

COMPARISON OF THE ABILITY OF FIFTEEN ONION (*Allium cepa* L.) CULTIVARS TO ACCUMULATE NITRATES

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Abstract

The aim of a two-year study was to characterise selected *Allium cepa* L. genotypes with regard to their ability to accumulate nitrates in bulbs as well as to search for a possible relation between NO_3^- concentration and dry matter content. Fifteen cultivars of edible onion, mostly of long-day genotype with different growing periods, bulb size and skin colour, were taken for the experiment. Seeds of particular cultivars were obtained from the following seed companies: Spółnia Nochowo ('Labrador', 'Takstar F₁', 'Tęcza', 'Warna', 'Zorza'), Polan ('Polanowska', 'Topolska'), PlantiCo Gołębiew ('Alibaba', 'Efekt', 'Kristine', 'Niagara F₁'), and PlantiCo Zielonki ('Bila', 'Irka', 'Wenta', 'Zeta'). Plants produced from seedlings were grown in the experimental field of the University of Agriculture in Kraków. After crop harvesting and additional drying, nitrate and dry matter content in bulbs of all cultivars were measured.

The following cultivars: 'Efekt', 'Labrador' and red-skinned 'Wenta', were characterized by the lowest ability to accumulate NO_3^- in bulbs. The highest nitrate content was noted in bulbs of 'Takstar F₁' (a very early-season cultivar), followed by 'Bila' and 'Tęcza'. A weak, yet statistically significant negative correlation between nitrate and dry matter content was observed. The highest dry matter content was determined in bulbs of white-skinned 'Alibaba', while the lowest – in brown-skinned 'Labrador'.

Key words: *Allium cepa* L., cultivars, bulbs, nitrate content, dry matter

INTRODUCTION

Studies on nitrate content in plants have been of great interest to numerous researchers for many years. Some authors focus on factors affecting nitrate bioaccumulation in edible parts of crop plants, particularly vegetables being of great value to the health of con-

sumers [1,2]. It is commonly known that an excessive level of nitrates in food can be harmful [3]. This fact is reflected in EU regulations for maximum levels of nitrate content, particularly in leafy vegetables, which are issued regularly [4].

The second group of studies on nitrates concerns the recognition of their metabolism in plant tissues as well as their uptake, distribution and the signal role that these compounds play in plants [5]. It has been demonstrated that nitrate ions are involved in osmoregulation in plants [6]. In the studies conducted by Cardenas-Navarro et al. [7], a highly significant positive correlation between nitrate and water content in tomato plants was noted.

According to some researchers, nitrate content is under genetic control and can vary between species or even cultivars [8]. Nevertheless, this problem remains unsolved for numerous species. Very little is known about the bioaccumulation potential of nitrates in various genotypes of onion (*Allium cepa* L.). Breeding studies conducted on this species allowed numerous interesting cultivars differing in flavor intensity, bulb size or skin color to be obtained.

The aim of this study was to characterize fifteen cultivars of *Allium cepa* L. with respect to the potential of nitrate accumulation in bulbs, together with testing the correlation between nitrate and dry matter content in onion bulbs. Additionally, the relation between NO_3^- content and bulb weight was sought.

MATERIALS AND METHODS

The study was conducted on fifteen cultivars of *Allium cepa* L. Seeds of individual cultivars were obtained from various seed companies in Poland,

including: Spójnia Nochowo ('Labrador', 'Takstar F₁', 'Tęcza', 'Warna', 'Zorza'), Polan ('Polanowska', 'Topolska'), PlantiCo Gołębiew ('Alibaba', 'Efekt', 'Kristine', 'Niagara F₁') and PlantiCo Zielonki ('Bila', 'Irka', 'Wenta', 'Zeta'). All cultivars, except 'Labrador', are classified as long-day with various growing periods: very early-season – 'Tęcza', 'Takstar F₁', 'Zorza'; mid-early – 'Zeta', 'Irka', 'Topolska', 'Warna'; mid-late – 'Alibaba', 'Efekt', 'Kristine', 'Niagara F₁', and late-season – 'Bila', 'Polanowska', 'Wenta'. 'Labrador' is a short-day winter cultivar. Individual cultivars also differ in bulb size and skin colour. 'Alibaba' and 'Wenta' bulbs have white and red skin, respectively, while bulbs of other cultivars are brown-coloured (from light to dark-brown).

