

THE EFFECT OF NITROGEN FERTILIZATION ON YIELDING AND CHEMICAL COMPOSITION OF RADICCHIO CHICORY FOR AUTUMN – HARVEST CULTIVATION

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Abstract. Chicory of radicchio type is a vegetable similarly cultivated to head lettuce, yet featuring relatively longer plant growing period. Most of this crop cultivars characterize intensive red color of leaves and white leaves venation. Field experiment carried out in 2005–2007 involved cultivation, from transplants, of radicchio type chicory of ‘Indigo’ cultivar for autumn harvest. Seeds were sown at the end of June and seedlings were transplanted to their final stand in the first week of August. Chicory heads harvesting took place in the half of October and in its course there were estimated the following parameters: total and marketable yield, as well as, in edible parts, the content of nitrates, macrolelements, dry matter, reducing and total sugars and vitamin C. The highest marketable yield of chicory in autumn cultivation was provided by nitrogen fertilization in the dose of $150 \text{ kg N} \cdot \text{ha}^{-1}$, the whole amount applied once, previously to plant growing period. Intensive nitrogen fertilization contributed to higher amount of accumulated nitrates, potassium, calcium, magnesium, reducing and total sugars, as well as vitamin C.

Key words: method of fertilization, dose of N, nutritional value, nitrates

INTRODUCTION

Chicory of radicchio type is a vegetable similarly cultivated to head lettuce, yet featuring relatively longer plant growing period. Most of this crop cultivars characterize intensive red color of leaves and white leaves venation. Nevertheless, there can be found plants with colorful leaves venation and also those of elongated heads which resemble Chinese cabbage. The origin of chicory cultivars is not homogenetic. The ones featuring red leaves belong to *Cichorium intybus* L. var. *foliosum* (Hegi) Bish., while the remaining cultivars, of colorful and green leaves, come from spontaneous or controlled crossbreeding with *Cichorium endivia* L. var. *latifolium* Hegi [Varotto et al. 1995].

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Characteristic property of this vegetable is its evidently bitter taste and, therefore chicory leaves are one of salads components or they can be grilled, which reduces bitterness intensity. The quality of marketable material, in the form of loose or compact chicory heads, depends on a number of factors, such as the course of weather conditions, the term and type of cultivation (from seed sowing and from transplants), soil moisture and fertilization [Rożek 2007, Biesiada and Kołota 2008, Francke and Makowska-Gadomska 2008]. In the conditions of a long day, temperature drops in the stage seedlings phase, mainly in germination period and high temperatures in growing period, plants tend to shoot in inflorescence.

Both in Polish and in foreign literature there are only few reports regarding chicory fertilization and most of them stress positive response of this plant to nitrogen fertilization. Radicchio is a vegetable cultivated mainly for autumn harvest, although some of chicory cultivars can also be planted in the spring or summer [Rożek 2007]. Biesiada and Kołota [2008] proved that radicchio chicory in cultivation for summer harvest satisfactorily responded to intensive nitrogen fertilization applied in two divided doses, each amounting $100 \text{ kg N} \cdot \text{ha}^{-1}$ previously to plant growing period and as top – dressing.

The aim of the research conducted in 2005–2007 in Department of Horticulture at Wrocław University of Environmental and Life Sciences was the assessment of the effect of the method and dose of nitrogen fertilization on yielding and chemical composition of radicchio chicory cultivated for autumn harvest.

MATERIAL AND METHODS

Field experiment was conducted in Experimental Station belonging to Department of Horticulture at Wrocław University of Environmental and Life Sciences, on clay soil of $\text{pH} = 7.6$ containing 1.8% of humus, $14 \text{ mg} \cdot \text{dm}^{-3} \text{ N-NO}_3$, $196 \text{ mg} \cdot \text{dm}^{-3} \text{ K}$, $95 \text{ mg} \cdot \text{dm}^{-3} \text{ P}$, $111 \text{ mg} \cdot \text{dm}^{-3} \text{ Mg}$, $1776 \text{ mg} \cdot \text{dm}^{-3} \text{ Ca}$. In the experiment there was assessed the effect of diversified nitrogen doses on yield size and quality of red leaf chicory ‘Indigo’ cultivar (from seed company Bejo Zaden B.V.), forming non-forcing heads. Nitrogen fertilization was supplied in one preplant rate of 50, 100, 150 and $200 \text{ kg N} \cdot \text{ha}^{-1}$ or was divided on preplant and top dressing: $50 + 50$, $100 + 50$, $100 + 100 \text{ kg N} \cdot \text{ha}^{-1}$.

