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EFFECT OF ORGANIC-MINERAL FERTILIZERS ON THE YIELD AND QUALITY OF ENDIVE (*Cichorium endivia* L.)

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Abstract. Endive is a leaf vegetable, not commonly known in Poland, although popular in Western and Southern Europe. It deserves attention because of its high nutritive value and bitter taste caused by sesquiterpene lactones. In the experiments carried out in the years 2008–2009 the effect of mineral-organic fertilizers (Goëmar Goteo, Aminoplant) on the yield and quality of curly endive ('Cigal') and escarole ('Excel') was investigated. Seeds were sown in three periods. After four weeks plants were transplanted into the field. Mineral-organic fertilizers were applied in accordance to the producer's recommendation: the Goëmar Goteo preparation was used twice for seedlings watering while the Aminoplant preparation was used for plants spraying in the second and third week after transplanting them into the field. Mineral-organic fertilizers did not affect the yield of the investigated cultivars. The highest commercial yield of endive and the highest mean weight of leaf rosette was obtained for the first term of cultivation. Plants in the third term of cultivation characterized with the highest dry matter content. The least amount of nitrates was cumulated in curly endive leaves. The highest content of calcium was observed in the first term of cultivation. The content of potassium and phosphorus was on similar level during the first and the second term of cultivation. The significant effect on the macroelement content due to applied preparations was not observed. The effect of mineral-organic fertilizers on the content of flavonoids was examined. Leaves of endive rosettes treated with mineral-organic fertilizers synthesized rutoside and higher amount of astragalin (3-O--kaempferol glucoside) in comparison with control combination.

Key words: endive, yielding, term of cultivation, nitrates, flavonoids

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INTRODUCTION

Endive (*Cichorium endivia* L.) is a leaf vegetable which belongs to *Asteraceae* family, nearly unknown in Poland, indigenous to eastern Mediterrenean areas and may have originated from the cross *C. intybus* and *C. pumilum* [Kalloo and Bergh 1993]. Endive is widely spread species in the west and south of Europe. It has achieved popularity due to its nutritional value and bitter taste caused by presence of sesquiterpene lactones [Rodkiewicz 2000, Koudela and Petrikova 2007].

The edible part of endive is leaf rosette. There are two botanic cultivars within this species which differ in leaf anatomical structure – escarole (*Cichorium endivia* L. var. *latifolium*) with smooth, wide leaves with smooth-margins and curly endive (*Cichorium endivia* L. var. *crispum*) with narrow and strongly frilled leaves [Rodkiewicz 1999, Ryder 1999, Papetti et al. 2002, Koudela and Petrikova 2007, Adamczewska-Sowińska and Uklańska 2009].

Preparations stimulating plant growth and development commonly called biostimulators are applied in modern horticulture in the whole world. In Poland they are registered as organic-mineral fertilizers [Dz.U. 2008, nr 119, poz.765]. These preparations are obtained from fishes and plant products, e.g. waterweeds [Potin et al. 2002]. Apart from organic components they also contain mineral components. Out of 2000 species of brown algae the most commonly applied in agriculture are *Ascophyllum nodosum*, *Fucus* spp., *Laminaria* spp., *Sargassum* spp. and *Turbinaria* spp. They are used as a source of organic matter, nutritional components, as components of biostimulators and biofertilizers. Extracts from algae show their activity even in solutions diluted to 1:1000 [Khan et al. 2009]. Some organic-mineral fertilizers are recommended to be applied together with other fertilizers, others should be used instead of mineral fertilizers [Edmeades 2002]. Preparations containing algae extract are destined to be applied both on the leaves and into the soil. They positively affect physico-chemical and biological properties of soil, favour the development of soil microorganisms and mycorrhizal fungi [Kohler et al. 2007]. They improve the growth and development of the root system facilitating the intake of water and mineral components and causing the increase of the leaf surface and the increase of the intensity and efficiency of photosynthesis which results in a plant resistance to stress [Crouch et al. 1990, Khan et al. 2009, Przybysz et al. 2010].

Organic-mineral fertilizers have stimulated also increase of secondary metabolism products such as flavonols and anthocyanins, which are widely distributed in plants and seem to play many different roles. Polyphenols (flavonols and anthocyanins) have been described to have grater antioxidant activity than vitamins C and E [Rice-Evans et al. 1997]. They are involved in protection mechanism against insects and pathogens, UV light damage, and in the regulation of plant growth and development [Cooper-Driver and Bhattacharya 1998].