The field experiment was conducted in the Experimental Station of the Faculty of Horticulture (University of Agriculture in Kraków) located in Mydlniki (Poland) during two successive growing seasons in 2006 and 2007. Based on soil analysis, mineral compounds were supplemented to a level of 190, 70 and 60 mg × dm⁻³ for K, P and Mg, respectively. Nitrogen fertilization in the form of ammonium nitrate was applied twice at a rate of 60 kg N ha⁻¹ and 40 kg N ha⁻¹ before and after planting, respectively.

Transplants were produced in a greenhouse and planted out in the field on 27th April 2006 and 19th April 2007. The experimental plots were established in a randomized design with two replications. In each plot, 150 transplants were planted in 7 × 30cm spacing. After harvesting (end of July/middle August) and yield estimation, 40 bulbs from each plot were weighed and then the weight of one bulb was calculated. Bulbs were kept for 2–3 weeks at low air humidity for additional drying and then thirty bulbs from each cultivar (fifteen from each replication) were randomly chosen as a laboratory mean sample. The remaining onion bulbs were used for other analyses [9].

Nitrate content in plant extracts (prepared in 0.02M Al₂(SO₄)₃ 18 H₂O) was determined using an ion-selective electrode connected to an ORION 920A+ ionometer. In order to determine dry matter content, the samples of plant material were dried at 95°C. The laboratory analyses were conducted in three replications.

The results were subjected to analysis of variance (ANOVA), and means separation by Neumann-Keuls test at $\alpha = 0.05$. The data were subjected to simple linear regression analysis using Statistica 9 tools.

RESULTS

According to the results presented in Table 1, in 2006 the significantly highest yield was obtained in the

case of 'Labrador', while the other varieties yielded at a lower equal level. In the next year, the yield of most varieties was similar to that of 'Labrador' and did not differ significantly. 'Tęcza', 'Zeta' and 'Zorza' achieved higher yields compared with 'Takstar F₁' (mean for 2006–2007).

Bulb weight was also related to the onion variety (Fig. 1). 'Labrador' produced bulbs of the highest weight, followed by 'Takstar F₁' and 'Tęcza'. It should be mentioned that the 'Alibaba' cultivar was characterized by the smallest bulbs, however there were no significant differences in bulb weight between this cultivar and 'Bila', 'Efekt', 'Kristine', 'Topolska' or 'Wenta'.

Every year, the highest dry matter content was found in bulbs of white-tunic 'Alibaba', while the lowest – in brown-skinned 'Labrador' (Table 2). The dry matter content in 'Topolska' (in 2006) and 'Wenta' (in 2007) was as high as in 'Alibaba' bulbs. According to the means for the two-year study, bulbs of 'Efekt' and 'Irka' were characterized by similar dry matter content. The differences in dry matter content between 'Bila', 'Kristine', 'Polanowska' and 'Warna' were not significant. 'Takstar F₁' and 'Zorza' bulbs were shown to have low dry matter content.

According to the results presented in Table 3, the nitrate level ranged between 57.45 and 146.86 mg NO₃⁻ kg⁻¹ fresh weight for 'Labrador' in 2006 and 'Takstar F₁' in 2007, respectively. In 2006 the lowest amount of nitrates was found in bulbs of the cultivars 'Efekt', 'Kristine', 'Labrador', 'Polanowska' and 'Wenta', whereas in 2007 – in 'Efekt' and 'Wenta'. It is worth noting that in the second year of experiment, on average, lower onion yield and a higher content of nitrates were observed (by about 15% and 30%, respectively). The results indicate that the average nitrate level for all the cultivars from both years of the study was 90.04 mg NO₃⁻ kg⁻¹ fresh weight (Fig. 2). The mean nitrate content in bulbs of most varieties was below this value.

Nitrate content was negatively correlated with dry matter content. The correlation coefficient $r = -0.215$ ($P < 0.05$) was low, yet statistically significant.

