Journal of Elementology

Quarterly Reports issued by
the Polish Society for Magnesium Research

Volume 13 Number 2 June 2008

Editorial Office
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http:// www.uwm.edu.pl/jelementol

Webmaster: Sławomir Krzebietke

Publishing company is funded by Ministry of Science and Higher Education
and cooperation by University of Warmia and Mazury in Olsztyn

Ark. wyd. 8,6; ark druk. 7,75; pap. offset. kl. III 80 g B-1
Druk: Zakład Poligraficzny UWM w Olsztynie, zam. 289

CONTENTS

SPIS TREŚCI

J. Elementol. 2008, 13(2): 167–173

EFFECT OF FLAT COVERS AND PLANT DENSITY ON YIELDING AND QUALITY OF KOHLRABI

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Abstract

Kohlrabi is a fast growing, cool season vegetable cultivated primarily for its enlarged stem, which is rich in nutritional components, especially vitamin C and potassium. In two factorial experiment conducted in 2004-2006 there was estimated the effect of plastic covers (perforated plastic film, non woven agrotextile) and plant density (20x15, 25x20 cm) on yield and nutritional value of kohlrabi cultivated in spring season. The significant highest early and marketable yields were obtained from plots covered with agrotextile. The higher density of plants resulted in increased kohlrabi yield. Kohlrabi cultivated under covers had lower level of dry matter, reducing and total sugars. There was not observed the effect of covers on vitamin C concentration. Kohlrabi grown in spacing 20x15 cm contained higher amount of nitrates, vitamin C and reducing sugars in comparison to spacing 25x20 cm.

Key words: kohlrabi, flat covers, spacing, yield, nutritional value.

WPŁYW OKRYĆ PŁASKICH I ROZSTAWY NA PLON I JAKOŚĆ KALAREPY W UPRAWIE WIOSENNEJ

Abstrakt

Kalarepa jest rośliną klimatu umiarkowanego o krótkim okresie wegetacji, uprawianą głównie dla jej smacznych, soczystych, zgrubiałych pędów bogatych w składniki odżywcze,

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w tym witaminę C i potas. W doświadczeniu dwuczynnikowym przeprowadzonym w latach 2004-2006 oceniano wpływ okryć płaskich (folia perforowana, włóknina polipropylenowa) i rozstawy (20x15, 25x20 cm) na plonowanie i wartość odżywczą kalarepy w uprawie wiosennej. Wykazano, że zastosowanie okryć płaskich zapewniło istotnie większy plon wczesny i handlowy zgrubień. Największy plon zgrubień uzyskano osłaniając rośliny włókniną polipropylenową. Większe zagęszczenie roślin w rozstawie 20x15 cm umożliwiło uzyskanie istotnie większego plonu kalarepy, a jednocześnie zmniejszenie jednostkowej masy zgrubienia. Okrycia płaskie przyczyniły się do spadku zawartości suchej masy, cukrów redukujących i ogółem, lecz miały mały wpływ na zawartość witaminy C w częściach jadalnych. W kalarepie uprawianej w rozstawie 20x15 cm stwierdzono większą zawartość azotanów, witaminy C oraz cukrów redukujących niż w rozstawie 25x20 cm.

Słowa kluczowe: kalarepa, okrycia płaskie, rozstawa, plon, wartość odżywcza.

INTRODUCTION

Kohlrabi, which belongs to an agriculturally important family of *Brassicaceae*, is a fast growing cool season vegetable crop. It is valued for its sweet taste and crisp and juicy texture of a turnip-like edible stem, which contains 6.2 g of carbohydrates, 1.7 g proteins and 3.6 g dietary fiber in 100 g of fresh matter (USDA National Nutrient Database 2006). It is also a source of vitamins (vitamin C – 65 mg, thiamin – 0.05 mg, niacin – 0.02 mg, riboflavin – 0.02 mg, pantothenic acid – 0.65 mg, vitamin B_6 – 0.15 mg and folate 16 µg)) and minerals: potassium – 350 mg, phosphorus – 46 mg, magnesium – 22 mg, copper – 0.13 mg and manganese – 0.14 mg (Kunachowicz et al. 2004). Its young leaves, which are richer in vitamins and minerals than stems (120–200 mg vitamin C, 3 mg β-carotene, 1.5 g fiber, 3.6 mg iron and 500 mg calcium per 100 g of f.w.), are used in Western Europe as a component of salads or cooked like spinach (Bielka 1968, Nurzyńska-Wierdak 2005).

Kohlrabi is a short growing season vegetable, which can be eaten fresh all year because it can be grown for early, summer and autumn market supply. Nowadays there are many cultivars which can produce high yields of good quality stems suitable for fresh market as well as for freezing (Vanparys 1999, 2000, Biesiada, Kołota 2007).

Kohlrabi can be grown from seeds, but more frequently it is cultivated from transplants, especially for early market supply. In that case, plants are covered with plastic flat covers to create favourable conditions for growth and development of field grown vegetables, to accelerate harvest by 7-10 days and to improve the quality of crop (Felczyński 1995, Rumpel, Grudzień 1996).

The quality of vegetables grown in the open field and under flat covers is quite similar (Siwek, Libik 2005). Capecka et al. 2003 did not observe any significant changes in the chemical composition (sugars, vitamin C, fiber, thiocyanates) of Japanese radish cultivated under covers.

The aim of the experiment conducted in 2004-2006 was to evaluate the effects of flat covers and planting density on yielding and nutritional value of kohlrabi.

MATERIAL AND METHODS

A field experiment was established in a two factorial split-plot design in four replications. The first factor involved two types of flat covers: non-woven polypropylene agrotextile P-17 and perforated PE film (with 50 holes per 1 m^2). The second factor was plant spacing: 20x15 and 25x20 cm. The plot area was 1.8 m^2.

The seeds of kohlrabi cv. 'Dworsk«ego' were sown to multicells filled with peat substrate. Individual cells of plug trays contained approximately 76.2 cm^3 of substrate. Four weeks old, well hardened transplants were planted in the first decade of April on plots supplied by ammonium nitrate in the dose of 100 kg $N \cdot ha^{-1}$. Flat covers were used after planting of seedlings and removed 5 weeks later. The kohlrabi was harvested four times at one week intervals, starting at the beginning of June, when the size of kohlrabi stem reached over 3 cm in diameter.

Each time, the total yield of plants (tubers and leaves) and marketable yield of tubers were evaluated. Plants from the first harvest were included in the early yield.

Fresh kohlrabi stems were assayed for vitamin C (according to PN-90/A--75101/11), total and reducing sugars (according to PN-90/A-75101/07) and dry matter (according to PN-90/A-75101/03). Nitrates were determined by the method described in PN-92/A-75112. The content of macronutrients: phosphorus, potassium, magnesium and calcium was determined according to Nowosielski method.

The results were analyzed with a standard statistical procedure and the least significant differences were calculated by Tukey's test at α=0.05.

RESULTS AND DISCUSSION

The data of the study presented as the means for three years showed that plant protection with flat covers was favourable for kohlrabi yield (Table 1). The significantly highest total yield of leaves and stems was obtained when plants were covered with non woven agrotextile, followed by treatment covered with plastic film and control. Early yield of kohlrabi stems in treatments with both flat covers was significantly higher than the control. The early yield of tubers obtained on plots covered with plastic film

Table 1

The effect of nitrogen fertilization on yielding of radicchio ($kg \cdot m^{-2}$)

Type of cover	Spacing (cm)	Total yield tubers+ +leaves	Marketable yield	Early yield	Mean weight of tubers in early yield (g)
Control	20x15	95.9	48.41	5.83	175.3
	25x20	79.6	41.39	4.63	177.3
Mean		87.75	44.90	5.23	176.3
Agrotextile	20x15	110.4	56.47	7.38	193.5
	25x20	93.8	51.76	6.89	235.3
Mean		102.1	54.12	7.13	214.4
Perforated foil	20x15	104.0	53.63	7.80	199.8
	25x20	85.3	42.82	7.19	249.5
Mean		94.65	48.22	7.50	224.7
Mean	20x15	103.4	52.84	7.00	189.5
	25x20	86.23	45.32	6.23	220.7
LSDα=0.05					
for cover		8.31	3.11	0.56	13.56
for spacing		9.22	4.75	0.59	16.27

was on average 7.50 $t \cdot ha^{-1}$, thus not considerably different compared to the treatment covered with plastic film – 7.13 $t \cdot ha^{-1}$.

On the plots with flat covers, the plants grew better, which resulted in higher mean weight of one tuber in the early yield than in the control.

The use of both types of flat covers for five weeks considerably increased marketable yield in comparison to the non-covered control. The highest yield of kohlrabi was obtained on plots covered with non woven agrotextile – 54.12 $t \cdot ha^{-1}$. The use of plastic film was less efficient, providing yield of 48.22 $t \cdot ha^{-1}$, while in the control treatment the marketable yield decreased to 44.90 $t \cdot ha^{-1}$.

Similar relations were observed by Rumpel and Grudzień (1993), who found better effects obtained with non-woven flat cover in comparison to plastic film in early cabbage production, but in the studies conducted by Rekowska et al. (1995) and Rumpel and Grudzień (1996) no significant differences were observed in yield of early broccoli and melon covered with non-woven agrotextile and plastic film. Adamczewska-Sowińska (1996) stated that in the cultivation of leek for early cropping, the use of flat plastic film with was more advantageous than that of non-woven agrotextile.

Significantly higher early yield of edible parts of kohlrabi was obtained in the treatment with plant spacing 20x15 cm, in comparison to the spacing 25x20 cm. It is in agreement to DOBROMILSKA (2005). According to the author, increased fennel planting density resulted in higher yield of the bulb, despite its lower unit weight.

CAPECKA et al. (2000) noted a lack of negative effect of flat covers on nutritional value of daikon radish. In the present experiment, too, only a negligible effect of covers on vitamin C concentration was noticed. However, the dry matter content of edible parts of kohlrabi covered with both materials was lower than in the control treatment (Table 2).

Table 2

Effect of flat covers and spacing on nutritional value of kohlrabi grown for spring cropping (mean for 2004-2006)

Type of cover	Spacing (cm)	Nitrates ($mg \cdot kg^{-1}$ f.m.)	Dry matter (%)	Vitamin C	Reducing sugars	Total sugars
				($mg \cdot kg^{-1}$ f.m.)		
Control	20x15	860	8.91	835.3	33.0	38.0
	25x20	720	9.93	684.8	30.5	34.0
Mean		790	9.42	760.0	31.7	36.0
Agrotextile	20x15	740	8.64	739.9	32.0	3.35
	25x20	700	8.39	868.8	23.5	26.5
Mean		720	8.51	804.4	27.8	30.0
Perforated foil	20x15	780	8.34	792.7	32.5	32.5
	25x20	630	8.48	704.3	26.0	28.0
Mean		705	8.41	748.5	29.3	30.3
Mean	20x15	793	8.63	809.3	31.8	33.3
	25x20	683	8.93	754.3	26.7	30.8
LSDα=0.05						
for cover		46.7	0.78	71.3	1.2	1.9
for spacing		58.5	0.85	82.4	1.5	1.2

The level of reducing and total sugars in kohlrabi was the highest in the control treatment (31.7 and 36.0 $mg \cdot kg^{-1}$ f.m. respectively), while in tubers of plants covered with non- woven agrotextile and plastic film, it decreased to 27.8 and 30.0 and 26.7 and 30.8 $mg \cdot kg^{-1}$ f.m., respectively.

The tubers of kohlrabi grown at the spacing of 20x15 cm contained considerably higher amounts of nitrates, vitamin C as well as reducing and total sugars than those grown at the lower planting density.

CONCLUSIONS

1. The application of flat covers with perforated polyethylene film and non- woven polypropylene agrotextile provided significantly higher early and marketable yield of kohlrabi in comparison to the non-covered control.

2. The planting of seedlings at a higher density resulted in a significant increase of early and marketable yield as well as a decrease of mean weight of kohlrabi tubers.

3. The application of flat covers resulted in less dry matter. reducing and total sugars, but had little effect on the level of vitamin C in edible parts of kohlrabi.

4. The stems of kohlrabi grown at the spacing of 20x15 cm contained more nitrates, vitamin C as well as total and reducing sugars in comparison to those grown at 25 x 20 cm.

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J. Elementol. 2008, 13(2): 175–180

THE EFFECT OF NITROGEN FERTILIZATION ON YIELD AND QUALITY OF RADICCHIO

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Abstract

In a field experiment conducted in 2005-2006 the effects of the rate and method of nitrogen fertilization on yield and chemical composition of cv. Indygo radicchio cultivated for summer cropping were studied. Nitrogen was used in a single pre-plant dose or in two rates: as a pre-plant and top dressing application conducted at the start of head formation in the total amounts of 50, 100, 100+100, 150, 100+50, 200, 100+100 kg $N \cdot ha^{-1}$. The highest yield and accumulation of nitrates were achieved in the treatment with 100+100 kg $N \cdot ha^{-1}$. The content of nitrates in radicchio leaves varied from 1,070 to 1,350 $mg \cdot kg^{-1}$ f.m. for the nitrogen rate of 200 kg $N \cdot ha^{-1}$ supplied in one pre-plant dose, and from 1,160 to 1,380 $mg \cdot kg^{-1}$ f.m. when the same rate was applied in two doses. The method of nitrogen fertilization had little effect on P and Mg concentration. Potassium and calcium level in leaves of radicchio decreased at higher nitrogen fertilization rates.

Key words: radicchio, nitrogen fertilization, yield, nitrates, macroelements.

WPŁYW NAWOŻENIA AZOTEM NA PLONOWANIE I JAKOŚĆ CYKORII TYPU RADICCHIO

Abstrakt

W doświadczeniu polowym przeprowadzonym w latach 2005-2006 oceniano wpływ dawki i sposobu nawożenia azotem na plonowanie i skład chemiczny cykorii typu radicchio odmiany Indygo uprawianej na zbiór letni. Azot stosowano w całości przedwegetacyjnie lub w dwóch dawkach przedwegetacyjnie i pogłównie, w ilości 50, 100, 50+50, 150, 100+50, 200, 100+100 kg $N \cdot ha^{-1}$ z użyciem saletry amonowej. Istotnie największy plon główek w doświadczeniu, lecz

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również największą zawartość azotanów w liściach, uzyskano wnosząc N w dwóch dawkach przedwegetacyjnie i pogłównie w ilości 200 (100+100) kg N·ha^{-1}. Zawartość azotanów po zastosowaniu N w całości przedwegetacyjnie była nieco mniejsza i wahała się od 1070 do 1350 mg·kg^{-1} św.m., zaś w przypadku dzielenia dawki N na dwie części wynosiła 1160-1380 mg·kg^{-1} św.m. Sposób wnoszenia azotu miał mały wpływ na zawartość P i Mg. Poziom potasu i wapnia w liściach radicchio malał pod wpływem wzrastających dawek N.

Słowa kluczowe: radicchio, nawożenie azotem, plon, azotany, makroskładniki.

INTRODUCTION

Radicchio is a form of chicory (*Cichorium intybus* var. *foliosum* Bisch.), known also as red chicory or Italian chicory. The most popular types of this leaf vegetable are Radicchio di Treviso with loose upright heads and Radicchio di Chioggia with round dense heads (ILLERT 2004, HILL 2004). Edible burgundy red colored leaves with white midribs have a low content of protein 1.4 g of and carbohydrates 4.5 g in 100 g of fresh matter. While considerable amounts of fiber (0.9 g), vitamins A (27.0 IU), C (8-14 mg), B_6 (0.1 mg), niacin (0.3 mg), carotenoids such as lutein and zeaxantin (8832 µg) as well as macro- and microelements: phosphorus (40 mg), potassium (302 mg), zinc (0.6 mg), cuprum (0.3 mg), iron (0.6-1.5 mg), selenium (0.9 µg). It also contains anthocyanins belonging to flavonoids that have numerous health benefits (ĆUSTIĆ and TOTH 2000, ĆUSTIĆ et al. 2000b, USDA National Nutrient Database 2006).

Radicchio is often eaten raw in salads, but in Italy it is usually grilled in olive oil or mixed into dishes such as risotto. Also salad mixes sold in supermarkets and grocery stores often contain some radicchio. It adds vibrant color to mixes of head lettuce and romaine. Served alone, radicchio is slightly bitter because it contains sesquiterpene lactones, but when mixed with other salad greens, its tangy taste is muted (HILL 2004). In Poland, radicchio is a rather unknown vegetable, cultivated sometimes on a small scale in home gardens.

Less attention has been paid in literature to the relationship between nitrogen doses and methods of fertilization versus the yield of this vegetable. Also, the question of its tendency to accumulate nitrates in edible parts of this type of chicory is insufficiently recognized.

Most of the data indicate the advantageous reaction of this plant to intensive nitrogen fertilization. (ĆUSTIĆ et al. 1994, OSINGA 1997, ĆUSTIĆ et al. 2000a, REICH and COFFEY 2002). The aim of the experiment established in 2005-2006 was to investigate the effect of doses and methods of nitrogen fertilization on yield and quality of radicchio chicory.

MATERIAL AND METHODS

In a field experiment on radicchio, nitrogen was supplied in a single pre-plant rate of 50, 100, 150 and 200 kg N·ha^{-1} or was divided into pre-plant and top dressing treatments: 50+50, 100+50, 100+100 kg N·ha^{-1}. In all the treatments ammonium nitrate was used as the source of nitrogen. Transplants of cv. Indygo radicchio chicory were produced in a greenhouse. The seeds were sown on 24 April in multicells filled with peat substrate. Individual cells of plug trays contained approximately 76.2 cm^3 of substrate. At the end of May the seedlings were planted out into the field at a spacing 30x20 cm. A one factorial experiment with seven treatments was established in four replications, with a plot area of 1.8 m^2.

During the harvest in the first decade of August, the total and marketable yields of heads were determined. The content of nitrates (potentiometrically), dry matter (according to PN-90/A-75101/03 method), and total and reducing sugars (according to PN-90/A-75101/07 method) were determined in edible parts of the heads. The content of macronutrients: phosphorus, potassium, magnesium and calcium was determined according to Nowosielski method.

The results were analysed with a standard statistical procedure and the least significant differences were calculated by Tukey's test at α=0.05.

RESULTS AND DISCUSSION

Nitrogen fertilization significantly influenced the yielding of radicchio in both years of the study. In the treatments with one pre-plant dose, the highest yield of heads was obtained when nitrogen rates increased to 150-200 kg N·ha^{-1}. The response to this method of nitrogen feeding was more pronounced in 2005 because of the more favourable rainfall distribution during the growing season.

The nitrogen fertilization with a dose of 200 kg N·ha^{-1} supplied in two rates as pre-plant and top dressing appeared to be more efficient for the plant growth and assured significantly higher total and marketable yields of heads in comparison to a single pre-plant application. These results confirmed the previous finding of Osinga (1997), who noticed that in radicchio rosso the highest yield of quality class I+II was provided in a treatment where a total dose of 150 kg N·ha^{-1} was divided in two rates: pre-plant 50 kg N·ha^{-1} and supplementary top dressing of 100 kg N·ha^{-1}.

Ćustić et al. (1994) did not observe significant differences in yield of radicchio chicory under different nitrogen fertilization. The results of our experiment are in agreement with Ćustić et al. (1994, 2000b), who found

Table 1

The effect of nitrogen fertilization on yielding of radicchio ($kg \cdot m^{-2}$)

N Rate ($kg \cdot ha^{-1}$)	Total yield			Marketable yield		
	2005	2006	mean	2005	2006	mean
50	4.53	4.24	4.39	3.86	3.32	3.59
100	5.49	4.45	4.97	4.58	3.38	3.98
150	5.72	4.62	5.17	4.73	3.57	4.15
200	6.37	4.56	5.46	5.66	3.37	4.51
50+50	5.56	4.65	5.10	4.68	3.45	4.06
100+50	6.62	4.77	5.69	5.39	3.85	4.62
100+100	6.98	5.29	6.14	5.92	4.29	5.10
NIRα=0.05	0.32	0.37	0.39	0.47	0.37	0.44

that a dose of 200 kg $N \cdot ha^{-1}$ was too high for radicchio when supplied in a single pre-plant dose.

The nitrogen fertilization influenced the content of nitrates in edible parts of radicchio (Table 2). At 50 kg $N \cdot ha^{-1}$ the level of nitrates in leaves was 375-493 $mg \cdot kg^{-1}$ f.m. Intensive nitrogen fertilization at 200 kg N ha^{-1} caused an increase in nitrates up to 1,160-1,380 $mg \cdot kg^{-1}$ f.m. in both years of the experiment

Table 2

The effect of nitrogen fertilization on content of nitrates and macronutrients in radicchio leaves

N Rate ($kg \cdot ha^{-1}$)	NO_3-N ($mg \cdot kg^{-1}$ f.m.)		P	K^+	Mg^{2+}	Ca^{2+}
	2005	2006	mean for 2005–2006 (%)			
50	375	493	0.44	5.42	0.23	0.37
100	896	776	0.49	5.22	0.24	0.35
150	961	998	0.50	5.12	0.25	0.32
200	1350	1070	0.49	4.80	0.20	0.28
50+50	728	630	0.57	5.12	0.23	0.29
100+50	1200	910	0.48	5.08	0.24	0.30
100+100	1380	1160	0.49	5.26	0.24	0.27

When nitrogen was split into pre-plant and top dressing fertilization, the concentration of nitrates was higher than when it was applied in a single pre-plant dose.

Ćustić et al. (1994) stated that radicchio has a rather limited tendency to accumulate nitrates and, at the rate of 160 kg N·ha^{-1}, the level of NO_3-N did not exceed 1,000 mg·kg^{-1} f.m. This agrees with the results of our experiment, which showed that the content of nitrates in edible parts of radicchio was considerably lower than admissible amounts for salad vegetables in Poland, equal 2,500 mg NO_3·kg^{-1} f.m. According to Ćustić et al. (2003), the effect of weather conditions on accumulation of nitrates in radicchio plants may be stronger than that of differentiated organic and mineral fertilization.

The nitrogen fertilization had a negligible effect on the concentration of phosphorus and magnesium in radicchio leaves. The content of phosphorus in leaves varied from 0.44 to 0.57% d.m. and magnesium from 0.20 to 0.25% d.m. The calcium concentration decreased under heavy nitrogen fertilization to 5.42 % in the treatment with a nitrogen dose of 50 kg N·ha^{-1} and to 4.80% when the dose of 200 kg N·ha^{-1} was used.

CONCLUSION

1. The highest yield of radicchio heads was obtained when a dose of 200 kg N·ha^{-1} was supplied in split treatments (100+100 kg N·ha^{-1}).

2. Radicchio fertilized with 200 kg N·ha^{-1} supplied in a single pre-plant dose had a lower concentration of nitrates in leaves, ranging from 1,070 to 1,350 mg·kg^{-1} f.m, whereas the split application of the same amount of nitrogen increased their level to 1,160-1,380 mg·kg^{-1} f.m.

3. The method of nitrogen application had a negligible effect on the content of P, K and Mg. The calcium level in radicchio leaves decreased under heavy nitrogen fertilization.

4. The concentration of phosphorus in leaves of radicchio varied from 0.44 to 0.57%, potassium from 4.80 to 5.42%, magnesium from 0.20 to 0.25% and calcium from 0.27 to 0.37%.

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J. Elementol. 2008, 13(2): 181–188

EFFECT OF THE TERM OF HARVEST ON YIELD AND NUTRITIONAL VALUE OF SPINACH BEET

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Abstract

In a field experiment conducted in 2004-2006, the influence of the harvest term on yield and crop quality of cv. Lukullus Spinach beet was examined. Seeds were sown to the field in the second decade of April and after thinning left at a spacing 45x25 cm. First harvest of leaves was conducted in mid-July and 2 subsequent harvests occurred in two week's intervals. The content of dry matter, vitamin C, phosphorus, potassium, calcium and magnesium were determined in samples of leaf blades and petioles.

The results proved that the yield of Spinach beet increased from 42.46 $t \cdot ha^{-1}$ in the first term of harvest to 72.04 $t \cdot ha^{-1}$ and 105.61 $t \cdot ha^{-1}$ in the subsequent terms. Delayed harvest date appeared to be beneficial for the content of dry matter and vitamin C, and resulted in the decrement of the amounts of potassium and magnesium as well as in the accumulation of nitrates in plants. Plants harvested later also contained a lower level of phosphorus in leaf blades.

Generally, higher amounts of dry matter, potassium and magnesium were observed in leaf blades, while petioles contained more phosphorus, calcium and nitrates.

Key words: Spinach beet, term of harvest, yield, nutritional value.

WPŁYW TERMINU ZBIORU NA PLON I WARTOŚĆ ODŻYWCZĄ BURAKA LIŚCIOWEGO

Abstrakt

W latach 2004-2006 badano wpływ terminu zbioru na wielkość i jakość plonu buraka liściowego odmiany Lukullus. Nasiona wysiewano w drugiej dekadzie kwietnia i po przerywce pozostawiono w rozstawie 45x25 cm. Pierwszy zbiór roślin przeprowadzono w drugiej dekadzie lipca,

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a kolejne dwa w odstępach dwutygodniowych. Podczas zbioru pobierano oddzielnie próby liści i ogonków liściowych, w których oznaczano zawartość suchej masy, azotanów, witaminy C, P i Mg, K i Ca. Wyniki badań poddano analizie statystycznej za pomocą testu *t*-Duncana na poziomie istotności α=0,05.

Wykazano, że w miarę opóźniania terminu zbioru plon buraka liściowego wzrastał średnio z 42,46 $t \cdot ha^{-1}$ w pierwszym terminie do 72,04 $t \cdot ha^{-1}$ po dwóch tygodniach i do 105,61 $t \cdot ha^{-1}$ przy zbiorze najpóźniejszym. Zarówno w blaszkach, jak i ogonkach liściowych zawartość azotanów, potasu i magnezu oraz fosforu w blaszkach liściowych zmniejszała się w miarę opóźniania terminu zbioru. Przedłużenie okresu uprawy przyczyniło się do wzrostu zawartości suchej masy zarówno w blaszkach, jak i ogonkach liściowych, a także witaminy C w blaszkach liściowych.

W blaszkach liściowych buraka liściowego stwierdzono większe nagromadzenie suchej masy, K i Mg, natomiast w ogonkach liściowych – większą zawartość P, Ca i azotanów.

Słowa kluczowe: burak liściowy, termin zbioru, plon, wartość odżywcza.

INTRODUCTION

Many species of vegetables, including Spinach beet, can be harvested at various phases of maturity which depends on requirements of the selling market and consumer preferences. Delayed vegetable harvesting time usually entails higher crop yields as well as changes in chemical composition. This, however, does not always result in improved nutritional value. Some research conducted on this subject has demonstrated that as the harvest time was postponed, dry matter content increased in leek and kohlrabi but decreased with zucchini fruits (BIESIADA et al. 2007). Earlier harvest time had a favourable effect on the level of vitamin C, as well phosphorus and potassium, but involved higher accumulation of nitrates (BOHNER et al. 2005, KOZIK 2006).

The goal of the research was to determine the effect of harvest time on crop yield and nutritious values of Spinach beet (*Beta vulgaris* L. var. *cicla* L.).

MATERIAL AND METHODS

Field experiments were carried out in 2004-2006 in the Vegetable and Ornamental Plants Research Station of the Department of Horticulture in Wrocław University of Environmental and Life Science, on soil containing 60 mg $P \cdot dm^{-3}$ and 200 mg $K \cdot dm^{-3}$. Pre-sowing fertilization with nitrogen at 150 kg $N \cdot ha^{-1}$ was applied. Seeds of cv. Lukullus were sown in the second decade of April at a spacing 45x25 cm. After emergence, at the phase of 2-4 true leaves, thinning was completed with one plant left in each spot. The first harvest of the plants was conducted in the second decade of July, and two subsequent harvests were conducted at two weeks' intervals.

