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THE EFFECT OF FORM AND DOSE OF NITROGEN FERTILIZER ON YIELDING AND BIOLOGICAL VALUE OF ENDIVE

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Abstract. Endive, like another leafy vegetables, as an annual plant with short time vegetation is prone to nitrate accumulation. The aim of research conducted in the years 2007––2009 was the assessment of the effect of diversified nitrogen doses on growth, yielding and nutritive value of two 'Excel' and 'Cigal' – endive cultivars. There were compared the effects of two kinds of fertilizer: ammonium saltpeter and Entec 26 containing DMPP nitrification inhibitor. On the basis of the results obtained it was possible to prove that 'Excel' endive cultivar gave marketable yield higher, average, by 19.4% as compared to Cigal cv. Significantly increased marketable yield of endive, regardless its variety, resulted from a single application of Entec 26 fertilizer, especially in the doses of 90 and 135 kg $N \cdot ha^{-1}$. The experiments also pointed to the fact that the method of fertilization, as well as nitrogen doses did considerably affect biological value of the examined endive varieties Excel cultivar characterized higher degree of nitrates accumulation and higher content of carotenoids, while Cigal cultivar featured increased content of vitamin C (average by 8.8%), dry matter and chlorophyll.

Key words: *Cichorium endivia* L., nitrogen fertilization, nitrates, nutritive value

INTRODUCTION

Endive, (*Cichorium endivia* L.), an annual plant, belonging to leafy vegetables group, has become very popular in West – European countries, yet it has been relatively less known in Poland. Endive characterizes a considerable nutritive value, as well as distinctive, slightly bitter taste. The plant occurs in two botanical varieties, endive (*Cichorium endivia* L. var. *crispum* Hegi) of a curly, mare`s tail shape of leaves and escariole (*Cichorium endivia* L. var. *latifolium* Hegi) featuring smooth leaves [Ryder 1999, Koudela and Petříkova 2007]. Endive is a long – day plant, of a short growing

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period and high, similar to that of lettuce, nitrogen requirements, as far as its nutrition is concerned. Due to the fact that excessive amount of $N\text{-}NO_3$ in consumed vegetable tissues is harmful to human health, it is highly important which chemical form and dose of nitrogen fertilizer is introduced in the course of endive cultivation [Kowalska et al. 2006].

The purpose of the experiment conducted was the assessment of the effect of different fertilization methods and nitrogen doses on growth, yielding and biological value two cultivars of endive. Research involved two kinds of fertilizers – ammonium saltpeter and Entec-26, producing by Compo company, a fertilizer of prolonged activity, containing DMPP – new generation inhibitor of nitrification (3,4-dimethyl-pyro phosphate). The latter fertilizer contains ammonium sulphate and ammonium saltpeter and it characterizes the following content of nutritive components: 26% N (7.5% $N\text{-}NO_3$ and 18.5% $N\text{-}NH_4$), 13% S, as well as 0.8% DMPP [Chohura and Kołota 2009].

MATERIAL AND METHODS

Three – factorial field experiment was carried out in the years 2007–2009 in Research Station of the Department of Horticulture at Wroclaw University of Environmental and Life Sciences. The experiment was established on IIIa class soil of pH 7.68, containing, average: 14 $mg \cdot dm^{-3}$ $N\text{-}NO_3$, 171 $mg \cdot dm^{-3}$ P, 112 $mg \cdot dm^{-3}$ K, 102 $mg \cdot dm^{-3}$ Mg and 2250 $mg \cdot dm^{-3}$ Ca. Factor A involved the assessment of two endive cultivars; Excel (var. *latifolium*) and Cigal (var. *crispum*) originating from Rijk Zwaan company, cultivated from transplants. Factor B consisted in comparison of fertilizers effects, namely of ammonium saltpeter and Entec 26, applied in split dose as plant and top – dressing or in a single dose used in before planting. Factor C were diversified nitrogen doses: 45, 90, 135 and 180 kg $N \cdot ha^{-1}$.