Taking into account all the obtained results, no significant correlation between average bulb weight and nitrate content was found. However, a tendency of smaller bulbs accumulating a lower content of nitrates was observed for most tested cultivars, with the exception of the low-nitrate accumulating cultivar 'Labrador' that gave the highest yield (Figs 1 and 2).

Table 1
Marketable yield (t ha⁻¹) of selected onion cultivars in two years of the study

<i>Allium cepa</i> L. cultivar	Year		Mean
	2006	2007	2006–2007
‘Alibaba’	35.45 ab*	29.35 a	31.90 a
‘Bila’	37.60 ab	36.40 abcd	37.00 ab
‘Efekt’	38.50 ab	33.35 ab	35.92 ab
‘Irka’	42.45 ab	39.70 abcd	41.07 abc
‘Kristine’	40.05 ab	33.20 ab	36.62 ab
‘Labrador’	68.45 c	49.60 cd	59.02 e
‘Niagara F ₁ ’	43.95 ab	33.50 ab	38.72 ab
‘Polanowska’	46.00 ab	40.00 abcd	43.00 bc
‘Takstar F ₁ ’	52.60 b	50.40 d	51.50 d
‘Tęcza’	50.35 ab	46.20 cde	48.27 cd
‘Topolska’	42.35 ab	32.25 ab	37.30 ab
‘Warna’	44.35 ab	35.25 abc	39.80 abc
‘Wenta’	37.15 ab	35.80 abcd	36.47 ab
‘Zeta’	49.30 ab	42.20 abcd	45.75 bcd
‘Zorza’	49.90 ab	39.00 abcd	44.45 bcd
Mean	45.23 B	38.35 A	

* In columns, values marked with the same small letters do not differ significantly; in the last row, capital letters concern the significance of differences between means for years.

Table 2
Dry matter content (%) in bulbs of selected onion cultivars

<i>Allium cepa</i> L. cultivar	Year		Mean
	2006	2007	2006–2007
‘Alibaba’	12.45 h*	11.79 f	12.12 j
‘Bila’	10.32 de	9.35 cd	9.83 def
‘Efekt’	10.70 e	9.54 cde	10.12 g
‘Irka’	10.44 de	9.77 cde	10.10 g
‘Kristine’	9.54 c	9.43 cde	9.48 d
‘Labrador’	5.55 a	5.37 a	5.46 a
‘Niagara F ₁ ’	11.84 g	10.29 e	11.06 h
‘Polanowska’	10.08 d	9.21 cd	9.64 de
‘Takstar F ₁ ’	7.98 b	8.26 b	8.12 b
‘Tęcza’	9.47 c	8.42 b	8.94 c
‘Topolska’	12.25 h	9.92 cde	11.08 h
‘Warna’	9.26 c	10.07 de	9.67 de
‘Wenta’	11.12 f	11.93 f	11.53 i
‘Zeta’	8.29 b	8.15 b	8.22 b
‘Zorza’	9.18 c	9.07 c	9.12 c
Mean	9.90 A	9.37 A	

* See explanation in Table 1

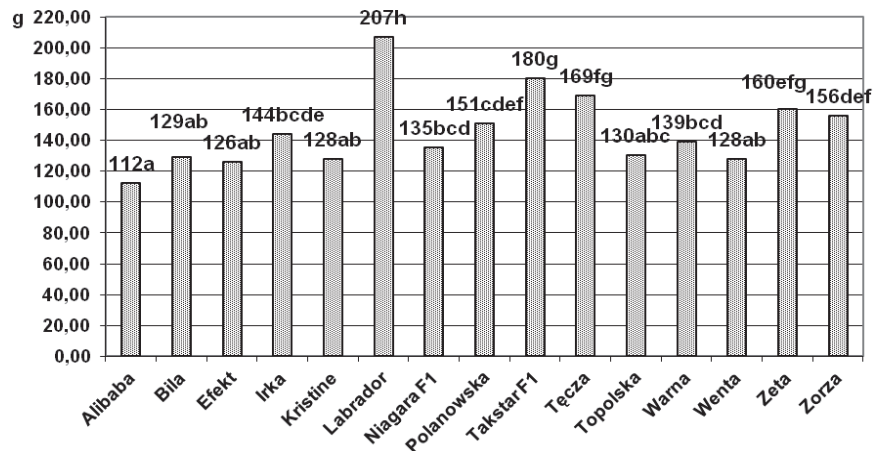


Fig. 1. Mean bulb weight (g) of *Allium cepa* L. cultivars – means for two years of the study.

