 with mass detector 4000 GC/MS/MS apparatus with VF-5ms column and with FID (J&W, USA) The dosimeter temperature was 250ºC. Temperature gradient 50ºC was applied for 1 minutes, then increase by 4ºC to 250ºC.

Achieved results were statistically processed applying variance analysis for mean values, while differences were estimated using Tukey test at the significance level of α=0.05.

RESULTS

The influence of studied factors on biological value of sweet basil herb is presented in Table 1. The yield of basil herb did not significantly differ due to applied nitrogen fertilizers, while the cultivar remarkably affected the quantity of fresh matter harvested. Mean total yield amounted to 227.7 g · plant^{-1}.

Table 1. Effect of cultivar and kind nitrogen fertilizer on the herb yield, plant size and biological value of sweet basil herb

Cultivar	Nitrogen fertilizer	Yield (g·plant^{-1})	Plant size (cm)	Vitamin C (mg·100g^{-1}f.m.)	Essentials oil (% d.m.)
green	$Ca(NO_3)_2$	237.8	80.22	12.92	0.40
	NH_4NO_3	232.6	76.56	14.87	0.25
	$CO(NH_2)_2$	241.6	81.78	17.74	0.40
Mean - green		240.6	79.51	15.18	0.35
violet	$Ca(NO_3)_2$	123.4	63.33	19.33	0.41
	NH_4NO_3	135.9	55.22	19.28	0.40
	$CO(NH_2)_2$	124.7	53.56	19.63	0.38
Mean - violet		128.0	57.37	19.41	0.40
round	$Ca(NO_3)_2$	302.4	72.00	22.51	0.57
	NH_4NO_3	318.2	71.78	12.59	0.65
	$CO(NH_2)_2$	332.7	67.00	14.88	0.53
Mean - round		317.8	70.26	16.66	0.58
Mean -	$Ca(NO_3)_2$	221.2	71.85	18.25	0.46
	NH_4NO_3	232.2	67.85	15.58	0.43
	$CO(NH_2)_2$	233.0	67.44	17.42	0.44
NIRα=0.05					
cultivar		21.477	2.246	0.806	0.140
fertilizer		i.d.	2.246	0.806	i.d.
cultivar x fertilizer		i.d.	5.207	1.976	i.d.

i.d. – insignificant differences

The plant's height substantially depended on the cultivar grown, type of the nitrogen fertilizer applied, and interaction between both factors. The green-leaved cultivar plants reached 79.5 cm, while purple-leaved 57.4 cm, and spherical 70.3 cm of height.

Examined factors – both cultivar and nitrogen fertilizer – remarkably affected the vitamin C content in raw sweet basil herb. The highest concentration of ascorbic acid was recorded at purple-leaved basil (19.4 mg·100g^{-1} FW).

The essential oil concentration in sweet basil herb significantly depended on the cultivar of analyzed plants. Spherical cultivar was characterized by the largest amounts of essential oils (0.55%), then medium content was found in purple-leaved, and lowest at green-leaved cultivar. Qualitative composition of isolated oil depended on the studied factors. Chromatographic analysis of the basil essential oil revealed that the following compounds dominated: linalol, 1,8-cineol, α-trans-bergamotene, methyl eugenol, D germacrene, epi-α-cadinol. Comparing the influence of applied fertilizers on concentrations of the main constituents of essential oil, it was noticeable that the highest levels of linalol was produced after applying calcium nitrate, both for green-leaved (62.86%) and spherical cultivar (58.19%), vs. ammonium nitrate and urea.

Studied cultivars of sweet basil along with diverse nitrogen nutrition differentiated the mineral composition of plants (Table 3). Total and nitrate nitrogen contents were dependent on experimental factors. Both item concentrations oscillated from 3.5 to 5.4% DM (total N) and from 0.05 to 1.14% DM ($N\text{-}NO_3$). Quantity of nitrates in basil herb varied within very wide range. The lowest amounts of nitrates were recorded at spherical plants (0.14% DM), slightly more at green-leaved cultivar, while the largest quantities of nitrates were found in purple-leaved plants.

Phosphorus, potassium, calcium, and magnesium contents in basil were considerably differentiated by the cultivar of plants grown. The highest phosphorus, potassium, and magnesium levels were found at purple-leaved, while calcium at green-leaved cultivar.

The analysis of microelements concentrations within experimental plants herb revealed significant differences between particular mean values for varied nitrogen nutrition and between cultivars. The purple-leaved plants were characterized by higher zinc, manganese, and copper contents as compared to green-leaved and spherical cultivars. Applying ammonium nitrate contributed to accumulation of zinc, iron, and copper quantities in sweet basil herb as compared to effects of calcium nitrate and urea.