Endive seeds of both cultivars were sown in the first decade of March into multipots of 54 cm^3 capacity, filled with peat substrate. Four weeks after sowing the transplants were subjected to hardening, and then planted in the field in the last decade of April. Experimental plots of 4.2 m^2 area were planted with endive in 40 × 35 cm spacing. Fertilization took place before planting of transplants and in the form of a top – dressing in the second decade of May, while harvesting – in the third decade of June. When harvesting, there were determined total and marketable yield of endive rosettes, and their quality was evaluated on the basis of analyses involving the content of vitamin C, dry matter, chlorophyll, carotenoids and nitrates. In leaves of endive there were determined nitrates content using an ion-selective electrode, as well as vitamin C content – according to the Tillmans method (The Polish Standard PN-90/A-75101/11), dry matter was examined by drying to constant weight at 105°C (PN-90/A-75101/03), chlorophyll and carotenoids – according to colorimetric method.

The experiment was established according to a split-plot method, in three replications. Statistical calculations were done according to standard methods and the smallest significant difference was found, using Tukey Test, at level of significance $\alpha = 0.05$.

RESULTS AND DISCUSSION

On the basis of the examinations and statistical analysis of the results it was possible to state that both cultivars and the method of fertilization did significantly affect marketable yield of endive. Average marketable yield for Excel cv. ranged 31.75 t·ha^{-1}, while for Cigal cv. it amounted 26.60 t·ha^{-1}, being lower by 16.2%.

Marketable yield obtained in our experiment did significantly depend on the kind of fertilization applied. The highest yield in both examined cultivars was observed after the use of Entec-26 in a single dose, where average yield ranged 31.77 t·ha^{-1} and the difference in, relation to the treatments with ammonium saltpeter introduced, amounted 1.72 t·ha^{-1}. The lowest yield was recorded when divided doses of Entec-26 and ammonium saltpeter were applied. In research carried out by Pasda et al. [2001] there was also reported lettuce yield increased by 1.4 t·ha^{-1}, as well as its improved quality ay the use of DMPP fertilizer with nitrification inhibitor.

Advantageous effect of sulphur contained in Entec-26 fertilizer (13% S) on plant yielding seems to be possible. Sulphur, as an indispensable macroelement, plays an important role in forming a primary and secondary metabolites in plants. Its optimum content in soil provides for more effective use of nitrogen and potassium [Hlušek et al. 2002]. Similar investigation, confirming the above thesis, was conducted by Kaczor and Łaszcz-Zakorczmenna [2003] with spring barley. However, not many works are devoted to sulphur as a nutrient for vegetables, because of the fact that the problem of sulphur deficit in Polish soils is a relatively new one.

Application of nitrogen fertilization in the dose of 45 kg·ha^{-1} allowed to obtain marketable yield higher by 12.9% in comparison to control treatments. According to the increase in N dose from 45 to 90 kg N·ha^{-1} endive yield was average higher by 6.5%. Further increase in nitrogen fertilizers dose, up to 135 and 180 kg N·ha^{-1} resulted in elevated yield data by 11.1 and 11.7% respectively in relation to the dose of 45 kg N·ha^{-1}. Introduction of the last, highest nitrogen dose, brought about merely significant increase in yield size as compared to endive yield in the case of Entec-26 fertilizer used in divided dose 4.4%, in relation to 135 kg N·ha^{-1} dose. In the remaining combinations there was recorded only slight decrease in plants yielding, amounting 2.1% for ammonium saltpeter and 0.7% for Entec-26 fertilizer applied in a single dose.

