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DYNAMICS OF SWEET BASIL (*Ocimum basilicum* L.) GROWTH AFFECTED BY CULTIVAR AND FOLIAR FEEDING WITH NITROGEN

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Abstract. Growing herbal plants is connected with obtaining the high yield of raw material, abundant in active substances. The growth and yield of these plants can be effectively improved by growing valuable cultivars and appropriate agrotechnical procedures. One of the latter is foliar feeding of plants with nitrogen, which is a fast-acting and extremely effective procedure. The conducted studies were aimed at comparing growth dynamics in four basil cultivars, including the Polish ones: Kasia and Wala, as well as determining the effect of foliar plant feeding with nitrogen upon their growth and development. The plants were grown from March till July 2008 and 2009 in an unheated foil tunnel. During the experiment the thermal conditions were generally favorable for basil development. Foliar feeding of basil was conducted with the use of hand spraying machine, dosing 0.5% urea solution. The examined basil cultivars were characterized by various growth dynamics, which was also related to temperature distribution in the growing period. The highest accretion was that of the Polish cultivar Kasia plants. The examined basil plants responded well to foliar nitrogen feeding. The application of urea contributed to a significant increase of the height of basil plants, as well as of the length and width of their leaf blades. However, this procedure did not simultaneously affect the plant diameter and number of sprout branchings.

Key words: *Lamiaceae*, morphological variability, plant growth, application of urea

INTRODUCTION

Sweet basil (*Ocimum basilicum* L.) is an annual, aromatic, herbal plant, belonging to the *Lamiaceae* family. It comes from the tropical regions of South-Eastern Asia and it is grown in many countries of the world as an ornamental, seasoning and medicinal plant. The aromatic basil leaves and flowers, as well as the essential oil distilled from the herb are used as aromas for food, perfume and cologne production and in medical therapy.

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The therapeutic properties of basil are first of all related to the presence of essential oil, whose properties, among other things antibacterial, antioxidant and psychotherapeutic, were confirmed in numerous scientific studies [Zamfirache et al. 2008, Zheljazkov et al. 2008, Hussain et al. 2008, Carović-Stanko et al. 2010, Runyoro et al. 2010]. The aim of basil growing is to obtain good herb yield with substantial contents of essential oil, the main biologically active substance.

The genus *Ocimum,* into which *Ocimum basilicum* L is included, is characterized by high morphological, developmental and chemical variability [Simon et al. 1990, Morales and Simon 1997, Tansi and Nacar 2000, Seidler-Łożykowska and Kaźmierczak 2001, Nurzyńska-Wierdak 2007a, b, Zheljazkov et al. 2008, Bączek-Kwinta et al. 2009, Carović-Stanko et al. 2010], which is proven by numerous cultivars and chemotypes, of different features of growth, yield and raw material quality. Morphological differentiation within the *Ocimum* genus was emphasized by many centuries of growing with the highest variability in pigmentation, size and shape of leaves, as well as in the aroma. Recently in Poland two first basil cultivars have been registered: Kasia and Wala, grown in the Institute of Herbal Plants and Products in Poznań (at present: Institute of Natural Fibers and Herbal Plants in Poznań). These are cultivars forming high plants of risen up habit (‘Wala’) and medium-high plants with rounded habit (’Kasia’), with large, green, conduplicate leaves and light-violet flowers [Golcz and Seidler-Łożykowska 2008].

Basil, due to its origin, has strict climatic requirements, especially as to light and temperature. The temperature of air significantly affects growth and development of the plants, as well as the contents and composition of essential oil, which, in turn, determines the usability of the herb for pharmaceutical purposes [Vieira and Simon 2006, Zamfirache et al. 2008, Carović-Stanko et al. 2010, Runyoro et al. 2010]. Similarly, light has a substantial influence on plant growth and chemical composition [Chang et al. 2008]. In order to increase the quantity and quality of yield in basil growing, organic and mineral fertilization is applied [Nguyen and Niemeyer 2008, Zheljazkov et al. 2008, Daneshian et al. 2009, Biesiada and Kuś 2010, Dzida 2010a, b, Phuong et al. 2010]. It is also recommended to fertilize the plants with multi-component manures, containing microelements, which favorably affects both the herb yield and the quality of essential oil [Refaat and Saleh 1998]. The aim of the conducted studies was to compare the growth dynamics of four basil cultivars, including the Polish cultivars ’Kasia’ and ‘Wala’, as well as determining the effect of foliar plant feeding with nitrogen upon their growth and development.