The aim of present investigation was determination of the effect of cultivation term and mineral-organic fertilizers application on yielding and chemical composition of selected cultivars of endive (*Cichorium endivia* L.).

MATERIAL AND METHODS

The experiment was carried out on the experimental field of the Department of Vegetable and Medicinal Plants of Warsaw University of Life Sciences – SGGW in the years 2008 and 2009 in the third terms of cultivation (tab. 1).

Table 1. Terms of cultivation measures in the crop of endive grown in the field
Tabela 1. Terminy zabiegów uprawowych w polowej uprawie endywii

Step – Etap	Years Lata	First term Termin pierwszy (I)	Second term Termin drugi (II)	Third term Termin trzeci (III)
Sowing Siew	2008	16 IV	4 VI	1 VII
	2009	6 IV	4 V	29 VI
Watering with Goteo solution 0.10% Podlewanie preparatem Goteo (0,10%)	2008	6 V, 13 V	17 VI, 24 VI	18 VII, 25 VII
	2009	20 IV, 27 IV	18 V, 25 V	13 VII, 20 VII
Seedling transplanting Sadzenie rozsady	2008	19 V	3 VII	2 VIII
	2009	5 V	3 VI	28 VII
Spraying with Aminoplant solution 0.20% Opryskiwanie preparatem Aminoplant (0,20%)	2008	2 VI, 12 VI	15 VII, 25 VII	16 VIII, 26 VIII
	2009	15 V, 25 V	15 VI, 25 VI	10 VIII, 20 VIII
Harvest Zbiór	2008	9 VII	4 VIII	4 XI
	2009	22 VI	29 VII	24 IX

Escarole cv. Exel and curly endive cv. Cigal, originating from Rijk Zwaan company, destined to all-year round cultivation, were used in the present experiment. During the growth of plants two preparations – Goëmar Goteo and Aminoplant were applied. Endive seeds were sown to multipots filled with the mixture of the high moor peat and bark in the greenhouse. The seedlings were planted into the open field in spacing 35 × 35 cm. N, P, K, content of the soil was kept at the optimum level with fertilizers applied to equal the average of 70 kg N ha^{-1}, 40 kg P ha^{-1}, and 130 kg K ha^{-1}. Field experiment was established in the split-split plot block design in three replications of 12 plants each. Average temperatures and rainfall sums were recorded (tab. 2).

The dry matter content was examined by drying to constant weight at 105ºC, results were presented in the mass fraction (%). The content of nitrates (NO_3^-) was determined using spectrophotometer Tecator Fiastar 5010 at the wave length 540 nm, results are presented in mg 100 g^{-1} of fresh matter. The content of phosphorus (P) was determined using the spectrophotometer Shimadzu 1700 at the wave length 460 nm, and the results are presented in mg 100 g^{-1} of fresh matter. Potassium (K) and calcium (Ca) content was determined using the flame spectrophotometer Scherwood Model 410 and the results are presented in mg 100 g^{-1} of fresh matter. The content of phenolic acids and flavonoids were determined using the HPLC method and the results are presented in mg 100 g^{-1} of dry matter.

Table 2. Average temperatures and the sums of rainfall for April – November in the years 2008–2009

Tabela 2. Średnie miesięczne temperatury powietrza i sumy opadów od kwietnia do listopada w latach 2008–2009

Months Miesiące	Temperature – Temperatura °C		Rainfall – Opady mm	
	2008	2009	2008	2009
April Kwiecień	9.6	11.3	31.9	8.0
May Maj	14.1	13.9	36.8	82.4
June Czerwiec	19.3	16.3	24.5	123.1
July Lipiec	19.7	20.2	97.8	123.3
August Sierpień	19.2	18.5	89.0	82.7
September Wrzesień	13.0	15.5	53.7	13.9
October Październik	10.4	6.9	19.9	100.3
November Listopad	5.8	5.7	30.9	62.5

The results were analysed statistically with the three and two factor analysis of variance at the level of significance $\alpha = 0.05$ (programme ANOVA 3 and ANOVA 2). Rutoside and kaempferol-3-o-glucoside were evaluated with two-way anova method (fertilizer, and cultivar as factors), remaining measurements – in three-way anova method (term of cultivation, fertilizer, and cultivar, as factors). The comparison of means was done using the Tukey's test.