Cigal cultivar yield ranged from 22.94 t·ha^{-1}, after fertilization with Entec in the dose of 45 kg N·ha^{-1} , to 32.04 t·ha^{-1} when Entec-26 was used in the amount of 135 kg N·ha^{-1}. The yielding of Excel cultivar under the influence of nitrogen fertilization was less diversified and amounted from 31.64 to 34.89 t·ha^{-1} and the highest yield was recorded also after application of Entec fertilizer in the dose of 90 kg N·ha^{-1}, while the lowest yield resulted from the use of ammonium saltpeter in the quantity 45 kg N·ha^{-1} (tab. 1).

Biological value of endive significantly depended on the examined factors. Only in the case of dry matter it was not possible to prove any statistical differences, although there was observed a slightly elevated value of dry matter content in Cigal cultivar. The content of vitamin C, chlorophyll, carotenoids and nitrates was dependent both on particular cultivar and on the kind of fertilizer introduced, as well as nitrogen dose. Average content of vitamin C equaled 25 mg·100 g^{-1} f.m. Cigal cultivar characterized sig-

nificantly higher value of vitamin C ranging a medium level of 26.1 mg·100 g^{-1} f.m., while its content in Excel cultivar was lower, average, by 8.1%. The highest amount of vitamin C in Excel was assayed in plants cultivated with the use of Entec-26 fertilizer in the quantity of 90 kg N·ha^{-1} (27.54 mg·100 g^{-1} f.m.) and 180 kg N·ha^{-1} (27.86 mg·100 g^{-1} f.m.), applied as a single dose, while in Cigal (30.58 mg·100 g^{-1} f.m.) – after using the same amount of Entec-26 fertilizer in a divided dose. In Cigal cultivar there was significantly higher level of chlorophyll content amounting, average, 0.788 mg·g^{-1} f.m., whereas in Excel cultivar it was lower by 2.7%. This relation was reversed in the case of carotenoids and nitrates content. Excel cultivar featured higher content of carotenoids, average by 1.3%. The highest content of those pigments, in both cultivars, characterized endive cultivated with the use of Entec-26 fertilizer in the dose of 45 kg N·ha^{-1}.

Table 1. Marketable yield of endive depending on fertilization method and nitrogen dose (mean values for 2007–2009)

Tabela 1. Plon handlowy endywii w zależności od sposobu nawożenia i dawki nawozu (średnio w latach 2007–2009)

Fertilization method and dose Sposób nawożenia, dawka nawozu kg N·ha^{-1}		Marketable yield – Plon handlowy t·ha^{-1}		
		Excel	Cigal	mean value
Ammonium saltpeter Saletra amonowa	45	31.64	23.84	27.74
	90	31.77	25.62	28.70
	135	33.34	31.11	32.23
	180	33.67	29.44	31.56
Mean – Średnia		32.61	27.50	30.05
Entec-26 in a single dose Entec w dawce pojedynczej	45	34.81	22.94	28.88
	90	34.89	31.58	33.24
	135	33.14	32.04	32.59
	180	35.64	29.10	32.37
Mean – Średnia		34.62	28.92	31.77
Entec-26 in divided dose Entec w dawce dzielonej	45+45	31.77	25.52	28.65
	90+45	32.19	27.13	29.66
	90+90	32.54	29.48	31.01
Mean – Średnia		32.17	27.38	29.77
Mean for doses Średnia dla dawek	45*	33.23	23.39	28.31
	90	32.81	27.57	30.19
	135	32.89	30.09	31.49
	180	33.95	29.34	31.65
Control without fertilization Kontrola bez nawożenia		27.62	22.60	25.11
Total mean – Średnia ogólna		31.75	26.60	29.18
LSD $_{\alpha = 0,05}$ for: variety – $NIR_{\alpha = 0.05}$ dla odmiany (A)				2.28
fertilization method – metody nawożenia (B)				1.37
N doses – dawki azotu (C)				1.82
interaction – interakcja: A × B				n.i.
A × B × C				n.i.