MATERIAL AND METHODS

The experiment was conducted in the period from March till June 2008 and 2009 in the Experimental Farm of the University of Natural Sciences in Lublin. The plants of four sweet basil cultivars were grown: Kasia, Wala, Genua Star and Opal. The sowing material came from the Institute of Natural Fibers and Herbal Plants in Poznań (Polish cultivars: Kasia, Wala) and from PNOS-Ożarów Mazowiecki (the remaining cultivars). The experiment was established with the use of complete randomization in four replications as a two-factor experiment. The first factor was the basil cultivar (four levels:

'Kasia' – medium-sized plants, rounded habit with large, dropping, rolling green leaves; 'Wala' – tall plants of uplifted habit with large, slightly rolling green leaves; 'Genua Star' – green-leaved, tall plants of uplifted habit; 'Opal' – purple-leaved, short-plants) the second factor: supplemental feeding the plants with nitrogen (two levels: feeding and non-feeding plants).

Seeds of the examined basil cultivars were sown in the third decade of March into sowing boxes filled with peat substrate in heated glasshouse. Before seeding the seeds had been dressed with a fungicide Dithane Neo Tec 75WG. The seedlings that reached the height of 6–7 cm were thinned into multiplates filled with peat substrate. At the end of April, after they had been hardened, the 15–16 cm high seedlings were planted into an unheated foil tunnel.

The lessive soil in the tunnel, derived from medium silty loam with 1.9% organic matter, pH_{H2O} 7.4, EC 0.31 mS cm^{-1}, 8.0 mg $N\text{-}NH_4$+$N\text{-}NO_3$, 60 mg P, 20 mg K and 60 mg Mg in 1 dm^{-3}, was prepared in accordance with the recommendations assumed for this species. Mineral fertilization was applied in the form of the compound fertilizer Azofoska in the dose of 45 kg · $100m^{-2}$, contributing into the soil: 306 mg $N\text{-}NH_4$+ $N\text{-}NO_3$, 65 mg P, 360 mg K and 60 mg Mg · dm^{-3}. The plants were planted in the spacing of 30 × 30 cm, there were 36 plants on one plot. The surface of the whole experiment was 90 m^2, and the surface of one plot equaled 4.2 m^2. The thermal conditions during the experiment were generally favorable for the development of basil. The mean air temperature during vegetation of the examined plants was similar to the multiannual mean. The temperature distribution in the particular 10-day periods of April, May and June was relatively regular, although certain differences were found in April 2009. Generally the temperature increased starting from the first and second to third decade of each month. The air temperature in April and May 2008 was slightly lower than in the year 2009. No symptoms were found on plants of the effect of low temperature, decreasing at night.

During vegetation manual weeding of plants was performed several times, as well as constant watering, by means of dripping lines. Foliar fertilization of basil was performed with the use of manual spraying machine, dosing 0.5% urea solution until total wetting of the leaf blade surface. The plants non-fertilized with nitrogen were at that time wetted with water in the same way. Nitrogen fertilization and wetting with water were performed four times, in 10-day intervals, starting from the third decade of May, when the plants were at the initial stage of exuberant vegetation growth, and finishing two weeks before herb harvest – about mid-June.

During vegetation, measurements of plant height were performed in the plants of examined basil cultivars; 6 or 8 measurements were performed in 7-day intervals, starting from the beginning of May. The number of measurements depended upon the speed of growth and development of plants of the examined cultivars. The measurements were ended when no further accretion of sprout was found. Next the selected biometric features of plants were determined, i.e. plant height and diameter, number of lateral branchings, width and length of leaf blades sampling from lateral branches of the middle story of plant. The measurements were performed on 6 plants from each replication (24 plants). The obtained results were statistically elaborated using the variance analysis method for double classification at the significance level $\alpha = 0.05$.