RESULTS AND DISCUSSION

Yielding of examined endive cultivars for all-year round cultivation was dependent on term of cultivation. In the experiment, the highest commercial yield (8.30 kg m^{-2}) and the weight of commercial rosette (1.21 kg) of endive were obtained in the first term of cultivation (tab. 3). It was bigger than that obtained by Rodkiewicz [1998 and 1999], where it came to 5.56 and 7,83 kg m^{-2}, respectively. However, leaf rosettes in the present investigations (tab. 3) showed the rosette weight similar to that obtained by Rodkiewicz [1999] or nearly by 90% bigger than in the case of investigations performed by Rodkiewicz [1998], where they amounted to 0.71 and 0.35 kg, respectively. 'Excel' cultivar was characterized by a higher commercial yield (5.74 kg m^{-2}) as compared to the 'Cigal' cultivar (4.78 kg m^{-2}). In the investigations by Łyszkowska et al. [2008] the application of Aminoplant preparation caused the increase of the commercial yield of lettuce in comparison to the yield obtained after the application of Goëmar Goteo preparations or both preparations Goëmar Goteo and Aminoplant together, however, it did not differ significantly as compared to the yield obtained in the control combination.

Table 3. Marketable yield and mean weight of endive rosettes (mean 2008–2009)
Tabela 3. Plon handlowy i średnia masa rozety endywii liściowej (średnia 2008–2009)

Term of cultivation Termin uprawy	Marketable yield – Plon handlowy $kg \cdot m^{-2}$						Mean weight of rosette – Średnia masa rozety kg					
	cultivar odmiana	combination* – kombinacja				mean for cultivar średnia dla odmiany	combination* – kombinacja				mean for cultivar średnia dla odmiany
		control kontrola	Goëmar Goteo	Aminoplant	Goëmar Goteo + Aminoplant		control kontrola	Goëmar Goteo	Aminoplant	Goëmar Goteo + Aminoplant	
I	Excel	7.41 a	8.91 a	9.21 a	9.34 a		1.14 a	1.27 a	1.30 a	1.40 a	
	Cigal	7.50 a	8.62 a	7.71 a	7.68 a		1.10 a	1.25 a	1.11 a	1.16 a	
Mean for term Średnia dla terminu		8.30 a					1.21 a				
II	Excel	4.92 a	4.28 a	4.48 a	4.49 a		0.64 a	0.59 a	0.60 a	0.59 a	
	Cigal	3.39 a	3.27 a	3.66 a	3.34 a		0.47 a	0.47 a	0.50 a	0.50 a	
Mean for term Średnia dla terminu		3.98 b					0.55 b				
III	Excel	3.70 a	3.99 a	3.92 a	4.23 a	5.74 a	0.55 a	0.57 a	0.54 a	0.57 a	0.81 a
	Cigal	3.28 a	2.99 a	2.79 a	3.09 a	4.78 b	0.44 a	0.48 a	0.38 a	0.45 a	0.69 a
Mean for term Średnia dla terminu		3.50 b					0.50 b				
Mean for combination Średnia dla kombinacji		5.03 a	5.34 a	5.30 a	5.36 a		0.72 a	0.77 a	0.74 a	0.78 a	

Values in columns and rows marked with the same letters do not differ significantly at $\alpha = 0.05$, Tukey's HSD test
Wartości w kolumnach i wierszach z tymi samymi literami nie różnią się istotnie przy $\alpha = 0{,}05$, test Tukeya HSD
* kind of fertilizer
*rodzaj nawozu

Table 4. Dry matter and nitrate content in the leaves of endive (mean 2008–2009)
Tabela 4. Sucha masa i zawartość azotanów w liściach endywii (średnia 2008–2009)

