

EFFECT OF NITROGEN FERTILIZATION ON YIELD AND QUALITY OF ENDIVE

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Summary

The aim of the experiments carried out in 2007-2008 was to assess the effect of various nitrogen doses on the growth, yield and nutritional value of two endive cultivars Cigal and Excel. The effects of two types of fertilizers were compared: that of ammonium nitrate with that of the product Entec-26. On the basis of the results obtained, it was shown that endive cv. Excel produced a marketable yield that was on average by 35.5% higher than that of the cultivar Cigal. A significantly higher marketable yield of endive was obtained by fertilizing with a single dose of the fertilizer Entec-26, particularly at the rates of 90 and 135 kg N·ha⁻¹, and also 180 kg N·ha⁻¹. The experiments also revealed a significant effect of the fertilization method and nitrogen application rate on the biological value of the endive cultivars under evaluation. The cultivar Excel was characterized by a higher degree of nitrate accumulation, whereas the cultivar Cigal had a higher vitamin C content, dry weight, and chlorophyll content.

key words: endive, N fertilization, Entec-26, ammonium nitrate, nitrates, biological value

INTRODUCTION

The endive (*Cichorium endivia* L.), a plant enjoying great popularity in the countries of Western Europe, is a little-known leaf vegetable in Poland, characterized by considerable nutritional value and a distinctive, slightly bitter taste. It is found as two botanical varieties: curled endive (*Cichorium endivia* L. var. *crispum* Hegi) with curly, very ragged leaves, and escarole (*Cichorium endivia* L. var. *latifolium* Hegi) with smooth leaves (Ryder 1999, Koudela & Petříkova 2007). As a leaf vegetable of a high growth rate, the endive, like the lettuce, has high nutritional demands in terms of nitrogen. Under favourable conditions it takes up and accumulates this element in large quantities in the form of nitrates. Due to the fact that excessive amounts of N-NO₃ in the tissues of consumed vegetables are harmful to human health, it is very important what kind and

quantity of nitrogenous fertilizer is used in the cultivation of endive (Kowalska *et al.* 2006).

The aim of the experiments presented here was to assess the effect of various nitrogen doses on the growth, yield and biological value of endive. Two kinds of fertilizer were compared – the quick-acting ammonium nitrate and Entec-26, a product containing a nitrification inhibitor and consisting of a mixture of ammonium sulfate and ammonium nitrate. It contains 26% nitrogen (7.5% nitrate N and 18.5% ammonium N) and 13% of water-soluble sulfur. In addition, it has a stabilizer of the ammonium form of nitrogen – DMPP (3,4 dimethylpyrazole phosphate), as a nitrification inhibitor (Kołota & Adamczewska-Sowińska 2007).

MATERIALS AND METHODS

A three-factorial field experiment was carried out at the Research and Education Station of the Department of Horticulture of the University of Environmental and Life Sciences in Wrocław. It was set up in a random sub-block design in three replicates, on a degraded black soil of quality Class IIIa, with a pH of 7.2. Factor A concerned an assessment of two endive cultivars: Cigal (var. *crispum*) and Excel (var. *latifolium*). Factor B involved a comparison of the effects of two fertilizers, ammonium nitrate and Entec-26, used in a split-dose, one prior to vegetative growth, the other as top-dressing, or as a single dose before planting seedlings. Factor C represented different nitrogen doses: 45, 90, 135, and 180 kg N·ha⁻¹.

Endive plants were cultivated from seedlings produced in multi-pots, with compartments of 54 cm³ each, filled with a peat substrate. The seeds being encapsulated were sown one by one on 7 March, the emerged seedlings were planted on 17-18 April at a spacing of 40 x 35 cm, on 4.2 m² plots, and the harvest of endive rosettes took place in the last ten days of June. Top-dressing with Entec-26 was carried out on 18 May. At harvest, the marketable yield of endive rosettes was determined, and its quality was assessed on the basis of the levels of dry matter, vitamin C, chlorophyll, and also N-nitrate and N in total. Also, biometric measurements of rosette weight and the number of leaves were carried out twice while the plants were growing - 5 weeks after planting and at harvest.

Statistical calculations were carried out using standard methods, with the lowest significant difference being calculated by means of Turkey's test at a significance level of P=0.05.