* Mean value representing the rate of 45 kg N ha^{-1} for ammonium nitrate and Entec-26 in single dose

* Średnia uwzględniająca dawkę 45 kg N ha^{-1} dla saletry amonowej i nawozu Entec-26 w dawce jednorazowej

Table 2. Biological value of endive cultivars depending on fertilization method and nitrogen dose (mean values for 2007–2009)
Tabela 2. Wartość biologiczna badanych odmian endywii w zależności od sposobu nawożenia (średnio w latach 2007–2009)

Fertilization method and nitrogen dose Sposób nawożenia oraz dawka nawozu kg N·ha^{-1}		Excel					Cigal				
		d.m.	vit. C	chlorophyll a+b	carotens	NO_3^-	d.m.	vit. C	chlorophyll a+b	carotens	NO_3^-
		%	mg·100g^{-1} f.m.	mg·g^{-1} f.m.	mg·g^{-1} f.m.	mg·100 g^{-1} d.m.	%	mg·100g^{-1} f.m.	mg·g^{-1} f.m.	mg·g^{-1} f.m.	mg·100g^{-1} d.m.
Ammonuim salp eter Saletra amonowa	45	6.63	24.96	0.751	2.430	1161.08	6.89	23.30	0.815	2.535	732.75
	90	6.47	24.12	0.769	2.617	1936.56	7.36	28.80	0.730	2.476	1452.89
	135	5.92	24.94	0.799	2.450	1956.67	6.89	30.09	0.843	2.548	1477.36
	180	6.55	23.87	0.754	2.544	2785.28	6.54	23.46	0.749	2.470	2016.81
Mean – Średnia		6,39	24.47	0.768	2.510	1959.90	6.92	26.41	0.784	2.507	1419.95
Entec in a single dose Entec w dawce pojedynczej	45	6.89	19.30	0.955	2.819	826.11	7.68	20.22	0.876	2.862	572.08
	90	6.43	27.54	0.832	2.631	1134.19	6.66	25.56	0.790	2.586	1155.83
	135	6.33	22.26	0.709	2.422	1362.50	7.07	23.75	0.833	2.655	1547.78
	180	6.62	27.86	0.804	2.632	2304.97	6.38	24.96	0.804	2.536	1494.03
Mean – Średnia		6.57	24.24	0.825	2.626	1406.94	6.95	23.62	0.826	2.660	1192.43
Entec in divided dose Entec w dawce dzielonej	45+45	6.34	25.81	0.744	2.482	1388.89	7.14	30.58	0.777	2.560	1223.89
	90+45	6.73	23.99	0.699	2.454	1741.46	6.69	24.40	0.852	2.623	1588.61
	90+90	6.47	21.54	0.781	2.606	1991.11	7.01	23.47	0.835	2.845	1705.75
Mean – Średnia		6.51	23.78	0.741	2.514	1707.15	6.95	26.15	0.821	2.676	1506.08
Control without fertilization		6.89	23.42	0.735	2.423	1003.19	6.75	28.18	0.720	2.101	461.53
Total mean – średnia ogólna		6.59	23.98	0.767	2.518	1519.30	6.89	26.09	0.788	2.486	1145.00
$LSD_{\alpha=0.05}$ for: varieties – $NIR_{\alpha=0,05}$ dla odmiany (A)							n.i.	0.45	0.008	0.007	132.96
Fertilization method – Metody nawożenia (B)							n.i.	0.55	0.002	0.004	139.78
N doses – Dawki azotu (C)							n.i.	0.73	0.003	0.005	184.54
Interaction of variety and fertilization method Interakcja pomiędzy odmianą a metodą nawożenia (A × B)							n.i.	0.77	0.009	0.006	n.i.
Interaction of variety, fertilization method and N dose Interakcja pomiędzy odmianą, metodą nawożenia oraz dawką azotu (A × B × C)							n.i.	1.79	0.008	0.011	n.i.