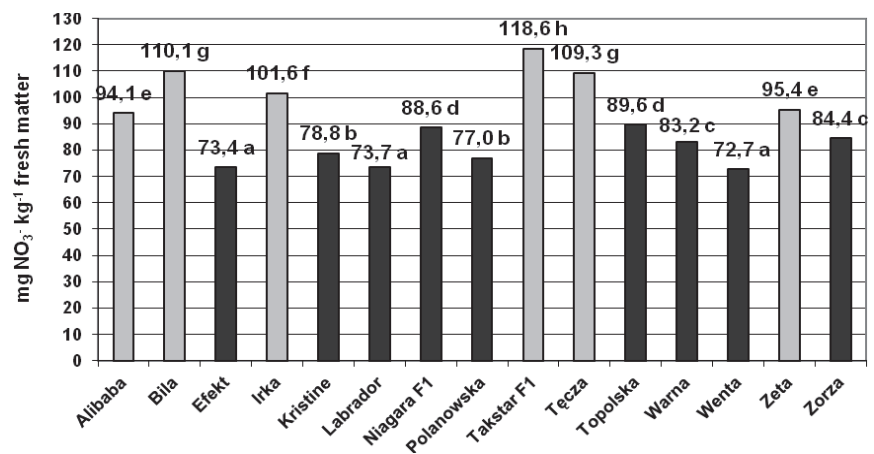


Fig. 2. Nitrate content (mg NO₃⁻ kg⁻¹ F.W.) in bulbs of *Allium cepa* L. cultivars – means for two years of the study. Grey columns present values above the average for all cultivars (90.04 mg NO₃⁻ kg⁻¹ F.W.), black columns – below this average.

Table 3

Nitrate content (mg NO₃⁻ kg⁻¹ F.W.) in bulbs of selected onion cultivars (means for 2006–2007 are presented in Fig. 2)

<i>Allium cepa</i> L. cultivar	Year	
	2006	2007
'Alibaba'	76.86 c*	111.39 f
'Bila'	93.58 e	126.71 h
'Efekt'	59.64 a	87.15 ab
'Irka'	95.26 e	108.03 e
'Kristine'	58.03 a	99.63 d
'Labrador'	57.45 a	90.00 b
'Niagara F ₁ '	76.06 c	101.09 d
'Polanowska'	59.49 a	94.45 c
'Takstar F ₁ '	90.29 d	146.86 i
'Tęcza'	95.18 e	123.43 g
'Topolska'	77.52 c	101.67 d
'Warna'	67.74 b	98.76 d
'Wenta'	59.42 a	85.91 a
'Zeta'	87.96 d	102.77 d
'Zorza'	69.78 b	99.05 d
Mean	74.95 A	105.13 B

* See explanation in Table 1

DISCUSSION

The main goal of this research was to compare the ability of the studied onion cultivars to accumulate nitrates. Due to the scope of the study (a field experiment), marketable yield of onion bulbs was also estimated. Short-day 'Labrador' was characterized by the significantly highest yield with a low nitrate level and the lowest dry matter content in bulbs in comparison with the other cultivars. In contrast, in 'Takstar F₁' bulbs a high level of nitrates was accompanied by low dry matter content. This cultivar is classified as the long-day onion genotype and is a high-yielding variety, as confirmed by the results of our research.

Throughout the experiment, the obtained values of NO₃⁻ concentration in onion bulbs were rather low. Similar contents of nitrates (29.46 – 81.81 mg NO₃⁻ kg⁻¹) were reported by Ionescu et al. [10] in cv. 'De Buzau' grown in open field culture with different nitrogen fertilization. These and other studies [11,12] allow us to classify onion in the group of species with low nitrate accumulation. It is additionally confirmed by Polish law regulations that set the maximum level of nitrates (V) in onion at 200 mg NO₃⁻ kg⁻¹ fresh weight [13].