RESULTS AND DISCUSSION

The results of the experiments revealed that the cultivar and the kind of fertilizer had a significant effect on the marketable yield of endive. The cultivar Excel was characterized by a higher yield in comparison with the cultivar Cigal. Its yield ranged from 14.61 t·ha⁻¹ (after using the fertilizer Entec-26 in a split-

dose of 90 kg N·ha⁻¹) to 23.21 t·ha⁻¹ (after applying the highest dose of ammonium nitrate - 180 kg N·ha⁻¹) (Table 1). The yield of cv. Cigal was on average by 26.2% lower, and amounted to 14.42 t·ha⁻¹.

Table 1. Marketable yield of endive depending on fertilization method and nitrogen dose (mean values for 2007-2008)

Fertilization method and nitrogen dose (kg N·ha ⁻¹)		Marketable yield (t·ha ⁻¹)		
		Excel	Cigal	Mean
ammonium nitrate	45	15.99	12.36	14.18
	90	19.24	14.13	16.68
	135	20.98	16.60	18.79
	180	23.21	15.11	19.09
Mean		19.86	14.55	17.19
Entec-26 single dose	45	19.08	11.85	15.47
	90	22.73	17.34	20.04
	135	23.18	18.58	20.88
	180	22.50	16.84	19.67
Mean		21.87	16.15	19.01
Entec-26 split dose	45+45	14.61	12.02	13.32
	90+45	17.71	12.35	15.03
	90+90	20.84	13.93	17.39
Mean		17.72	12.77	15.25
Mean for doses	45*		14.82	
	90		16.68	
	135		18.23	
	180		18.72	
Control – not fertilized		14.46	11.91	13.19
Total mean		19.54	14.42	16.98
LSD _{0.05} for: cultivar (A)				2.61
fertilization method (B)				1.75
N dose (C)				2.36
interaction A x B				ns
A x B x C				ns

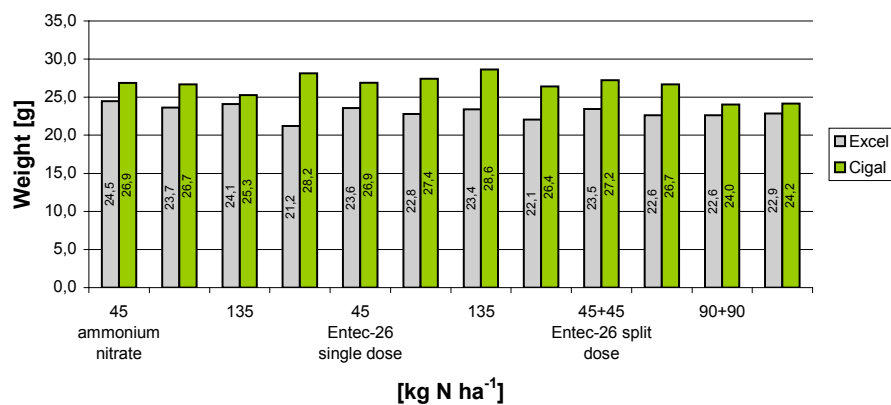
* Mean value representing the rate of 45 kg N ha⁻¹ for ammonium nitrate and Entec-26 in single dose

The use of the product Entec-26 in a single dose made it possible to obtain a significantly higher yield of endive (19.01 t·ha⁻¹) in comparison with the plots fertilized with ammonium nitrate and Entec-26 in split doses. The differences were 1.82 t·ha⁻¹ and 3.76 t·ha⁻¹, respectively.

It was also found that the yield of endive increased as the N-dose increased from 45 to 90 and then to 135 kg N·ha⁻¹ on average by 12.6 % and 23.0 %, respectively. Application at the rate of 180 kg N·ha⁻¹ did not result in a further increase in the yield of this vegetable. Only on the plots where Entec-26 was used in a split-dose, the yield of endive fertilized at 180 kg N·ha⁻¹ was by 15.7%