RESULTS

High differentiation in the growth dynamics of the examined basil cultivars was demonstrated. The fastest growth was characteristic of ‘Kasia’ plants, whereas the ‘Opal’ cultivar was distinguished by even, gradual growth (fig. 1). Among the examined plants the highest accretions were reported in the period from the 14th to 21st May. At that time the most intense accretion distinguished the plants of ‘Genua Star’ and ‘Kasia’ (respectively: 13.9 and 13,8 cm), whereas the weakest was that of Opal cultivar. In the period from the 6th to 14th May, slow growth of plants was reported, which was probably connected with nightly fall of temperature. In fig. 1 the effect of foliar feeding of basil plants with nitrogen upon the dynamics of their growth was presented. In ‘Kasia’ and ‘Wala’ the highest plant growth accretion was reported from the 14th to 21st May, and the higher plant height accretion took place in non-feeding plants than in feeding ones. Until the 18th and 21st day of May (respectively: ‘Kasia’ and ‘Wala’) the basil plants were characterized by even growth (fig. 1). Later, after the urea application, it was found that the growth pace was different in the plants of ‘Kasia’ feeding or not feeding with nitrogen and intense height accretion in the plants of ‘Wala’ feeding with nitrogen. In ‘Genua Star’ the largest height accretion (15 cm) was reported a little later than in the remaining cultivars. It occurred in non-feeding plants in the period from the

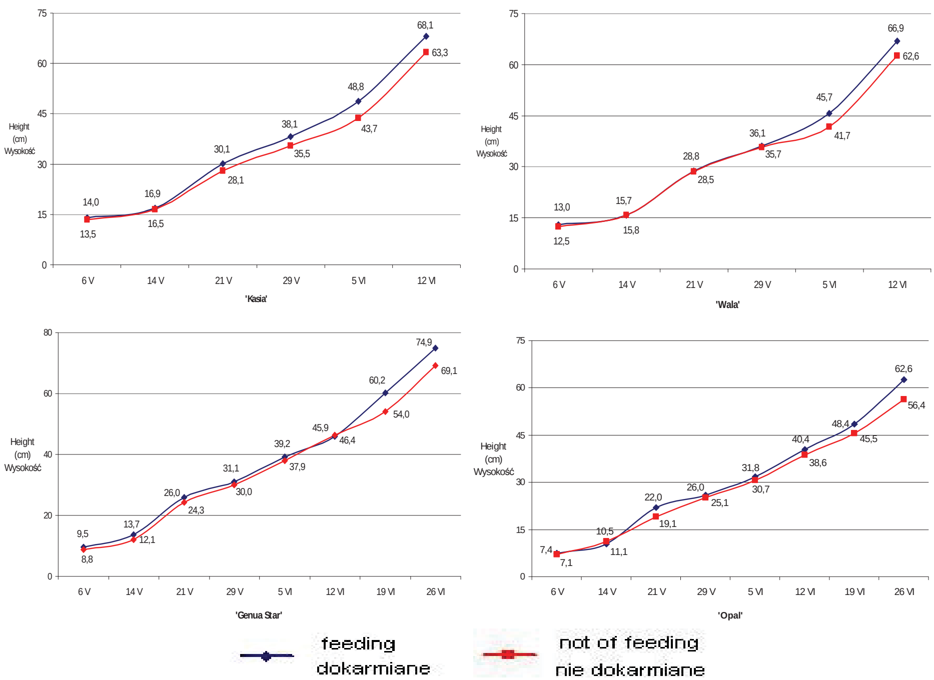

Fig. 1. Effect of nitrogen feeding of on the dynamics of plant growth basil (2008–2009)
Ryc. 1. Wpływ żywienia azotem na dynamikę wzrostu roślin bazylii (2008–2009)

Table 1. Effect of cultivar and foliar feeding with nitrogen on the chosen features of basil plants at the harvest time
Tabela 1. Wpływ odmiany i dokarmiania dolistnego azotem na wybrane cechy roślin bazylii w okresie zbioru