Chicory seeds were sown in the first week of July to multipots filled with peat substrate, each pot capacity was 72 cm^3 . At the beginning of August ready seedlings were transplanted to the field, in spacing $30 \times 20 \text{ cm}$. Nitrogen fertilization took place before planting of transplants and as top-dressing three weeks after planting date. The experiment was established according to randomized split – plot method in four replications. The area of plot equaled 3 m^2 .

Plant harvesting took place in the second decade of October and assessment of marketable yield of radicchio heads was evaluated. In fresh matter of edible parts there were determined the contents of vitamin C, reducing and total sugars, as well as nitrates, dry matter and macroelements: P, K, Mg and Ca.

The measurements made use of the following methods: in fresh material nitrates content – potentiometrically, vitamin C according to Tillmans method, total and reducing sugars – due to Lane Eynon method according to PN-90/A-75101/07. Dry matter

was estimated by drying to constant weight at 105°C according to The Polish Standard PN-90/A-75101/03 method. The contents of macronutrients: phosphorus, potassium, magnesium and calcium were determined using Nowosielski method [Nowosielski 1974].

The results were analyzed by standard statistical procedure and the least significant differences were calculated by Tukey test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

The results of the experiment proved that nitrogen dose did significantly affect the yielding of radicchio – type chicory (tab. 1). When applied once, previously to plant growing period, nitrogen fertilization allowed to obtain the highest marketable yield at the dose of 150 kg N·ha⁻¹ and resulting yield size amounted 2.78 kg·m⁻², while further increase in nitrogen dose brought about decreased values of chicory heads yield to 2.27 kg·m⁻². There was not recorded any advantageous influence of divided nitrogen dose on chicory yields obtained at fertilization applied previously to plant growing period, as well as in the case of top – dressing fertilization. In treatments with divided nitrogen dose significantly highest yield belonged to those fertilized with 100 kg N·ha⁻¹ before plant growing period with the dose of 50 kg N·ha⁻¹ featuring top – dressing fertilization. Further increase in N amount, up to 100 + 100 kg N·ha⁻¹ resulted in obtaining the smallest marketable yield size in the experiment involving 1.90 kg·m⁻² nitrogen dose. Ćustić et al. [1994] did not observed the significant differences in yield of radicchio chicory under different nitrogen fertilization. Osinga [1997] noticed that in radicchio rosso cultivation the highest yield of quality class I + II was achieved in treatment where total dose of nitrogen of 150 kg N·ha⁻¹ was divided on two rates: preplant 50 kg N·ha⁻¹ with supplementary top dressing of 100 kg N·ha⁻¹.

Table 1. The effect of nitrogen fertilization on radicchio marketable yield and mean weight of head (mean for 2005–2007)

Tabela 1. Wpływ nawożenia azotem na plon handlowy i średnią masę główki radicchio (średnio z lat 2005–2007)

Dose of nitrogen Dawka azotu kg N·ha ⁻¹	Yield with mean head weight Plon o masie główek kg·m ⁻²			Marketable yield Plon handlowy kg·m ⁻²	Mean weight of head Średnia masa główki g
	< 200 g	200–400 g	> 400 g		
	50	0.31	1.34		
100	0.19	1.69	0.44	2.32	278
150	0.32	2.02	0.50	2.78	294
200	0.32	1.49	0.46	2.27	264
50 + 50	0.37	1.20	0.47	2.04	261
100 + 50	0.26	1.43	0.49	2.18	266
100 + 100	0.29	1.15	0.46	1.90	252
Mean – Średnia	0.29	1.47	0.45	2.22	265
LSD _{$\alpha=0.05$}	0.04	0.11	0.03	0.14	18

Chicory of radicchio type generally formed large heads, weighing 200–400 g, regardless nitrogen dose used. The highest weight per one head characterized the treatment fertilized with a full dose once, previously to plant growing period, with nitrogen dose of 150 kg N·ha⁻¹. Elevated doses of nitrogen up to 200 kg N·ha⁻¹ applied once before chicory growing period or as top – dressing with divided nitrogen dose contributed to the decrease in radicchio chicory head weight.