Whole leaves (blades and petioles) were recognized as marketable yield of plants. During the harvest, samples of edible parts were taken for determinations of dry matter (drying at 105°C), nitrates (reflectometric method), vitamin C (Tillmans's method), P and Mg (colorimetric method), K and Ca (photometric method). Results of the study were evaluated statistically using the t-Duncan's test at the significance level α=0.05.

RESULTS AND DISCUSSION

Crops of Spinach beet in subsequent years of the experiments were considerably dependent on the harvesting time. As means for the 3 year period, the plants picked up in the earliest term yielded at the level of 42.46 t·ha^{-1}. Delaying the harvest by two and four weeks caused essential growth of the crop quantity up to 72.04 t·ha^{-1}, to 105.61 t·ha^{-1} (Table 1). Similar dependencies were found by DYDUCH and JANOWSKA (2004) in leafy parsley and by REKOWSKA and SŁODKOWSKI (2005) in corn salad.

Upon the data of chemical analysis for the three years of experiments, it can be concluded that average dry matter contents in leaf blades was much higher than in petioles (Table 1). Similar dependencies were indicated by DYDUCH and NAJDA (2005) as well as by KMIECIK et al. (2005) in their research on celery and dill. It was observed that along with a delay of harvesting time, the level of dry matter was increasing considerably both in blades and leaf petioles. In leaf blades its level was growing from 10.93% to 15.09%, and in leaf petioles from 7.42% to 9.61%. Significantly the highest dry matter contents appeared in leaf blades of plants picked up in 2006 in the second and third term of harvest (15.51% and 16.17% respectively), and the lowest one also in 2006 in plants collected in the first term (9.60%).

Evaluation of the nitrate level in leaf blades and petioles demonstrated considerable differences between the harvesting times (Table 1). Significantly the highest quantities of nitrates appeared in leaf blades of plants picked up the earliest term (869 mg·kg^{-1} fresh weight). In plants from the remaining two harvest times, no significant differentiation in contents of nitrates was observed, as they equalled 420 and 276 mg·kg^{-1} fresh matter respectively. On average, in 2004-2006, the lowest level of nitrates in leaf blades was determined in plants picked in 2005 in the third term (160 mg·kg^{-1} fresh weight), and the highest one in plants harvested in 2004 in the first term (1260 mg·kg^{-1}). Similarly to the blades, a significant effect of the harvest time on nitrate level was observed in leaf petioles. In plants picked in the earliest date, their level was the highest (4079 mg·kg^{-1} fresh weight), being much lower for the second term harvest (3348 mg·kg^{-1}), and the lowest in plants picked in the third term

Table 1

Yield of Spinach beet and content of dry matter and NO_3-N in relation to the term of harvest (mean for 2004-2006)

Year	Term of harvest	Yield ($t \cdot ha^{-1}$)	Dry matter (%)		NO_3-N ($mg \cdot kg^{-1}$ f.w.)		Vitamin C ($mg \cdot 100\ g^{-1}$ f.w.)
			blades	petioles	blades	petioles	blades petioles
2004	I	36.24	11.47	7.52	1260	3953	49.52
	II	62.23	12.19	8.21	379	2445	51.07
	III	99.67	15.33	9.44	277	878	53.75
		66.05	13.00	8.39	639	2425	51.45
2005	I	45.42	11.73	7.58	540	3383	29.60
	II	75.57	13.35	9.20	330	3300	30.91
	III	110.52	13.78	9.58	160	463	44.55
		77.17	12.95	8.79	343	2382	35.02
2006	I	45.73	9.60	7.14	808	4900	35.00
	II	78.32	15.61	9.13	550	4300	36.50
	III	106.62	16.17	9.81	390	1000	43.33
		76.89	13.79	8.69	583	3400	38.28
Mean	I II III	42.46 72.04 105.61	10.93 13.72 15.09	7.42 8.85 9.61	869 420 276	4079 3348 780	38.04 39.49 47.21
		73.37	13.25	8.63	522	2736	41.58
LSDα=0.05 for: term of harvest years interaction (I x II)		 16.18 n.s. n.s.	 1.00 n.s. 1.73	 1.06 n.s. n.s.	 181 181 314	 424 424 734	 4.20 4.20 n.s.

(780 $mg \cdot kg^{-1}$ fresh weight). Significantly lower contents of nitrates in leaf petioles was observed in plants grown in 2004–2005 (2425 and 2382 $mg \cdot kg^{-1}$ fresh weight), and the higher in 2006 (3400 $mg \cdot kg^{-1}$). The results confirm research by other authors, who proved that the nitrate level decreases along with a delay of the harvest time (Bohner et al. 2005, Kozik 2006), and accumulation of nitrates in leaf petioles is usually much higher than in blades (Kmiecik et al 2005).

The harvest time delay had a significant effect on the contents of vitamin C in leaf blades of Spinach beet. Plants picked in the latest term demonstrated a higher level of vitamin C (47.21 $mg \cdot 100\ g^{-1}$ fresh weight) than those in the remaining periods (38.04-39.49 $mg \cdot 100\ g^{-1}$ fresh weight).

Table 2

Content of P, K, Ca and Mg in blades and petioles of Spinach beet ($g \cdot kg^{-1}$) in relation to the term of harvest, mean for 2004–2006

Year	Term of harvest	P		K		Ca		Mg	
		blades	petioles	blades	petioles	blades	petioles	blades	petioles
2004	I	3.9	4.0	79.7	79.7	1.0	1.9	6.3	3.1
	II	3.9	3.6	49.4	74.6	1.1	1.3	4.3	3.0
	III	3.8	4.4	57.6	43.2	1.1	1.4	4.0	2.1
		3.8	4.0	62.3	65.8	1.1	1.5	4.8	2.7
2005	I	4.3	3.8	42.2	43.7	0.8	1.0	7.9	2.9
	II	3.0	3.1	57.2	42.5	1.1	1.5	6.0	2.2
	III	2.4	2.9	43.1	36.8	1.0	1.6	4.5	1.9
		3.2	3.2	47.5	41.0	1.0	1.4	6.1	2.3
2006	I	4.3	3.2	61.7	73.3	1.2	1.4	6.7	2.0
	II	3.0	4.2	54.7	47.5	1.2	1.7	4.7	1.8
	III	3.0	4.0	49.0	38.5	1.1	1.4	3.2	1.5
		3.4	3.8	55.1	53.1	1.2	1.5	4.9	1.8
Mean	I II III	4.1 3.3 3.0	3.7 3.6 3.8	61.2 53.8 49.9	65.6 54.9 39.5	1.0 1.2 1.1	1.5 1.5 1.5	6.9 5.0 3.9	2.7 2.3 1.8
		3.5	3.7	55.0	53.3	1.1	1.5	5.3	2.3
$LSD_{\alpha=0.05}$ for: term of harvest years interaction (I x II)		 0.6 n.s. n.s.	 n.s. 0.4 0.7	 6.2 6.2 10.7	 6.6 6.6 11.4	 n.s. n.s. n.s.	 n.s. n.s. 0.3	 0.5 0.5 n.s.	 0.3 0.3 n.s.

In 2004, the level of vitamin C in leaf blades (51.45 mg·100 g^{-1} fresh weight) was significantly higher than in 2005-2006 (35.02-38.28 mg·100 g^{-1} fresh weight).

The level of phosphorus in leaf blades was decreasing along with a delay in harvest time. In plants picked in the earliest time, the level of phosphorus was 4.1 g·kg^{-1}, while in the subsequent periods it decreased down to 3.3 g·kg^{-1} and 3.0 g·kg^{-1} (Table 2). No significant effect of this factor on the phosphorus level was found in leaf petioles. It is worth noticing that higher contents of this component appeared in plants grown in 2004 and 2006 (4.0 and 3.8 g·kg^{-1}), and lower in 2005 (3.2 g·kg^{-1}).

Significant effect of the harvest time on potassium contents was observed both in leaf blades and petioles. The highest level of this element in leaf blades occurred in plants picked in the earliest term (61.2 g·kg^{-1}), while those coming from the remaining two periods did not differ from each other considerably (53.8 and 49.9 g·kg^{-1}). The significantly highest amounts of potassium in leaf petioles appeared in plants picked in the earliest term (65.6 g·kg^{-1}); in the crop from second and third term this level dropped down to 54.9 g·kg^{-1}, and 39.5 g·kg^{-1} respectively. The highest level of potassium in leaf blades and petioles was observed in plants grown in 2004 (62.3 and 65.8 g·kg^{-1} respectively), and the lowest one in 2005 (47.5 and 41.0 g·kg^{-1}).

The harvesting time did not have any effect on the level of calcium in the plants, although the influence of this factor on the level of magnesium was significant. Both in leaf blades and petioles, as the harvest time was postponed, the magnesium contents was decreasing from 6.9 g·kg^{-1} of dry matter down to 3.9 g·kg^{-1} in blades and from 2.7 to 1.8 g·kg^{-1} in petioles.

CONCLUSIONS

1. Delayed harvesting time of Spinach beet resulted in enhancement of crop yield and contents of dry matter in leaf blades and petioles, as well as vitamin C in leaf blades. Simultaneously, a decrease in the level of nitrates, K and Mg in leaf blades and petioles and of P in leaf blades was observed.

2. Spinach beet leaf blades contained more dry matter, K and Mg, while leaf petioles were richer in P, Ca and had over 5-fold more nitrates compared with the blades.

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J. Elementol. 2008, 13(2): 189–198

THE EFFECT OF NUTRIENT SOLUTION PH ON PHOSPHORUS AVAILABILITY IN SOILLESS CULTURE OF TOMATO

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Abstract

Greenhouse experiments with tomato were conducted in the years 2004-2006. The aim was to study the effect of nutrient solution pH on the availability of phosphorus in soilless culture of tomato. Tomato plants were grown on mats made of shredded rye straw, and on slabs of peat and rockwool. The plants were fertilized with a standard nutrient solution of different pH: 4.5, 5.0, 5.5, 6.0 and 6.5. Such different pH levels of the nutrient solution used in soilless culture modified the pH of the root growth zone. This effect was more evident in rockwool than in the organic media (especially straw). The phosphorus content in the root zone was closely associated with the pH value of the supplied nutrient solution and the kind of growing medium. Considerably lower concentrations of phosphorus were recorded in the organic media (straw, peat) than in rockwool. As the pH level of the nutrient solution increased, so did the pH of the root zone, whereas the amount of available P-PO_4 decreased. The course of these changes was similar in all the substrates. However, the dynamics of the changes was weaker in the organic media. With an increase in the pH of the nutrient solution, the average phosphorus content in tomato leaves decreased. The P-PO_4 concentration was higher in the leaves of tomato plants growing in rockwool compared to those in the organic media. A significantly higher marketable yield was obtained from tomato plants cultivated in rockwool than in the organic media. For all the growing media, the highest yield of tomatoes was obtained after feeding the plants with the nutrient solution of pH 5.5.

Key words: pH, nutrient solution, phosphorus, straw, peat, rockwool.

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WPŁYW ODCZYNU POŻYWKI NA DOSTĘPNOŚĆ FOSFORU W BEZGLEBOWEJ UPRAWIE POMIDORA

Abstrakt

Badania prowadzono w warunkach szklarniowych w latach 2004-2006. Celem badań było określenie wpływu odczynu pożywki na dostępność fosforu w bezglebowej uprawie pomidora w podłożach organicznych i inertnym. Uprawę prowadzono w matach wykonanych z rozdrobnionej słomy żytniej, w workach z torfem oraz w wełnie mineralnej. Rośliny nawożono standardowymi roztworami pożywek o zróżnicowanym odczynie (pH): – 4,5, 5,0, 5,5, 6,0, 6,5. Zróżnicowany odczyn pożywki stosowanej do upraw bezglebowych na podłożach organicznych, szczególnie na słomie, w mniejszym stopniu modyfikował pH środowiska korzeniowego niż na wełnie mineralnej. Zawartość dostępnego fosforu w środowisku korzeniowym była ściśle związana z odczynem dozowanej pożywki oraz podłożem uprawowym. Zdecydowanie mniejsze zawartości dostępnego fosforu oznaczano w podłożach organicznych (słoma, torf) w porównaniu z wełną mineralną. Wraz ze wzrostem pH pożywki, wzrastało pH środowiska korzeniowego oraz malała zawartość dostępnego fosforu. Przebieg tych zmian był podobny zarówno w podłożach inertnym, jak i organicznych. Tempo tych zmian było wolniejsze w podłożach organicznych. Wraz ze wzrostem pH stosowanych pożywek malała średnia zawartość fosforu w liściach pomidora. Wyższą zawartość $P\text{-}PO_4$ w liściach pomidora stwierdzono na wełnie mineralnej. Na wełnie mineralnej uzyskano istotnie wyższy plon handlowy pomidora w porównaniu z plonem z podłoży organicznych. Najlepsze plonowanie pomidora, niezależnie od stosowanych podłoży, stwierdzono w przypadku stosowania pożywki o pH 5,5.

Słowa kluczowe: pH, pożywka, fosfor, słoma, torf, wełna mineralna.

INTRODUCTION

In soilless culture of tomato, mineral, organic and inert growing media are used. The pH of the root zone affects the availability of nutrients taken up by plants (NELSON 1991). In organic-mineral substrates, the effect of pH is greater than in soil (PETERSEN 1982, quoted by NELSON 1991). According to many authors, nutrient solution used to cultivate tomato in rockwool should have a pH of 5.5-6.0 (SONNEVELD 1991, MICHAŁOJĆ, NURZYŃSKI 2002, KOMOSA et al. 2004, DYŚKO, KOWALCZYK 2005, KOWALCZYK, KANISZEWSKI 2005). In inert substrates, the availability of some nutrients depends directly on the pH of the root zone. In soilless cultures with organic substrates, the pH of the nutrient solution is modified not only by the plants and the changes in the surrounding environment (as is the case of inert substrates), but also by the organic matter of the substrate used. BADORA (2002) reports that the specific adsorption of molybdate, phosphate and sulphate ions decreases as the pH increases, whereas their immobilization occurs in an acidic environment. The pH of a growing medium has the greatest influence on the availability of phosphorus, manganese and iron (KOWALCZYK, KANISZEWSKI 2005, KOWALCZYK et al. 2006). Phosphorus is an element which occurs in forms that are strongly dependent on environment pH. In the root zone, active phosphorus can be found as

PO_4^{-3}, HPO_4^{-2}, and $H_2PO_4^-$ ions. Most phosphorus is taken up by plants in the form of the two latter ions. The largest amounts of phosphorus available to plants grown on inert substrates are present in nutrient solutions that are slightly acidic (pH 5.0). In alkaline and highly acidic solutions, retardation takes place, i.e. a decrease in the concentration of available ions. A literature review indicates that the experimental work on the effect of nutrient solution pH has involved mainly inert substrates, and there have been no reports concerning organic growing media.

The aim of this work was to determine the effect of nutrient solution pH on the availability of phosphorus in soilless culture of tomato grown in organic and inert substrates.

MATERIAL AND METHODS

The work was carried out under greenhouse conditions in the years 2004–2006. The experiment was set up in a two-factorial design, in an independent system with four replications. The experimental factors included:

a) growth substrates – peat, rye straw, rockwool;
b) pH of nutrient solution – pH of 4.5, 5.0, 5.5, 6.0, 6.5.

Shredded rye straw was used to make cultivation mats in the shape of 100 cm long x 20 cm wide x 10 cm thick slabs. Mats of the same dimensions were also made of peat. The inert substrate used in the experiment was 'Grodan-Master' rockwool in 100x20x7.5 cm slabs. Each slab of a substrate was used to grow 3 tomato plants of cultivar Blitz F_1. The experimental plot size was 3 m^2. The plants were planted in a permanent place of cultivation in early April and grown in an extended cycle until mid-October. The required pH of the nutrient solution was obtained by adding to water 65% HNO_3 and 33% HCl. The amount of acid needed to bring the nutrient solution to the required pH level was determined on the basis of a water acidification curve, with the nitric acid used to fix the pH at 6.5, while the other acidification levels were achieved with the hydrochloric acid (so as not to vary the nitrogen content in the experimental combinations). After seedlings had been planted, regular fertigation was carried out, adjusted to climatic conditions and plant growth stage. For irrigation, water of the following composition was used (in $mg \cdot dm^{-3}$): HCO_3^- – 349, N-NO_3 – 0.25, N-NH_4 – 0.05, P – 0.05, K – 2.72, Ca – 101, Mg – 15.0, Na – 10.5, Cl – 12.9, S-SO_4 – 33.5, Fe – 0.042, Mn – 0.022, Cu – 0.020, Zn – 1.680, B – 0.025; EC – 0.56 $mS \cdot cm^{-1}$, pH – 7.2, total hardness – 17.6°dH. Parameters of the applied nutrient solution: pH 4.5-6.5, depending on the combination; EC 2.0--3.0 $mS \cdot cm^{-1}$; composition ($mg \cdot dm^{-3}$): N – 200-260, P – 40, K – 220-380, Mg – 60-80, Ca – 180-200, S-SO_4 – 80, Fe – 2.5, Mn – 0.8, B – 0.43, Zn – 0.33, Cu – 0.1, Mo – 0.05. While growing the tomato plants, the concentration of the nutrient solution was maintained at EC = 2.3-2.8 mS·cm^{-1} when the weather was sunny, at EC = 3.0 mS·cm^{-1} when it was cloudy with low light levels, and at EC = 2.7-3.0 mS·cm^{-1} during vigorous plant growth and harvest. During the initial period of plant growth, until the third or fourth fruit cluster had set, the nitrogen content in the nutrient solution was at a level of 260 mg·dm^{-3}. Then the level of nitrogen was lowered to 200 mg·dm^{-3}. Tomato fruits were picked twice a week. Marketable fruit yield was recorded.

Samples of the solutions from cultivation mats were analysed for phosphorus content once every fortnight. The samples for chemical analyses were taken after the second watering cycle from in between two plants in the centre of the mat. Chemical analyses for phosphorus content in the leaves were carried out 3 times during the cultivation period: when the third cluster was in flower, at the time of picking the third fruit cluster, and 2 weeks before the end of cultivation. For that purpose, the fifth leaf from the top of the plant was taken as a sample. pH was measured with an ORION pH meter, while P-PO_4 concentration was determined by means of an Atom Scan 16 plasma spectrometer. The results were processed statistically using the variance analysis method. Mean values were compared with Newman-Keuls test at p=0.05. The changes in phosphorus concentration in the cultivation mats and its dependence on pH were determined using the methods of correlation and linear and parabolic regression (PIELAT, VISCARDI 1988).

RESULTS AND DISCUSSION

The pH value of the nutrient solution delivered to the tomato plants had an effect on the pH changes in the root zone during the cultivation period. The average pH values presented in Table 1, which represent the samples of the nutrient solution taken from the cultivation mats, are a general indicator of the response of the root environment to the application of the nutrient solution at different pH levels. There was a weaker response to the variations in pH of the supplied nutrient solution in organic substrates, straw in particular. Because of its very good buffering properties, straw maintained in the root zone a high pH level with very little variation. In the peat substrate, the changes in pH were also very small, as both low and high pH levels of the nutrient solution only slightly changed the pH of the root zone only. In rockwool, however, the changes in pH of the root zone depended on the pH of the nutrient solution. Low pH of the applied nutrient solution (pH 4.5) was found to maintain the pH in the root zone at a level of 5.8, whereas high pH (6.5) sustained a level of 7.5.

The available phosphorus content was very closely associated with the pH of the nutrient solution being supplied and the growing medium used (Figures 1-5). Regardless of the pH value of the applied nutrient

Table 1

The effect of pH of nutrient solution on the pH of root zone of tomato (2004-2006)

pH of nutrient solution	pH of root zone		
	straw	peat	rockwool
4.5	7.1	6.4	5.8
5.0	7.4	6.5	6.0
5.5	7.5	6.7	6.2
6.0	7.6	6.9	6.7
6.5	7.8	7.2	7.5

solution, the least variation in the available phosphorus content was found in the solution taken from the cultivation mats made of straw. Over the whole period of tomato cultivation in straw, the least amounts of phosphorus were measured when the nutrient solution had a pH of 6.5. The dynamics of the changes in the phosphorus content in straw was described by rectilinear regression lines. With the nutrient solution of pH 4.5, the phosphorus content in the solution sampled from the straw mats increased during the cultivation period, whereas at pH 6.5 it showed a downward trend throughout the whole period of cultivation. A comparison of the substrates used in the experiment reveals that the least amounts of available phosphorus were found in straw. Compared to straw, there was greater availability of phosphorus in the peat substrate. In this substrate, the highest phosphorus amounts were measured when the pH of the nutrient

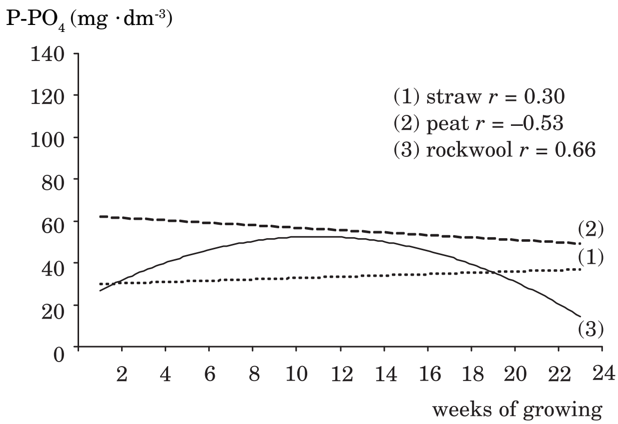

Fig. 1. Changes of $P\text{-}PO_4$ concentrations in root zone of tomato at pH 4.5 of the nutrient solution

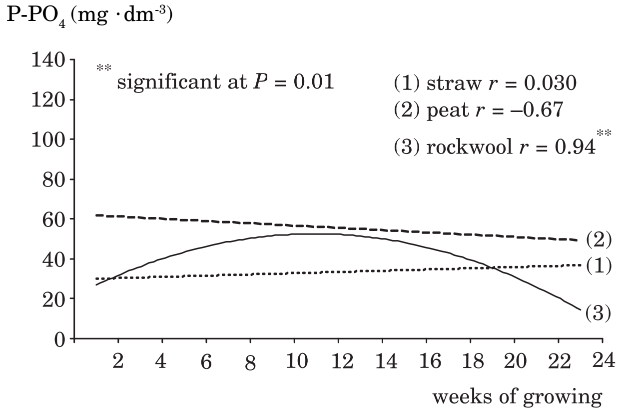

Fig. 2. Changes of $P\text{-}PO_4$ concentrations in root zone of tomato at pH 5.0 of the nutrient solution

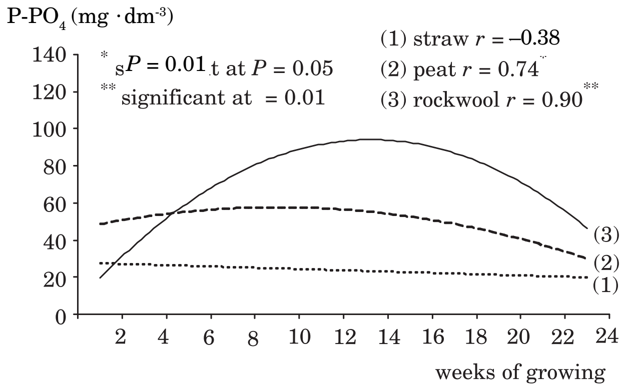

Fig. 3. Changes of $P\text{-}PO_4$ concentrations in root zone of tomato at pH 5.5 of the nutrient solution

solution was 4.5, and the lowest when the solution pH was 6.5. The changes in the phosphorus concentration in the root zone in the peat substrate proceeded in a similar way for the nutrient solutions with pH 4.5, 6.0, and 6.5, and were represented by a straight line. In contrast, the changes for pH 5.0 and 5.5 were described by a parabolic curve. It should be noted that the course of the changes in the phosphorus content did not depend on the stage of cultivation at the pH levels used and was of no statistical significance. When the pH of the applied nutrient solution was 6.5, the highest availability of phosphorus in all the substrates used was found in peat. In rockwool, the pH of the nutrient solution significantly changed the amounts of phosphorus available to plants. The resulting parabolic regression lines clearly demonstrate a significant relationship be-

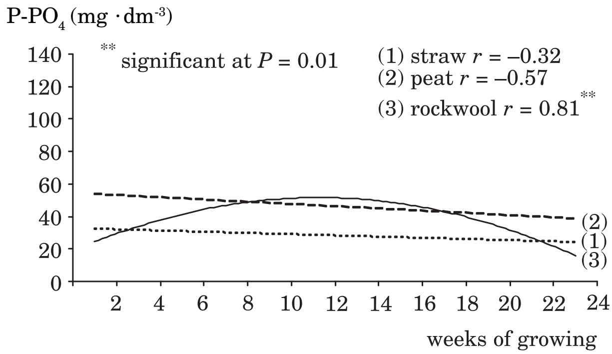

Fig. 4. Changes of $P\text{-}PO_4$ concentrations in root zone of tomato at pH 6.0 of the nutrient solution

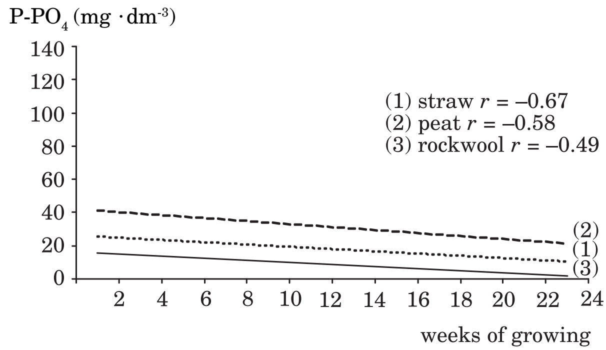

Fig. 5. Changes of $P\text{-}PO_4$ concentrations in root zone of tomato at pH 6.5 of the nutrient solution

tween phosphorus concentration in the root zone and plant development stage when the nutrient solution was used at pH 5.0, 5.5, and 6.0. At these pH levels, the highest amounts of available phosphorus were found in the middle of the plant cultivation period. At pH 4.5, the trend curve for the phosphorus content in rockwool was similar to the curves obtained at pH 5.0, 5.5 and 6.0, but the changes were not proven statistically. The lowest concentrations of phosphorus in rockwool were recorded when the pH of the applied nutrient solution was 6.5. At pH 6.5, the phosphorus content in the various cultivation mats (straw, peat, rockwool) can be described by 3 parallel straight lines displaced, on average, by about 15 mg $P\text{-}PO_4 \cdot dm^{-3}$ relative to each other, with the lowest values recorded for rockwool, and the highest for peat. When the nutrient solution was supplied at pH 6.5, higher levels of phosphorus in the growth substrates were measured at the beginning of the cultivation period, and then, as the plants developed, these values decreased. MICHAŁOJĆ and NURZYŃSKI (2002), and KOWALCZYK and KANISZEWSKI (2005) during the cultivation of tomatoes on rockwool, also found a significant drop in the levels of phosphorus in the root zone at high pH values of the nutrient solution. In the experiments by DE RIJCK and SCHREVENS (1999) with pure nutrient solutions, the effect of pH on phosphorus levels was rectilinear in character.

The pH of the supplied nutrient solution, as well as the kind of substrate, produced significant variations in the nutritional status of tomato plants in respect of phosphorus (Table 2). With increasing pH of the nutrient solution, the average phosphorus content in the tomato plants fell. Similar results were obtained by KOMOSA et al. (2004), and KOWALCZYK, KANISZEWSKI (2005) while growing tomatoes in rockwool at different pH values of the nutrient solution. The highest levels of phosphorus were obtained in the plants grown on rockwool. The lowest phosphorus content of 3.3 $g \cdot kg^{-1}$ d.w. was found while growing tomatoes on peat supplied with the nutrient solution of pH 6.5. According to ADAMS (1996), a concentration of $P<0.2\%$ d.w. in the leaves indicates phosphorus deficiency in the plant.