Cultivar Odmiana	Supplemental fertilization with nitrogen Uzupełniające nawożenie azotem	Height Wysokość (cm)			Plant diameter Średnica rośliny (cm)			Number of branches (per plant) Liczba rozgałęzień na roślinie		
		2008	2009	mean	2008	2009	mean			
Kasia	foliar feeding with nitrogen dokarmianie dolistne azotem	72.7	63.5	68.1	40.2	41.6	40.9	6.5	12.0	9.3
Wala		73.3	60.4	66.9	41.3	38.1	39.7	9.5	10.1	9.8
Genua Star		71.6	78.1	74.9	39.5	36.9	38.2	9.9	12.2	11.1
Opal		71.4	53.7	62.6	37.3	39.9	38.6	7.1	12.8	10.0
Mean – Średnio		72.2	63.9	68.1	39.6	39.1	39.4	8.3	11.8	10.1
Kasia	without foliar feeding with nitrogen bez dokarmiania dolistnego azotem	67.3	59.2	63.3	39.7	37.2	38.5	8.0	11.5	9.8
Wala		63.9	61.3	62.6	38.5	37.7	38.1	6.3	10.1	8.2
Genua Star		59.4	78.8	69.1	36.4	39.8	38.1	6.0	12.9	9.5
Opal		63.0	49.7	56.4	33.9	34.7	34.3	7.0	11.4	9.2
Mean – Średnio		63.4	62.2	62.9	37.1	37.4	37.3	7.0	11.5	9.2
Kasia		70.0	61.4	65.7	40.1	39.4	39.7	7.3	11.7	9.6
Wala		68.6	60.8	64.8	39.9	37.9	38.9	8.0	10.1	9.0
Genua Star		65.5	78.4	72.0	38.0	38.3	38.2	8.0	12.5	10.3
Opal		67.2	51.7	59.5	35.6	37.3	36.5	7.7	12.1	9.6
$LSD_{0.05}$ $NIR_{0,05}$										
Cultivar – Odmiana		4.1	5.3	6.8	n. s.	n. s.	n. s.	0.6	1.4	n. s.
Foliar feeding – Dokarmianie dolistne		2.2	n. s.	5.6	n. s.	n. s.	n. s.	2.1	n. s.	n. s.
Cultivar × foliar feeding – Odmiana × dokarmianie dolistne		n. s.	n. s.	11.2	n. s.	n. s.	n. s.	n. s.	n. s.	n. s.

12th to 19th June. More intense growth of feeding plants, compared to non-feeding ones, was found in the period from the 5th to 19th June. The most harmonious growth was that of the plants of 'Opal' (fig. 1). The largest height accretion was reported in the period from the 14th to 21st May. In addition, the feeding plants grew faster than non-feeding ones.

The examined factors, as well as their interaction, significantly affected the height of basil plants, which was 65.5 cm on average (tab. 1). The highest plants (72.0 cm), were characteristic of 'Genua Star', whereas the lowest (59.6 cm) – of 'Opal'. The applied procedure of urea application affected the increase of mean height of basil plants. The plants grown in the first study year, except 'Genua Star', had greater mean height that the plants of the second year.

Lack of significant effect of the examined factors, as well as their co effect upon the diameter of basil plants was demonstrated (tab. 1). The largest diameter (39.7 cm) was that of 'Kasia' plants and the smallest (36.5 cm) – the plants of 'Opal', but the differences were not statistically significant. Similarly, plants fed with nitrogen had greater diameters than the remaining ones, which, however, have not been statistically proven. The mean diameter of the examined basil plants equaled 38.3 cm.

Table 2. Effect of cultivar and foliar feeding with nitrogen on the chosen features of basil leaves at the harvest time

Tabela 2. Wpływ odmiany i dokarmiania dolistnego azotem na wybrane cechy liści bazylii w okresie zbioru

Basil cultivar	Supplemental fertilization with nitrogen Uzupełniające nawożenie azotem	Length of leaf blade Długość blaszki liściowej (cm)			Width of leaf blade Szerokość blaszki liściowej (cm)		
		2008	2009	mean	2008	2009	mean
Kasia	foliar feeding with nitrogen dokarmianie dolistne azotem	7.3	7.5	7.4	4.2	4.4	4.3
Wala		9.1	8.4	8.8	5.3	4.2	4.8
Genua Star		9.0	9.3	9.2	5.5	5.1	5.3
Opal		6.5	9.2	7.9	4.4	4.9	4.7
Mean – Średnio		8.0	8.6	8.3	4.7	4.6	4.8
Kasia	without foliar feeding with nitrogen bez dokarmiania dolistnego azotem	7.0	7.3	7.2	3.8	4.0	3.9
Wala		6.0	8.5	7.3	3.7	4.3	4.0
Genua Star		6.0	9.2	7.6	3.5	5.1	4.3
Opal		7.1	8.6	7.9	4.4	4.6	4.5
Mean – Średnio		6.4	8.4	7.5	3.9	4.5	4.2
Kasia		7.3	7.4	7.3	4.1	4.2	4.1
Wala		7.4	8.4	8.1	4.3	4.3	4.4
Genua Star		7.2	9.3	8.4	4.5	5.1	4.8
Opal		7.0	8.9	7.9	4.2	4.8	4.6
$LSD_{0.05}$ $NIR_{0,05}$							
Cultivar – Odmiana		0.6	1.3	1.1	0.5	0.6	0.5
Foliar feeding – Dokarmianie dolistne		0.4	n. s.	0.8	0.2	n. s.	0.6
Cultivar × foliar feeding – Odmiana × dokarmianie dolistne		0.9	n. s.	0.9	0.6	n. s.	0.5