Increased dose of nitrogen did significantly affect nitrates content in chicory leaves, resulting in higher amounts of this component (tab. 2). At the dose of 50–100 kg N·ha⁻¹ introduced before plant growing period nitrates level ranged from 516 to 636 mg·kg⁻¹ weight of fresh matter, while N dose applied once, amounting 200 kg N·ha⁻¹ provided for nitrates level increased to 1150 mg·kg⁻¹. The whole nitrogen dose divided into that introduced before plant growing period and the one used as top – dressing fertilization resulted in considerably higher nitrates content in radicchio leaves, from 930 to 1110 mg·kg⁻¹ f. m. at the doses of 50 + 50 and 100 + 50 kg N·ha⁻¹ respectively and to 1330 mg·kg⁻¹ f. m. when nitrogen quantity equaled 100 + 100 kg N·ha⁻¹. Nitrates level in autumn – cultivated chicory was comparable to that determined for plants cultivated for spring harvest [Biesiada and Kołota 2008]. Chen et al. [2004] achieved optimum yield of turnip, Chinese cabbage, and spinach when applying 0.3 g N·kg⁻¹ of soil, whereas the increase in nitrogen dose to 0.45 g N·kg⁻¹ of soil caused the decrease in plants yields. Those authors also obtained elevated nitrates levels due to increasing nitrogen rates. The latter result was confirmed in our own research, as well as the findings by the other authors [Michalik et al. 1980, Kozik and Gleń 1995, Santamaria et al. 1999].

Table 2. Content of nitrates and macroelements in radicchio heads (mean for 2005–2007)
Tabela 2. Zawartość azotanów i makroelementów w główkach radicchio (średnio z lat 2005–2007)

Dose of nitrogen Dawka azotu kg N·ha ⁻¹	Nitrates Azotany mg·kg ⁻¹ f.m	P	K	Mg	Ca
		% d.m.			
50	516	0.27	5.00	0.17	0.40
100	636	0.26	5.25	0.24	0.47
150	1000	0.27	5.75	0.23	0.60
200	1150	0.28	5.65	0.22	0.75
50 + 50	930	0.26	5.50	0.21	0.80
100 + 50	1110	0.24	5.25	0.20	0.85
100 + 100	1330	0.25	6.00	0.22	0.95
Mean – Średnia	938	0.26	4.81	0.21	0.69
LSD _{α=0.05}	78	0.02	0.34	0.01	0.05

Ćustic et al. [1994] stressed that radicchio chicory showed a certain tendency to excessive accumulation of nitrates, which could be confirmed by our own investigation. At the highest nitrogen doses the amount of nitrates in edible parts was by far lower than permissible values for leafy vegetables, including lettuce and spinach, equals 2500 mg NO₃-N·kg f. m. [Rozp. Ministra Zdrowia 2003].

Radicchio chicory heads characterized significantly higher content of K, Mg and Ca in treatments intensively fertilized with nitrogen, while phosphorus content featuring that treatments was dependent on nitrogen dose only to a small degree.

The content of dry matter in edible parts of plants fertilized with nitrogen and it ranged from 5.20 to 6.30% (tab. 3). There was reported advantageous effect of intensive nitrogen fertilization on total and reducing sugars content. Khalf et al. [2003] found that increasing N levels up to 120 kg·ha⁻¹ significantly affected head diameter, number of leaves per head, fresh weight of head, leaves and stem and leaf dry weight of lettuce.