Table 2

The effect of pH of nutrient solution and type of growing medium on the P content ($g \cdot kg^{-1}$ d.m.) in tomato leaves (2004-2006)

pH of nutrient solution	Growing medium			
	straw	peat	rockwool	*x*
4.5	4.20	3.83	5.47	4.50 *a*
5.0	3.90	4.07	5.33	4.43 *a*
5.5	3.73	3.60	4.80	4.04 *ab*
6.0	3.77	3.60	4.63	4.00 *ab*
6.5	4.07	3.30	4.07	3.81 *b*
x	3.93 ^{b}	3.68 *b*	4.86 *a*	-

Means followed by the same letter are not significantly different at $p = 0.05$.

On the basis of the experimental results it was concluded that both the pH of the applied nutrient solution and the kind of substrate used had a significant effect on the size of the marketable yield of tomatoes (Table 3). However, no evidence of a combined effect of solution pH and the type of substrate was found in this respect. The highest marketable yield was obtained when tomatoes were grown on rockwool. This yield was significantly higher than the yields obtained from cultures on the organic substrates (straw, peat). Comparing the different pH values of the supplied nutrient solution, irrespective of the kind of a substrate used, the highest marketable yield was obtained at pH 5.5. The marketable yield obtained with the nutrient solution of pH 5.5 was significantly higher in relation to the yield obtained at pH 6.5, but it did not differ significantly from the yields obtained at pH 4.5, 5.0, and 6.0. Similar re-

Table 3

The effect of pH of nutrient solution and type of growing medium on marketable yield of tomato cv. Blitz F1 (2004-2006)

pH of nutrient solution	Yield ($kg \cdot m^{-2}$)			
	straw	peat	rockwool	*x*
4.5	39.97	38.31	45.63	41.30 *ab*
5.0	37.14	40.84	46.14	41.38 *ab*
5.5	41.58	41.87	47.53	43.66 *a*
6.0	39.01	40.87	45.32	41.73 *ab*
6.5	36.47	38.25	39.23	37.98 *b*
x	38.83 *b*	40.03 *b*	44.77 *a*	41.21

Means followed by the same letter are not significantly different at $p = 0.05$.

sults were obtained by CHOHURA et al. (2004) while studying the effects of solution pH (at the same levels as in this experiment) on tomato cultures grown only on rockwool. KOWALCZYK (2003), who cultivated tomato on rockwool, obtained a significantly lower marketable yield after using a nutrient solution with a high pH value (pH 6.5). In the experiments by WILLUMSEN (1980) with tomato aquacultures, different pH levels (4.5–6.5) of the nutrient solution were not found to have an effect on marketable yield. However, nutrient solution pH of 4.5 was found to reduce fruit size.

CONCLUSIONS

1. Different pH levels of the nutrient solution used in soilless cultures with organic growing media, particularly straw, modified the pH of the root zone to a lesser extent than in an inert substrate (rockwool).

2. The concentration of available phosphorus in the root zone was closely associated with the pH level of the applied nutrient solution and the kind of a cultivation substrate used. Less available phosphorus was found in organic substrates (straw, peat), more in rockwool.

3. With an increase in pH of the applied nutrient solution, there was a drop in the average phosphorus content in leaves of tomato plants. Higher phosphorus levels in leaves were found in tomato cultures set up on rockwool than those on organic substrates.

4. Irrespective of the kind of substrate used, the best yielding of tomato plants was obtained at pH 5.5 of the nutrient solution. A significantly higher marketable yield was obtained from plants growing on rockwool than on organic substrates.

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EFFECT OF PLANTING DATE AND METHOD ON THE CHEMICAL COMPOSITION OF RADICCHIO HEADS

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Abstract

The aim of the experiment, conducted from 2005 to 2006, was to determine the effect of planting date (spring, summer/fall) and method (seedlings, direct sowing) on the content of dry matter, selected organic components and nitrates in the heads of Italian chicory radicchio, cv. Palla Rossa 3. Statistical analysis revealed that both experimental factors had a significant effect on the content of dry matter and simple sugars in the edible parts of radicchio. Dry matter content was significantly affected by planting method, while the concentration of total sugars – by planting date. Chemical analysis of the harvested plant material indicated that radicchio grown in the spring contained more dry matter, L-ascorbic acid, simple sugars and total sugars. Plants obtained from seedlings accumulated more L-ascorbic acid and simple sugars, whereas those grown from directly sown seeds contained more dry matter and total sugars. The nitrate content of radicchio heads was found to be significantly dependent on both experimental factors. A significantly higher (by over 33%) concentration of nitrates was recorded in the edible parts of radicchio grown in the summer/fall. The impact of planting method on nitrate content was less noticeable, but radicchio plants grown from directly sown seeds accumulated more nitrates (by almost 11% on average) than those obtained from seedlings. The interaction between the analyzed factors had a significant effect on the bioaccumulation of dry matter, L-ascorbic acid, simple sugars, total sugars and nitrates.

Key words: radicchio, planting date, planting method, nutritive value, nitrates.

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ZAWARTOŚĆ WYBRANYCH SKŁADNIKÓW CHEMICZNYCH W GŁÓWKACH CYKORII RADICCHIO W ZALEŻNOŚCI OD TERMINU I SPOSOBU UPRAWY

Abstrakt

W latach 2005–2006 oceniano zawartość suchej masy, wybranych składników organicznych i azotanów w główkach cykorii radicchio odmiany Palla Rossa 3 w zależności od terminu i metody uprawy. Cykorię uprawiano dwiema metodami – z rozsady przygotowanej uprzednio w szklarni oraz z siewu bezpośredniego w pole – w dwóch terminach – wiosennym i letnio-jesiennym. Analiza statystyczna wykazała istotny wpływ obydwu analizowanych czynników doświadczenia na zawartość witaminy C i cukrów prostych w częściach jadalnych cykorii. Na ilość zgromadzonej suchej masy istotnie wpłynęła metoda, natomiast cukrów ogółem – termin uprawy. Przeprowadzone po zbiorze badania chemiczne materiału roślinnego wykazały, iż zawartość suchej masy, kwasu L-askorbinowego, cukrów prostych i ogółem była większa w główkach cykorii z wiosennego terminu uprawy. Rośliny uprawiane z rozsady zgromadziły więcej kwasu L-askorbinowego i cukrów prostych, natomiast uprawiane z siewu bezpośredniego – więcej suchej masy i cukrów ogółem. Na gromadzenie azotanów w główkach cykorii istotny wpływ wywarły obydwa analizowane czynniki. Istotnie więcej azotanów (o ponad 33%) oznaczono w częściach jadalnych cykorii radicchio uprawianej w terminie letnio-jesiennym. Wpływ sposobu uprawy na badany czynnik nie był tak wyraźny – rośliny z siewu bezpośredniego zgromadziły średnio prawie o 11% azotanów więcej niż uprawiane z rozsady. Współdziałanie badanych czynników na bioakumulację suchej masy, kwasu L-askorbinowego, cukrów prostych i ogółem oraz azotanów było istotne.

Słowa kluczowe: cykoria radicchio, termin, metoda uprawy, wartość odżywcza, azotany.

INTRODUCTION

The pattern of vegetable consumption per household in Poland indicates a clear dominance of a few species only. The intake of leaf vegetables, known for their high nutritive value and health-promoting properties, is well below the recommended levels. The optimistic news is that the area under vegetables – including less popular species – continues to increase steadily. This is of paramount importance, since too low food variety and dietary diversity contributes to a higher incidence of civilization-related diseases (NALBORCZYK 1999, ADAMCZYK 2002, DYDUCH, NAJDA 2005). Of particular note is Italian chicory – radicchio, widely appreciated for its specific, slightly bitter taste and very attractive appearance. The red and white leaves of radicchio make an excellent base for salads.

The aim of the study was to determine the effect of planting date and method on the content of dry matter, selected organic components and nitrates in the heads of Italian chicory (radicchio).

MATERIALS AND METHODS

The study was conducted during the years 2005–2006, at the Experimental Garden of the University of Warmia and Mazury in Olsztyn. Italian chicory (radicchio) cv. Palla Rossa 3 was grown in the spring or in the summer/fall, by two methods: from seedlings produced in a greenhouse over four weeks, and from seeds sown directly in the field. The experiment was performed in a randomized complete block design, in three replications. Plot area was 1.8 m^2 . Twenty seedlings were planted per plot, at the 30 x 30 cm spacing. Both in the spring and summer, seeds were sown and seedling April and 31 July 2006. Radicchio heads were harvested from particular treatments once only, in a period from 4 to 27 July and from 20 to 27 October respectively.

Fresh plant material was collected from all treatments to determine the content of: dry matter – by the gravimetric method (according to the Polish Standard PN-90/A-75101/03), L-ascorbic acid – by the Tillmans method modified by Pijanowski (PN-90/A-75101/11), total sugars – by the Luff-Schoorl method (PN-90/A-75101/07). After harvest samples of the edible parts of vegetables were dried at 65°C in a KBC G 65/250 drier and ground in an electric mill. Nitrate concentration was determined by the colorimetric method, with the use of salicylic acid (Krauze, Domska 1991). The percentage content of N – NO_3 was calculated according to the following formula:

$$X = \alpha \cdot 100 \cdot b^{-1},$$

where:

- a – deviation from the standard curve, mg N-NO_3;
- b – sample weight;
- 100 – expressed as percentage.

The results were verified statistically. The significance of differences between mean values was estimated by Tukey's test at a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Chemical analysis of the harvested plant materials indicated that plants grown from directly sown seeds contained significantly more (almost 1.5-fold) dry matter than plants obtained from seedlings. The differences were more noticeable in the summer/fall. A higher dry matter content was determined in the leaves of plants grown in the spring compared to those harvested in the fall (8.15% vs. 7.87% on average), but the effect of planting date on dry matter content was not confirmed by the statistical analysis.

L-ascorbic acid concentration in radicchio heads ranged from 46.4 to 144.5 mg·100 g^{-1}. Similar results were reported by Rożek (2002). L-ascorbic acid content was almost twofold higher in plants grown in the spring. Radicchio grown in the spring accumulated also more simple and total sugars – on average by 55.9% and 39.4% respectively. Other authors also reported higher concentrations of vitamin C and sugars in spring-grown leaf vegetables, such as lettuce (Majkowska-Gadomska, Wierzbicka 2005b), Chinese cabbage (Krężel, Kołota 2003), leaf mustard (Capecka 2006) and lamb's lettuce (Adamczewska-Sowińska, Kołota 2000). Plants obtained from seedlings accumulated more L-ascorbic acid and simple sugars, whereas those grown from directly sown seeds contained more dry matter and total sugars (Table 1).

Table 1

The content of dry matter and some chemical components in radicchio heads (mean for years 2005-2006)

Planting date	Method	Dry matter (%)	L-ascorbic acid (mg·100 g^{-1})	Simple sugars (g·100 g^{-1})	Total sugars (g·100 g^{-1})
Spring	seedling direct sowing	6.960 9.340	144.5 93.7	2.210 1.747	2.447 2.270
Mean		8.150	119.1	1.978	2.358
Summer - -autumn	seedling direct sowing	5.800 9.930	68.7 46.4	1.320 1.220	1.500 1.883
Mean		7.865	57.5	1.270	1.692
Mean	seedling direct sowing	6.380 9.635	106.6 70.0	1.765 1.483	1.973 2.077
$LSD_{0.05}$ I term of cultivation II method I × II		 n.s. 0.552 0.780	 2.08 2.08 2.94	 0.072 0.072 0.101	 0.111 n.s. 0.157

Statistical analysis revealed that both experimental factors had a significant effect on nitrate accumulation in radicchio heads. A substantially higher concentration of nitrates was determined in the edible parts of radicchio plants grown in the summer/fall compared to those grown in the spring (1534.7 mg·kg^{-1} fresh weight vs. 1130.2 mg·kg^{-1} fresh weight on average). These results are consistent with the findings of Jaworska and Kmiecik (1999). The cited authors demonstrated that spinach grown in the fall contained nearly 16-fold more nitrates in comparison with spinach grown in the spring. Their observations were confirmed by Krężel and Kołota (2003) for Chinese cabbage, by Wierzbicka et al. (2002) and Majkowska-Gadomska, Wierzbicka (2005a) for lettuce and by Francke (2005) for *Eruca sativa*. The above is a consequence of, among others, much lower light intensity in the fall. According to Sade et al. (1995), insufficient daylight always leads to excessive nitrate accumulation in crops. A significantly higher concentration of nitrates was recorded in the edible parts of radicchio plants grown from directly sown seeds. The interaction between planting date and method was statistically significant. However, the average nitrate content of radicchio heads did not exceed the maximum permissible limits set for green vegetables (Journal of Laws No. 2 of 2005, item 9) – Table 2.

Table 2

Nitrate content in heads of cichory radicchio cv. Palla Rosa 3 as dependent on cultivation time and methods (mg $N\text{-}NO_3 \cdot kg^{-1}$ f.m.)

Method		2005	2006	Mean
		spring		
Seedling		1013.7	1221.7	1117.7
Direct sowing		1312.0	968.2	1142.6
Mean		1162.9	1095.0	1130.2
Summer – Autumn				
Seedling		1509.7	1310.4	1410.3
Direct sowing		1893.6	1417.7	1660.0
Mean		1701.7	1364.1	1534.7
Mean	seedling direct sowing	1261.7 1602.8	1266.1 1193.0	1264.0 1400.9
$LSD_{0.05}$ I term of cultivation II method I × II		 13.6 13.6 19.2	 20.0 20.0 28.3	 10.0 10.0 14.1

CONCLUSIONS

1. Chemical analysis of the harvested plant materials indicated that radicchio grown in the spring contained more dry matter, L-ascorbic acid, simple sugars and total sugars.

2. Plants obtained from seedlings accumulated more L-ascorbic acid and simple sugars, whereas those grown from directly sown seeds contained more dry matter and total sugars.

3. A significantly higher (by over 33%) concentration of nitrates was recorded in the edible parts of radicchio plants harvested in the fall. Radicchio plants grown from directly sown seeds accumulated more nitrates (by almost 11% on average) than those obtained from seedlings. The average nitrate content of radicchio heads did not exceed the maximum permissible limits set for green vegetables.

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J. Elementol. 2008, 13(2): 205–210

EFFECT OF A SUBSTRATE ON YIELDING AND QUALITY OF GREENHOUSE CUCUMBER FRUTIS

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Abstract

Cucumber has high climatic demands especially in relation to temperature. Humidity, air temperature and UV light intensity are main factors affecting cucumber crop quality and quantity. Due to the instability of the above during the changing seasons in Poland, all-year-round cultivation of cucumber is difficult. In our experiment we used three types of substrates: rock wool, perlite and wood fibre. Cucumber cultivation was carried out in three times of the year. These two were main changing factors of the experiment. Our research proved that the best quality cucumbers was obtained in the second cultivation period – between April and August, due to the optimum climatic conditions for that species. The type of a substrate also affected the quantity of crops – the highest crops were on wood fiber, slightly lower on perlite. Higher content of dry matter, vitamin C, total sugars, calcium and phosphorus was observed in cucumber fruits from summer cultivation and a high content of nitrogen and potassium was found in cucumber fruits from autumn cultivation.

Key words: rock wool, perlite, wood fiber, term cultivation, chemical composition.

WPŁYW PODŁOŻY NA PLONOWANIE I JAKOŚĆ OWOCÓW OGÓRKA SZKLARNIOWEGO

Abstrakt

Ogórek jest gatunkiem o wysokich wymaganiach klimatycznych, szczególnie w stosunku do temperatury. Temperatura powietrza, wilgotności, oraz natężenie napromieniowania są czynnikami wpływającymi na plonowanie i jakość owoców. Zmienność parametrów w ciągu roku w

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Polsce utrudnia uprawę całoroczną tego gatunku. Doświadczenie prowadzono w całorocznym cyklu produkcyjnym, w trzech terminach uprawy, z zastosowaniem trzech podłoży: wełny mineralnej, perlitu, włókna drzewnego. Termin uprawy oraz zastosowane podłoże były głównymi czynnikami doświadczenia. Największe plony oraz najlepszej jakości owoce otrzymano w drugim terminie uprawy (kwiecień – sierpień) charakteryzującym się optymalnymi warunkami dla tego gatunku. Na wielkość plonowania miało również wpływ zastosowane podłoże. Największe plony otrzymano w uprawie na włóknie drzewnym, nieznacznie mniejsze w uprawie na perlicie. Największą zawartość suchej masy, cukrów ogółem, witaminy C, wapnia i fosforu miały owoce ogórka z uprawy w terminie letnim, a wyższą zawartość azotu i potasu owoce z uprawy w terminie jesiennym

Słowa kluczowe: wełna mineralna, perlit, włókno drzewne, terminy uprawy, skład chemiczny.

INTRODUCTION

Cucumber is one of the vegetable species which are often grown under covers. Production profitability is conditioned by the volume of yield per 1 m^2 of surface. Yielding in turn depends mainly on the time of cultivation and the substrate type used. The main advantage of growing vegetables on inert substrate is high yielding. The most popular substrate in cucumber cultivation is rock wool, which is difficult to utilize (BENOIT, CEUSTERMANS 1998). Thus, investigations are carried out on the usefulness of other substrates, both natural (organic, mineral) and synthetic (PIRÓG 1999, SHINOHARA i in. 1997, KOMOSA 2005), such as perlite, wood fibre or polyurethane foam. MARTYR (1982), WILSON (1984) i OŚWIĘCIMSKI (1996) recommend growing tomato and cucumber in perlite placed in polypropylene sacks of 40–60 dm^3 capacity. This conclusion results from the investigations carried out by SCHNITZER et al (1996) on wood fibre, which showed that the greenhouse cultivation of cucumber in hydroponics gave yields comparable with those obtained on other substrates. Compared with other species cultivated under covers, cucumber fruits have the highest content of water (96-97%), the lowest energy value (about 56 kJ (14 kcal) per 100 g of fresh matter) but are rich in mineral salts (KUNACHOWICZ et al. 2005).

The aim of the present investigation was to assess yielding and fruit quality of cucumber fruit in the all-year-round cultivation on rock wool, perlite and wood fibre.

MATERIAL AND METHODS

The investigations were performed in the greenhouse of the Department of Vegetable and Medicinal Plants, Warsaw University of Life Sciences

– SGGW in 2006. They were performed on two greenhouse cucumber cultivars (Pacto F_1 by De Ruiter Seeds and Melen F_1 by Enza Zaden) cultivated in an all-year-round production cycle on three substrates: rock wool (Grodan), perlite (Pelar Poland) and wood fibre (Steico).

Times of cultivation: 1 – spring sowing 21.12.2005, planting 27.01.2006, folding up 24.04.2006; 2 – summer sowing 29.03.2006, planting 25.04.2006, folding up 7.08.2006; 3 – autumn sowing 12.07.2006, planting 8.08.2006, folding up 22.11.2006.

For each cultivation period seedlings were produced in blocks of rock wool. Substrate for the cultivation of seedlings was prepared from single fertilizers according to the standard recommendations for this cucumber growth stage. Plants were grown as one shoot and during the cultivation they underwent systematical clearing (removal of side shoots and low leaves) and shoot lowering. During the vegetation fruits were picked successively and the total yield was determined ($kg \cdot m^{-2}$).

Chemical analysis of fruits included the determination of dry matter by drying at 104°C, the content of vitamin C by the titration method, total sugars by Luffa-Schoorl's method and the contents of basic macroelements: N was determined by the flow method at a wavelength of 560 nm, P was determined by spectrophotometry at a wavelength of 460 nm, whereas K and Ca were assayed by the flame method using a flame photometer.

Statistical analysis of the test parameters was done with the help of Statgraphics Plus programme. Detailed comparison of means was performed by the Tukey's test at α=0.05

RESULTS AND DISCUSSION

One of the essential factors in vegetable cultivation under covers is the season. This is connected with climatic conditions, especially irradiation intensity. Light deficit causes a decrease in the number of fruits set and their proper growth. Under optimum cultivation conditions, plants are better developed and they yield earlier (Medrano et al. 2005). Our results point to the fact that the time of cultivation significantly affected yielding. In summer, which is characterized by high irradiation intensity (97 sunny days), the yield was much higher than in spring (37 sunny days) and autumn (38 sunny days) – Table 1. The investigations by Verwer (1978) and Os (1981) as well as Piróg (2001) prove that in cucumber greenhouse cultivation, the type of a substrate used is not insignificant. The results of the present investigations prove that the highest yield was obtained from the cultivation on wood fibre, slightly lower yield was characteristic for plants grown on perlite and the lowest yield was obtained on rock wool (Table 1). According to Komosa (1994) the quality of cucumber

Table 1

The total yield of fruit (kg·m^{-2}) – mean for two cultivars

Terms	Substrats			
	rock wool	perlite	wood fiber	mean
Spring	9.612 *b**	9.610 *b*	11.95 *a*	10.38
Summer	24.52 *a*	28.63 *a*	27.10 *a*	26.75
Autum	12.42 *a*	14.18 *a*	13.24 *a*	13.28
Mean	15.51	17.47	17.43	

* values with the same letter do not differ significantly at $a = 0.05$

Table 2

The content of dry matter, vitamin C, total sugars in cucumber fruit (mean for two cultivars)

Terms	Substrats								
	rock wool			perlite			wood fiber		
	dry matter (g 100 g^{-1})	vitamin C (mg kg^{-1})	total sugars (g kg^{-1})	dry matter (g 100 g^{-1})	vitamin C (mg kg^{-1})	total sugars (g kg^{-1})	dry matter (g 100 g^{-1})	vitamin C (mg kg^{-1})	total sugars (g kg^{-1})
Spring	3.220 *a**	0.067 *b*	932 *b*	3.240 *a*	0.071 *b*	871 *b*	3.121 *a*	0.067 *b*	931 *b*
Summer	3.850 *a*	0.108 *a*	1661 *a*	3.561 *a*	0.118 *a*	1510 *a*	3.932 *a*	0.112 *a*	1821 *a*
Autum	2.840 *b*	0.076 *b*	1220 *a*	2.921 *b*	0.091 *b*	1271 *a*	3.012 *a*	0.0911 *b*	1142 *a*
Mean	3.330	0.084	1271	3.240	0.093	1217	3.355	0.090	1298

* see Table 1

Table 3

The content of phosphorus and calcium (g·kg^{-1}) in fruit cucumber (mean for two cultivars)

Terms	Substrats							
	rock wool		perlite		wood fiber		mean	
	P	Ca	P	Ca	P	Ca	P	Ca
Spring	0.639 *a**	0.080 *a*	0.628 *a*	0.060 *a*	0.592 *a*	0.067 *a*	0.619	0.069
Summer	0.541*b*	0.053 *b*	0.585 *b*	0.053 *a*	0.523 *a*	0.061 *a*	0.549	0.056
Autum	0.488 *b*	0.053 *b*	0.536 *b*	0.047 *b*	0.459 *b*	0.047 *b*	0.494	0.049
Mean	0.556	0.062	0.583	0.053	0.524	0.058	-	-

* see Table 1

fruits depended, to a high degree, on substrate, fertilization and the state of plant nutrition. The present investigations revealed that the time of cultivation is another very important factor of fruit quality. Higher dry matter content, vitamin C and total sugars were characteristic for fruits obtained in the summer harvest (Table 2). Fruits picked in the spring time showed a higher content of calcium and phosphorus and fruits from the autumn cultivation were richer in nitrogen and potassium (Tables 3 and 4).

Table 4

The content of nitrogen and potassium ($g \cdot kg^{-1}$) in fruit cucumber (mean for two cultivars)

Terms	Substrats							
	rock wool		perlite		wood fiber		mean	
	$N\text{-}NO_3$	K	$N\text{-}NO_3$	K	$N\text{-}NO_3$	K	$N\text{-}NO_3$	K
Spring	0.492 *b**	0.716 *a*	0.391 *b*	0.701 *a*	0.564 *b*	0.706 *a*	0.482	0.707
Summer	0.359 *b*	0.725 *a*	0.472 *b*	0.737 *a*	0.431 *b*	0.754 *a*	0.420	0.738
Autum	0.741 *a*	0.768 *a*	0.548 *a*	0.743 *a*	0.672 *a*	0.743 *a*	0.653	0.751
Mean	0.530	0.736	0.470	0.727	0.555	0.734	-	-

* see Table 1

CONCLUSIONS

1. Low intensity of irradiation during spring time was a significant cause of much lower yielding as compared to summer and autumn cultivations.

2. The substrate used in the experiment was a factor affecting the yielding volume. The highest crops were obtained from plants cultivated on wood fibre and perlite.

3. Cucumber fruits obtained from summer cultivation were characterized by the highest content of dry matter, total sugars, vitamin C, calcium and phosphorus and a higher content of nitrogen and potassium was observed in fruits from autumn cultivation.

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J. Elementol. 2008, 13(2): 211–220

ESTIMATION OF BIOLOGICAL VALUE AND SUITABILITY FOR FREEZING OF SOME SPECIES OF SPICE HERBS

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Abstract

The studies were carried out in the years 2003 and 2004 in the Laboratory of Plant Raw Material Processing and Storage and in the Department of Vegetable Crops of Agricultural University in Szczecin. The aim of the experiment was to estimate the biological value, and suitability for freezing and freeze-storage of tarragon (*Artemisia dracunculus* L.), hyssop (*Hyssopus officinalis* L.) and chervil (*Anthriscus cerefolium* L.) were carried out. The chemical analysis were carried out in a raw, frozen and stored material. The determinations included the content of dry matter, total ash, total nitrogen, nitrates, vitamin C as L-ascorbic acid, titratable acidity, total sugars and crude fibre. Among tested in the experiment species the highest amount of dry matter, total nitrogen and nitrates was noted for hyssop. Chervil was characterized by a high content of total ash, total sugars, titrable acidity and L-ascorbic acid. The highest content of crude fibre was found in tarragon. After freezing the level of dry matter, total ash, total nitrogen, crude fibre, total sugars, titrable acidity and L-ascorbic acid decreased. The samples of herbs were frozen and stored at –25 ÷ –27°C for 6 and 12 months. Twelve-month storage had a significant influence on the further decrease of the content of total nitrogen, titrable acidity and L-ascorbic acid. Tested in the experiment spice herb cultivars showed a good ability for freezing and long-period cold storage. The dry matter loss after twelve month storage was on average 1.5%. According to the color, taste and aroma the highest quality after twelve month cold storage was noted for chervil. However, better preservation of L-ascorbic acid was found for hyssop and tarragon.

Key words: tarragon, hyssop, chervil, biological value, freezing, freeze-storage.