The number of branchings of the main sprout in the examined basil plants did not remain under significant effect of the examined factors and their interaction (tab. 1). The highest number of branchings (10.3) was that of 'Genua Star', and the lowest (9.0) – that of 'Wala'. The mean number of sprout branchings in the examined plants was 9.6. More bifurcated plants occurred in the series with foliar feeding, as compared to the remaining ones, which, however, was not statistically proven. Distinct differences occurred in the degree of basil plant bifurcation in the studied years of the experiment. The plants grown in the year 2009 were distinguished by a greater number of branchings than in 2008.

A significant effect of examined factors and their co effect upon the size of basil leaves was demonstrated (tab. 2). The plants of 'Wala' and 'Genua Star' formed leaves with longer blades than the remaining ones. The leaf blades in plants of Genua Star and Opal cultivars in turn, were wider than in the remaining ones. Application of urea caused a significant increase both of the length and width of basil leaf blades. Comparing the plants grown in the years 2008 and 2009, to which urea was applied, it could be noticed that the highest variability as to leaf blade size was that of 'Opal', and in the case of non-nitrogen-feeding plants: 'Wala' and 'Genua Star'.

DISCUSSION

Growth of basil plants to a significant extent depends on the course of weather conditions during vegetation period [Vieira and Simon 2006, Chang et al. 2008, Zamfirache et al. 2008, Carović-Stanko et al. 2010, Runyoro et al. 2010], the basil plants, however, exposed to chill stress, were not distinguished by significant slowing down of growing processes [Bączek-Kwinta et al. 2009]. On the other hand, however, Borowski and Blamowski [2009] demonstrated that periodical chill significantly decreased the content of chlorophyll a+b, maximum quantum yield of chlorophyll, as well as gas exchange course in basil plants, whereas the effluence of electrolytes, water deficit and proline contents in leaves were greater in these conditions. Similarly, in the presented studies, the nightly fall of temperature in the 2^{nd} decade of May and June most probably contributed to slowing down of basil plant growth pace, in spite of the shield in the form of a foil tunnel. This would indicate a significant effect of temperature upon the pace of basil growth. Measurements of basil growth dynamics revealed the differences in the intensity of plant growth in the examined cultivars. The fastest growing pace was characteristic of the Polish cultivars Kasia and Wala, which can be defined as medium-average. The cultivars Genua Star and Opal achieved harvest maturity (full flowering) two weeks later [Nurzyńska-Wierdak et al. 2011]. Comparing the examined factors, it can be stated that it was the cultivar, not foliar nitrogen feeding that had greater effect upon basil growth dynamics. In the case of three cultivars, however, it was demonstrated that the feeding plants grew more intensely than the remaining ones.

The species *Ocimum basilicum* L. is characterized by high morphological and developmental variability [De Masi et al. 2006, Nurzyńska-Wierdak 2007a, b, Golcz and Seidler-Łożykowska 2008], which confirms the results of the foregoing studies. The Genua Star cultivar had the highest plants, the largest number of branchings, as well as the longest and widest leaf blades. It has to be remarked that the plants of this cultivar and the remaining ones turned out to be substantially larger than those described in previous works [Nurzyńska-Wierdak 2007a, b] and those described by Nazim et al. [2009], however the length and width of leaf blades was comparable. This confirms the conclusions reached by Eckelmann [2002], who argued that the height and width of basil plants depend mainly upon the environmental conditions, whereas the shape, surface and edge of the leaf blade are genetically conditioned and can constitute the identification features of cultivars.