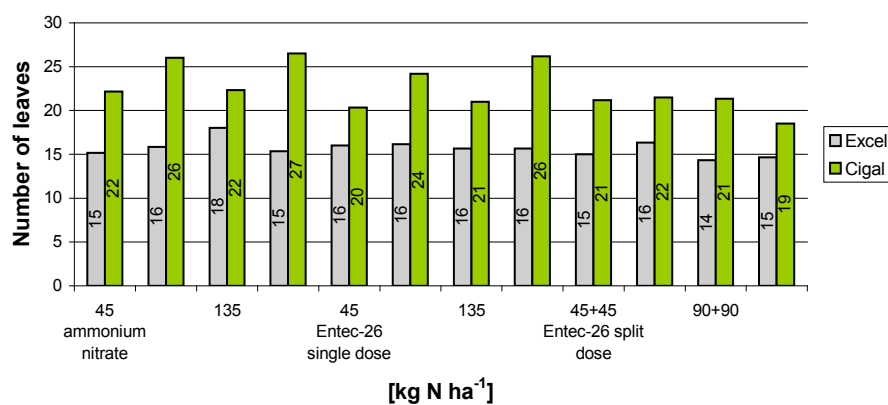
higher than for the rate of $135 \text{ kg N}\cdot\text{ha}^{-1}$. Pasada *et al.* (2001) had found that using a nitrification inhibitor in the fertilization of leaf vegetables can contribute to an increase in yield and improve the quality of the vegetables grown. In the experiments they carried out the yield of lettuce had increased by $1.4 \text{ t}\cdot\text{ha}^{-1}$. The positive yield-enhancing effect may also be associated with the presence of sulfur (13% S) in the fertilizer Entec-26, which favourably affects yielding and helps in the uptake of potassium and nitrogen by plants, as had been confirmed by the experiments of Kaczor & Łaszcz-Zakorczmenna (2003) on spring barley. There are very few reported results on the effect of sulfur on plants, particularly vegetables, since the problem of sulfur deficiency in Polish soils is a relatively new issue.

The statistical analysis of the results showed that the method of fertilization did not have a significant effect on the weight and the number of leaves counted during biometric measurements in the middle of vegetative growth. All that was found was a significant effect of nitrogen doses on the size of endive rosettes (heads). The cultivar Cigal produced rosettes with a larger number of leaves and had a greater unit weight (Fig. 1, 2). That weight, irrespective of the method and rate of fertilization, fell within the range of 24.0-28.6 g, whereas the number of leaves was between 21 and 27. The unit weight of Excel rosettes was on average lower by 12.8%, and the number of leaves by 30.4%. Plant biometrics at harvest revealed a significant effect of the method of fertilization as well as the type and application rate of fertilizer on the weight and diameter of rosettes regardless of the cultivar, with significant differences between the cultivars noted only for the number of leaves. The weight of plants of both cultivars stayed at a similar level – an average of 608 g for Excel and 576 g for Cigal (Fig. 3). The largest rosettes in terms of weight were collected from the plots fertilized with single doses of Entec-26 at 90 and $135 \text{ kg N}\cdot\text{ha}^{-1}$. The weight of those rosettes was 668-733 g for Excel and 747 g for Cigal. They were composed of the highest number of leaves, which was 92-100 and 79-81, respectively (Fig. 4). It was also found that by increasing the fertilizer dose from 45 to $135 \text{ kg N}\cdot\text{ha}^{-1}$ it was also possible to improve the quality of endive rosettes. In the experiments conducted by Tzortzakis (2009), endive plants grown in a glasshouse achieved weight at a level of 318 g, with the average number of leaves being 31.



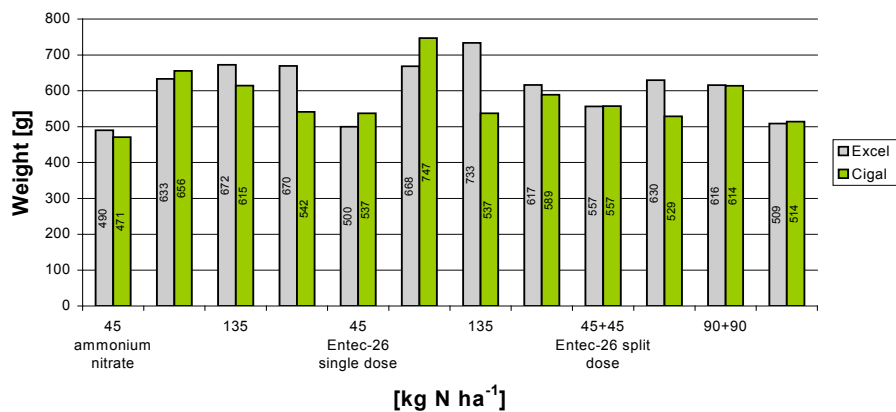
LSD_{0.05} for: cultivar (A) ns
 fertilization method (B) ns
 N dose (C) 10.27

Fig. 1. Effect of fertilization method and fertilizer dose on the weight of endive rosettes 5 weeks after planting (mean values for 2007-2008)