Term of cultivation Termin uprawy		Dry matter – Sucha masa %					NO_3^- mg·100 g^{-1} f.w.				
	cultivar odmiana	combination* – kombinacja				mean for cultivar średnia dla odmiany	combination* – kombinacja				mean for cultivar średnia dla odmiany
		control kontrola	Goëmar Goteo	Aminoplant	Goëmar Goteo + Aminoplant		control kontrola	Goëmar Goteo	Aminoplant	Goëmar Goteo + Aminoplant	
I	Excel	5.11 a	6.25 a	6.01 a	5.68 a		40.51 a	36.55 a	35.04 a	43.42 a	
	Cigal	5.21 a	5.16 a	5.46 a	5.24 a		25.80 a	45.06 a	48.40 a	34.66 a	
Mean for term Średnia dla terminu		5.52 b					38.68 ab				
II	Excel	5.56 a	6.00 a	6.24 a	5.75 a		36.13 a	56.37 a	35.33 a	47.33 a	
	Cigal	5.43 a	4.95 a	4.86 a	5.02 a		42.72 a	33.35 a	29.87 a	39.24 a	
Mean for term Średnia dla terminu		5.47 b					40.04 a				
III	Excel	7.08 a	7.14 a	6.74 a	7.39 a	6.24 a	54.01 a	40.26 a	35.85 a	27.84 a	40.72 a
	Cigal	6.62 a	5.95 a	7.16 a	7.07 a	5.68 b	25.46 a	19.90 a	18.06 a	22.09 a	32.05 b
Mean for term Średnia dla terminu		6.89 a					30.43 b				
Mean for combination Średnia dla kombinacji		5.83 a	5.91 a	6.08 a	6.02 a		37.44 a	38.88 a	33.76 a	35.77 a	

Values in columns and rows marked with the same letters do not differ significantly at $\alpha = 0.05$, Tukey's HSD test
Wartości w kolumnach i wierszach z tymi samymi literami nie różnią się istotnie przy $\alpha = 0{,}05$, test Tukeya HSD test
* kind of fertilizer
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Table 5. Calcium and potassium content in the leaves of endive (mean 2008–2009)
Tabela 5. Zawartość wapnia i potasu w liściach endywii (średnia 2008–2009)

Term of cultivation Termin uprawy	Cultivar Odmiana	Ca, mg·100 g^{-1} f.w. – św.m.					K, mg·100 g^{-1} f.w. – św.m.				
		combination* – kombinacja				mean for cultivar średnia dla odmiany	combination* – kombinacja				mean for cultivar średnia dla odmiany
		control kontrola	Goëmar Goteo	Aminoplant	Goëmar Goteo + Aminoplant		control kontrola	Goëmar Goteo	Aminoplant	Goëmar Goteo + Aminoplant	
I	Excel	24.98 a	25.16 a	21.62 a	24.65 a		255.22 a	234.60 a	226.00 a	232.86 a	
	Cigal	19.12 a	26.02 a	22.77 a	24.35 a		197.81 a	209.98 a	200.33 a	201.56 a	
Mean for term Średnia dla terminu		23.58 b					219.79 a				
II	Excel	18.18 a	29.59 a	17.07 a	25.34 a		221.06 a	238.81 a	213.86 a	210.35 a	
	Cigal	25.03 a	26.53 a	22.52 a	16.56 a		223.38 a	215.28 a	235.09 a	203.12 a	
Mean for term Średnia dla terminu		22.60 b					220.12 a				
III	Excel	29.50 a	26.47 a	30.64 a	27.76 a	25.08 a	242.69 a	203.69 a	215.37 a	213.03 a	225.63 a
	Cigal	25.30 a	31.31 a	23.35 a	27.75 a	24.22 a	177.08 a	188.10 a	167.26 a	185.20 a	200.35 b
Mean for term Średnia dla terminu		27.76 a					199.05 b				
Mean for combination Średnia dla kombinacji		23.68 a	33.03 a	23.00 a	24.40 a		219.54 a	243.58 a	209.65 a	207.69 a	

Values in columns and rows marked with the same letters do not differ significantly at $\alpha = 0.05$, Tukey's HSD test
Wartości w kolumnach i wierszach z tymi samymi literami nie różnią się istotnie przy $\alpha = 0{,}05$, test Tukeya HSD
* kind of fertilizer
*rodzaj nawozu

Similar use of both preparations in one combination allowed obtaining a bigger lettuce head weight than in the case of using these preparations separately. However, also in that case it did not differ significantly from the control combination.