Application of urea contributed to the significant increase in the height of basil plants, as well as the height and width of the leaf blade. Nitrogen, being one of the most important plant nutrients, is a component of proteins and nucleic acids, as well as of many non-protein compounds of primary importance, such as chlorophyll, enzymes, or other compounds. Applying nitrogen in the form of foliar feeding increases the reserve of this element in the plant and, consequently, growth and photosynthesis in many plants [Zhao et al. 2008, del Amor et al. 2009, Borowski and Michałek 2010]. In the previous study [Nurzyńska-Wierdak et al. 2011] we demonstrated that foliar application of nitrogen increased the weight and yield of sweet basil fresh herb. It also caused the increase concentrations of $N\text{-}NO_3$ and $N\text{-}NH_4$, K, Ca, but not significantly affect total nitrogen, protein, phosphorus and magnesium content, as compared to control plants. To make foliar feeding effective, spraying should be performed when the plants have formed enough well developed leaves. The basic principle is to select the appropriate concentration of fertilizing solution. In the experiment under discussion the basil plants were in the appropriate developmental phase, and the applied concentration of urea solution was optimal, which is confirmed by the condition and look of the plants, as well as the achieved effects of spraying application. Lack of the influence of foliar feeding the plants with urea upon their diameter and number of branchings can be related to the characteristic growth and habit of basil cultivars, which seems to be strongly genetically conditioned. The Polish basil cultivars, Kasia and Wala, distinguished by fast and intense growth, reached harvest maturity (full flowering) two weeks earlier than the others cultivars: Genua Star and Opal, which allows for including them into the group of mid-early cultivars.

CONCLUSIONS

1. The examined basil cultivars were characterized by various growth dynamics. The highest accretion of the height was that of the plants of the Polish cultivar Kasia. The plants of 'Opal' were characterized by even, gradual growth.

2. The highest accretion of the height of: 'Kasia', 'Wala' and 'Opal' basil plants was reported in the period from the 14^{th} to 21^{st} May. In the 'Genua Star' the greatest increase of plant height occurred later, i. e. from the 12^{th} to 19^{th} June.

3. The Polish basil cultivars, Kasia and Wala were distinguished by fast and intense growth, reaching harvest maturity (full flowering) two weeks earlier than the remaining ones.

4. The examined basil plats responded well to foliar feeding with nitrogen. The application of urea contributed to a significant increase of the basil plants' height, as well as the length and width of their leaf blades.

5. Basil diameter, as well as the number of branchings seem to be strongly genetically conditioned features, the proof of which may be lack of the effect of foliar feeding basil plants with urea upon these features.

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DYNAMIKA WZROSTU BAZYLII POSPOLITEJ (*Ocimum basilicum* L.) POD WPŁYWEM ODMIANY ORAZ POZAKORZENIOWEGO DOKARMIANIA ROŚLIN AZOTEM

Streszczenie. Uprawa roślin zielarskich związana jest z otrzymaniem wysokiego plonu surowca bogatego w substancje aktywne. Wzrost i plon tych roślin można skutecznie poprawić poprzez uprawę wartościowych odmian i odpowiednie zabiegi agrotechniczne. Jednym z tych ostatnich jest dokarmianie pozakorzeniowe roślin azotem, będące zabiegiem szybko działającym i niezwykle efektywnym. Przeprowadzone badania miały na celu porównanie dynamiki wzrostu czterech odmian bazylii, w tym polskich odmian Kasia i Wala oraz określenie efektywności dokarmiania dolistnego roślin azotem na ich wzrost. Rośliny uprawiano w okresie od marca do czerwca 2008 i 2009, w nieogrzewanym tunelu foliowym. Warunki termiczne w czasie wykonywania doświadczenia były na ogół sprzyjające rozwojowi bazylii. Dokarmianie dolistne bazylii przeprowadzono za pomocą opryskiwacza ręcznego, dozując 0,5% roztwór mocznika. Badane odmiany bazylii charakteryzowały się różną dynamiką wzrostu. Największym przyrostem odznaczały się rośliny polskiej odmiany Kasia. Badane rośliny bazylii dobrze reagowały na dokarmianie dolistne azotem. Aplikacja mocznika przyczyniła się do istotnego zwiększenia wysokości roślin bazylii oraz długości i szerokości blaszki liściowej, jednocześnie zabieg ten nie wpłynął na średnicę roślin i liczbę rozgałęzień pędu.

Słowa kluczowe: *Lamiaceae*, zróżnicowanie morfologiczne, wzrost roślin, aplikacja mocznika

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