Table 2. Effect of cultivar and kind nitrogen fertilizer on the main chemical compound of sweet basil essential oil

Compound	green			violet			round		
	$Ca(NO_3)_2$	NH_4NO_3	$CO(NH_2)_2$	$Ca(NO_3)_2$	NH_4NO_3	$CO(NH_2)_2$	$Ca(NO_3)_2$	NH_4NO_3	$CO(NH_2)_2$
β-pinene	0.91	0.95	0.93	1.22	1.11	1.14	0.48	0.37	0.40
1.8- cineole	9.51	7.59	9.32	13.08	10.95	12.41	5.51	4.30	4.30
Linalool	62.86	60.15	61.39	52.65	53.67	54.45	58.19	52.92	54.54
Camphor	0.23	0.22	0.24	Tr.	Tr.	Tr.	1.38	1.66	1.70
4-ol-terpinen	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	1.65	1.83	2.06
eugenol	1.95	3.39	2.25	0.24	Tr.	Tr.	2.44	1.77	2.43
Methy eugenol	Tr.	0.29	0.28	1.22	1.06	1.43	10.57	17.63	13.81
α-trans-bergamotene	9.65	10.26	9.59	14.15	14.41	13.42	4.72	4.23	4.78
D germacrene	1.51	1.52	1.55	1.71	2.13	1.75	0.98	1.05	0.84
γ-cadinene	1.30	1.48	1.29	1.22	1.28	1.14	1.40	1.22	1.15
Epi-α-cadinol	3.51	4.03	3.67	3.55	2.94	3.26	3.17	2.61	2.64

Table3. Effect of cultivar and kind nitrogen fertilizer on macro- and microelement concentrations in sweet basil herb

Cultivar	Nitrogen fertilizer	% d.m.						mg·kg^{-1}d.m.			
		N-total	N-NO_3	P	K	Ca	Mg	Zn	Mn	Fe	Cu
green	$Ca(NO_3)_2$	3.85	0.13	0.48	3.83	2.45	0.56	55.70	336.5	92.2	9.45
	NH_4NO_3	4.35	1.14	0.66	3.96	2.23	0.51	69.50	579.0	143.2	14.0
	$CO(NH_2)_2$	4.65	0.17	0.61	3.82	2.49	0.36	59.20	577.0	122.4	14.0
Mean - green		4.28	0.48	0.58	3.87	2.39	0.47	61.47	497.5	119.2	12.48
violet	$Ca(NO_3)_2$	4.4	1.04	0.52	4.36	1.87	0.48	90.90	427.0	165.6	13.4
	NH_4NO_3	4.9	1.03	0.78	4.31	1.48	0.54	114.65	730.5	174.5	17.15
	$CO(NH_2)_2$	5.4	0.63	1.12	3.89	1.10	0.37	107.90	795.5	169.6	14.05
Mean - violet		4.9	0.90	0.8	4.18	1.48	0.46	104.48	651.0	169.9	14.87
round	$Ca(NO_3)_2$	3.95	0.24	0.4	3.32	1.33	0.43	75.35	461.0	166.8	10.6
	NH_4NO_3	3.6	0.14	0.34	2.80	1.05	0.37	63.25	429.0	204.9	10.35
	$CO(NH_2)_2$	3.5	0.05	0.36	2.83	1.15	0.36	61.15	412.0	156.5	7.1
Mean - round		3.68	0.14	0.36	2.98	1.17	0.38	66.58	434.0	176.1	9.35
Mean - $Ca(NO_3)_2$		4.06	0.47	0.47	3.83	1.88	0.49	73.98	408.2	141.5	11.15
Mean - NH_4NO_3		4.28	0.77	0.59	3.69	1.58	0.47	82.47	579.5	174.2	13.83
Mean - $CO(NH_2)_2$		4.51	0.28	0.7	3.51	1.58	0.36	76.08	594.8	149.5	11.72
NIR α=0.05											
cultivar		0.076	0.040	0.245	0.163	0.465	0.068	6.08	15.10	6.55	0.84
fertilizer		0.076	0.040	i.d.	0.163	i.d.	0.068	6.08	15.10	6.55	0.84
cultivar x fertilizer		0.186	0.098	i.d.	0.399	i.d.	i.d.	14.91	37.02	16.06	2.05

i.d. – insignificant differences

DISCUSSION

The yields of sweet basil and its biological value were diverse depending on a cultivar and nitrogen fertilizer form. The spherical plants fertilized with urea produced the highest yields of fresh weight (333 g·plant^{-1}) with medium vitamin C content (15 mg·100 g^{-1} FW) as compared to plants of the same cultivar treated with ammonium nitrate and calcium nitrate. Numerous authors indicated that basil yields also depended on other factors. Golcz et al. [4] as well as Golcz and Politycka [5] reported that nitrogen nutrition significantly enhanced the basil leaves weight. Omer et al. [15], when analyzing *Ocimum americanum* L., recorded higher herb and dry matter yields after ammonium sulfate application instead of ammonium nitrate and urea.