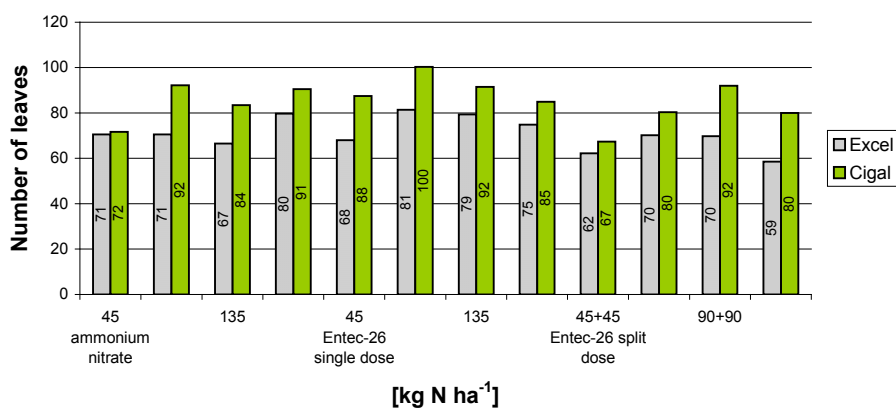
LSD_{0.05} for: cultivar (A) 2.62
 fertilization method (B) ns
 N dose (C) 1.88

Fig. 2. Effect of fertilization method and fertilizer dose on the number of leaves in rosettes 5 weeks after planting (mean values for 2007-2008)



LSD_{0.05} for: cultivar (A) ns
 fertilization method (B) 30.22
 N dose (C) 50.25

Fig. 3. Effect of fertilization method on the weight of endive rosettes at harvest (mean values for 2007-2008)



LSD_{0.05} for: cultivar (A) 6.27
 fertilization method (B) 2.66
 N dose (C) 3.93

Fig. 4. Effect of fertilization method and fertilizer dose on the number of leaves in rosettes at harvest (mean values for 2007-2008)

Table 2. Biological value of endive cultivars depending on fertilization method (mean values for 2007-2008)

Fertilization method and nitrogen dose (kg N·ha ⁻¹)	Excel					Cigal				
	d.w. (%)	vit. C (mg·100g ⁻¹ f.w.)	chlоро- phyll a+b (mg·g ⁻¹ f.w.)	NO ₃ ⁻ (mg·100g ⁻¹ d.w.)	N in total (%)	d.w. (%)	vit. C (mg·100g ⁻¹ f.w.)	chlоро- phyll a+b (mg·g ⁻¹ f.w.)	NO ₃ ⁻ (mg·100g ⁻¹ d.w.)	N in total (%)
45	7.00	28.14	0.775	1260	3.08	7.62	27.07	0.880	797	3.11
ammonium	6.88	26.51	0.768	1806	3.58	8.03	30.99	0.781	1311	3.68
nitrate	6.20	27.17	0.806	2015	3.67	7.66	31.19	0.795	1595	3.63
180	6.67	25.77	0.833	3065	3.62	7.14	27.78	0.824	2019	3.54
Mean	6.69	26.90	0.795	2037	3.49	7.61	29.26	0.820	1430	3.49
45	6.87	22.20	0.883	645	2.99	8.61	25.56	0.967	419	2.81
Entec-26	6.62	28.00	0.841	1379	3.28	7.24	29.62	0.763	1540	3.35
single dose	6.94	31.02	0.815	1629	3.44	7.46	29.59	0.877	1883	3.30
180	6.85	27.52	0.849	1982	3.60	6.88	28.84	0.831	1777	3.71
Mean	6.82	27.19	0.847	1409	3.33	7.55	28.40	0.860	1405	3.29
45+45	6.56	25.72	0.753	1569	3.52	7.95	34.47	0.783	1478	3.40
Entec-26	6.59	25.64	0.706	1844	3.88	7.15	25.30	0.936	2010	3.74
split dose	7.05	29.06	0.812	1996	3.46	7.51	27.83	0.863	2112	3.37
Mean	6.73	26.81	0.757	1803	3.62	7.54	29.20	0.860	1867	3.50
Control – not fertilized	6.76	25.23	0.726	1237	3.19	7.30	34.30	0.802	533	3.29
Total mean	6.75	26.53	0.781	1621	3.41	7.50	30.29	0.836	1309	3.39
LSD $\alpha=0.05$						d.w.	vit. C	chlороphyll	nitrites	N total
Interaction for cultivar and fertilization method (A x B)						ns	0.22	0.005	ns	ns
cultivar, fertilization method and N dose (A x B x C)						ns	0.58	0.012	ns	ns

The nutritional value of the endive cultivars depended on the experimental factors. Vitamin C and chlorophyll content depended on the cultivar, the kind of fertilizer and fertilization rate. Vitamin C content was on average $30.29 \text{ mg}\cdot 100\text{g}^{-1}$ f.w. for the cultivar Cigal, and $26.53 \text{ mg}\cdot 100\text{g}^{-1}$ f.w. for Excel. Chlorophyll a+b content in both cultivars ranged from 0.706 to $0.967 \text{ mg}\cdot \text{g}^{-1}$ f.w. and was significantly higher for the cultivar Cigal, on average by 7%.