Excel cultivar showed a noticeable tendency towards nitrates accumulation. Their average content equaled 1519 mg·100g^{-1} d.m., while in Cigal cultivar their content was 1145 mg·100 g^{-1} d.m. The highest nitrates content was recorded in the samples of plants provided with nitrogen in the form of ammonium saltpeter. After introduction of this fertilizer in the amount 180 kg N·ha^{-1} in Excel cultivar it ranged 2785 mg·100 g^{-1} d.m., while in Cigal – 2017 mg·100 g^{-1} d.m. (tab. 2). The lowest nitrates content was observed in plants cultivated on soil supplied with Entec-26 fertilizer in a single dose. This relation was due to DMPP nitrification inhibitor, a component of Entec fertilizer. The use of fertilizers containing nitrification inhibitors is very advantageous, especially in cultivation of vegetables featuring stronger tendency to nitrates accumulation [Hähndel and Zerulla 2001]. In the case of endive, botanical variety can also be of some importance, since both in research by Koudela and Petříkova [2007] and in our own investigation, it was proved that endive cultivars of escariole group (var. *latifolium*) characterize higher tendencies to nitrogen accumulation in the form of nitrates in comparison to endive cultivars belonging to curly – leaved group. Reininik et al. [1994], examining 23 endive cultivars, did not report, however, any significant correlation between botanical variety and tendency to nitrates accumulation.

Polish law does not determine maximum level of nitrates content in endive since it only involves the most common leafy vegetables. In other countries of the European Union the mentioned level is specified and it ranges, maximum, 2500 mg·kg^{-1} f.m. in spring – summer endive cultivation [Santamaria 2006]. Similar amounts have been assumed for lettuce. In examination carried out by the authors of this work the level specified above was not exceeded in any of experimental combinations, even in that invoving the use of ammonium salper in the quantity of 180 kg N·ha^{-1}.

CONCLUSIONS

1. Yield of Excel cultivar was significantly higher (by 19.4%) as compared to Cigal cultivar.

2. Optimal method of fertilization for both varieties was application of Entec-26 fertilizer in the single dose of 90 and 135 kg N·ha^{-1}, which allowed to obtain higher marketable yield of better quality, containing considerably lower level of nitrates.

3. Cigal cultivar characterized higher amounts of vitamin C, chlorophyll and dry matter in comparison to Excel cultivar, although it contained less carotenoids and accumulated, average, by 33%, less nitrates.

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WPŁYW FORMY I DAWKI NAWOZU AZOTOWEGO NA PLONOWANIE I WARTOŚĆ BIOLOGICZNĄ ENDYWII

Streszczenie. Endywia, podobnie jak pozostałe warzywa liściowe, jako roślina roczna o krótkim okresie wegetacji, jest skłonna do gromadzenia azotanów. Celem przeprowadzonych w latach 2007–2009 badań była ocena wpływu różnych dawek azotu na wzrost, plonowanie i wartość odżywczą dwóch odmian endywii Excel i Cigal. Porównywano działanie dwóch rodzajów nawozów: saletry amonowej oraz Entec 26, zawierającego inhibitor nitryfikacji DMPP. Na podstawie uzyskanych wyników wykazano, że endywia Excel wydała średnio o 19,4% większy plon handlowy w porównaniu z odmianą Cigal. Istotnie większy plon handlowy endywii, niezależnie od odmiany, uzyskano stosując nawożenie jednorazową dawkę nawozu Entec 26, zwłaszcza w ilości 90 i 135 kg $N \cdot ha^{-1}$. Przeprowadzone badania wykazały także istotny wpływ sposobu nawożenia oraz dawki azotu na wartość biologiczną badanych odmian endywii. Odmiana Excel charakteryzowała się wyższym stopniem akumulacji azotanów oraz większą zawartością karotenoidów, zaś odmiana Cigal większą zawartością witaminy C (średnio o 8,8%), suchej masy oraz chlorofilu.

Słowa kluczowe: *Cichorium endivia* L., nawożenie azotem, azotany, wartość odżywcza

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