The examined plants of sweet basil reached their medium height of 69 cm, which is similar to data reported by Golcz et al. [6], whereas much larger than those found by Martyniak-Przybyszewska and Wojciechowski [11]. Results from the present study indicate that the height of basil plant depended on the cultivar and form of nitrogen fertilizer.

The achieved results on ascorbic acid concentration substantially depended on the cultivar and the type of nitrogen nutrition. The highest vitamin C content (22.5 mg·100 g^{-1} FW) was recorded at plants of spherical shape treated with calcium nitrate. Analyzing the vitamin C concentration as affected by a cultivar, Dzida [2] reported that Polish Kasia cv. accumulated more vitamin C (26.5 mg · 100 g^{-1} FW) than Wala cv. (20.4 mg · 100 g^{-1} FW). Martyniak-Przybyszewska and Wojciechowski

[11] recorded lower concentrations of ascorbic acid in fresh weight of basil (11.9 mg·100 g^{-1}); these authors reported that garden marjoram, common thyme, garden savory, and oregano were more abundant in that compound. Grzeszczuk and Jadczak [7, 8], when analyzing the *Lamiaceae* family plants, found that they could be stored as frozen; however these authors informed that the process had destructive effects on vitamin C level.

Concentration of essential oils in plants depends on many factors, among which genetic, climatic, cultivating, harvesting phase, cultivar, and fertilizing reasons are the most important. The essential oil content in studied material significantly depended on the cultivar and nitrogen fertilizer applied and amounted to 0.45%, on average. The achieved results are similar to those recorded by Suchorska and Osińska [21], Marotti et al. [10], as well as Nurzyńska-Wierdak [13, 14].

Linalol, the content of which reached 61.5% at green-leaved, 55.2% at spherical, and 53.6% at purple-leaved cultivar, was the main constituent of sweet basil essential oil. Based on that fact, the examined cultivars can be numbered among linalol chemotype and European type according to Lawren's as well as Suginur and Toi's classifications [21]. Similar classification was assigned by Marotti et al. [10], when defining the linalol type as chemically little diverse with great amounts of linalol (up to 70%), containing no estragole (methyl chavicol) nor eugenol, but with quite high concentration of 1,8-cineol (13%). Other components of basil essential oil present at remarkable levels were: α-trans-bergamotene, 1,8-cineol, epi-α-cadinol, and eugenol. Nurzyńska-Wierdak [13], who studied the purple-leaved and green-leaved basil cultivars, found that linalol dominated in their essential oils: 73.5% and 69%, respectively. Much lower concentrations were shown by 1,8-cineol (6.6% and 5.4%), germacrene D (2.6% and 2.5%), as well as β-elemen (2.6% and 1.8%).

The nitrate concentration at sweet basil herb was low, which proves quite good quality of produced material. Seidler-Łożykowska et al. [19], when examining the basil of Wala cv. originating from conventional cultivation and organic farming, recorded much lower total nitrogen content ranging within 2.42-3.77%. Golcz et al. [4] reported that total nitrogen content in basil herb depended on the cultivar and nitrogen fertilizer rate, and it ranged from 1.24% to 3.96% DM for Wala cv. Analyzing the influence of calcium fertilizer and cultivar, Dzida [1] observed higher concentrations of total nitrogen at studied plants; its mean content amounted to 5.35% DM.

Potassium concentration in the examined plants ranged from 2.8 to 4.36% DM. Similar potassium content in basil herb was reported by Őzcan et al. [17] (4.0%), whereas Seidler-Łożykowska et al. [19] found that the element content in basil plants oscillated within quite wide range (2.98-5.21% DM), which depended on the soil type and cultivation method. According to Őzcan and Akbulut [16] as well as Őzcan [18], potassium concentration in basil herb was from 2.48% to 2.76%.

The levels of microelements in the examined plants were significantly differentiated by nitrogen fertilizers applied and basil cultivars grown. Golcz et al. [3], when examining basil plants originating from different cultivating sites, reported that manganese content was 175.7 mg·kg^{-1} DM, iron 438.9 mg·kg^{-1} DM, copper 15.6 mg·kg^{-1} DM, and zinc 80 mg·kg^{-1} DM. Suchorska-Orłowska et al. [22] as well as Witoszyńska and Jendryczko [23] indicated that the quantity of microelements in herbal material could be characterized by significant variation resulting from the development phase, as well as the species and part of analyzed plant.