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OCENA WARTOŚCI BIOLOGICZNEJ ORAZ PRZYDATNOŚCI DLA ZAMRAŻALNICTWA WYBRANYCH GATUNKÓW ZIÓŁ PRZYPRAWOWYCH

Abstrakt

W latach 2003–2004 oceniano wartość biologiczną świeżego ziela oraz wpływy zamrażania i zamrażalniczego przechowywania na zawartość wybranych składników chemicznych w zielu bylicy estragon (*Artemisia dracunculus* L.), hyzopu lekarskiego (*Hyssopus officinalis* L.) oraz trybuli ogrodowej (*Anthriscus cerefolium* L.). W materiale doświadczalnym (świeże ziele) oznaczono zawartość: suchej masy, popiołu ogólnego, azotu ogólnego, azotanów, kwasu L-askorbinowego, cukrów ogółem, błonnika surowego oraz kwasowość ogólną. Oprócz surowca świeżego ocenie składu chemicznego poddano również surowiec po zamrożeniu oraz po 6 i 12 miesiącach zamrażalniczego składowania. Spośród ocenianych w doświadczeniu gatunków ziół istotnie większą zawartością suchej masy, azotu ogólnego oraz azotanów wyróżniał się hyzop lekarski. W przypadku trybuli ogrodowej wykazano wysoką zawartość popiołu ogólnego, cukrów ogółem, kwasu L-askorbinowego oraz kwasowość ogólną. Najwyższą zawartość błonnika surowego stwierdzono natomiast w przypadku bylicy estragon. Po zamrożeniu surowca odnotowano straty w zawartości: suchej masy, popiołu, azotu, błonnika, cukrów, kwasowości ogólnej oraz kwasu L-askorbinowego. Zamrożony produkt był przechowywany przez 6 i 12 miesięcy w komorze zamrażalniczej, w temp. –25 ÷ –27°C. Po rocznym okresie zamrażalniczego składowania obserwowano dalszy spadek w przypadku zawartości azotu ogólnego, kwasowości ogólnej oraz kwasu L-askorbinowego. Oceniane gatunki ziół przyprawowych wykazały dobrą przydatność do zamrażania i długotrwałego zamrażalniczego przechowywania. W dobrym stopniu zachowały swój charakterystyczny aromat, barwę, a ubytki suchej masy nie przekroczyły 1,5%. Uwzględniając cechy organoleptyczne, najlepszą jakość po 12 miesiącach zamrażalniczego przechowywania miała trybula ogrodowa, natomiast lepiej zachowywały kwas L-askorbinowy hyzop lekarski oraz bylica estragon.

Słowa kluczowe: estragon, hyzop, trybula, wartość biologiczna, zamrażanie, zamrażalnicze przechowywanie.

INTRODUCTION

Spice herbs are very important components of our food as they improve its taste and give a characteristic aroma. The main chemical compounds of spice herbs are essential oils, alkaloids, tannins, glycosides, phytoncides, saccharides (basic component of dry matter), organic acids, vitamins and minerals (SEIDLER-ŁOŻYKOWSKA, KAŹMIERCZAK 2002).

The essential oil content in hyssop leaves varies from 0.3 to 1%, while in its inflorescences from 0.9 to 2% (WOLSKI et al. 2006). Tarragon herb contains from 0.6 to 1% of essential oil, depending on the time of harvest (OLSZEWSKA-KACZYŃSKA, SUCHORSKA 1996).

The results of many studies proved that fruits and vegetables are the best sources of antioxidants in our diet. These substances protect the organism by neutralization and disposal of cancerogenic free radicals. Lately, the presence of many efficient antioxidants has been detected in numerous herbs. In marjoram, ginger and pepper there are phenolic diterpenes, phenolic acids, flavonoids. Oszmiański and Lamer-Zarawska (1996) suggest that dietary fibre, folic acid and chlorophylline play a protective role in many cancer illnesses.

Increased environmental contamination has raised levels of chemical impurities in soil, drinking water, agricultural yields and also in herbs. Among such impurities are nitrates and nitrites (Wierzchowska-Renke et al. 1994). Many studies have been conducted, both in Poland and abroad, on the influence of the intake of nitrates and nitrites with daily diets on the health of adults, small children and infants. Nevertheless, we still lack enough data on the content of nitrates and nitrites in herbs. The growing interest in herbal medicine or in world cuisine as well as easier transportation have enriched the assortment of herbs available in our country. However, we should remember that except medicated components, herbs may contain nitrates and nitrites, which are easily extracted and passed to water solutions (Wierzchowska-Renke et al. 1994).

We use fresh or dried spice herbs. Fresh herbs are more valuable than dried ones because they contain vitamins and high quantities of oils. The latest method of herb storage is freeze-storage (Grzeszczuk et al. 2005).

The aim of the experiment was to compare the biological value of some spice herb species (tarragon, hyssop, chervil) and to estimate their suitability for freezing and freeze-storage.

MATERIAL AND METHODS

The experiment was conducted in the Laboratory of Processing and Storage of Plant Raw Material of the Agricultural University in Szczecin in 2003-2004.

The research material was produced at the Horticultural Experiment Station in Dołuje, which belongs to the Department of Vegetable Growing of the Agricultural University in Szczecin. The material consisted of three spice herb species: tarragon (*Artemisia dracunculus* L.), hyssop (*Hyssopus officinalis* L.), chervil (*Anthriscus cerefolium* L.).

The chemical analyses of raw, frozen and stored plant material included determination of the content of dry mattter (drying at 105°C to constant weight), total ash (incineration of samples in 500°C), total sugars (by the method of Luff-Schoorl), vitamin C as L-ascorbic acid (by the method of Tillmans), titratable acidity (Krełowska-Kułas 1993), total nitrogen (by the method of Kjeldahl), nitrates (by colorimetric method, Zalewski (1971) and crude fibre (Klepacka 1996).

Before freezing, the plant material was fragmented to small pieces (about 1 cm long) with a steel knife. Then the samples were packed in 0.05 mm thick polythene bags, 500 g of herbs each. Frozen samples were stored in a freezing chamber at -25, -27°C for 6 and 12 months.

The results of each year were subjected to an analysis of variance. The means of two years were separated by the Tukey's test at *p*=0.05.

RESULTS AND DISCUSSION

In the present work significant differences occurred in the chemical composition of the three species. Significantly more dry matter, irrespectively of the processing stage, was noted for chervil (on average 15.07%) and hyssop (on average 14.92%) – Table 1. The content of dry matter in tarragon herb was significantly lower, on average by 1.78% in comparison with chervil and hyssop. The level of dry matter in the raw herbs of the test species was assessed as low. MARTYNIAK-PRZYBYSZEWSKA and WOJCIECHOWSKI (2004) claim that tarragon herb contains 21.9% of dry matter. SÁNCHEZ-CASTILLO et al. (1995) assessed 23.4% of dry matter in mint herb and 27.5%. d.m. in leaves of leafy parsley. JADCZAK (2007) determined 18.85% of dry matter for savory and MARTYNIAK-PRZYBYSZEWSKA and WOJCIECHOWSKI (2004) cited the following shares of dry matter: 12.5 for basil %, 25.6% for oregano, 22.9% for marjoram and 21.0% for thyme.

Among the herb species analysed in the present experiment, tarragon had a significantly lower content of total ash and total nitrogen. The highest amount of total ash was determined for chervil (on average 2.67%), while the highest content of total nitrogen appeared in hyssop (on average 0.95%). Moreover, hyssop was characterized by a significantly higher level of nitrates, on average by 402.59 mg $NaNO_3 \cdot kg^{-1}$ f.m., in comparison with chervil and tarragon, which in turn did not differ significantly in this respect. However, it was noted that the content of nitrates in raw hyssop herb was not high: 1,317.16 mg $NaNO_3 \cdot kg^{-1}$ f.m. (i.e. 961.43 mg $N\text{-}NO_3 \cdot kg^{-1}$ f.m.). According to the Decree of Health Minister of 13 January 2003, the level of nitrates in dill leaves, for example, should not be higher than 1,500, and in frozen spinach must not exceed 2,000 mg $N\text{-}NO_3 \cdot kg^{-1}$ f.m. SEIDLER-ŁOŻYKOWSKA et al. (2007) determined 2,522.80 mg $N\text{-}NO_3$ kg^{-1} f.m in basil herb. WIERZCHOWSKA-RENKE et al. (1995), who analysed dried, packed herbs, found assessed for example: 15,820 mg $KNO_3 \cdot kg^{-1}$ d.m. (i.e. about 1456 mg $N\text{-}NO_3 \cdot kg^{-1}$ f.m.) in mint herb, – 16,919 mg KNO_3 (i.e. 1557 mg $N\text{-}NO_3$) in salvia and and 3,821 mg KNO_3 (i.e. 352 mg $N\text{-}NO_3$) in lemon balm.

Determination of the crude fibre content in the plant material showed the highest crude fibre amount in tarragon, lower – in hyssop and the lowest one – for chervil (Table 2). The content of total sugars was significantly higher for chervil, 0.5% more than in tarragon and 1.15% more than in hyssop. Significantly higher levels of titratable acidity was noted in chervil and tarragon (on average 0.31% citric acid), and lower in hyssop (on average 0.24%).

Table 1

The content of dry matter, total ash, total nitrogen and nitrates in the fresh, frozen and stored frozen plant material (mean in 2003–2004)

Plant species	Stage of processing	Dry matter	Total ash	Total nitrogen	Nitrates ($mg\ NaNO_3 \cdot kg^{-1}$)
		(%)			
Tarragon	A	13.40	1.41	1.16	688.79
	B	13.07	1.34	1.14	1161.75
	C	13.12	1.34	0.57	650.70
	D	13.27	1.36	0.57	617.29
	mean	13.21	1.36	0.86	779.63
Hyssop	A	15.35	1.84	1.29	1317.16
	B	14.91	1.81	1.25	1275.01
	C	14.59	1.80	0.63	943.57
	D	14.82	1.79	0.63	1121.77
	mean	14.92	1.81	0.95	1164.38
Chervil	A	15.13	2.66	1.20	629.56
	B	14.91	2.58	1.17	604.67
	C	15.14	2.56	0.63	844.03
	D	15.11	2.87	0.61	897.48
	mean	15.07	2.67	0.90	743.94
Mean for processing stage	A	14.62	1.97	1.22	878.50
	B	14.30	1.91	1.19	1013.81
	C	14.28	1.90	0.61	812.77
	D	14.40	2.01	0.60	878.85
$LSD_{\alpha=0.05}$ for:					
species		0.28	0.07	0.02	241.60
processing stage		0.15	0.07	0.01	182.15
interaction		0.27	0.12	0.02	315.50

A – raw material
B – directly after freezing
C – frozen material after 6 month storage
D – frozen material after 12 month storage

Chervil was also characterized by a higher content of L-ascorbic acid, on average by 10.98 $mg \cdot 100\ g^{-1}$ f.m. in comparison with hyssop and by 28.10 $mg \cdot 100\ g^{-1}$ compared with tarragon. L-ascorbic acid content in the raw herb of chervil was very high – 104.34 $mg \cdot 100\ g^{-1}$ f.m. The amounts

Table 2

The content of crude fibre, total sugars, titratable acidity and L-ascorbic acid in the fresh, frozen and stored frozen plant material (mean in 2003-2004)

Plant species	Stage of processing	Crude fibre	Total sugers	Titratable acidity (% citric acid)	L-ascorbic acid (mg 100·g^{-1})
		(%)			
Tarragon	A	1.99	0.89	0.30	35.64
	B	1.95	0.98	0.26	6.60
	C	1.98	1.10	0.34	4.08
	D	2.00	0.99	0.29	3.66
	mean	1.98	0.99	0.30	12.49
Hyssop	A	1.63	0.34	0.21	63.60
	B	1.63	0.37	0.24	22.20
	C	1.77	0.37	0.29	17.72
	D	1.83	0.28	0.23	14.94
	mean	1.72	0.34	0.24	29.61
Chervil	A	1.32	1.70	0.40	104.34
	B	1.23	1.13	0.39	32.22
	C	1.31	1.69	0.26	17.34
	D	1.29	1.44	0.25	8.46
	mean	1.29	1.49	0.32	40.59
Mean for processing stage	A	1.65	0.98	0.31	67.86
	B	1.61	0.83	0.30	20.34
	C	1.69	1.05	0.30	13.05
	D	1.71	0.90	0.26	9.02
LSD $_{\alpha=0.05}$ for:					
species		0.14	0.02	0.05	3.98
processing stage		n.s.	0.01	0.03	3.53
interaction		n.s.	0.02	0.06	6.11

A – raw material
B – directly after freezing
C – frozen material after 6 month storage
D – frozen material after 12 month storage

of L-ascorbic acid determined for hyssop (63.60 mg·100 g^{-1} f.m.) and tarragon (35.64 mg·100 g^{-1} f.m.) were also high. MARTYNIAK-PRZYBYSZEWSKA and WOJCIECHOWSKI (2004) cited a lower level of vitamin C for tarragon (9.8 mg·100 g^{-1} f.m.). For the other herb species, for example basil, savory or marjoram, their results varied from 11.9 to 19.9 mg·100 g^{-1} f.m. Capecka et al. (2005) reported a higher content of vitamin C for herbs of *Lamiaceae* family – from 23.1 to 53.2 mg·100 g^{-1} f.m.

Among the test spice herb species, chervil was characterized by a high biological value. In comparison with tarragon and hyssop, it contained more dry matter, total ash, total sugars, titratable acidity and L-ascorbic acid.

Freezing and freeze-storage had a significant influence on the changes of chemical composition of the three herb species. There were statistically significant differences in the content of all the compounds determined in the experiment, except crude fibre. Directly after freezing, most chemical parameters decreased, for example: dry matter – by 0.32% on average, total ash – by 0.06% f.m., total nitrogen – by 0.03% f.m., total sugars – by 0.15% f.m. and L-ascorbic acid – by 47.52 mg·100 g^{-1} f.m. Changes in titratable acidity were not statistically significant, while the content of nitrates significantly increased in comparison with the raw material (on average by 13.35%). A similar direction of the changes in nitrates was noted by Lisiewska and Kmiecik (1997), who proved that freezing and three-month cold storage of leafy parsley leaves resulted in an increased content of nitrates. However, further storage (6 and 9 months) caused a decrease of the level of nitrates.

In the present study, after 6 months of freeze-storage further decrease in dry matter, total ash, total nitrogen and L-ascorbic acid content was observed. Also, the level of nitrates significantly decreased – on average by 204.04 mg $NaNO_3 \cdot kg^{-1}$ f.m., in comparison with the material analysed directly after freezing.

After 12 months of cold storage, the content of total nitrogen, total sugars, titratable acidity and L-ascorbic acid significantly decreased.

Freeze-storage of the test spice herb species had a pronounced effect on the changes in the content of L-ascorbic acid. Its concentration decreased by 81%, after 6 months and by a further 6% after 12 months. Similar data are given by Lisiewska and Kmiecik (1997).

The spice herb species examined in our experiment proved to be suitable for freezing and long-period freeze-storage. They preserved their characteristic aroma and colour very well. The loss of dry matter did not exceed 1.5%. The best colour, aroma, taste after 12 months freeze-storage were noted for chervil. This species was also characterized by good preservation of dry matter, total ash and total nitrogen. However, tarragon and hyssop were better at preserving the content of L-ascorbic acid. Moreover, these two species were characterized by some desirable changes in the content of nitrates. At the beginning of the freezing process, the level of nitrates increased only to gradually decrease later, falling by 10.4% in tarragon and by 14.8% in hyssop herb after 12 months of storage, in comparison with the raw material. In chervil the content of nitrates was constantly increasing, rising by 29.8% after 12 months of freeze-storage.

CONCLUSIONS

1. Among the test spice herb species, the highest biological value of the raw herb was assigned for chervil.

2. Freezing and freeze-storage had a significant effect on changes in the chemical composition of the plant material. In tarragon and hyssop herb, changes in the content of most of the parameters we observed were desirable ones.

3. After 12 months of freeze-storage, chervil's quality improved according to the organoleptic characteristics (colour, aroma, taste).

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EFFECT OF A SOWING DATE ON THE QUANTITY AND QUALITY OF THE YIELD OF TARRAGON (*ARTEMISIA DRACUNCULUS* L.) GROWN FOR A BUNCH HARVEST

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Abstract

The aim of the study was to estimate the influence of a sowing date (10 April, 25 April and 10 May) on the quantity and quality of the yield of tarragon grown for a bunch harvest. The yields of tarragon plants were assayed in 2004-2006. Chemical analyses were made in the years 2004 and 2005. In the dry plant material, the content of macro- and microelements: total nitrogen, phosphorus, potassium, calcium, sodium, magnesium, manganese, zinc, iron and copper was assessed. Moreover, the content of essential oils in dry plant material was estimated. In the raw plant material, the content of L-ascorbic acid and the scavenging effect on DPPH radical were measured. It was proved that the sowing dates had a significant effect on the yield quantity. Significantly higher yield (424.5 $kg \cdot 100\ m^{-2}$) was obtained when seeds were sown on 10 May. The yield significantly decreased when seeds were sown on 10 April. The test sowing dates had no significant effect on the biometrical characteristics of tarragon plants during the harvest; only the leaves were significantly wider when the earliest sowing date was used. The yields were characterized by a high content of mineral compounds. However, the content of iron was twice as high in 2004 as in 2005. Also, the content of zinc and copper was higher in the first year of the study, respectively by 87.2% and 76.9%, compared with the yield obtained in the year 2005. The content of essential oils (mean for years of the study) was 0.59%, that of L-ascorbic acid was 10.08 $mg \cdot 100\ g^{-1}$ f.m. and the scavenging effect of tarragon herb on DPPH-radical was 26.74%.

Key words: tarragon, yield, macro- and microelements content, essential oil, L-ascorbic acid, DPPH percent inhibition.

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WPŁYW TERMINU SIEWU NASION NA WIELKOŚĆ I JAKOŚĆ PLONU BYLICY ESTRAGONU (*ARTEMISIA DRACUNCULUS* L.) UPRAWIANEJ NA ZBIÓR PĘCZKOWY

Abstrakt

W latach 2004–2006 badano wpływ terminu siewu nasion (10 i 25 kwietnia oraz 10 maja) na wielkość i jakość plonu bylicy estragonu, uprawianej na zbiór pęczkowy. W części laboratoryjnej badań (2004 i 2005), w próbie zbiorczej – ze wszystkich zbiorów i terminów uprawy – oceniono zawartość makro- i mikroskładników: azotu ogólnego, fosforu, potasu, wapnia, magnezu i sodu oraz cynku, manganu, żelaza i miedzi. Zawartość olejku eterycznego oznaczono w powietrznie suchym zielu metodą destylacji próbki surowca z wodą. W świeżej masie ziela wykonano oznaczenie zawartości kwasu L-askorbinowego oraz aktywność zmiatania rodników DPPH.

Wykazano, iż badane terminy siewu wpłynęły istotnie na wielkość plonu ziela estragonu. Istotnie największy plon (424,5 kg·100 m^{-2}) otrzymano z wysiewu w najpóźniejszym terminie (10 maja). Plon ten istotnie zmniejszał się wraz z przyspieszaniem terminu siewu, tj. do ok. 10 kwietnia. Terminy siewu nie miały istotnego wpływu na parametry biometryczne roślin w czasie ich zbioru, jedynie szerokość liści była istotnie większa w przypadku najwcześniejszego terminu uprawy.

W uzyskanym plonie estragonu stwierdzono wysoką zawartość składników mineralnych, zbliżoną w poszczególnych latach badań. Największe różnice wystąpiły w zawartości żelaza, którego w roślinach w 2004 r. było ponad dwukrotnie więcej niż w kolejnym roku badań. Również w tym roku odnotowano w estragonie znacznie wyższą zawartość cynku (o 87,2%) i miedzi (o 76,9%) w porównaniu z zebranym w 2005 roku.

Zawartość olejku eterycznego (średnio w latach badań) wyniosła 0,59%, kwasu L-askorbinowego 10,08 mg·100 g^{-1} ś.m.), a zdolność redukcji rodników DPPH kształtowała się na poziomie 26,74%.

Słowa kluczowe: bylica estragon, plon, makro- i mikroskładniki, olejek eteryczny, kwas L-askorbinowy, procent inhibicji DPPH.

INTRODUCTION

Tarragon (*Artemisia dracunculus* L.) is a perennial herb with slender, branched stems. It grows up to 150 cm and has narrow, dark green leaves (SZCZYGLEWSKA 2002). Tarragon is native to a wide area of steppes and wharves along the rivers of Ukraine, Caucasus and moderate climatic zones of Asia and North America. In Poland, tarragon grows only in the culture. The aroma of tarragon is produced by essential oils in the herb's leaves. The content of these essential oils is about 0.8%. Apart from essential oils, tarragon herb contains tannins, bitter principles, vitamins and minerals.

Fresh tarragon leaves have a very strong flavour and aroma. They preserve well the taste and aroma whether they are frozen or used to flavour oil and vinegar (JADCZAK, GRZESZCZUK 2005).

The aim of our experiment was to estimate the effect of a date of sowing seeds on the quantity and quality of tarragon yield.

MATERIAL AND METHODS

The experiment was carried out in 2004-2006 at the Department of Vegetable Crops of the Agricultural University in Szczecin. The aim of this study was to estimate the effect of a sowing date on the quantity and quality of the yield of tarragon grown for a bunch harvest.

Three dates of sowing were examined: 10 April, 25 April and 10 May. Sowing ration was 10 $kg \cdot ha^{-1}$. The experiment was established in randomized blocks with four replications. The field was prepared according to agronomic recommendations for this species. Mineral fertilization was quantified according to the results of chemical analysis of the soil. During the growing season, the crop management treatments were carried out. These included mainly irrigation, weeding and soil cultivation.

The tarragon plants were harvested when they reached the height of about 40 cm and their shots were not lignified. The yield was harvested four times. The plant shots were cut 5-10 cm above the soil surface. After the harvest, the quantity of the yield was assessed. Moreover, measurements of the following morphological features were taken: shots length, bunch mass, leaf mass in the bunch (10 shots), length and width of leaf blade, and the participation of leaf mass in the herb mass. Also, the content of dry matter was determined in the yield of each harvest.

In the years 2004 and 2005 the laboratory part of the experiment was conducted. It was based on a representative sample consisting of the samples of all sowing dates. Total nitrogen was determined according to Kjeldahl's method, phosphorus by colorimetric method, potassium, calcium and sodium by flame photometry and copper, zinc, manganese, iron and magnesium using the method of atomic absorption spectrophotometry (AAS) (Krełowska-Kułas 1993). The essential oils content was determined in aerially dried herb with the use of distillation of the sample mixed with water in Deryng's apparatus. In the raw herb, L-ascorbic acid was assessed by the method of Tillmans. The scavenging effect of fresh tarragon herb on DPPH-radical was determined according to the method of Yen i Chen (1995). The results were statistically evaluated by the analysis of variance. Significance of the differences was tested by Tukey's test at p=0.05.

RESULTS AND DISCUSSION

Results of tarragon yielding (total yield) are presented in Table 1. Statistical analysis showed a significant effect of the sowing dates on the quantity of the yield. In the years 2004 and 2005 the highest yield (311.9 and 572.5 kg 100 m^{-2} respectively) was obtained from the last sowing date, while the smallest one (150.0 and 305.0 $kg \cdot 100\ m^{-2}$ respectively) appeared

Table 1

The yield quantity of tarragon grown for a bunch harvest

Sowing date	Yield (kg 100 m^{-2})			
	2004	2005	2006	2004–2006
10 IV	150.0	305.0	476.6	310.5
25 IV	288.5	367.2	375.9	343.9
10 V	311.9	572.5	389.0	424.5
Mean	250.1	414.9	413.8	359.6
LSD α=0.05	19.41	30.9	67.5	19.12

when tarragon seeds were sown on 10 April. In the last year of the study, the yield obtained as a result of sowing on 10 April was significantly higher (476.6 kg·100 m^{-2}) than the yields obtained from the next two dates of sowing.

The mean results obtained from all of the years of the study proved that, similarly to the first two years of the experiment, significantly lower yield occurred for the sowing date of 10 April (310.5 kg·100 m^{-2}) and that it was increasing when the sowing date was postponed. When tarragon seeds were sown on 25 April, the yield was 343.9 kg·100 m^{-2} and when they were sown on 10 May it rose to 424.5 kg·100 m^{-2}. JADCZAK (2007) also proved a significant effect of a sowing date on the yield of savory grown for a bunch harvest. In this case, the highest yield was obtained when seeds were sown on 25 April. Whereas in the study concerning basil grown for a bunch harvest, it was found that the date of sowing had no significant effect on the quantity of the marketable yield of the herb (JADCZAK 2007).

Independently of the dates of sowing, the mean yield obtained in the first year of the study was 39.7% lower than the yield obtained in 2005 and 39.6% lower than the yield in 2006.

The sowing dates used in the experiment had no significant influence on the biometrical characteristics of tarragon plants (Table 2). Only the leaf blade was significantly wider (1.15 cm) when the date of sowing was the earliest, but the difference was significant only versus 10 May. In Poland, herbs are usually available as a dried product. In general, the value of dried herbs is much lower than fresh one (JADCZAK, GRZESZCZUK 2005). It is so because essential oils occur on the leaf surface. Another reason is that there are changes in the content of vitamins, mineral compounds, enzymes, colors and other biologically active compounds when herbs are dried. One of the main factors which determine the quality of raw material is the percentage leaf mass in the total herb mass (JADCZAK, GRZESZCZUK 2006). SUCHORSKA-ORŁOWSKA et al. (2006) found significantly higher amounts of microelements in spice herbs than in their shots. In this study, the contribution of leaf mass in the herb mass was on average 68.6%.

Table 2

Biometrical characteristics of harvested tarragon plants grown for a bunch harvest (mean for the years 2004-2006)

Sowing date	Shots lenght (cm)	Leaf length (cm)	Leaf width (cm)	Bunch mass (10 shots) (g)	Leaf mass (10 shots) (g)	Participation of leaf mass in the herb mass (%)
10 IV	43.0	8.93	1.15	130.7	89.6	68.5
25 IV	45.9	7.93	0.93	122.6	84.0	68.5
10 V	45.1	7.30	0.70	123.8	85.3	68.9
Mean	44.7	8.05	0.93	125.7	86.3	68.6
LSD α=0.05	n.s.	n.s.	0.38	n.s.	n.s.	–

n.s. – non-significant differences

Macro- and microelements level in the yield of tarragon were similar in all the years of the research (Table 3). The highest differences were found in the iron content: in 2004 it was two-fold higher than in the next year of the research. Moreover, in the same year the content of zinc was 87.2% higher and that of copper 76.9% higher than in 2005. The amounts of microelements determined in the experiment were close to the data given by SUCHORSKA-ORŁOWSKA et al. (2006).

Table 3

Content of dry matter, macro- and microelements in the yield of tarragon

Years of the study	Dry matter (%)	Content of macroelements ($g \cdot kg^{-1}$ d.m.)						Content of microelements ($mg \cdot kg^{-1}$ d.m.)			
		N	P	K	Mg	Ca	Na	Mn	Zn	Fe	Cu
2004	14.90	23.0	4.4	37.0	1.4	9.0	0.3	22.0	74.5	212.8	18.4
2005	15.96	36.0	4.3	48.1	1.5	14.3	0.5	21.6	39.8	99.2	10.4
Mean	15.43	29.5	4.35	42.55	1.45	11.65	0.4	21.8	57.15	156.0	14.4

In the tarragon yield, the content of essential oils was on average 0.59% and the content of L-ascorbic acid reached 10.08 $mg \cdot 100 g^{-1}$ f.m. The scavenging effect of tarragon on DPPH-radical was 26.74% as an average of the three years (Table 4).

Table 4

The content of essential oils, L-ascorbic acid and scavenging effect on the DPPH radical in the yield of tarragon

Years of the study	Content of		Scavenging effect on DPPH radical (% DPPH)*
	essential oils (%)	L-ascorbic acid ($mg \cdot 100\ g^{-1}$ f.m.)	
2004	0.56	9.60	17.30
2005	0.62	10.56	36.19
Mean	0.59	10.08	26.74

* 400 times dilution in 70% methanol

CONCLUSIONS

1. The sowing dates had a significant effect on the yield quantity of tarragon. Significantly higher yield was obtained when seeds were sown on 10 May. The yield of tarragon significantly decreased along with accelerating of the sowing date up to 10 April.

2. There was no significant effect of a sowing date on the biometrical characteristics of tarragon plants. Only the leaves were significantly wider following the earliest sowing date.