The accumulation of nitrates in endive leaves depended on the kind of the fertilizer used, with the lowest level of nitrates (an average of $1407 \text{ mg}\cdot 100\text{g}^{-1}$ d.w.) noted in both cultivars for the single doses of Entec-26, and the highest nitrate level obtained after using ammonium nitrate in the cultivation of the cultivar Excel (an average of $2037 \text{ mg}\cdot 100\text{g}^{-1}$ d.w., which corresponds to $1363 \text{ mg}\cdot \text{kg}^{-1}$ f.w.), and also when Entec-26 had been used in split doses for the cultivar Cigal (an average of $1867 \text{ mg}\cdot 100\text{g}^{-1}$ d.w., or $1408 \text{ mg}\cdot \text{kg}^{-1}$ f.w.). The use of fertilizers containing a nitrification inhibitor contributes to the reduction in nitrate content (Hähndel & Zerulla 2001). This relationship has been confirmed in the present study, where the use of Entec-26 had caused a reduction in nitrate content by nearly 19%. Being a member of a specific botanical variety can also have a significant effect on the accumulation of these compounds. In their studies, Koudela & Petříkova (2007) had found that the escarole endive contains larger amounts of nitrates and at the same time has lower dry weight in comparison with the curly endive. In our own experiments, the cultivar Excel was marked by a higher average NO_3^- content by nearly 11% compared with the cultivar Cigal. Reininik *et al.* (1994), while studying 23 endive cultivars had found, however, that the botanical variety does not affect nitrate content.

In Polish legislation there is no information concerning the maximum allowable nitrate content in endive. In other European Union countries, this level is specified as a maximum of $2500 \text{ mg}\cdot \text{kg}^{-1}$ f.w. for spring-summer cultivation (Santamaria 2006). The experiments described here revealed the maximum NO_3^- content at a level of $3065 \text{ mg}\cdot 100\text{g}^{-1}$ d.w., or $2044 \text{ mg}\cdot \text{kg}^{-1}$ f.w. for the cultivar Excel grown with the use of ammonium nitrate at the highest fertilization rate of $180 \text{ kg N}\cdot \text{ha}^{-1}$.

CONCLUSIONS

1. The endive cultivar Excel produced a higher yield, on average by 26.2%, than the cultivar Cigal.
2. The optimal fertilization method for both endive cultivars was the use of the fertilizer Entec-26 in single doses at 90 and $135 \text{ kg N}\cdot \text{ha}^{-1}$. This made it possible to obtain the highest yield of endive rosettes with the lowest nitrate content in their leaves.
3. The cultivar Cigal was characterized by a lower level on nitrate accumulation, had a higher dry weight, and higher vitamin C and chlorophyll a+b content in comparison with the cultivar Excel.

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WPŁYW NAWOŻENIA AZOTEM NA WIELKOŚĆ I JAKOŚĆ PLONU ENDYWII

Streszczenie

Celem przeprowadzonych w latach 2007-2008 badań była ocena wpływu różnych dawek azotu na wzrost, plonowanie i wartość odżywczą dwóch odmian endywii Cigal i Excel. Porównywano działanie dwóch rodzajów nawozów: saletry amonowej oraz Entec 26. Na podstawie uzyskanych wyników wykazano, że endywia Excel dała średnio o 35,5% większy plon handlowy w porównaniu z odmianą Cigal. Istotnie wyższy plon handlowy endywii uzyskano stosując nawożenie jednorazową dawkę nawozu Entec 26, zwłaszcza w ilości 90 i 135 kg N·ha⁻¹ oraz 180 kg N·ha⁻¹. Przeprowadzone badania wykazały także istotny wpływ sposobu nawożenia oraz dawki N na wartość biologiczną badanych odmian endywii. Odmiana Excel charakteryzowała się wyższym stopniem akumulacji azotanów, zaś odmiana Cigal wyższą zawartością witaminy C, suchej masy oraz chlorofilu.