CONCLUSIONS

The achieved results allow for concluding that plant nutrition and proper selection of a cultivar are factors that have remarkable influence on the yield size and quality of sweet basil herb.

The spherical cultivar was characterized by the largest amounts of essential oils and the lowest levels of nitrates. Linalol concentration also depended on nitrogen fertilizer applied and cultivar grown. The highest contents of linalol were recorded in green-leaved basil treated with urea.

The examined plants of sweet basil showed diverse abilities to accumulate macronutrients and microelements, which was probably the result of varietal features and different nutrition types. However, the studied herbal material contained quite high levels of minerals, thus it can be a source of readily available elements for human diet.

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SUMMARY

Rational cultivation of herbs results in their higher quality and leads to unification of the material. Commercial sale of increasing number of pot plants for spices and medicinal products leads to the necessity of developing strict nutrition recommendations for such plants. The aim of the research was to define changes of volatile oil content and its qualitative composition, yield and biological value of *Ocimum basilicum* L. influenced by diversified nitric nutrition and cultivars. Experiment with *Ocimum basilicum* L. (cultivars with green and purple leaves and spherical habit) was conducted in a green house. Nutrients were used in the following amounts (per $g \cdot dm^{-3}$ of medium): N-0,6 (calcium nitrate, ammonium nitrate and urea); P-0,5 (superphosphate 20,2% P); K-1,0 (potassium sulphate); Mg-0,4 (magnesium sulphate monohydrate). The results of the experiment were very interesting. Yield of *Ocimum basilicum* L. did not significantly differ as the effect of applied nitrate fertilizer. Yet the cultivar had significant effect of the size of plant fresh weight. Average total yield equaled 228.7 g $plant^{-1}$. It should be emphasized that the experimental factors in use had significant influence on the concentration of volatile oil, nitrates and vitamin C in *Ocimum basilicum* L. The cultivar with spherical habit was characterized by the greatest content of volatile oil and the smallest amount of nitrates. Linalool concentration in the oil depended also on the type of nitrate fertilizer applied and on cultivar. The highest content of this compound was noted in *Ocimum basilicum* L. with green leaves fed with urea. Based on the acquired results, conclusion can be made that plant feeding and cultivar selection are those factors that affect the size and quality of material of *Ocimum basilicum* L.

Keywords: Ocimum basilicum L., nitrogen, cultivar, macroelements

STRESZCZENIE

Racjonalna uprawa ziół pozwala podnieść ich jakość oraz otrzymać jednolity surowiec. Sprzedaż na rynku coraz większej ilości roślin przyprawowych i leczniczych w pojemnikach stwarza konieczność opracowania ścisłych zaleceń żywieniowych tak uprawianych roślin. Badania miały na celu określenie zmian zawartości olejku eterycznego i jego składu jakościowego, plonu oraz wartości biologicznej bazylii pospolitej pod wpływem zróżnicowanego żywienia azotowego i odmiany. Doświadczenie z bazylią pospolitą (odmiany o liściach zielonych i fioletowych oraz o pokroju kulistym) przeprowadzono w szklarni. Składniki pokarmowe zastosowano w ilościach ($g \cdot dm^{-3}$ podłoża): N-0,6 (saletra wapniowa, saletra amonowa i mocznik); P-0,5 (superfosfat 20,2% P); K-1,0 (siarczan potasu); Mg-0,4 (siarczan magnezu jednowodny). Otrzymano interesujące wyniki. Plon ziela bazylii pospolitej nie różnił się istotnie pod wpływem stosowanych nawozów azotowych, natomiast odmiana w sposób istotny wpływała na wielkość świeżej masy roślin. Średni plon ogółem wynosił 228,7 g $\cdot$ roślina^{-1}. Należy podkreślić, iż zastosowane czynniki badawcze w istotny sposób oddziaływały na koncentrację olejku eterycznego, azotanów i witaminy C w zielu bazylii. Największą zawartością olejku eterycznego z najmniejszą ilością azotanów charakteryzowała się bazylia odmiany o pokroju kulistym. Koncentracja linalolu w olejku zależała również od rodzaju zastosowanego nawozu azotowego i odmiany. Najwyższą zawartość tego związku odnotowano w bazylii o liściach zielonych żywionej mocznikiem. Na podstawie otrzymanych wyników można stwierdzić, iż żywienie roślin oraz dobór odmiany to czynniki wpływające na wielkość i jakość surowca bazylii pospolitej.

Słowa kluczowe: Ocimum basilicum L., azot, odmiana, makroelementy