3. Tarragon herb is characterized by a high content of mineral compounds. Their level was similar in all the years of the study, except iron, zinc and copper. The amounts of these compounds were higher in the first year of the analyses.

4. The content of essential oils in tarragon herb was on average 0.59%, that of L-ascorbic acid was 10.08 mg 100 g^{-1} f.m. and the average scavenging effect on DPPH-radical was 26.74%.

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J. Elementol. 2008, 13(2): 227–234

THE EFFECT OF NITROGEN FERTILIZATION ON CONTENT OF MICROELEMENTS IN SELECTED ONIONS

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Abstract

The effect of nitrogen fertilization on microelements (iron, manganese, copper and zinc) content in the yield of onion (*Allium cepa* L. var. *cepa* Helm.), top onion (*Allium cepa* var. *proliferum* Targioni-Tozzetti) and shallot onion (*Allium cepa* L. var. *ascalonicum*) was examined in a three-year field experiment conducted at the Vegetable Experimental Station in Dołuje. Urea, ammonium nitrate and calcium nitrate were applied in two different nitrogen doses: 100 kg $N \cdot ha^{-1}$ and 200 kg $N \cdot ha^{-1}$. The bulbs were planted in field at the beginning of April. The planting density was 30 x 5 cm (onion) and 30 x 10 cm (top onion and shallot onion). During the growing season, the soil tillage and plant cultivation treatments were conducted according to standard methods. Onion and shallot onion were harvested during the last days of July or the first days of August, after 75% of the plants had bent leaves. Top onion was harvested at the end of September. The content of microelements in dry matter of the analyzed plants was determined by atomic absorption spectrometry, after wet mineralization of the samples in a mixture of concentrated nitric and perchloric acids mixed in a 3:1 ratio.

The applied nitrogen fertilization significantly affected microelements in all the tested onions. The content of iron and manganese in onion bulbs increased with the increasing nitrogen doses, while that of copper and zinc decreased. The analysis of the results led to a conclusion that a significant effect on the chemical composition of yield produced by onion, top onion and shallot onion was produced by the applied nitrogen dose but not its form. The content of microelements and extent of the changes caused by the nitrogen fertilization depended on the tested type of onion.

Key words: nitrogen fertilization, microelements content, onion, top onion, shallot.

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WPŁYW NAWOŻENIA AZOTEM NA ZAWARTOŚĆ MIKROELEMENTÓW W WYBRANYCH ODMIANACH BOTANICZNYCH CEBULI

Abstrakt

W trzyletnim doświadczeniu polowym przeprowadzonym w Warzywniczej Stacji Doświadczalnej w Dołujach badano wpływ nawożenia azotem na zawartość mikroelementów (żelaza, manganu, miedzi i cynku) w plonie cebuli zwyczajnej (*Allium cepa* L. var. *cepa* Helm.), cebuli piętrowej (*Allium cepa* var. *proliferum* Targioni-Tozzetti) i szalotki (*Allium cepa* L. var. *Ascalonicum*). Zastosowano następujące nawozy: mocznik, saletrę amonową i saletrę wapniową w zróżnicowanych dawkach nawożenia azotem – 100 i 200 kg $N \cdot ha^{-1}$. Cebulki wysadzano do gleby na początku kwietnia w rozstawie 30 x 5 cm (cebula zwyczajna) i 30 x 10 cm (cebula piętrowa i szalotka). W okresie wegetacji roślin wykonywano standardowe zabiegi pielęgnacyjne i agrotechniczne. Cebulę zwyczajną i szalotkę zbierano w ostatnich dniach lipca lub pierwszych dniach sierpnia, kiedy ok. 75% roślin miało załamany szczypior. Cebulę piętrową zbierano w końcu września. Zawartość mikroelementów w suchej masie badanych roślin oznaczano metodą absorpcyjnej spektrometrii atomowej, po wcześniejszym zmineralizowaniu próbek w mieszaninie stężonych kwasów azotowego(V) i chlorowego(VII) zmieszanych w stosunku 3:1.

Nawożenie azotem spowodowało istotne zmiany zawartości mikroelementów w plonie wszystkich badanych odmian. Pod wpływem wzrastających dawek azotu nastąpiło zwiększenie zawartości żelaza i manganu oraz zmniejszenie koncentracji miedzi i cynku.

Analiza statystyczna wyników wykazała, że czynnikiem istotnie odpowiedzialnym za zmiany w składzie chemicznym cebuli zwyczajnej, cebuli piętrowej i szalotki była zastosowana w nawożeniu dawka azotu, a nie rodzaj użytego nawozu. Zawartość oznaczanych mikroelementów oraz zakres zmian spowodowanych nawożeniem zależały od badanej odmiany botanicznej cebuli.

Słowa kluczowe: nawożenie azotem, mikroelementy, cebula zwyczajna, cebula piętrowa, szalotka.

INTRODUCTION

Owing to their nutritional, medicinal and taste values, bulbous vegetables are among the most popular vegetables in Poland. Although mainly used as seasoning vegetables, bulbs make an important contribution to man's diet, having many vitamins, flavonoids, macro- and microelements. There is a direct relationship between microelement nourishment of plants and health of plant consumers (RUSZKOWSKA, WOJCIESKA-WYSKUPAJTYS 1996).

Microelements, being components or activators of numerous enzymes, play a catalytic role in many life processes and are necessary for correct growth of humans, animals and plants. Such elements as iron, manganese, zinc or copper participate in photosynthesis, decarboxylation, processes of nitrogen fixation, metabolism of carbohydrates and proteins.

Among all the factors which intensify plant production, nitrogen fertilization is the most effective method. However, during intensive fertilization amounts of macro- and microelements taken up by plants may differ significantly. Changes in the composition of microelements in a plant can accelerate or inhibit certain physiological processes. As a consequence, the plant's is disturbed, leading to depressed yield or its reduced nutritional value.

The aim of the present study was to determine the effect of several forms and doses of nitrogen fertilizers applied in field cropping of onion (*Allium cepa* L. var. *cepa* Helm.), top onion (*Allium cepa* var. *proliferum* Targioni-Tozzetti) and shallot onion (*Allium cepa* L. var. *Ascalonicum*) on the content of some microelements like iron, manganese, copper and zinc absorbed by the plants.

MATERIAL AND METHODS

An experiment on three types of onion: onion, top onion and shallot onion, was carried out at the Vegetable Experimental Station in Dołuje in 2000-2003. The onions were cultivated on post-marshy soil (classified as typical black earth, of soil quality class IIIb) of pH_{KCl} 6.6-7.2. The experiment was set up in a randomized block design in four replications on 2.7 m^2 (1.8 x 1.5 m) plots, and included the following factors:

1^{st} factor – forms of nitrogen fertilizer (urea, ammonium nitrate and calcium nitrate);

2^{nd} factor – nitrogen dose (100 and 200 kg $N \cdot ha^{-1}$).

Each year before planting onion bulbs, the soil in all the experimental plots was fertilized with an identical dose of phosphorus (80 kg $P \cdot ha^{-1}$) and potassium (200 kg $K \cdot ha^{-1}$). Then, single applications of nitrogen, in different forms and rates, were applied. Onion bulbs were planted in early April at 30 x 5 cm (onion) and 30 x 10 cm (top onion and shallot) spacing. During the vegetative growth, the soil tillage and plant cultivation were conducted according to the specific recommendations for each variety. The plants were harvested when *ca* 75% of the plants' leaves began to wilt. The harvest date thus determined took place in late July or early August, depending on the weather conditions. Top onion was picked up in the last days of September.

From the marketable yield, about 2 kg of fresh onion bulbs was sampled randomly. After removing the shells, the bulbs were cut, dried at 60°C and ground to obtain uniform, representative material for chemical determinations. Total content of microelements in dry matter was determined by atomic absorption spectrometry following wet mineralization of the samples in a 3:1 mixture of concentrated nitric and perchloric acids.

The results were analysed statistically by means of two-factor variance analysis in a system of randomized blocks with one test field. Significance of differences between means was estimated by Tukey's test at significance level α=0.05.

RESULTS AND DISCUSSION

Nitrogen fertilization affected significantly the content of microelements in yields of bulb onion, top onion and shallot. Increased rates of nitrogen resulted in higher amounts of iron and manganese but depressed quantities of copper and zinc (Table 1). Increased content of iron and manganese in nitrogen-fertilized onion has been observed by COOLONG et al. (2004). According to these authors, nitrogen fertilization also induced higher zinc content in onion while leaving the copper content unaffected. However, other studies on nitrogen fertilization of other crops (CZUBA 1986, SAWICKA 1996) prove that high dosage of nitrogen decreases the concentration of copper and zinc in the plants they examined.

The authors' own studies demonstrate that the three types of onion responded differently to the applied nitrogen fertilization. An average content of iron in onion, top onion and shallot was similar (41.86, 39.24 and 43.70 $mg \cdot kg^{-1}$ d.m., respectively). The fertilization treatments increased similarly the content of iron in onion and shallot. Bulbs of these onion species collected from the fertilized fields contained on average more iron than bulbs from the test field (by 11.6 and 10.9%, respectively). Regarding top onion, nitrogen fertilization increased the iron concentration by 14.5% on average.

The highest content of manganese was found in shallot (on average 10.36 $mg \cdot kg^{-1}$ d.m.), and the lowest one - in top onion (on average 7.50 $mg \cdot kg^{-1}$ d.m). Nitrogen fertilization raised the manganese content on average by 16.6% in onion, by 19.8% in top onion and 20.4% in shallot (as compared to the test field).

Statistical analysis of the results proved that the content of iron and manganese in dry matter of onion, top onion and shallot significantly increased following the application of higher nitrogen doses, being independent from the form of the applied fertilizer. The nitrogen dose of 200 kg $N \cdot ha^{-1}$ helped to increase the iron content (compared to the test field) by 13.8% in onion, by 20.3% in top onion and by 15.6% in shallot. The same nitrogen dose raised the manganese level by 24% in onion and by 27% in top onion and shallot.

Likewise, copper and zinc in onion, top onion and shallot were affected by the nitrogen dose and not its form. The content of copper and zinc in dry matter of the tested plants diminished significantly due to the increased nitrogen doses, whereas the form of nitrogen fertilizer had no particular effect.

The average amounts of copper in onion, top onion and shallot were similar: 6.02, 6.45 and 5.14 $mg \cdot kg^{-1}$ d.m., respectively. The biggest modification in the content of this element caused by the nitrogen fertilization occurred in top onion, and the smallest one – in shallot. The higher fertilization rate of 200 kg $N \cdot ha^{-1}$ decreased (compared to the test field) the copper content in top onion by 29.1% and in shallot by 16.6%.

Table 1

Effect of nitrogen fertilization on the content of microelements ($mg \cdot kg^{-1}$ d.m.) in selected onion cultivars (mean for three years)

Fertilizer object	Nitrogen dose*	Onion				Top onion				Shallot onion			
		Fe	Mn	Cu	Zn	Fe	Mn	Cu	Zn	Fe	Mn	Cu	Zn
Control	0	38.08	8.74	6.74	30.24	34.92	6.42	7.72	60.00	39.95	8.82	5.71	41.19
Urea	100	41.56	9.79	6.13	27.58	37.86	7.20	6.85	52.19	43.11	9.98	5.26	35.73
	200	44.14	11.06	5.57	23.25	43.10	8.22	5.38	45.64	46.76	11.14	4.81	31.73
Amonium nitrate	100	39.70	9.61	6.26	27.26	38.22	7.29	7.35	51.91	42.09	9.98	5.41	36.09
	200	44.38	11.17	5.59	23.55	41.53	8.36	5.35	46.42	45.96	11.67	4.65	32.32
Calcium nitrate	100	40.68	9.28	6.27	26.89	37.74	7.13	6.83	51.49	42.21	10.10	5.31	35.52
	200	44.46	10.21	5.58	23.68	41.37	7.91	5.69	45.15	45.85	10.86	4.81	32.91
		41.86	9.98	6.02	26.06	39.24	7.50	6.45	50.40	43.70	10.36	5.14	35.07
$\overline{x}$ for fertilizer objects		42.49	10.19	5.90	25.37	39.97	7.69	6.24	48.80	44.33	10.62	5.04	34.05
Mean for fertilizer forms													
Control		38.08	8.74	6.74	30.24	34.92	6.42	7.72	60.00	39.95	8.82	5.71	41.19
Urea		42.85	10.43	5.85	25.42	40.48	7.71	6.12	48.92	44.93	10.56	5.04	33.73
Amonium nitrate		42.04	10.39	5.93	25.41	39.88	7.83	6.35	49.17	44.03	10.83	5.03	34.21
Calcium nitrate		42.57	9.75	5.93	25.29	39.56	7.52	6.26	48.32	44.03	10.48	5.06	34.22
$LSD_{0.05}$		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Mean for nitrogen dose													
0 ($kg N \cdot ha^{-1}$)		38.08	8.74	6.74	30.24	34.92	6.42	7.72	60.00	39.95	8.82	5.71	41.19
100 ($kg N \cdot ha^{-1}$)		40.65	9.56	6.22	27.24	37.94	7.21	7.01	51.86	42.47	10.02	5.33	35.78
200 ($kg N \cdot ha^{-1}$)		43.33	10.81	5.58	23.49	42.00	8.16	5.47	45.74	46.19	11.22	4.76	32.32
$LSD_{0.05}$		1.06	0.63	0.17	1.02	0.84	0.32	0.60	2.07	1.22	0.39	0.23	1.03

*($kg N \cdot ha^{-1}$); $\overline{x}$ – mean; n.s. – not significant

The three types of onion plants were highly diverse in zinc concentration. The highest content of this element was found in top onion (on average 50.40 $mg \cdot kg^{-1}$ d.m.), followed by shallot (on average 35.07 $mg \cdot kg^{-1}$ d.m.), and onion (on average 26.06 $mg \cdot kg^{-1}$ d.m.). In the analysed onions, nitrogen fertilization caused similar reduction (compared to the test field) in the zinc content (by, on average, 16.1% in onion, 17.3% in shallot and 18.75 in top onion). The zinc content in dry matter of bulbs from the fields fertilized with 200 kg $N \cdot ha^{-1}$ was 21–23% lower (depending on the type of onion) compared to the zinc content found in dry mass of bulbs from the test field.

The three types of onion plants responded differently to nitrogen fertilization, which confirms earlier observations by LANCASTER et al. (2001), ABBEY et al. (2002), ARIYAMA et al. (2006). The largest variations in the content of microelements caused by the applied fertilization occurred in top onion; however, the levels of microelements were either similar or lower than those observed in the two other types of onion.

It should be noted that the changes in the accumulation of microelements due to the nitrogen fertilization in onion, top onion and shallot did not deteriorate their biological value, since the determined concentrations of the microelements were within the threshold limits set for foodstuffs (Regulation of the Minister for Health of 13 January 2003, published in the Journal of Law no 37, of 4 March 2003).

CONCLUSIONS

1. Increasing nitrogen fertilization raised the content of iron and manganese and decreased the amount of copper and zinc in bulbs of all studied onions.

2. Content of microelements in onion, top onion and shallot significantly depended on the applied nitrogen dosage but was independent from the fertilizer form whereas (urea, ammonium nitrate and calcium nitrate).

3. The types of onion plants differed in the modifications of the content of microelements content caused by nitrogen fertilization.

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J. Elementol. 2008, 13(2): 235–244

EFFECT OF DRIP IRRIGATION AND CULTIVATION METHODS ON THE YIELD AND QUALITY OF PARSLEY ROOTS

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Abstract

In the years 2005–2007, research work on the influence of surface and subsurface drip irrigation on the yield and quality of roots of parsley grown on ridges and on flat ground was carried out. Irrigation water was supplied via drip lines, which in subsurface irrigation were placed at a depth of 50 mm below the surface of the ridges, along the centreline between two rows of plants. In the case of surface irrigation, the drip lines were placed on the surface of the ridges between two rows of plants. Irrigation started when soil water potential was between -30 and -40 kPa. Nitrogen fertilizers (100 $kg \cdot ha^{-1}$) were applied in two doses. The first dose was applied pre-plant, while the second one was delivered by fertigation. In the control treatment without irrigation, the second dose of nitrogen was applied by broadcasting. Both surface and subsurface irrigation used in the cultivation on ridges and on flat ground had a significant effect on the marketable yield of parsley roots. However, no significant differences in the yield between surface and subsurface drip irrigation were found. The yield of non-marketable parsley roots in flat cultivation was twice as high as that in ridge cultivation. Parsley plants cultivated on ridges produced significantly longer, better-shaped storage roots compared to those cultivated on flat ground. Surface and subsurface drip irrigation significantly decreased the total N and K content in parsley roots.

Key words: root parsley, cultivation method, drip irrigation, fertigation.

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WPŁYW NAWADNIANIA KROPLOWEGO I METODY UPRAWY NA PLON I JAKOŚĆ KORZENI PIETRUSZKI

Abstrakt

W latach 2005–2007 badano wpływ nawadniania kroplowego powierzchniowego i podpowierzchniowego na plonowanie korzeni pietruszki uprawianej na płaskim gruncie i na redlinach. Nawadnianie prowadzono z użyciem przewodów nawadniających, z wewnętrznie wtopionymi co 35 cm emiterami z kompensacją ciśnienia, które przy nawadnianiu podpowierzchniowym umieszczono na głębokości 50 mm, pośrodku dwóch rzędów roślin. Nawadnianie rozpoczynano, gdy potencjał wodny gleby wynosił od -30 kPa do -40 kPa. Nawozy azotowe (100 kg $N \cdot ha^{-1}$) wprowadzano w dwóch dawkach: pierwszą zastosowano przedwegetacyjnie, drugą podano przez fertygację. W kontroli drugą dawkę wniesiono w nawożeniu posypowym. Nawadnianie kroplowe powierzchniowe i podpowierzchniowe zastosowane zarówno na redlinach, jak i na płaskim gruncie powodowało istotny wzrost plonu handlowego korzeni pietruszki. Natomiast nie stwierdzono różnic w plonie pietruszki po zastosowaniu powierzchniowego i podpowierzchniowego sposobu nawadniania kroplowego. W uprawie pietruszki na redlinach udział korzeni niekształtnych w plonie był o 100% mniejszy w porównaniu z uprawą na płaskim gruncie. Pietruszka uprawiana na redlinach wytwarzała dłuższe korzenie spichrzowe, o lepszym kształcie w porównaniu z uprawą na płaskim gruncie. Nawadnianie powierzchniowe i wgłębne powodowało istotny spadek zawartości azotu ogólnego i potasu w korzeniach pietruszki.

Słowa kluczowe: pietruszka korzeniowa, metody uprawy, nawadnianie kroplowe, fertygacja.

INTRODUCTION

Root parsley (*Petroselinum hortense* ssp. *microcarpum* Hoffm.) is one of the basic spice vegetables in Poland. The total area under its cultivation is around 7 000 ha, which is around 3% of the total land area under vegetable crops. Yields of root parsley are relatively low and on average amount to 15 $t \cdot ha^{-1}$. The reasons for the low yields include poor germination rate caused by unfavourable weather patterns, particularly the distribution of precipitation (infrequent rainfall during germination and field emergence) and lack of irrigation. Root parsley, like other small-seed root vegetables cultivated by direct sowing, requires the soil to have the optimal moisture content during germination and emergence. Lack or excess of precipitation at that time causes the top layer of the soil to dry up or become waterlogged, the soil surface becomes encrusted and more compact, which reduces the rate of germination or even, in extreme cases, halts it altogether (BŁAŻEWICZ-WOŹNIAK 1997). Dry weather or excess water at the time when the storage root is forming and growing (July, August) are also responsible for poor yields. The shape and size of parsley roots change considerably in response to the way parsley plants are cultivated (RUMPEL, KANISZEWSKI 1994). Cultivation on ridges or ploughing prior to sowing have a favourable effect on the yield and shape of parsley roots (Błażewicz-Woźniak 1998, 2003). When the moisture content in the soil is not right while the main root mass is growing, the number of forked and deformed roots increases. According to Kaniszewski (2006), it is necessary to start irrigating parsley plants when soil moisture falls to 60 – 65% FWC.

The aim of the experiment was to compare the effects of surface and subsurface drip irrigation on the yield of root parsley plants grown on ridges and on flat ground.

MATERIALS AND METHODS

The work was carried out in the years 2005-2007, in an experimental field of the Institute of Vegetable Crops in Skierniewice, on a podsolic soil containing 15-17% of leachable components in the Ap layer (0-25 cm) and 1.15% of organic matter, with a pH of 6.8 in H_2O. The experiment was set up in a two-factorial design (cultivation method, irrigation system) in 4 replications. The size of each experimental plot was 10.8 m^2 (2.7 x 4 m).

Experimental treatments:

1) cultivation on ridges – subsurface drip irrigation,
2) cultivation on ridges – surface drip irrigation,
3) cultivation on ridges – no irrigation,
4) cultivation on flat ground – subsurface drip irrigation,
5) cultivation on flat ground – surface drip irrigation,
6) cultivation on flat ground – no irrigation,

Irrigation was set up with drip lines, which in subsurface irrigation were placed 50 mm below the surface of the ridge, along the centreline between two rows of plants. In surface irrigation, the drip lines were placed on the surface of the ridge between two rows of plants. The distance between the centrelines of the ridges was 67.5 cm. Seeds were sown on the ridges at a rate of 50 per 1 running meter, in 2 rows 10 cm apart. The same procedure was applied on flat ground. The irrigation system was equipped with a Dosatron proportional fertilizer feeder. Irrigation times were determined by means of a Watermark moisture meter made by Irrometer. Irrigation began when soil water potential was between -30 and -40 kPa. Potassium fertilizers (200 $kg \cdot ha^{-1}$ K_2O) were applied pre-plant on a one-off basis. Nitrogen fertilizers (100 $kg\ N \cdot ha^{-1}$) were delivered in two doses. The first dose of 50 $kg \cdot ha^{-1}$ was applied preplant, while the other half was applied in the form of a solution via the fertigation system. In the control combinations, without irrigation, the second dose of nitrogen was delivered by broadcasting. Fertigation with nitrogen finished at the end of August. Broadcasting of the second dose of nitrogen was carried out in the second half of July. In the successive years of the experiment seeds of cv. Berliner parsley were sown on 16, 9 and 22 May, with harvest taking place on 18, 12 and 17 October, respectively. The basic information on soil moisture and watering rates is presented in Tables 1 and 2. Samples of roots for analyses were taken at harvest time. Concentrations of mineral elements (P, K, Mg, Ca) in parsley roots were determined by emission spectrometry using an ICP plasma spectrometer. Total nitrogen was determined by Kjeldhal's method. The results were evaluated statistically with an analysis of variance. Mean values were compared with Newman-Keuls test at P=0.05.

Table 1

Monthly sum of rainfall in the vegetation period of parsley in Skierniewice

Years	Rainfall (mm)							
	Apr	May	June	July	Aug	Sept	Oct	Apr-Oct
Long-period averages	40	48	60	92	79	43	35	397
2005	22.3	71.9	35.4	96.0	38.3	16.5	3.4	283.8
2006	45.9	44.0	35.5	16.7	141.4	22.9	18.8	325.2
2007	28.2	65.1	81.2	63.8	52.5	46.7	18.0	355.5
Mean of 3 years	32.1	60.3	50.7	58.8	77.4	28.7	13.4	320.5

Table 2

Seasonal irrigation rates applied for parsley (mm)

Specification	Years		
	2005	2006	2007
Surface trickle irrigation	242	118	125
Subsurface trickle irrigation	218	106	112

RESULTS AND DISCUSSION

The experimental results seem to indicate that the use of surface and subsurface drip irrigation in the cultivation of root parsley on ridges and on flat ground has a beneficial effect on the yield of parsley plants (Table 3). The average marketable yield of parsley storage roots in the cultivation on ridges was 15.47 $t \cdot ha^{-1}$ for the three years of the experiment, and was significantly higher in comparison with the cultivation on flat ground, for which the average marketable yield was 11.96 $t \cdot ha^{-1}$. However, the difference in the total yield of parsley roots between the two cultivation methods was not significant. This was caused by yield of non-marketable roots

Table 3

Influence of cultivation methods and drip irrigation on root yield of parsley (2005-2007)

Cultivation methods	Irrigation treatments	Yield of parsley roots ($t \cdot ha^{-1}$)		
		marketable	non marketable	total
Ridges	subsurface	17.77	5.50	23.27
	surface	19.47	4.77	24.23
	without irrigation	9.17	3.43	12.60
	mean	15.47	4.57	20.03
Flat ground	subsurface	12.23	10.13	22.37
	surface	15.73	10.33	26.07
	without irrigation	7.90	7.40	15.30
	mean	11.96	9.29	21.24
Mean for irrigation treatments				
surface		15.00	7.90	22.90
subsurface		17.60	7.60	25.20
without irrigation		8.60	5.50	14.00
$LSD_{\alpha=0.05}$ for:				
cultivation methods (A)		3.22	3.26	n.i.
irrigation (B)		4.91	n.i.	5.76
interaction A (B)		n.i.	n.i.	n.i.
B(A)		n.i.	n.i.	n.i.

(deformed, forked and small roots) in the cultivation on ridges being significantly lower than in flat cultivation. In the cultivation on flat ground there were twice as many misshapen roots as in the ridge cultivation. In both plant cultivation methods, surface and subsurface drip irrigation contributed to a significant increase in marketable and total yields of parsley roots in comparison with the non-irrigated treatment. No significant differences in yield were found between the surface-irrigated and the subsurface-irrigated parsley plants. In both flat and ridge cultivation there was a noticeable tendency towards achieving higher yields with surface drip irrigation than with subsurface irrigation. Drip irrigation did not have any effect on the size of non-marketable yield. Dyśko and Kaniszewski (2007) found similar effects of the cultivation and irrigation methods on the yield of carrot plants. According to Błażewicz-Woźniak (1998), the total yield of parsley roots depends largely on the weather pattern during the vegetative period, especially on the moisture content of the soil. Compared to the cultivation on flat ground, parsley roots in the cultivation on ridges were found to be significantly longer. The average length of a parsley root was 21.38 cm in ridge cultivation and 17.26 cm in flat cultivation (Table 4).