In the present investigation the dry matter content and the content of nitrates were determined. It was stated that the highest content of dry matter and the lowest content of nitrates was characteristic for the leaves of endive from the third term of cultivation (tab. 4). Koudela and Petrikova [2007], Adamczewska-Sowińska and Uklańska [2010] report that endive cultivars with the frizzy leaves cumulated smaller amounts of nitrates than escarole. Also in the present investigations a lower content of nitrates was characteristic for the cultivar with the frizzy leaves 'Cigal' (32.05 mg 100 g^{-1} of fresh matter) as compared to the 'Excel' cultivar (40.72 mg 100 g^{-1} of fresh matter). In the investigations carried out by Łyszkowska et al. [2008] dry matter content in the lettuce leaves increased and the content of nitrates decreased as a result of Goëmar Goteo + Aminoplant preparations application. However, similarly as in the case of commercial yield or head weight, obtained values were at the same level as those obtained in the control combination.

In presented investigations leaves of endive from the third term of cultivation contained the highest amount of calcium (tab. 5). On the other hand the highest amount of potassium (tab. 5) and phosphorus (tab. 6) were observed in the first and the second

Table 6. Phosphorus content in the leaves of endive (mean 2008–2009)
Tabela 6. Zawartość fosforu w liściach endywii (średnia 2008–2009)

Term of cultivation Termin uprawy	Cultivar Odmiana	P, mg·100 g^{-1} f.w. – św.m.				
		combination* – kombinacja				mean for cultivar średnia dla odmiany
		control kontrola	Goëmar Goteo	Aminoplant	Goëmar Goteo + Aminoplant	
I	Excel	11.04 a	12.63 a	11.65 a	13.02 a	
	Cigal	11.80 a	10.57 a	10.13 a	13.17 a	
Mean for term Średnia dla terminu		11.75 a				
II	Excel	11.83 a	12.44 a	12.17 a	11.21 a	
	Cigal	10.80 a	7.69 a	10.29 a	8.11 a	
Mean for term Średnia dla terminu		10.57 a				
III	Excel	10.02 a	9.66 a	10.92 a	10.70 a	11.76 a
	Cigal	7.68 a	7.79 a	8.01 a	7.88 a	9.49 b
Mean for term Średnia dla terminu		9.08 b				
Mean for combination Średnia dla kombinacji		10.53 a	10.73 a	10.53 a	10.68 a	

Values in columns and rows marked with the same letters do not differ significantly at $\alpha = 0.05$, Tukey's HSD test
Wartości w kolumnach i wierszach z tymi samymi literami nie różnią się istotnie przy $\alpha = 0{,}05$, test Tukeya HSD
* kind of fertilizer
*rodzaj nawozu

Table 7. Rutoside and kaempferol-3-o-glucoside (astragalin) content in leaves of endive (mean 2008–2009)
Tabela 7. Zawartość rutozydu i 3-O-glukozydu kemferolu (astragaliny) w liściach endywii (średnia 2008–2009)

Cultivar Odmiana	Rutoside – Rutozyd mg·100 g^{-1} d.w. – s.m.					Kaempferol-3-O-glucoside (astragalin) – 3-O-glukozyd kemferolu (astragalina) mg·100 g^{-1} d.w. – s.m				
	combination* – kombinacja				mean for cultivar średnia dla odmiany	combination* – kombinacja				mean for cultivar średnia dla odmiany
	control kontrola	Goëmar Goteo	Aminoplant	Goëmar Goteo + Aminoplant		control kontrola	Goëmar Goteo	Aminoplant	Goëmar Goteo + Aminoplant	
Excel	0.00 d	125.89 a	92.93 b	61.91 c	70.18 a	113.56 a	418.77 a	194.39 a	141.33 a	217.01 a
Cigal	0.00 d	134.90 a	79.93 bc	87.39 bc	75.55 a	101.64 a	279.36 a	167.18 a	148.86 a	174.26 a
Mean for combination Średnia dla kombinacji	0.00 c	130.39 a	86.43 b	74.65 b		107.60 b	349.06 a	180.79 b	145.09 b	