In the present study, it was interesting to compare the nitrate level in bulbs of the individual cultivars in two subsequent years of onion cultivation. The mean rainfall amounts and air temperatures during both growing seasons were presented earlier [9]. The nitrate contents measured in 2007 were higher when compared to the results obtained in the previous year. This might have been due to higher rainfall in July 2007 just before the harvest time. Accordingly, the dry matter content in bulbs was slightly lower in 2007 compared to 2006. A similar correlation was observed in the case of pyruvic acid content [9]. Irrespective of weather conditions, onion cultivars such as 'Efekt', 'Labrador' and red-skinned 'Wenta' were characterized by the lowest ability to accumulate NO₃⁻ in bulbs in both years of the experiment. The highest nitrate content in bulbs was shown for 'Takstar F₁', followed by 'Bila' and 'Tęcza'. Thus, it can be assumed that the above-mentioned cultivars can be generally described as being able to accumulate relatively low or high levels of nitrates, respectively.

A low, yet statistically significant negative correlation between nitrate and dry matter content was additionally observed, with a relatively low value of correlation coefficient ($r = -0.215$). Therefore, this study did not confirm a strict relation between nitrate content and onion tissue hydration. In the work presented by Cardenas-Navarro et al. [7], the value of the correlation coefficient between nitrate content and water content in tomato plants was equal to 0.99. Also

Dapigny et al. [14] showed that nitrate content was positively correlated with water content in lettuce leaves. The results presented by the cited authors as well as those included in this work indicate the significant role of the genetic factor (plant species, cultivar) affecting the discussed relationship.

CONCLUSIONS

1. *Allium cepa* L. cultivars such as 'Efekt', 'Labrador' and red-skinned 'Wenta' were characterized by the lowest ability to accumulate NO₃⁻ in bulbs in both years of the experiment.
2. The highest nitrate content in bulbs was shown for 'Takstar F₁', followed by 'Bila' and 'Tęcza'.
3. A low negative correlation between nitrate (V) and dry matter content was observed.
4. The highest dry matter content was determined in onion bulbs of white-skinned 'Alibaba', while the lowest – in brown-skinned 'Labrador'.

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Authors' contributions

The following declarations about authors' contributions to the research have been made: concept of the study – RW, AK, field work – AK, data analyses – RW, AK, writing the manuscript – RW.

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Porównanie zdolności do bioakumulacji azotanów (V) piętnastu odmian cebuli jadalnej (*Allium cepa* L.)

Streszczenie

Celem dwuletnich badań była próba scharakteryzowania poszczególnych genotypów *Allium cepa* L. pod względem zdolności do akumulacji azotanów (V) w cebulach oraz poszukiwanie związku pomiędzy zawartością NO₃ i suchej masy. Obiektem badań było 15 odmian cebuli jadalnej, w większości należących do genotypów dnia długiego o zróżnicowanym okresie wegetacji, różniących się zabarwieniem łuski i wielkością cebul. Nasiona pochodziły z polskich firm nasiennej Spółnia Nochowo, Polan, PlantiCo Gołębiew i Zielonki. Uprawę prowadzono z rozsady na polu doświadczalnym Uniwersytetu Rolniczego w Krakowie. Po zbiorze (połowa sierpnia) i 3-tygodniowym dosuszeniu cebul, oznaczono w nich zawartość azotanów (V) i suchej masy.

Cebule odmian ‘Efekt’, ‘Labrador’ i ‘Wenta’ (o czerwonej łusce) charakteryzowały się najmniejszą zdolnością do akumulacji azotanów (V). Najwięcej azotanów oznaczono w cebulach odmiany ‘Tęcza’. Stwierdzono niewysoką, aczkolwiek istotną ujemną korelację pomiędzy zawartością azotanów (V) i suchej masy w cebulach. Największą zawartość suchej masy wykazano w cebulach o białej łusce ‘Alibaba’, a najmniejszą – w cebulach o brązowej łusce ‘Labrador’.

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