Drip-irrigated parsley plants cultivated on ridges produced more slender roots than those cultivated without irrigation. There was a negative

Table 4

Influence of cultivation methods and drip irrigation on the length and dry matter content of parsley roots (2005–2007)

Cultivation methods	Irrigation treatments	Length of roots (cm)	Dry matter content of roots (%)
Ridges	subsurface	21.37	27.99
	surface	21.60	27.70
	without irrigation	21.17	26.99
	mean	21.38	27.56
Flat ground	subsurface	17.00	26.26
	surface	17.40	26.28
	without irrigation	17.37	27.31
	mean	17.26	26.62
$LSD_{\alpha=0.05}$ for:			
cultivation methods (A)		2.24	n.i.
irrigation (B)		n.i.	n.i.
interaction A(B)		n.i	n.i.
B(A)		n.i.	n.i.

correlation between root diameter and root length. As the length increased, there was a significant, linear decrease in the diameter of the roots of the plants that were irrigated and growing on ridges (Figure 1). On flat ground, however, irrigation contributed to a significant increase in the thickness of roots, which grew longer (Figure 2). In the cultivation

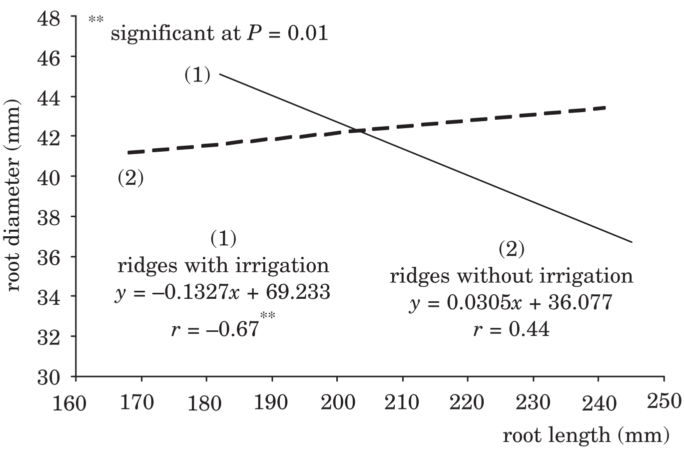

Fig. 1. Influence of drip irrigation of parsley cultivated on ridges on the root shape

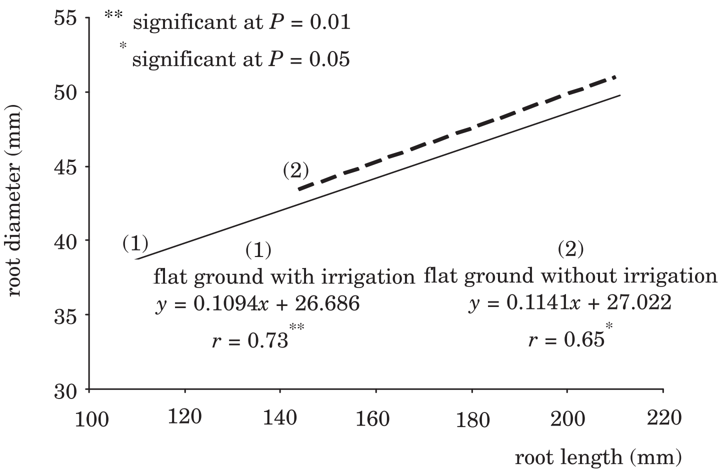

Fig. 2. Influence of drip irrigation of parsley cultivated on flat ground on the root shape

without irrigation, both on ridges (Figure 1) and on flat ground (Figure 2), as the length increased, the root diameter also increased significantly. This relationship was significant at $\alpha = 0.01$ for ridge cultivation, and at $P = 0.05$ for flat cultivation, and was rectilinear in character. In the estimation of BŁAŻEWICZ-WOŹNIAK (1998), the shape and length of parsley roots are greatly influenced by a soil tillage method prior to sowing, which changes soil density, porosity and compactness. Properly prepared ridges are able to maintain the same soil compactness across the entire profile, thus providing root vegetables with the right conditions to grow in (BABIK, DUDEK 2000). In experiments on carrot, it was found that carrot plants cultivated on ridges produced considerably longer roots than those cultivated traditionally on flat ground (DYŚKO, KANISZEWSKI 2007). The cultivation methods and the drip irrigation systems used in the experiment did not have a significant effect on dry matter content in parsley roots (Table 4). EVERS et al. (1997) found higher levels of dry matter in carrots cultivated on ridges compared to those grown on flat ground. In the experiment by ROLBIECKI and RZEKANOWSKI (1996), neither sprinkling nor drip irrigation reduced dry matter content in carrot roots. Different results, however, were obtained by DYŚKO and KANISZEWSKI (2007). Their experiment showed that dry matter content in carrot roots decreased significantly as a result of drip irrigation.

The plant cultivation methods used in this experiment did not have a significant effect on the concentration of minerals in parsley roots (Table 5). Drip irrigation, both surface and subsurface, brought about a decrease in the total nitrogen and potassium content, but did not affect the concentrations of phosphorus, magnesium or calcium in the roots. In the cultivation of carrot plants, drip irrigation was also found to reduce total nitrogen content in their storage roots (DYŚKO, KANISZEWSKI 2007).

Table 5

Influence of cultivation methods and irrigation on the content of macronutrients in parsley roots (2005–2007)

Cultivation methods	Irrigation treatments	Macronutrients ($g \cdot kg^{-1}$ d.m.)				
		N	P	K	Mg	Ca
Ridges	subsurface	12.8	2.74	26.09	2.42	2.95
	surface	13.6	2.78	24.39	2.64	2.98
	without irrigation	17.1	3.18	32.38	2.63	3.26
	mean	14.5	2.90	27.62	2.56	3.07
Flat ground	subsurface	13.6	2.97	24.93	2.43	2.86
	surface	13.2	3.03	25.81	2.49	3.17
	without irrigation	16.4	2.99	29.79	2.55	3.25
	mean	14.4	2.99	26.85	2.49	3.09
Mean for irrigation treatments						
subsurface		13.2	2.90	25.60	3.90	2.90
surface		13.4	2.90	25.10	2.60	3.10
without irrigation		16.8	3.10	31.10	2.60	3.30
$LSD_{\alpha=0.05}$ for:						
cultivation methods (A)		n.i.	n.i.	n.i.	n.i.	n.i.
irrigation (B)		2.4	n.i.	3.7	n.i.	n.i.
interaction A(B)		n.i.	n.i.	n.i.	n.i.	n.i.
B(A)		n.i.	n.i.	n.i.	n.i.	n.i.

CONCLUSIONS

1. Surface and subsurface drip irrigation used both on ridges and on flat ground caused a significant increase in the marketable yield of parsley roots.

2. In the cultivation of root parsley on ridges, the percentage of misshapen roots in the whole crop was half of that obtained in the cultivation on flat ground.

3. The method of laying irrigation drip lines (surface or subsurface) did not have a significant effect on the yield of parsley plants.

4. Longer roots of a better shape were obtained in the cultivation of parsley on ridges than on flat ground.

5. Surface and subsurface irrigation both resulted in a decrease in the total nitrogen content and potassium content in parsley roots.

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EFFECT OF NUTRIENT SOLUTION pH REGULATED WITH HYDROCHLORIC ACID ON THE CONCENTRATION OF Cl^- IONS IN THE ROOT ZONE IN SOILLESS CULTURE OF TOMATO

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Abstract

The experiment was carried out in a greenhouse in the years 2004-2006. Tomato plants of *cv.* Blitz F_1 were fertilized with a nutrient solution of different pH: 4.5, 5.0, 5.5, 6.0 and 6.5. The required nutrient solution pH was obtained by adding adequate amounts of 65% HNO_3 and 33% HCl. Nitric acid was used to adjust the nutrient solution's acidity to pH 6.5. Lower pH levels were obtained adding hydrochloric acid. The amount of the acid needed to adjust the nutrient solution pH to a required level was determined against a water acidification curve. Tomato plants were grown on organic media (peat and rye straw) and an inert medium (rockwool). Changes in the Cl^- concentration in the root zone during the cultivation period depended on the kind of substrate and the concentration of chlorides in the applied nutrient solution. In the straw substrate, irrespective of the applied nutrient solution pH, higher concentrations of Cl^- occurred in the early stages of cultivation. The concentration of chlorides in peat and rockwool increased during the tomato cultivation period at all of the applied pH levels of the nutrient solution. More chloride ions accumulated in the growth substrates when the nutrient solution has lower pH. Higher Cl^- concentration was a result of larger doses of hydrochloric acid. However, when pH is regulated with hydrochloric acid, the permissible chloride concentration levels in the applied nutrient solution and in the root zone of tomato plants are not exceeded. As the concentration of chlorides in the nutrient solution increases, so does the Cl^- content in leaves of tomato plants.

Key words: chloride, pH, hydrochloric acid, straw, peat, rockwool.

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WPŁYW pH POŻYWKI REGULOWANEGO KWASEM CHLOROWODOROWYM NA ZAWARTOŚĆ JONÓW Cl^- W STREFIE KORZENIOWEJ W BEZGLEBOWEJ UPRAWIE POMIDORA

Abstrakt

Badania prowadzono w latach 2004-2006 w warunkach szklarniowych. Pomidory odmiany Blitz F_1 nawożono pożywką o zróżnicowanym odczynie (pH): 4,5, 5,0, 5,5, 6,0, 6,5. Wymagany odczyn pożywki stosując dodatek 65% HNO_3 oraz 33% HCl. Ilość kwasu potrzebnego do doprowadzenia pożywki do wymaganego odczynu ustalono na podstawie krzywej zakwaszenia wody, do pH 6,5 za pomocą kwasu azotowego, a dalsze zakwaszenie za pomocą kwasu chlorowodorowego. Pomidory uprawiano w podłożach organicznych (torf, słoma) oraz inertnym (wełna mineralna). Przebieg zmian stężenia Cl^- w strefie korzeniowej w czasie uprawy pomidora zależał od rodzaju podłoża oraz zawartości chlorków w dozowanych pożywkach. W podłożu ze słomy, niezależnie od pH stosowanej pożywki, większe zawartości Cl^- oznaczano w początkowym okresie uprawy pomidora. Zawartość chlorków w torfie i wełnie mineralnej w przypadku wszystkich badanych poziomów pH wzrastała w trakcie uprawy. Większą akumulację jonów Cl^- w badanych podłożach stwierdzono po zastosowaniu pożywek o niższych poziomach pH, w których zawartość chlorków wynikająca z większej dawki kwasu solnego, była wyższa. Regulacja odczynu kwasem chlorowodorowym nie powodowała przekroczenia dopuszczalnych stężeń Cl^- w pożywce oraz strefie korzeniowej pomidora. Wraz ze wzrostem koncentracji chlorków w pożywce wzrastała zawartość Cl^- w liściach pomidora.

Słowa kluczowe: chlorki, pH, kwas chlorowodorowy, słoma, torf, wełna mineralna.

INTRODUCTION

Chlorine plays an important role in many physiological processes in plants (e.g. it affects photosynthesis and water balance) and, although it is considered to be a microelement, the average concentration of chlorine in plants is 2-20 $mg \cdot g^{-1}$ of dry weight, which is a concentration typical of macroelements (MARSCHNER 1995). For the optimal growth of most plant species, however, the demand for chlorine delivered in fertilizers is only 0.2-0.4 $mg \cdot g^{-1}$ d.w. (MARSCHNER 1995). Plants take up chlorine from a variety of sources: fertilizers, atmospheric precipitation, irrigation waters or polluted air. Consequently, toxic amounts of this element are more widespread than its deficiency. Optimum concentrations of chlorine in hydroponic nutrient solutions have not yet been established precisely. Until recently, the recommended concentration of Cl^- ions in nutrient solutions for growing tomatoes in rockwool was 35 ppm in the applied solution and 70 ppm in the root zone. The latest reports suggest that proper fertilization of tomato plants requires chlorine concentrations of 50 ppm in the nutrient solution delivered to the plants and 100 ppm in their root zone, even though the tolerance limit for chlorides in tomato is much higher (JAROSZ 2006). According to NURZYŃSKI and MICHAŁOJĆ (1998), the maximum concentration of Cl^- ions in the root zone that will not affect the growth and yielding of tomato plants can be as high as 1300 $mg \cdot dm^{-3}$. To obtain the required pH level of a nutrient solution, nitric and phosphoric acids as well as modifications in the concentration of NH_4^+ ions are most often used (WILLUMSEN 1980). In adjusting the pH of a nutrient solution, nitric acid can be partly replaced with hydrochloric acid (especially when there are some problems reducing the amount of nitrogen in the solution), which is also a source of Cl^- for plants. PAPADOPOULOS and PARARAJASINHAM (1998), who compared the use of nitric, phosphoric and hydrochloric acids in the NFT method of growing tomatoes, obtained the best yield improvement after stabilizing the nutrient solution pH by means of hydrochloric acid.

The aim of the experiment was to determine the effect of a nutrient solution pH adjusted with hydrochloric acid on the chlorides concentration in the root zone and in tomato plants grown in inert and organic media.

MATERIAL AND METHODS

The experimental work was conducted in 2004-2006, in a greenhouse of the Institute of Vegetable Crops in Skierniewice. The experiment was carried out on Blitz F_1 greenhouse variety of tomato grown on Grodan Master rockwool mats measuring 100 x 20 x 7.5 cm, and on mats of the same size made of shredded rye straw and peat substrate. The experiment was set up in a two-factorial design, in an independent system with four replications. On each experimental plot 6 plants were grown. The plants were planted in their permanent place of cultivation at the beginning of April and grown in an extended cycle until mid-October. Nutrient solution pH levels of 4.5, 5.0, 5.5, 6.0 and 6.5 were obtained by adding nitric and hydrochloric acids to water. The amount of acid needed to fix the required pH level was calculated on the basis of a water acidification curve. Concentrated nitric acid (65%) was used to adjust the pH of the nutrient solution to 6.5, whereas the lower pH values were achieved with 33% hydrochloric acid. The water used for irrigation had the following parameters: composition in $mg \cdot dm^{-3}$ – HCO_3 – 349, N-NO_3 – 0.25, N-NH_4 – 0.05, P – 0.05, K – 2.72, Ca – 101, Mg – 15.0, Na – 10.5, Cl – 12.9, S-SO_4 – 33.5, Fe – 0.042, Mn – 0.022, Cu – 0.020, Zn – 1.680, B – 0.025; EC – 0.56 $mS \cdot cm^{-1}$; pH – 7.2; total hardness – 17.6^{o}dH. In the nutrient solution of pH 6.5, the concentration of chlorides was a result of their presence in the water used for irrigation and ranged from 12 to 25 $mg \cdot dm^{-3}$. The concentration of chlorides in the nutrient solution whose pH was adjusted with HCl was 138 $mg \cdot dm^{-3}$ at pH 4.5, 130 $mg \cdot dm^{-3}$ at pH 5.0, 114 $mg \cdot dm^{-3}$ at pH 5.5, and 60 $mg \cdot dm^{-3}$ at pH 6.0. The amounts of nutrients were as follows (in $mg \cdot dm^{-3}$): N – 200-260, P – 40, K – 220-380, Mg – 60-80, Ca – 180-200, S-SO_4 – 80, Fe – 2.5, Mn – 0.8, B – 0.43, Zn – 0.33, Cu – 0.1, Mo – 0.05.

The chemical analyses for chloride concentration in the solutions taken from the cultivation mats were carried out once a fortnight. For this purpose, samples of the nutrient solution were taken from between two plants in the centre of the mat after the second watering cycle. The chemical analyses for chloride content in leaves of the tomato plants were carried out 3 times over the cultivation period: during the flowering of the third cluster, while picking fruits from the third cluster, and 2 weeks before the end of the cultivation period. For these analyses, the fifth fully-developed leaf, counting from the top of the plant, was taken as a sample. pH was measured with an ORION pH meter; Cl^- concentration in the solution was determined with an ion analyser with a selective chloride electrode, and the chloride content in the plants was determined using the HPLC method. The experimental results were evaluated statistically with an analysis of variance. Mean values were compared with Newman-Keuls test at P=0.05. Changes in the concentration of chlorides in the cultivation mats and their dependence on pH were determined by the methods of correlation and linear and parabolic regression (PIELAT, VISCARDI 1988).

RESULTS AND DISCUSSION

The chemical analyses of the solutions taken from the cultivation mats revealed that the changes in pH in the root zone depended on the pH level of the nutrient solution being supplied, the growing medium and the plant development stage. How the pH of the root zone was changing, depending on the pH of the nutrient solution and the kind of substrate used, can be seen in Figures 1–3. The cultivation of tomatoes on straw, using the nutrient solution of low pH, i.e. pH 4.5, 5.0, and 5.5, caused the pH in the root zone to fall significantly, whereas at the higher pH levels of 6.0 and 6.5, the pH in the root zone was high and did not change much over the entire period of cultivation. As for the peat mats, when the nutrient solution was supplied at the higher pH values of 6.5, 6.0 and 5.5, there was a significant increase in the pH value in the root zone during the cultivation period (Figure 2). The nutrient solution pH levels of 4.5 and 5.0 did not produce significant modifications in the pH level of the root growth environment. In rockwool, the nutrient solution pH levels of 5.0, 5.5 and 6.0 significantly lowered the root zone pH during cultivation. However, supplying the nutrient solution at a pH close to neutral (pH 6.5) or acidic (pH 4.5) did not cause a significant decrease in the pH of the root zone (Figure 3). The organic growing media, in comparison with rockwool, did not respond so much to the different pH levels of the nutrient solution because of their high sorptive capacity and some buffering properties. According to DECHNIK and WIATER (2002), organic matter has a stabilizing effect on soil pH.

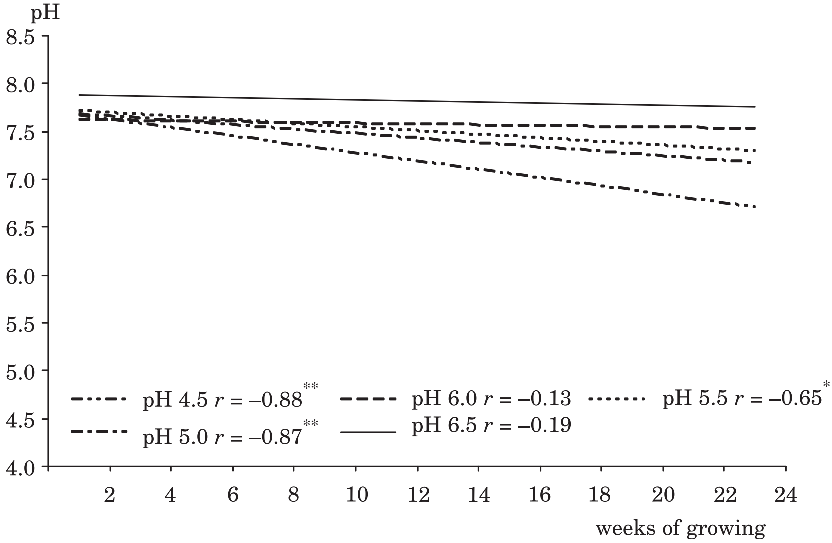

Fig. 1. Changes of pH in the root zone of tomato grown on straw medium depending on pH of the nutrient solution (* significant at $P = 0.05$, **significant at $P = 0.01$)

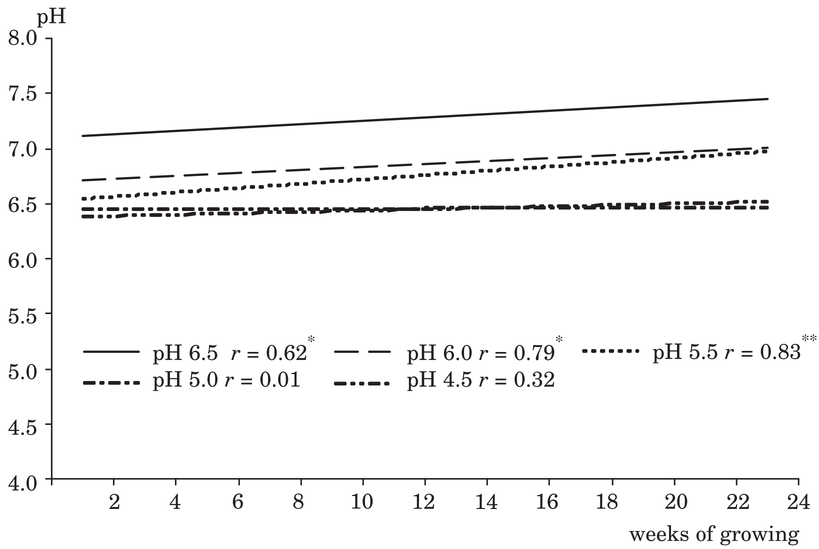

Fig. 2. Changes of pH in the root zone of tomato grown on peat medium depending on pH of the nutrient solution (* significant at $P = 0.05$, **significant at $P = 0.01$)

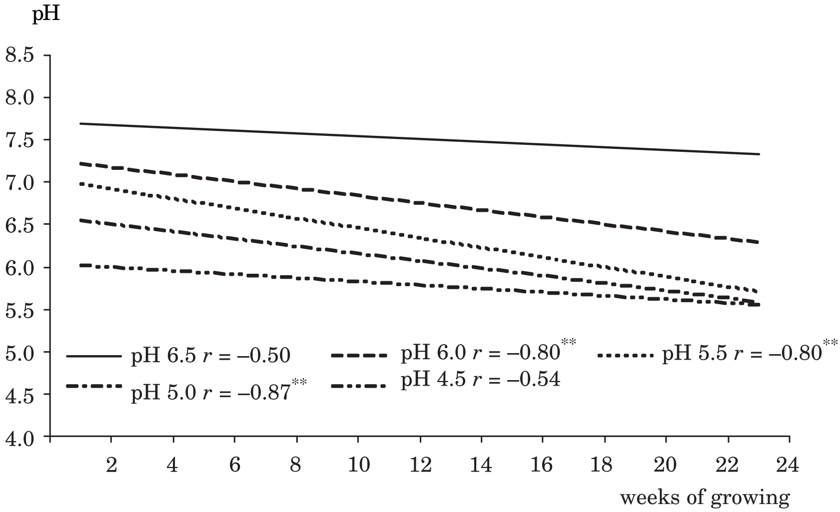

Fig. 3. Changes of pH in the root zone of tomato grown on rockwool depending on pH of the nutrient solution (* significant at P = 0.05, **significant at P = 0.01)

Changes in the Cl^- concentration in the root zone during the cultivation period depended on the kind of substrate and the concentration of chlorides in the nutrient solution supplied to plants. In the substrate made of straw, the highest Cl^- concentrations were measured in the early stages of cultivation (Figure 4). Even at pH 6.5 of the nutrient solution not adjusted with hydrochloric acid, the Cl^- concentration was high (around 200 mg·dm^{-3} Cl^-). With time, the concentration of chlorides in the straw substrate decreased. For the first 12 weeks of the cultivation, the Cl^- concentration in the root zone stayed at a similar level when the nutrient solution was supplied at pH 4.5, 5.0 and 5.5. Later, however, the Cl^- concentration showed more variation, increasing at pH 4.5 and falling at pH 5.5. The changes over time in the concentration of chlorides in the root zone in the straw substrate followed parabolic regression curves, which were significant at all of the applied nutrient solution pH values. Higher chloride concentration in the root zone in the initial stages of cultivation was caused by the leaching of chlorides from the straw. Straw of cereal crops is rich in chlorides, on average 0.90% in dry matter (HOUBA, UITTENBOGAARD 1994).

In the cultivation of tomatoes on peat and rockwool, lower concentrations of chlorides in the root zone, in all the cases, were found during the early stages of cultivation (Figures 5 and 6). With time, the concentration of chlorides in these substrates increased. In the experiments by NURZYŃSKI and MICHAŁOJĆ (1998) with tomatoes growing on rockwool, the concentration of chlorides during the vegetative period also increased, reaching 450 mg·dm^{-3} at

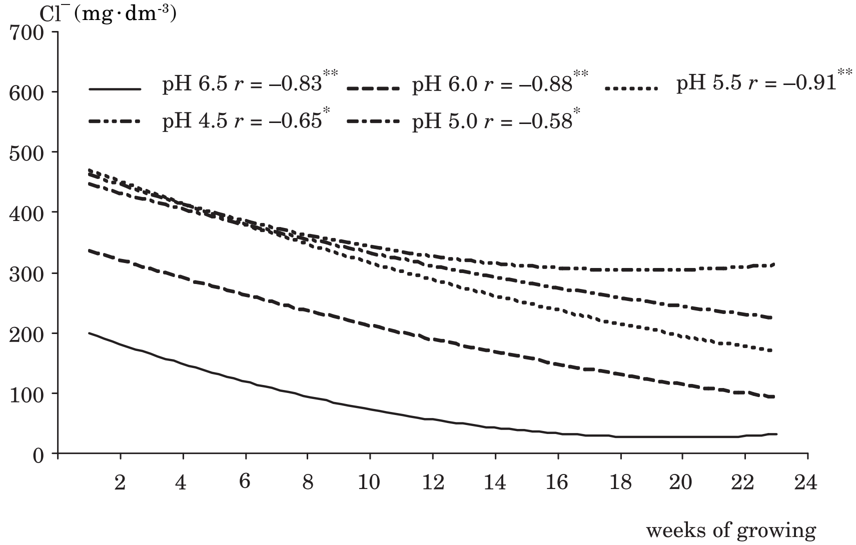

Fig. 4. Changes of the chlorides concentration the root zone of tomato grown on straw medium depending on pH of the nutrient solution (* significant at $P = 0.05$, **significant at $P = 0.01$)

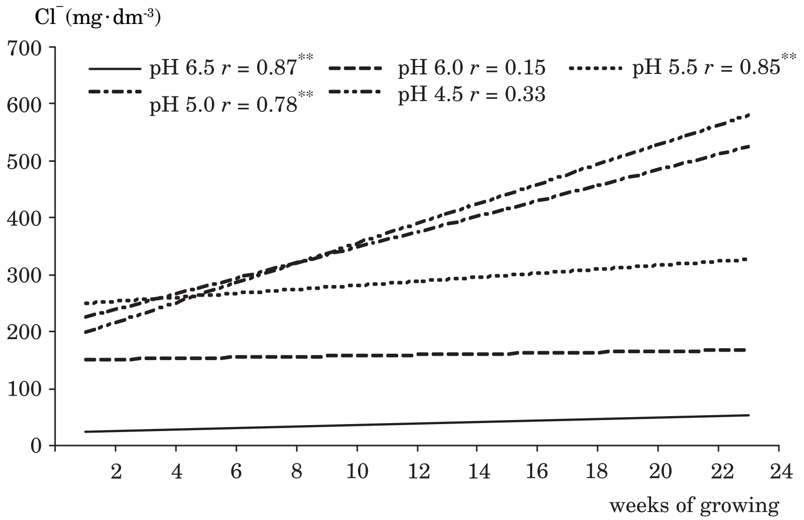

Fig. 5. Changes of the chlorides concentration in the root zone of tomato grown on peat depending on pH of the nutrient solution (* significant at $P = 0.05$, **significant at $P = 0.01$)

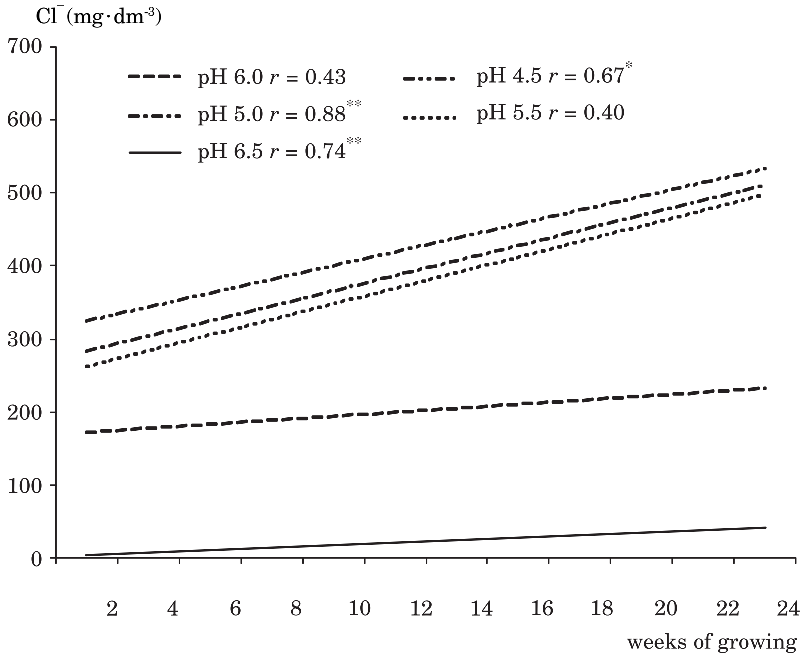

Fig. 6. Changes of the chlorides concentration in the root zone of tomato grown on rockwool depending on pH of the nutrient solution (* significant at $P = 0.05$, **significant at $P = 0.01$)

the peak of fruiting. More Cl^- ions accumulated in the root zone when the nutrient solution was supplied at the lower pH values, carrying higher concentrations of chlorides, which was due to the larger doses of hydrochloric acid used for fixing pH. The concentration of chloride ions in the straw substrate, after using the nutrient solution at pH 4.5, 5.0 and 5.5, fell significantly in the course of cultivation, and the regression trend lines obtained for these pH values were not significantly different from one another (Figure 4). Therefore, the pH of the nutrient solution, in this range, was not found to have an effect on the concentration of chloride ions in the root zone. In contrast, with tomatoes grown on rockwool, supplying the nutrient solution at pH 4.5 and 5.0 resulted in a significant increase in the Cl^- concentration in the substrate (Figure 6). However, the resulting regression lines for the changes in Cl^- concentration with time, analogously to straw, did not differ significantly from one other. In the peat substrate, the trend lines for chloride concentration changes were not significantly different only for pH 4.5 and 5.0 (Figure 5). Lowering the pH of the nutrient solution from 5.5 to 4.5 does not require as much hydrochloric acid as, say, adjusting from pH 6.5 to 5.5. This is a consequence of the non-linear (logarithmic) nature of the relationship between the pH value and the concentration of H^+ ions. The Cl^- concentration in all the substrates and at all the pH levels used did not exceed the value of 750 mg $Cl^{-} \cdot dm^{-3}$ given by ADAMS and BAILEY-ANGUISH (1988), and quoted by PAPADOPOULOS and PARARAJASINHAM (1998) and NUKAYA et al. (1991). In the experiments by JAROSZ (2006), the Cl^{-} concentration in a nutrient solution used for growing tomatoes was 120 $mg \cdot dm^{-3}$, whereas the average chloride concentration in the root zone was at a level similar to our results, reaching 427 $mg \cdot dm^{-3}$ in rockwool, and 396 $mg \cdot dm^{-3}$ in peat. This means that by using hydrochloric acid to regulate the pH of a nutrient solution, the permissible chloride concentrations in the solutions used to fertigate tomato plants are not exceeded. The use of hydrochloric acid to adjust nutrient solution pH, and at the same time the Cl^{-} concentration in the root zone, had a significant effect on the chloride content in tomato leaves (Table 1). A significantly higher Cl^{-} content (10.0 $g \cdot kg^{-1}$ d.w., on average) was found in the leaves of tomato plants fertilized at pH 4.5–5.5 of the nutrient solution. The average chloride content in the leaves taken from the treatment where HCl was not used (pH 6.5), was 5.53 g $Cl^{-} \cdot kg^{-1}$ d.w. The growing media used in the experiment did not have a significant effect on the chloride content in leaves of tomato plants. NURZYŃSKI and MICHAŁOJĆ (1998), and CHAPAGAIN and WIESMAN (2004), using KCl and $MgCl_2$ to fertilize tomato plants in soilless culture, also found that as the chloride concentration in the substrate increased, the chloride content in tomato plants also increased.