Values in columns and rows marked with the same letters do not differ significantly at $\alpha = 0.05$, Tukey's HSD test
Wartości w kolumnach i wierszach z tymi samymi literami nie różnią się istotnie przy $\alpha = 0{,}05$, test Tukeya HSD
* kind of fertilizer
*rodzaj nawozu

term of cultivation. In the present investigation the application of mineral-organic fertilizers did not cause the yield increase, level of dry matter, content of mineral components or decrease of the nitrite content (tab. 3, 4, 5 and 6). However, it contributed to the synthesis rutoside and the increase of the astragalin content. DuPont et al. [2000], Lee and Kader [2000], Baur et al. [2004] reported, that antioxidant compounds are susceptible to variation among cultivars, growing periods, processing and storage conditions on the biologically active compounds. In the present study the term of cultivation did not influence on synthesis of rutoside and kaempferol-3-o-glucoside. However the organic-mineral fertilizers significant influenced on the content of biologically active compounds. The most effective proved to be the Goëmar Goteo preparation, which caused synthesis of the highest amounts of rutoside (130.39 mg·100 g^{-1} of dry matter). The leaves of endive which was treated with the Goëmar Goteo preparation also contained the biggest amounts of astragalin (349.06 mg·100 g^{-1} of dry matter). The application of two remaining combinations with the preparations did not cause a significant increase of the astragalin content as compared to plants from the control combination (tab. 7). The study conducted by Llorach et. al. [2007] showed that polyphenols determined in five cultivars of lettuce and endive escarole allowed to identification of two compounds previously not reported in lettuce quercetin and luteolinchamnosyl-hexosides. In this investigation caffeic acid derivatives were the main phenolics in lettuce green cultivars, while flavonols were detected in higher quantities in lettuce red cultivars and endive escarole. The highest total phenolic content was observed in lettuce red-leafed varieties. In the investigations by Romani et. al. [2002] the polyphenol compounds content in the lettuce leaves to verify whether two different growing environments (greenhouse and open air) affected both the qualitative and quantitative phenol patterns. All open air samples had higher flavonol contents than the greenhouse ones.

CONCLUSIONS

1. Mineral-organic fertilizers did not affect the yield of the investigated cultivars.
2. Yielding of endive's cultivars adapted to the all-year cultivation was dependent on the term of cultivation. A higher yield of endive was obtained in the first term cultivation than in the second or third term of cultivation.
3. The lowest content of nitrates was characteristic of endive cultivated in the third term of cultivation. Less nitrates was noted in curly endive ('Cigal').
4. Mineral-organic fertilizers affected the content of biologically active compounds causing the synthesis of rutoside and the increase of astragalin content.

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WPŁYW NAWOZÓW ORGANICZNO-MINERALNYCH NA PLON I JAKOŚĆ ENDYWII (*Cichorium endivia* L.)

Streszczenie. Endywia jest warzywem liściowym, mało znanym w Polsce, w porównaniu z Europą Zachodniej i Południowej. Zasługuje na uwagę ze względu na wysoką wartość odżywczą i gorzki smak powodowany przez laktony seskwiterpenowe. Celem badań przeprowadzonych w latach 2008–2009 było określenie wpływu nawozów mineralno-organicznych (Goëmar Goteo, Aminoplant) na plon i jakość endywii kędzierzawej (Cigal) i eskarioli (Excel). Uzyskane wyniki wykazały, że nawozy mineralno-organiczne nie wpłynęły na wielkość plonu badanych odmian. Najwyższy plon handlowy endywii i średnią masę rozety liściowej uzyskano w pierwszym terminie uprawy. Zawartość suchej masy była najwyższa w trzecim terminie uprawy. Najmniej azotanów kumulowały liście endywii odmiany Cigal. Najwyższa zawartość wapnia została zaobserwowana w pierwszym terminie uprawy. Zawartość potasu i fosforu kształtowała się na podobnym poziomie w pierwszym i drugim terminie uprawy. Nie stwierdzono wpływu zastosowanych preparatów na zawartość makroelementów. Zbadano wpływ nawozów mineralno-organicznych na zawartość flawonoidów. W liściach roślin traktowanych nawozami mineralno-organicznymi dochodziło do syntezy rutozydu i zwiększenia zawartości astragaliny (3-O-glukozydu kemferolu).

Słowa kluczowe: endywia, plonowanie, termin uprawy, azotany, flawonoidy

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