Table 3. Content of dry matter, vitamin C, total and reducing sugars in radicchio edible parts (mean for 2005–2007)

Tabela 3. Zawartość suchej masy, witaminy C, cukrów redukujących i ogółem w częściach jadalnych radicchio (średnio z lat 2005–2007)

Dose of nitrogen Dawka azotu kg N·ha ⁻¹	Dry matter Sucha masa %	Reducing sugars Cukry redukujące % f.m.	Total sugars Cukry ogółem % f.m.	Vitamin C Witamina C mg·100 g ⁻¹ f.m.
50	5.20	1.58	1.80	6.71
100	6.50	1.98	2.12	7.14
150	6.30	2.11	2.22	8.25
200	6.00	2.09	2.22	8.54
50 + 50	6.10	1.85	2.23	6.69
100 + 50	6.10	2.09	2.26	7.25
100 + 100	6.30	2.15	2.24	8.13
Mean – Średnia	6.07	1.97	2.15	7.53
LSD _{α=0.05}	0.09	0.10	0.11	0.22

In radicchio chicory leaves the content of total and reducing sugars increased according to the increase in nitrogen dose, both applied once as a whole dose and the divided on preplant and top – dressing fertilization. According to Hoque et al. [2005] increasing N and P rates gradually elevated glucose content in lettuce. Also the content of vitamin C did significantly increase under the influence of increasing nitrogen doses. Nitrogen fertilizers at high rates tend to decrease the vitamin C content in many fruits and vegetables [Mozofar 1993], but Kansal et al. [1981] and Dzida and Pitura [2008] also recorded that vitamin C and sugars contents in above – ground parts of spinach and Swiss chard increased as an effect of increasing nitrogen fertilizer rate applied. According to USDA nutrient database [2009] radicchio is vegetable with low level of vitamin C in edible parts (8 mg in 100 g of f.m.) what is in agreement with results of experiment. Francke and Majkowska-Gadomska [2008] as well as Rożek [2007] found higher level of vitamin C especially in spring grown radicchio.

CONCLUSIONS

1. The highest marketable yield of radicchio in autumn cultivation was provided by nitrogen fertilization in the amount of 150 kg N·ha⁻¹ introduced as one preplant dose.

2. The increase in nitrogen dose favored accumulation of K and Ca by this vegetable crop.

3. Radicchio chicory intensively fertilized with nitrogen in the amount of 150–200 kg N·ha⁻¹ characterized higher contents of vitamin C, as well as reducing and total sugars.

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WPLYW NAWOŻENIA AZOTEM NA PLON I SKŁAD CHEMICZNY CYKORII TYPU RADICCHIO W UPRAWIE NA ZBIÓR JESIENNY

Streszczenie. Cykoria typu radicchio jest warzywem uprawianym podobnie jak sałata, ale charakteryzuje się dłuższym okresem uprawy. Istnieje wiele typów i odmian cykorii radicchio, z których część ma intensywnie czerwony kolor blaszek liściowych oraz białe nerwy. W doświadczeniu przeprowadzonym w latach 2005–2007 uprawiano z rozsady cykorię typu radicchio odmiany 'Indigo' na zbiór jesienny. Nasiona wysiewano pod koniec czerwca, rośliny sadzono na miejsce stałe w pierwszym tygodniu sierpnia, zaś zbiór główek przeprowadzono w połowie października. Przy zbiorze oceniono plon ogólny i handlowy cykorii, zaś w częściach jadalnych zawartość azotanów, makroskładników, suchej masy, cukrów redukujących i ogółem oraz witaminy C. Największy plon handlowy cykorii w uprawie jesiennej zapewniło nawożenie azotem w dawce 150 kg N·ha⁻¹ stosowanej w całości przedwegetacyjnie. Intensywne nawożenie azotem sprzyjało większemu nagromadzeniu w częściach nadziemnych azotanów, potasu, wapnia, cukrów redukujących i ogółem oraz witaminy C.

Słowa kluczowe: metoda nawożenia, dawka N, jakość plonu, wartość odżywcza, azotany

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