Table 1

The effect of nutrient solution pH on the content of chlorides in leaves ($g \cdot kg^{-1}$ d.m.) of tomato (2004–2006)

pH	Growing medium			
	peat	straw	rockwool	*x*
4.5	10.8	11.2	8.80	10.3 *a*
5.0	10.4	10.3	7.77	9.45 *a*
5.5	10.2	12.1	10.2	10.8 *a*
6.0	6.44	7.86	7.92	7.41 *b*
6.5	3.92	5.87	6.79	5.53 *c*
x	8.34 *a*	9.44 *a*	8.29 *a*	-

Means with the same latter are not significant at $P = 0.05$.

CONCLUSIONS

1. Changes in Cl^{-} concentration in the root zone during cultivation of tomato depended on the kind of substrate and the concentration of chlorides in the nutrient solution supplied to the plants.

2. In the substrate made of straw, irrespective of the pH level of the nutrient solution being used, higher Cl^- concentrations were measured in the initial stages of tomato cultivation.

3. The concentration of chlorides in peat and rockwool increased in the course of tomato cultivation at all of the applied pH levels of the nutrient solution.

4. Adjusting pH by means of hydrochloric acid did not result in exceeding the permissible Cl^- concentration levels in the nutrient solution or the root zone of tomato plants.

5. As the chloride concentration in the nutrient solution increased, so did the Cl^- content in leaves of tomato plants.

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J. Elementol. 2008, 13(2): 255–260

THE EFFECTS OF NITROGEN FERTILIZATION ON YIELDING AND BIOLOGICAL VALUE OF CHINESE CABBAGE GROWN FROM SEEDLINGS FOR AUTUMN HARVEST

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Abstract

In a field experiment conducted in 1999-2001 the effect of nitrogen nutrition on yield and biological value of cv. Optiko Chinese cabbage grown from transplants for autumn harvest was evaluated. Nitrogen was supplied in a single pre-plant dose in the amounts of 50, 100, 150, 200 $kg \cdot ha^{-1}$ or in a split application: 100+50 or 100+50+50 $kg \cdot ha^{-1}$, with top dressing conducted 2 and 4 weeks after planting.

The results of the study did not show any significant response of Chinese cabbage yield to higher nitrogen rates. The level of nitrogen raised from 50 to 150 $kg \cdot ha^{-1}$ was favourable for vitamin C and total sugars content, while the application of 200 $kg \cdot ha^{-1}$ had a negative effect on accumulation of these constituents. Split application of 150 and 200 kg $N \cdot ha^{-1}$ resulted in decreased vitamin C and dry matter contents in comparison to single pre-plant doses of nitrogen used in the same amounts. Plant heavily supplied with nitrogen contained the highest level of nitrates.

Key words: Chinese cabbage, nitrogen fertilization, yield, nitrate content, nutritional value.

WPŁYW NAWOŻENIA AZOTEM NA PLONOWANIE I WARTOŚĆ BIOLOGICZNĄ KAPUSTY PEKIŃSKIEJ UPRAWIANEJ Z ROZSADY NA ZBIÓR JESIENNY

Abstrakt

W doświadczeniu przeprowadzonym w latach 1999-2001 oceniano wpływ nawożenia azotem na plonowanie i wartość biologiczną kapusty pekińskiej, odmiany Optiko, uprawianej z rozsady

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na zbiór jesienny. Porównywano obiekty nawożone azotem w postaci saletry amonowej przedwegetacyjnie w dawkach 50, 100, 150, 200 kg N·ha^{-1} oraz w dawkach dzielonych 100+50 i 100+50+50 kg N·ha^{-1}. Pogłównie nawóz wysiewano po 2 i 4 tygodniach od sadzenia

Stwierdzono bark istotnej reakcji kapusty pekińskiej na wzrastające dawki azotu. Wzrastające dawki azotu (od 50 do 150 kg N·ha^{-1}) przyczyniały się do zwiększania zawartości witaminy C i cukrów ogółem w główkach kapusty, natomiast zastosowanie 200 kg N·ha^{-1} spowodowało ich zmniejszenie. Zastosowanie azotu w dawkach dzielonych 100+50 i 100+50+50 kg N·ha^{-1} miało wpływ na zmniejszenie poziomu witaminy C, azotanów i suchej masy w roślinach, w porównaniu z zawartością stwierdzoną w kapuście nawożonej takimi samymi dawkami azotu tylko przedwegetacyjnie. Zawartość azotanów w główkach kapusty pekińskiej wzrastała wraz ze zwiększeniem dawki azotu.

Słowa kluczowe: kapusta pekińska, nawożenie azotowe, plon, wartość odżywcza.

INTRODUCTION

Chinese cabbage is a "long day" plant and for optimal development it requires long period of light and high temperature during the initial phase of its growth, whereas low temperature and short day are required at the time of head formation (Balvoll 1995). Such optimal conditions usually occur in autumn (Felczyński 1997). This vegetable can be also cultivated for the spring or summer harvest, although then the risk of flower shoot formation is greater. It can be reduced by choosing cultivars less susceptible to bolting (Staugaitis and Starkute 1999, Krężel and Kołota 2002, Kalisz 2005) and using flat plant covers during the spring period (Balvoll 1995). Finally, Chinese cabbage can be seeded directly to the field or grown from bare root or potted transplants. For the spring harvest, however, it is particularly suitable to grow Chinese cabbage from transplants, which can also be done when cabbage is grown for summer and autumn harvest (Martyniak-Przybyszewska 2000, Kalisz and Cebula 2002).

This vegetable produces significant amount of leaf mass during a short vegetation period, which raises its nutritional demand, including particularly high nitrogen requirements. Unfortunately, high nitrogen intake is associated with high accumulation of nitrates in the foliage (Li Jun Liang et al. 2003, Wang Zheng Yin et al. 2003, Krężel and Kołota 2004, Ye Jing Xue et al. 2004).

The goal of the present experiment was to evaluate the effects of nitrogen fertilisation on the yielding and biological value of Chinese cabbage grown from seedlings for the autumn harvest.

MATERIALS AND METHODS

The experiment was designed using the method of random blocks in four replications, and it was performed at the Experimental Station of the Horticulture Department UP, Wrocław in 1999-2001. Nitrogen was used as ammonium nitrate at the doses of 50, 100, 150 or 200 kg $N \cdot ha^{-1}$ applied prior to planting or in split doses of 100+50, 100+50+50 kg $N \cdot ha^{-1}$, applied pre-planting and top dressing 2 and 4 weeks after planting the seedlings. Phosphorus and potassium were applied according to the results of the soil analyses to attain the levels of 60 mg P dm^{-3} and 200 mg $K \cdot dm^{-3}$ of soil.

Chinese cabbage (cv. Optiko) was planted using pot seedlings produced in multicell trays. The seeds treated with fungicide *Zaprawa nasienna* T ($4g \cdot kg^{-1}$ seed) were sown in the second part of July. The seedlings were planted out in the fields in mid-August, at spacing of 45x30 cm. At harvest, conducted in mid-October, total yield of aerial mass as well as total and marketable yield of heads were evaluated. In addition, plant samples were collected for determination of dry matter, sugars (Lane-Eynona method), vitamin C (Tillmans method) and nitrates (calorimetric method).

The results were analysed using Tukey's test at the confidence coefficient α=0.05.

RESULTS AND DISCUSION

As it is shown in Table 1, the highest yield of aerial mass, as well as total and marketable yield of heads were obtained using the highest dose of nitrogen applied in the amount of 100 $kg \cdot N\ ha^{-1}$ prior to planting and 50+50 kg $N \cdot ha^{-1}$ as top dressing at 2 and 4 weeks after planting (86.99, 56.44 and 49.14 $t \cdot ha^{-1}$ respectively). The differences in the head yield, including both the total and marketable yield, were not statistically significant. There was, however, a tendency towards higher head yields when the nitrogen doses had increased from 50 to 150 kg $N \cdot ha^{-1}$, but it was followed by lower yields at 200 kg $N \cdot ha^{-1}$. Split application of nitrogen (100+50 kg $N \cdot ha^{-1}$) did not modify yielding as compared to an analogous single dose used prior to the vegetation period. At 200 kg $N \cdot ha^{-1}$, the change nitrogen application from single pre-vegetation to split application (100+50+50) treatment slightly enhanced the crop yield. These data are in contrast with those reported by WANG ZHENG YIN et al. (2003), who observed increased yielding along with enlarged doses of nitrogen up to 225 kg $N \cdot ha^{-1}$.

The highest percentage of marketable heads with respect to total yield were found in the experiment with 100 and 100+50 kg $N \cdot ha^{-1}$ (87.86%), whereas the lowest performance was observed when using 150 kg $N \cdot ha^{-1}$

Table 1

Effect of nitrogen fertilization on yielding of Chinese cabbage grown from seedlings for autumn harvest

Rate of nitrogen (kg·ha^{-1})	Total yield of aerial mass (t·ha^{-1})	Total yield of heads (t·ha^{-1})	Marketable yield of heads (t·ha^{-1})	Share in total yield	
				marketable heads	small non marketable heads
50	77.01	52.36	45.99	87.84	7.91
100	82.12	55.50	48.77	87.86	7.19
150	84.85	55.69	48.46	87.01	8.50
100+50	84.54	55.38	48.66	87.86	8.67
200	79.82	52.01	45.55	87.58	8.83
100+50+50	86.99	56.44	49.14	87.07	9.62
$LSD_{\alpha=0.05}$	7.51	r.n.	r.n.	-	-

before planting. The smallest percentage of small and not fully grown heads in total yield occurred when using 100 kg N·ha^{-1} (7.19%), whereas the highest one after split application of 100+50+50 kg N·ha^{-1} (9.62%). A similar tendency had been observed and reported previously by Krężel and Kołota (2004).

The mean weight of Chinese cabbage marketable head decreased gradually with doses of nitrogen increasing from 100 kg N·ha^{-1} to 200 kg N·ha^{-1} when used as single application treatments before planting (Figure 1). Interestingly, application of the same total amounts in split doses of nitrogen (100+50 and 100+50+50 kg N·ha^{-1}) resulted in an increased mean head weight (657 g and 664 g respectively).

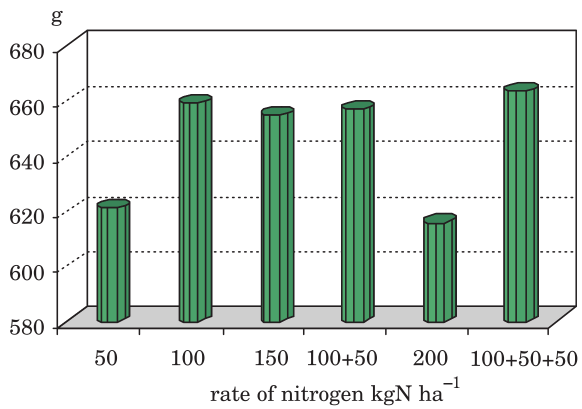

Fig. 1. The effect of nitrogen fertilization on mean weight of head of Chinese cabbge grown from seedlings for autumn harvest

Table 2

Effect of nitrogen fertilization on content of dry matter, sugars, vitamin C and NO_3, in Chinese cabbage grown from seedling for autumn harvest

Rate of nitrogen ($kg \cdot ha^{-1}$)	Dry matter (%)	Reducing sugars (%)	Total sugars (%)	Vitamin C ($mg \cdot kg^{-1}$ fresh weight)	NO_3 ($mg \cdot kg^{-1}$ fresh weight)
50	5.80	2.09	2.30	307.3	630
100	6.14	2.11	2.34	325.7	980
150	6.29	2.11	2.40	376.1	1103
100+50	5.61	2.12	2.25	328.9	1068
200	6.29	2.17	2.24	358.7	1186
100+50+50	6.14	2.19	2.28	336.6	1126

The dry mass content was the highest (6.29%) under a single application of 150 and 200 kg $N \cdot ha^{-1}$ prior to the vegetation period, whereas the application the same amounts in split doses 100+50 and 100+50+50 kg $N \cdot ha^{-1}$ lead to significant reduction of dry matter (Table 2). The content of reducing sugars was not significantly affected by the dose or the term of nitrogen application, although a increasing tendency was observed with higher doses of nitrogen. The total sugar and vitamin C content increased proportionally to the nitrogen doses up to 150 kg $N \cdot ha^{-1}$, attaining 2.40% and 376.1 $mg \cdot kg^{-1}$ of fresh weight, respectively. The application of 200 kg $N \cdot ha^{-1}$ in a single dose before the vegetation period and in split doses (100+50 and 100+50+50 kg $N \cdot ha^{-1}$) caused reduction of total sugar and vitamin C levels. The sugar content reported by Staugaitis and Starkute (1999), was significantly higher, whereas the vitamin C levels were strongly reduced in comparison with the present study. The accumulation of nitrates increased with increasing doses of nitrogen and varied from 630 mg kg^{-1} of fresh weight after the application of 50 kg $N \cdot ha^{-1}$ up to 1186 $mg \cdot kg^{-1}$ of fresh weight at the dose of 200 kg $N \cdot ha^{-1}$. Such relations between nitrogen fertilization and nitrates content are in agreement with previous reports of Wang Zheng Yin et al. (2003).

CONCLUSIONS

1. An increase of a nitrogen dose from 50 to 100 kg $N \cdot ha^{-1}$ caused a slight but not significant enhancement of the yield of commercial heads of Chinese cabbage. This effect was not observed at higher doses equal to 150 and 200 kg $N \cdot ha^{-1}$.

2. The highest content of dry matter and nitrates occurred after the application of 200 kg $N \cdot ha^{-1}$, whereas the highest total sugars and vitamin C were found in the cabbage after the application of 150 kg $N \cdot ha^{-1}$.

3. The use of split doses of 100+50 and 100+50+50 kg N·ha^{-1} caused a higher reducing sugars content, but lower levels of vitamin C, nitrates and content the dry matter compared to treatments with a single application of 150 and 200 kg N·ha^{-1} before planting.

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J. Elementol. 2008, 13(2): 261–268

EFFECT OF SOIL SUBSTRATE ON THE CHEMICAL COMPOSITION OF FRUIT OF SOME TOMATO CULTIVARS GROWN IN AN UNHEATED PLASTIC TUNNEL

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Abstract

The effect of cultivar and soil substrate on the chemical composition of tomato fruit was studied in an experiment conducted over the years 2004-2006 in an unheated plastic tunnel. The experimental materials comprised eight tomato cultivars: Atut F_1, Baron F_1, Bekas F_1, Carmello F_1, Gracja F_1, Ognik F_1, Słonka F_1, Terra F_1, as well as two types of soil: peat substrate purchas and hotbed soil. Tomato fruit was assayed for the content of: dry matter, L-ascorbic acid, total sugars, simple sugars, organic acids and nitrates. The levels of dry matter and L-ascorbic acid in tomato fruit were found to be significantly dependent on both the cultivar and the cultivar-substrate interaction. Cultivar Atut F_1 had the lowest water content of fruit, while cv. Terra F_1 was the richest source of L-ascorbic acid. The fruit of tomato cultivars grown in hotbed soil accumulated more dry matter. Hotbed soil, compared to peat substrate, had a more beneficial influence on the concentrations of sugars and nitrates in tomato fruit. The average $N\text{-}NO_3$ content of the fruit of the investigated tomato cultivars was below the maximum permissible level, whose exceedance would pose a hazard to human health. The fruit of all tomato cultivars accumulated more nitrates when grown in peat substrate. The lowest nitrate content was recorded in cv. Bekas F_1.

Key words: tomato, cultivar, soil substrate, chemical composition.

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WPŁYW PODŁOŻA NA SKŁAD CHEMICZNY OWOCÓW KILKU ODMIAN POMIDORA UPRAWIANEGO W TUNELU FOLIOWYM NIEOGRZEWANYM

Abstrakt

Badania wpływu odmiany i podłoża zastosowanego w uprawie pomidora na skład chemiczny owoców przeprowadzono w nieogrzewanym tunelu foliowym w latach 2004-2006. Materiał do badań stanowiło osiem odmian pomidora: Atut F_1, Baron F_1, Bekas F_1, Carmello F_1, Gracja F_1, Ognik F_1, Słonka F_1, Terra F_1 oraz dwa podłoża: torfowe i ziemia inspektowa. Owoce pomidora poddano analizie chemicznej na zawartość: suchej masy, kwasu L-askorbinowego, cukrów ogółem i prostych, kwasów organicznych oraz azotanów. Poziom zawartości suchej masy i kwasu L-askorbinowego w owocach pomidora istotnie zależał od uprawianej odmiany oraz jej współdziałania ze stosowanym podłożem. Najmniej wody w owocach zawierała odmiana Atut F_1, a najwięcej kwasu L-askorbinowego – odmiana Terra F_1. Owoce z uprawy roślin w ziemi inspektowej nagromadziły więcej suchej masy. Podłoże z ziemi inspektowej, w porównaniu z torfem wysokim, miało również korzystny wpływ na zawartość cukrów i azotanów w owocach pomidora. Średnia zawartość $N\text{-}NO_3$ w owocach badanych odmian pomidora była mniejsza od dopuszczalnego poziomu uznanego za szkodliwy dla zdrowia ludzkiego. Podłoże torfowe miało jednak wpływ na zwiększone gromadzenie azotanów w owocach wszystkich odmian. Najmniejszą ich zawartość odnotowano w owocach odmiany Bekas F_1.

Słowa kluczowe: pomidor, odmiana, podłoże, skład chemiczny.

INTRODUCTION

The increasing economic significance of tomato fruit is a consequence of their high biological value, specific taste and flavor as well as a wide range of uses and applications. Tomatoes are consumed throughout the year, both raw (approx. 50%) and canned or processed, in the form of juice, paste and concentrate (Statistical Yearbook 2005).

The chemical composition of tomatoes grown under protective structures may be controlled by selecting the appropriate substrate type and cultivars marked by a high nutritive value of fruit (Martyniak-Przybyszewska 2000, Kobryń et al. 2007, Winiarska, Kołota 2007).

The objective of this study was to compare the chemical composition of fruit of eight tomato cultivars grown in two types of soil substrate in an unheated plastic tunnel.

MATERIALS AND METHODS

A two-factorial experiment was performed in an unheated plastic tunnel at the Experimental Garden of the University of Warmia and Mazury in Olsztyn, during the years 2004-2006, in a randomized complete block design, in three replications. The first experimental factor was eight tomato cultivars: Atut F_1, Baron F_1, Bekas F_1, Carmello F_1, Gracja F_1, Ognik F_1, Słonka F_1 and Terra F_1, and the second experimental factor was two types of soil: peat substrate and hotbed soil.

Seedlings were grown in a hothouse. Seeds were sown each year in the middle of March. Seedlings were planted in pots (10 cm in diameter), filled with peat substrate or hotbed soil. The chemical composition of peat substrate, saturated with mineral nutrients, was as follows: N-NO_3 – 100, P – 80, K – 215, Ca – 1240, Mg – 121 mg·dm^{-3}; pH in H_2O – 5.9, salt concentration – 1.5 g·dm^{-3}. Hotbed soil was a mixture of organic and mineral components: N-NO_3 – 200, P – 390, K – 185, Ca – 2330, Mg – 284 mg·dm^{-3}; pH in H_2O – 6.9, salt concentration – 1.9 mg·dm^{-3}. In the first week of May seedlings were planted in an unheated plastic tunnel, at the 100x50 cm spacing, 5 plants per replication. Tomato plants were allowed to develop one stem and six clusters. Cultivation was carried out in accordance with the recommendations for tomatoes grown under protection.

Fruit were harvested from the third week of July to the middle of September. A total of around 15 harvests were conducted each year. Fifteen ripe tomato fruit were picked per treatment to determine the content of: dry matter – by drying the collected plant material at 105°C to constant weight, L-ascorbic acid – by the Tillmans method modified by Pijanowski, sugars – by the Luff-Schoorl method, organic acids – expressed as malic acid equivalents, as described by Pieterburgski, and nitrates – with the use of salicylic acid.

The results were verified statistically by analysis of variance. The significance of differences between mean values was estimated with the use of Tukey's confidence intervals at a significance level of 5%.

RESULTS AND DISCUSSION

The biological value of fresh tomato fruit is dependent on weather conditions during the growing season, and on agronomic factors (Martyniak-Przybyszewska, 2000, Kołota, Winiarska 2005). According to Halmann, Kobryń (2002) and Nurzyński (2002), the most suitable organic substrates for growing tomatoes under protection include: low-moor peat mixed with pine bark, coconut fiber and straw. The present experiment revealed that the chemical composition of the edible parts of tomato plants is affected by cultivar, substrate type and their interaction (Table 1).

The dry matter content of tomato fruit ranged from 4.44% to 6.28%, and it was significantly dependent on both the cultivar and the cultivar-substrate interaction. The results are similar to those reported by Rożek (2001), Martyniak-Przybyszewska (2000) and Winiarska and Kołota (2007).

Table 1

Chemical composition of tomato fruit – means of the years 2004-2006

Cultivar	Substrate	Dry matter (%)	L-ascorbic acid ($mg \cdot 100 g^{-1}$)	Sugar total ($g \cdot 100 g^{-1}$)	Sugar mono-saccharides ($g \cdot 100 g^{-1}$)	Organic acids
Atut F_1	peat substrate	6.23	9.42	2.03	1.98	0.40
	hotbed soil	6.19	14.36	2.45	2.24	0.47
	average	6.21	11.89	2.24	2.11	0.44
Baron F_1	peat substrate	5.20	14.81	2.45	0.97	0.54
	hotbed soil	5.75	14.81	1.20	0.97	0.27
	average	5.39	14.81	1.83	0.97	0.40
Bekas F_1	peat substrate	5.00	17.95	1.20	0.48	0.34
	hotbed soil	5.75	13.46	3.30	2.24	0.60
	average	5.38	15.71	2.25	1.36	0.57
Carmello F_1	peat substrate	4.44	14.36	1.22	1.20	0.60
	hotbed soil	5.42	9.87	2.45	1.98	0.54
	average	4.93	12.12	1.84	1.59	0.47
Gracja F_1	peat substrate	5.95	11.22	1.47	0.80	0.54
	hotbed soil	5.58	14.36	1.72	1.62	0.47
	average	5.77	12.79	1.60	1.21	0.50
Ognik F_1	peat substrate	5.19	13.46	2.03	1.72	0.34
	hotbed soil	6.28	11.67	3.30	1.47	0.54
	average	5.75	12.57	2.67	1.60	0.44
Słonka F_1	peat substrate	6.16	17.95	1.62	1.22	0.40
	hotbed soil	4.72	11.67	3.30	2.24	0.27
	average	5.44	14.91	2.46	1.73	0.34
Terra F_1	peat substrate	6.02	15.71	1.72	1.62	0.40
	hotbed soil	5.94	18.85	2.24	1.20	0.40
	average	5.98	17.28	1.98	1.41	0.40
Average	peat substrate	5.52	14.36	1.72	1.25	0.45
	hotbed soil	5.68	13.63	2.50	1.75	0.44
$LSD_{0.05}$						
cultivar		0.75	3.05	n.s.	n.s.	n.s.
substrate		n.s.	n.s.	0.44	0.37	n.s.
interaction		0.89	1.99	0.90	0.84	n.s.

Fruit of cv. Ognik F_1 grown in hotbed soil had the highest dry matter content, while fruit of cv. Carmello F_1 grown in peat substrate – the lowest (4.44%).

L-ascorbic acid concentration in tomato fruit was also affected by cultivar and cultivar-substrate interaction, and it varied from 9.42 to 18.85 mg per 100 g of edible parts. These values are similar to those reported by KUNACHOWICZ et al. (2006), and the fact that particular tomato cultivars differ with respect to L-ascorbic acid content has been previously demonstrated by KOBRYŃ et al. (2007) and WINIARSKA and KOŁOTA (2007). Fruit of cv. Terra F_1 contained the largest quantities of L-ascorbic acid, and fruit of Atut F_1 – the smallest. An analysis of the interactions between experimental factors indicated that L-ascorbic acid concentration in the edible parts of tomato plants decreased significantly in cv. Atut F_1 grown in peat substrate, and it reached the highest level in cv. Terra F_1 grown in hotbed soil.

The content of total and simple sugars in the edible parts of tomato plants was significantly affected by substrate type and substrate-cultivar interaction. In both cases the concentration of the above compounds in tomato fruit was higher in plants grown in hotbed soil and lower in those grown in peat substrate, with the difference reaching 0.78 $g \cdot 100\ g^{-1}$ for total sugars and 0.50 $g \cdot 100\ g^{-1}$ for simple sugars. An increase in the sugar content of tomato fruit was noted in cv. Ognik F_1, Bekas F_1 and Słonka F_1, grown in hotbed soil.

The average organic acid content of tomato fruit, expressed as malic acid equivalents, ranged from 0.27 to 0.60 $g \cdot 100\ g^{-1}$, but these differences were statistically non-significant. Comparable amounts of organic acids were reported by MARTYNIAK-PRZYBYSZEWSKA (2000) and ROŻEK (2001).

The average nitrate content of fruit of the investigated tomato cultivars was below the maximum permissible level, whose exceedance would pose a hazard to human health (250 mg $N\text{-}NO_3 \cdot kg^{-1}$ fresh weight) (Journal of Laws No. 2 of 2005, item 9). Nitrate accumulation was influenced by tomato cultivar and substrate type, and it varied from 52.6 to 193.5 mg $N\text{-}NO_3 \cdot kg^{-1}$ fresh weight (Figure 1). Among the analyzed tomato cultivars, the lowest $N\text{-}NO_3$ content was recorded in cv. Bekas F_1, while the highest – in cv. Gracja F_1. A particularly small quantity of the above compounds was observed in cv. Baron F_1 grown in hotbed soil, whereas cv. Słonka F_1 grown in peat substrate was characterized by the highest nitrate concentration. The effect of cultivar and substrate on nitrate levels in the edible parts of vegetables has been previously described by ROŻEK (2000).

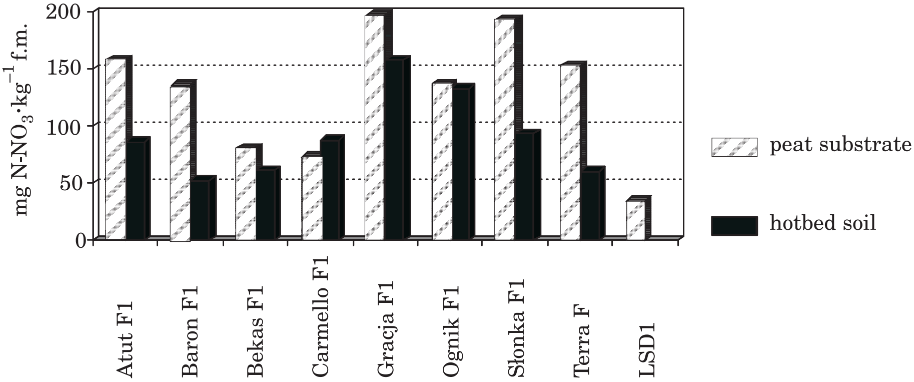

Fig. 1. Effect of cultivar and soil substrate on the nitrate content of tomato fruit

CONCLUSIONS

1. The content of dry matter and L-ascorbic acid in the edible parts of tomato plants was significantly affected by cultivar. The highest concentrations of dry matter and vitamin C were recorded in cv. Atut F_1 and Terra F_1 respectively.

2. Hotbed soil, compared to peat substrate, contributed to a significant increase in sugar concentrations and to a significant decrease in nitrate levels in tomato fruit.

3. Substrate-cultivar interaction was found to exert a statistically significant effect on the content of dry matter, L-ascorbic acid, total sugars and simple sugars in the edible parts of tomato plants. Fruit of cv. Ognik F_1 grown in hotbed soil had the highest content of dry matter and total sugars, in comparison with the other treatments.

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J. Elementol. 2008, 13(2): 269–274

CONTENT OF MACROELEMENTS IN EGGPLANT FRUITS DEPENDING ON NITROGEN FERTILIZATION AND PLANT TRAINING METHOD

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Abstract

Eggplant fruits are known for being low in calories but rich in minerals, which is good for human health. They are rich in potassium, whose content ranges from 200 to 600 mg $K \cdot 100\ g^{-1}$ of fresh mass, depending on a cultivar. Eggplant fruits are also a source of magnesium, calcium and iron. Research on the agro-techniques of eggplant culture in a plastic tunnel has implicated that, on account of a very intensive growth of the plant, both plant pruning and training have a decisive influence on the final amount of fresh mass. Since we lack information concerning the fertilization recommendation for growing eggplants under a plastic tunnel, a study has been undertaken to specify such nutritional needs of this vegetable. The aim of this work has been to determine the influence of nitrogen forms and plant training methods on the content of nitrogen, phosphorus, potassium, calcium and magnesium in eggplant fruits. The experiment on cv. Epic F_1 eggplant was carried out in years 2004-2005, with eggplants growing in an unheated plastic tunnel. The eggplants were cultivated in cylinder plastic wraps of 10 dm^3 volume, in peat. The experiment was carried out in two stages, in a completely random design, with each stage examining different factors. The following factors were examined: I – nitrogen forms: NH_4^+ (ammonium sulphate – $(NH_4)_2SO_4$ (20,5% N); NO_3^- (calcium nitrate – $Ca(NO_3)_2$ (15,5% N); NH_2 (urea – $CO(NH_2)_2$ (46% N), II – plant training method: natural form of the plant, 3 shoots.

Nitrogen was used in the amount of 10 g $N \cdot plant^{-1}$. Samples of fruits used for further laboratory tests were collected in the 2nd decade of August, in the middle of fructification. The fruits were harvested at the marketable stage. N-total, P, K, Ca, Mg were determined in the fruits. The results were elaborated statistically using analysis of variance. Generally, considerably higher content of nitrogen was determined in eggplant fruits fertilised with the N ammonium form; also the content of potassium and magnesium was much higher in comparison to

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the other nitrogen forms examined. Moreover, significant influence of the plant pruning method on the content of the elements was found, independently of the applied nitrogen fertilization.

Key words: eggplant fruits, nitrogen form, plant training, chemical composition.

ZAWARTOŚĆ MAKROSKŁADNIKÓW W OWOCACH OBERŻYNY W ZALEŻNOŚCI OD FORMY ZASTOSOWANEGO NAWOZU AZOTOWEGO I SPOSOBU PROWADZENIA ROŚLIN

Abstrakt

Owoce oberżyny odznaczają się niską kalorycznością oraz korzystnym dla człowieka składem mineralnym. Są przede wszystkim zasobne w potas, którego zawartość waha się w zależności od odmiany od 200 do 600 mg K·100 g^{-1} świeżej masy. Są również źródłem magnezu, wapnia i żelaza. W badaniach nad agrotechniką oberżyny uprawianej pod folią wykazano, że ze względu na intensywny wzrost roślin, zabiegiem plonotwórczym kształtującym ilość zielonej masy jest cięcie i formowanie roślin. Z powodu braku informacji o zaleceniach nawozowych do uprawy oberżyny pod osłonami, podjęto badania nad określeniem potrzeb nawożenia tego warzywa. Celem pracy było określenie wpływu formy nawozu azotowego oraz sposobu prowadzenia roślin na zawartość azotu, fosforu, potasu, wapnia i magnezu w owocach oberżyny. Badania oberżyny odmiany Epic F_1 wykonano w nieogrzewanym tunelu foliowym w latach 2004-2005. Oberżynę uprawiano w torfie ogrodniczym, w cylindrach z folii sztywnej o pojemności 10 dm^3. Doświadczenie dwuczynnikowe przeprowadzono w układzie kompletnej randomizacji. Badano wpływ czynników: I – forma azotu: NH_4^+ [siarczan amonu – $(NH_4)_2SO_4$ – 20,5% N]; NO_3^- [saletra wapniowa – $Ca(NO_3)_2$ – 15,5% N]; NH_2 [mocznik – $CO(NH_2)_2$ – 46% N]; II – sposobu prowadzenia roślin: forma naturalna; 3 pędy. Azot zastosowano w ilości 10 g N·$roślina^{-1}$. Próby owoców do badań laboratoryjnych pobrano w 2 dekadzie sierpnia, w połowie okresu owocowania. Owoce zbierano w fazie dojrzałości użytkowej i oznaczono w nich N-og., P, K, Ca, Mg. Wyniki opracowano metodą analizy wariancji. Największą zawartość azotu ogółem, potasu i magnezu stwierdzono w owocach roślin nawożonych siarczanem amonu, w porównaniu z pozostałymi zastosowanymi nawozami. Ponadto stwierdzono wyższą zawartość makroskładników w owocach roślin prowadzonych na 3 pędy.

Słowa kluczowe: owoce oberżyny, formy azotu, prowadzenie roślin, skład chemiczny.

INTRODUCTION

Interest in eggplant cultivation and consumption has recently been growing in Poland. Eggplant fruits are low in calories and have mineral composition which is beneficial for human health. They are abundant in potassium: from 200 to 600 mg K·100 g^{-1} of fresh matter. They are also a rich source of magnesium, calcium, and iron (Herrmann 1996, Lawende, Chowan 1998, Kowalski et al. 2003, Markiewicz, Golcz 2003, Golcz et al. 2005).

Studies on agronomic aspects of covered eggplant culture have revealed that as the plants grow intensively, the pruning and forming of eggplants are the yield-forming operations that mostly shape the green matter quantity (Ambroszczyk, Cebula 2000, 2003, Passarakli, Dris 2003). There is little information in the available literature on nutritional requirements of eggplants grown in covered culture. Up-to-date fertilization recommendations for this vegetable are based on the tomato's nutritional needs (Uliński, Glapś, 1998). At present, experiments have been undertaken to evaluate fertilization requirements of eggplants with a view to achieving quality yields (Golcz et al. 2005, Michałojć, Buczkowska 2007).

The present paper aims at evaluating the influence of nitrogen form and plant training on nitrogen, phosphorus, potassium, calcium, and magnesium content in eggplant fruits.

MATERIAL AND METHODS

In 2004-2005, trials on cv. Epic F_1 eggplant under unheated plastic tunnel were carried out at the Experimental Farm in Felin, University of Agriculture, Lublin. Potted eggplant seedlings were prepared in accordance with the commonly accepted recommendations for this species. In both years, plants were set under the covering at the beginning of June. The cultivation period from seed sowing until harvest was about 7 months (beginning of March – mid of September).

Eggplants were cultivated in plastic cylinder wraps of 10 dm^3 volume on horticultural peat (initial pH_{H_2O} 4.6) limed with $CaCO_3$ to pH 6.5. A two-factorial experiment was set in a completely random design. Every experimental object was represented by 8 experimental units.

The influence of the two following factors was studied:

nitrogen form: NH_4^+ – ammonium sulfate [$(NH_4)_2SO_4$ (20.5% N)]; NO_3^- – calcium nitrate [$Ca(NO_3)_2$ (15.5% N)]; NH_2 - urea [$CO(NH_2)_2$ (46% N)];

plant training system: natural form; 3 shoots.

Fertilization expressed in $g \cdot plant^{-1}$ was: nitrogen (N) – 10; phosphorus (P) – 7.0 as superphosphate [$Ca(H_2PO_4)_2 \cdot H_2O$ – 20.2% P]; potassium (K) – 16 as potassium sulfate [K_2SO_4 – 41.6% K]; magnesium (Mg) – 7.0 as magnesium sulfate ($MgSO_4 \cdot H_2O$ 17.4% Mg). The microelements were applied as: EDTA – Fe, $CuSO_4 \cdot 5H_2O$, $ZnSO_4 \cdot 7H_2O$, $MnSO_4 \cdot H_2O$, H_3BO_3, $(NH_4)_2Mo_7O_{24} \cdot 4H_2O$ at the rates recommended for peat substrates. When preparing the growing medium, all the microelements, half a phosphorus dose and 1/7 nitrogen, potassium, and magnesium doses were applied before planting the seedlings. The remaining amounts of nitrogen, potassium, and magnesium were subsequently sown in 6 doses every 10 days, while the remaining phosphorus was added at the beginning of eggplant ripening.

Plants were trained in two systems: in their natural form with no pruning and with 3 main shoots left. The pruning was gradually performed as the shoots were growing. Eggplant fruits were harvested at the marketable stage, i.e. when the skin was glossy, deep purple (the weight of harvested fruits ranged from 250 to 300 g). The harvest repeated every 7-10 days since the end of July to the end of September.

Fruit samples for laboratory analyses were collected in the 2^{nd} decade of August, in the middle of fructification. The following elements were determined after wet digestion: N – total with Kjeldahl's method (Kjel-Foss) and after dry combustion at 550°C; P – colorimetrically using ammonium molybdenate; K, Ca, Mg – applying the AAS technique (Perkin–Elmer). All determinations were made in 3 replications and the final results of N, P, K, Mg, and Ca were expressed in $g \cdot kg^{-1}$ of dry matter.

The results were statistically processed using analysis of variance. Significant differences were found by Tukey's multiple confidence intervals at 5% level.

RESULTS AND DISCUSSION

Total nitrogen content in eggplant fruits was from 17.7 to 22.1 g $N \cdot kg^{-1}$ d.m. The nitrogen forms and plant training methods examined significantly differentiated the level of nitrogen in eggplant fruits. Considerably more nitrogen was found in plants fertilized with the reduced ($N\text{-}NH_4$, NH_2) rather than oxidized nitrogen form ($N\text{-}NO_3$) – Table 1. Higher conversion rate of reduced nitrogen forms in eggplant can account for such a dependence, which was confirmed by Asiegbu et al. (1991), Golcz et al. (2005), Michałojć, Buczkowska (2007).

The content of phosphorus was from 2.7 to 2.9 g $P \cdot kg^{-1}$ d.m. No significant influence of the applied nitrogen forms on its concentration in eggplant fruits was observed. Seviader, Morse (1982) found a similar content of the element in their studies on phosphorus fertilization of eggplant.

The level of potassium ranged from 22.6 to 30.2 g $K \cdot kg^{-1}$ d.m. and, like nitrogen, was significantly differentiated by the experimental factors. Considerably more potassium was found in eggplant fruits from plants fertilized with ammonium sulfate (27.9 g $K \cdot kg^{-1}$ d.m.), as compared to those fertilized with other nitrogen forms. Potassium is easily taken up and transported within a plant, thus it is found in high concentrations in plants' generative parts. Abdel Hafeez, Cornillon (1976), Savvas i Lenz (1994), Russo (1996) found similar or even higher levels of potassium in eggplant fruits.

The concentration of calcium level was from 1.2 to 1.7 g $Ca \cdot kg^{-1}$ d.m. Significantly more calcium was found in plants fertilized with ammonium sulfate, less in the objects where calcium nitrate was applied as a fertilizer.

Table 1

The content of macroelements in eggplant fruits depending on nitrogen fertilization and plant training method

Nitrogen fertilization	Plant training method 1* natural form 2* 3 stems	Content of mineral elements (mg·kg^{-1} d.m.)				
		N - total	P	K	Ca	Mg
$(NH_4)2SO_4$	1*	22.1	2.90	25.60	1.50	1.30
	2*	21.8	2.80	30.20	1.70	1.50
	average	22.0	2.90	27.90	1.60	1.40
$Ca(NO_3)_2$	1*	17.7	2.60	24.60	1.30	1.30
	2*	21.6	2.90	27.70	1.40	1.30
	average	19.6	2.70	26.10	1.30	1.30
$CO(NH_2)_2$	1*	19.8	2.70	22.60	1.20	1.10
	2*	21.9	2.90	25.60	1.70	1.30
	average	20.9	2.80	24.10	1.50	1.20
Average	1*	19.9	2.70	24.30	1.30	1.20
	2*	21.8	2.90	27.80	1.60	1.40
	average	20.9	2.80	26.00	1.50	1.30
LSD p=0.05 for kind of nitrogen fertilization		1.910	n. s.	2.340	0.19	n. s.
LSD p=0.05 for plant training method		1.290	0.130	1.610	0.13	0.19
LSD p=0.05 for interaction (a x b)		3.330	n. s.	4.130	0.34	n. s.

Magnesium content in eggplant fruits was similar to that of calcium: from 1.1 to 1.5 g Mg·kg^{-1} d.m. No significant influence of the nitrogen fertilizer on magnesium level in eggplant fruits was found. Tests by GOLCZ and MARKIEWICZ (2005) on eggplants cultivated on organic soils used several times revealed similar calcium and magnesium levels.

Regardless of the nitrogen form applied, significant influence of the plant training method on the total nitrogen, phosphorus, potassium, calcium, and magnesium contents in eggplant fruits was observed. Considerably higher levels of these elements were found in fruits of plants trained for 3 shoots than growing in the natural form. There are no data on the influence of a plant training methods on mineral content in eggplant fruits in available literature; nonetheless, AMBROSZCZYK and CEBULA (2000) demonstrated that the regulation of fruit bud number trained for a single shoot affected the biological value of eggplant fruits.

CONCLUSIONS

1. The highest concentrations of total nitrogen, potassium, and magnesium were determined in fruits of plants fertilized with ammonium sulfate as compared to other fertilizers.

2. Higher contents of macroelements were found in fruits of plants trained for 3 shoots.

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J. Elementol. 2008, 13(2): 275–280

EFFECT OF USING COVERS IN EARLY CROP POTATO CULTURE ON THE CONTENT OF PHOSPHPRUS AND MAGNESIUM IN TUBERS

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Abstract

Potassium is the main mineral component of potato tubers. With a high level of potato consumption, the crop also supplies the human organism with magnesium and phosphorus. The content of mineral components in potato tubers may change as an effect of agro-technical factors. The aim of the study was to determine the effect of the type of cover (perforated polyethylene film, polypropylene fibre) and date of its removal (2 and 3 weeks after plant emergence) on phosphorus and magnesium in tubers of early potato cultivars (Aksamitka, Cykada). The potatoes were harvested 60 days after planting. Accelerated plant growth under covering resulted in the phosphorus content in tubers of cv. Aksamitka being 0.088 g kg^{-1} d.m. higher in comparison with thecontrol, but did not affect the content of magnesium. With perforated film used to cover potato plants, an average content of phosphorus in tubers was by 0.217 g kg^{-1} d.m than when polypropylene fibre cover was applied. The content of magnesium in tubers was on average 0.067 g kg^{-1} d.m. higher under polypropylene fibre cover. Duration of the period when potato plants grew under cover did not significantly affect the phosphorus and magnesium accumulation in tubers.

Key words: early potato, perforated film, polypropylene fibre, phosphorus, magnesium.

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WPŁYW STOSOWANIA OSŁON W UPRAWIE ZIEMNIAKA NA WCZESNY ZBIÓR NA ZAWARTOŚĆ FOSFORU I MAGNEZU W BULWACH

Abstrakt

Głównym składnikiem mineralnym bulw ziemniaka jest potas. Spożywanie ziemniaków pokrywa również częściowo zapotrzebowanie organizmu człowieka na fosfor i magnez. Zawartość składników mineralnych w bulwach ziemniaka może ulegać zmianom pod wpływem czynników agrotechnicznych. Celem badań było określenie wpływu rodzaju osłony (folii perforowanej, włókniny polipropylenowej) i terminu jej zdjęcia (2 i 3 tygodnie po wschodach roślin) na zawartość fosforu i magnezu w bulwach wczesnych odmian ziemniaka (Aksamitka, Cykada). Ziemniaki zbierano po 60 dniach od sadzenia. Przyspieszenie wegetacji roślin przez stosowanie osłon spowodowało zwiększenie zawartości fosforu w bulwach odmiany Aksamitka średnio o 0,088 $g \cdot kg^{-1}$ s.m. w porównaniu z uprawą bez osłaniania roślin, ale nie miało wpływu na gromadzenie w bulwach magnezu. W przypadku stosowania folii perforowanej zawartość fosforu w bulwach była większa, średnio o 0,217 $g \cdot kg^{-1}$ s.m., niż przy stosowaniu włókniny. Większą zawartość magnezu, średnio o 0,067 $g \cdot kg^{-1}$ s.m., stwierdzono po zastosowaniu włókniny. Długość okresu okrycia roślin nie miała wpływu na zawartość obu pierwiastków w bulwach ziemniaka.

Słowa kluczowe: ziemniak wczesny, folia perforowana, włóknina polipropylenowa, fosfor, magnez.

INTRODUCTION

Potato tubers contain over 1% mineral compounds, mainly potassium, in fresh mass. With a high potato consumption in some countries, this crop can also supply the human organism with magnesium and phosphorus. Two-hundred grams of potatoes provide 8-15% recommended daily amount of magnesium and 8-12% of phosphorus (Kolasa 1993, Leszczyński 2000). The content of mineral components in potato tubers depends on the genetic characters of a cultivar, but may change under climatic and agro-technical factors (Czekała, Gładysiak 1995, Klikocka 2001, Kołodziejczyk, Szmigiel 2005).

Until now, studies on the effect of covers used in early crop potato culture on the chemical composition of tubers have focused mostly on organic compounds (Lachman et al. 2003, Wadas et al. 2003, 2007, Dvořák et al. 2006). The aim of the present study was to determine the effect of potato plants being covered, for various lengths of time, on phosphorus and magnesium in immature potato tubers.

MATERIAL AND METHODS

The effect of the type of cover (perforated polyethylene foil, polypropylene fibre) and the date of its removal (I – 2 weeks after plant emergence, II

– 3 weeks after plant emergence) on phosphorus and magnesium in tubers of early potato cultivars (Aksamitka, Cykada) was investigated.

The study was carried out in the years 2002–2004 at the Department of Vegetable Crops, University of Podlasie in Siedlce. The field experiment was established in a split–block split–plot design with the control object not covered, on soil characterised by a low to moderate content of available potassium and moderate to high content of phosphorus and magnesium, pH_{KCl} 6.1–6.7. In each year of the study spring triticale was grown as a potato forecrop. Farmyard manure was applied in autumn, at a rate of 30 t ha^{-1}. Mineral fertilizers were applied in spring at the recommended rates of 60 kg N (ammonium nitrate 34%), 26 kg P (60 kg P_2O_5, granular superphosphate 19%) and 75 kg K (90 kg K_2O, potassium sulphate 60%) per 1 ha. In the successive years 8-week pre-sprouted seed potatoes were planted on 9, 16 and 13 April. The potatoes were harvested 60 days after planting. The content of phosphorus with vanadium-molibdenum colorimetric method and magnesium with atomic absorption spectrometry (AAS) method were determined. The analysis of the results was conducted using the orthogonal contrast to compare the control with the test objects.

The most favourable weather conditions for early crop potatoes were in a very warm and wet vegetation period of 2002 (Table 1). The year 2003 was warm but with the whole potato growth season was marked by seasonal drought. In contrast, the year 2004 was the coldest one with the least rainfall from mid–May to mid–June.

Table 1

Mean air temperature and precipitation sums in the vegetation period of potato

Years	Temperature (°C)			Precipitation (mm)		
	April	May	June	April	May	June
2002	9.0	17.0	17.2	12.9	51.3	61.1
2003	7.1	15.6	18.4	13.6	37.2	26.6
2004	8.0	11.7	15.4	35.9	97.0	52.8
Mean 1981–2000	8.1	11.2	16.7	49.6	48.2	67.7

RESULTS AND DISCUSSION

The content of phosphorus in potato tubers ranged from 2.730 to 3.733 g kg^{-1} d.m.; that of magnesium varied from 1.267 to 1.670 g kg^{-1} d.m. (Tables 2 and 3). Irrespective of the potato culture method, most phosphorus and magnesium was accumulated by potato tubers in 2003 and 2004, when drought occurred in the period of tuber formation and growth, which was in contrast to a very warm and wet year 2002. According to Czekała and

Table 2

Phosphorus content in potato tubers (g·kg^{-1} d.m.)

Years	Cultivar	Control object no covering	Kind and date of cover removal						Mean for covers
			perforated film			polypropylene fibre			
			I	II	mean	I	II	mean	
2002	Aksamitka	2.967	2.967	3.000	2.983	2.767	2.933	2.850	2.917
	Cykada	3.033	2.767	3.100	2.933	2.767	2.730	2.750	2.842
	mean	3.000	2.867	3.050	2.958	2.767	2.832	2.800	2.879
2003	Aksamitka	3.067	3.133	3.300	3.217	2.900	2.867	2.883	3.050
	Cykada	3.100	3.267	3.130	3.200	2.833	2.870	2.850	3.025
	mean	3.083	3.200	3.215	3.208	2.867	2.868	2.867	3.038
2004	Aksamitka	3.133	3.400	3.733	3.567	3.333	3.400	3.367	3.467
	Cykada	3.267	3.633	3.267	3.450	3.467	3.230	3.350	3.400
	mean	3.200	3.516	3.500	3.508	3.400	3.320	3.358	3.433
Mean		3.094	3.194	3.255	3.225	3.011	3.010	3.008	3.117

$LSD_{0.05}$:
years = 0.146
comparison the control object with remaining (contrast) = n.s.
contrast x cultivar = 0.068
kind of cover = 0.159
date of cover removal = n.s.

GŁADYSIAK (1995), phosphorus in potato tubers was negatively correlated with the air temperature prevailing from plant emergence to flowering, while magnesium was reversely correlated with the field water capacity from flowering to the early canopy drying time, the finding which was confirmed in the present study. According to other authors, potato tubers harvested in a wet year contain more magnesium, whereas the accumulation of phosphorus does not depend on meteorological conditions (KOŁODZIEJCZYK, SZMIGIEL 2005).

Stimulating plant growth by using plant covers resulted in increased phosphorus content in tubers of cv. Aksamitka (by 0.088 g·kg^{-1} d.m., on average) in a three-year period in comparison with the cultivation without plant covering, but did not significantly affect the content of this element in tubers of cv. Cykada. The use of covers in the early crop potato culture slightly affected the accumulation of magnesium in tubers. The present study showed a significant affect of the type of cover on phosphorus and magnesium content in tubers. Phosphorus content was higher by an average of 0.217 g·kg^{-1} d.m. over a three-year period when perforated film cover was applied. The content of magnesium content rose by 0.067 g·kg^{-1} d.m. when polypropylene fibre cover was used. Polypropylene fibre plant cover proved to be most effective in enhancing magnesium concentration in tu-

Table 3

Magnesium content in potato tubers ($g \cdot kg^{-1}$ d.m.)

Years	Cultivar	Control object no covering	Kind and date of cover removal						Mean for covers
			perforated film			polypropylene fibre			
			I	II	mean	I	II	mean	
2002	Aksamitka	1.267	1.300	1.167	1.233	1.367	1.367	1.367	1.300
	Cykada	1.333	1.267	1.170	1.217	1.333	1.300	1.317	1.267
	mean	1.300	1.283	1.168	1.225	1.350	1.334	1,342	1.283
2003	Aksamitka	1.533	1.600	1.567	1.583	1.633	1.600	1.617	1.600
	Cykada	1.567	1.567	1.500	1.533	1.533	1.670	1.600	1.567
	mean	1.550	1.583	1.534	1.558	1.583	1.635	1.608	1.583
2004	Aksamitka	1.500	1.500	1.500	1.500	1.500	1.533	1.517	1.508
	Cykada	1.500	1.533	1.400	1.467	1.467	1.570	1.517	1.492
	mean	1.500	1.517	1.450	1.483	1.483	1.552	1.517	1.500
Mean		1.450	1.461	1.384	1.422	1.472	1.507	1.489	1.456

$LSD_{0.05}$:
years = 0.081
comparison the control object with remaining (contrast) = n.s.
kind of cover = 0.028
years x kind of covers = 0.048
date of cover removal = n.s.

bers in the warm and moderately wet vegetation period of the year 2002. With this type of cover, the average magnesium content in tubers was higher by 0.117 $g \cdot kg^{-1}$ d.m. compared to that in tubers grown under perforated film. Polypropylene fibre plant cover also created more favourable conditions for potassium accumulation in tubers (WADAS et al. 2007).

The length of time when potato plants were covered did not significantly affect phosphorus and magnesium accumulation in tubers (Tables 2, 3). Prolongation of the perforated film cover period to 3 weeks after plant emergence raised the phosphorus concentration in tubers but depressed their magnesium content. However, the interaction between the type of cover material and the date when the cover was removed was not statistically confirmed.

The content of phosphorus and magnesium in tubers of very early potato cultivars Aksamitka and Cykada was similar.

CONCLUSIONS

1. Phosphorus and magnesium content in tubers was higher in years with less rainfall in the potato growth season.

2. Plant vegetation being accelerated by application of covering resulted in higher phosphorus content in the tubers of cv. Aksamitka, but had only very weak effect on magnesium.

3. Phosphorus content was higher when perforated film cover was applied; magnesium accumulated best under polypropylene fibre cover.

4. Duration of the period when potato plants grew under cover did not significantly affect the phosphorus and magnesium accumulation in tubers.

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