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EFFECT OF AGROTECHNICAL FACTORS UPON CHEMICAL COMPOSITION OF FENNEL BULBS AND LEAVES *Foeniculum vulgare* Mill. var. *azoricum* (Mill.) Thell.

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Abstract

The field experiment was conducted in the years 2003-2005 in Felin Experimental Station of the University of Life Sciences in Lublin (Poland). The following factors were taken into consideration in the studies: 2 fennel cultivars – Rudy F_1 and Zefa Fino, 3 terms of sowing the seeds – April, May, June; 3 kinds of shields – covering the soil with black polyethylene foil (PE), covering the soil with black polypropylene unwoven (PP 50 g m^{-2}) and flat covering the plants with white polypropylene unwoven (PP 17 g m^{-2}), as well as control (without cover); 3 bulb harvest terms: after 10, 12 and 14 weeks from sowing; bulb weight: <200 g; 200-350 g; >350 g.

The applied mulches, made of PE foil and PP50 unwoven, as well as shielding the plants with PP17 unwoven did not significantly affect the contents of examined nutrients in the fennel bulbs and leaves. Fennel leaves contained more dry matter, N-total, Ca and Mg than the bulbs. The bulbs were more abounding with P and K. The bulbs of plants from June sowing contained the most N-total, nitrates, K, Ca and Mg. In the leaves the most N-total and nitrates were determined after June sowing term, and Ca and Mg after April sowing. Bulbs and leaves of Rudy F_1 cultivar contained more N-total and Ca than these of Zefa Fino cultivar. As the harvest term was delayed, the contents of N-total, P, K, Mg and nitrates in the bulbs decreased, whereas the dry matter content increased. The bulbs with weight < 200 g contained the most N-total, potassium and nitrates, and the least phosphorus. The least potassium, nitrogen and nitrates was found in the bulbs with weight > 350 g.

Key words: fennel, mulching, flat covering, sowing term, harvest term

INTRODUCTION

Fennel - *Foeniculum vulgare* Mill. – is a plant from the Mediterranean Sea basin. It was known and valued already in the antiquity, as a medicinal and seasoning plant. The interest in fennel that has lasted for centuries stemmed from its chemical composition of the oil contained in fruit and gaining fruit was the main aim of growing this species [Németh and Bernáth, 2001].

Foeniculum vulgare Mill. var. *azoricum* (Mill.) Thell. is grown as a vegetable because of its tasty bulbs formed of fleshy and juicy leaf capsules. Fennel bulbs

are easily digestible and have low calorific value, which is merely 98 kJ (24 kcal) in 100 g of fresh weight. However, they are distinguished by high biological value. They are rich in vitamins (C, B_1, B_2, B_6, K, PP, β-carotene) and mineral salts (especially potassium, calcium, sodium, magnesium and phosphorus) [Mencarelli et al. 1996; Tei, 2001; Matthäus and Gysi, 2002; Koudela and Petříková, 2008]. The most fennel is grown in Italy, from where 85% of its production comes [Mencarelli, 2004]. In Poland it is not a very popular vegetable, both in cultivation and consumption.

The aim of conducted studies was to determine the effect of sowing and harvest term, covering the soil and plants, as well as bulb weight upon the chemical composition of two fennel cultivars from field crops.

MATERIAL AND METHODS

The field experiment was conducted in years 2003-2005 in Felin Experimental Station of the University of Life Sciences in Lublin (Poland, 51°23'N, 22°56'E), on a grey-brown podzolic soil derived from loess (Orthic Luvisol), laying on chalk marl, with grain size distribution typical of medium silt loam. In the cultivated layer of soil (0-20 cm) the following were determined (mean values): 16.15-17.28 mg P, 23.82-29.53 mg K and 6.68-10.02 mg Mg $100g^{-1}$ of soil. The soil reaction was contained in the interval from 5.69 to 6.34 pH. The experiment was established by means of completely randomized blocks in 4 replications. The surface of plot for harvest was 3.2 m^2. The following factors were considered in the studies: 3 seed sowing terms – April, May, June (in the third decade of each month); 3 kinds of shields – covering the soil with black polyethylene foil (PE), covering the soil with black polypropylene unwoven (PP 50g m^{-2}) and flat covering the plants with white polypropylene unwoven (PP 17g m^{-2}), as well as control (without cover); 2 cultivars – Rudy F_1 and Zefa Fino; 3 bulb harvest terms: after 10, 12 and 14 weeks from sowing; bulb weight: <200 g; 200-350g; >350g.

The forecrop for fennel was winter wheat. Before winter the field was deep ploughed and in spring it was harrowed and then cultivated. Fertilization was applied before sowing in the amounts of: 80 kg N (ammonium saltpeter), 35.2 kg P (triple superphosphate) and 91.3 kg K (potassium salt) per 1 ha. The seeds were sown in rows - every 40 cm in the amounts of 6 kg ha^{-1}. After the plants have developed 2 proper leaves, thinning was performed, leaving plants every 20 cm in a row. The PP17 unwoven plant covering was removed after ca. 4 weeks from the beginning of emergences. Fennel bulbs and leaves were analyzed in respect to their chemical composition. Immediately after bulb harvest in the fresh material of the usable parts of plants dry matter content was determined (using drier-scales method). We also determined N-total content (by means of Kjeldahl's method, on a Kjeltec System 1002 Distilling Unit apparatus; N-NH_4 and N-NO_3 – in 2% extract of CH_3COOH, using Bremner's distillation method, modified by Starck; phosphorus - colorimetrically; potassium and calcium – using atomic absorption method (ASA). The obtained results were statistically elaborated, by means of variance analysis method. The significance of differences was determined with the use of Tukey's confidence intervals, at the significance level p= 0.05.

Table. 1.
Content of nutrients in fennel bulbs and leaves according to kind of coverings, sowing dates and cultivars in the years 2003-2005

Factors		Dry matter in %		Nutrient in % d.m.											
				Total N		NO_3-N		P		K		Ca		Mg	
		Z	L	Z	L	Z	L	Z	L	Z	L	Z	L	Z	L
Kind of covering	Control	6.51	12.11	2.17	3.46	0.20	0.18	0.50	0.38	6.51	6.11	0.55	1.74	0.20	0.29
	PE	6.37	12.04	2.25	3.42	0.26	0.20	0.50	0.37	6.68	6.07	0.52	1.74	0.19	0.28
	PP50	6.24	12.33	2.33	3.47	0.23	0.24	0.50	0.37	6.69	5.89	0.52	1.75	0.19	0.28
	PP17	6.37	11.89	2.24	3.53	0.21	0.20	0.50	0.38	6.75	5.87	0.54	1.69	0.19	0.28
Month of sowing	IV	6.13	12.67	1.99	3.40	0.18	0.15	0.49	0.38	6.66	5.60	0.54	1.89	0.18	0.30
	V	6.97	12.11	2.07	3.12	0.11	0.17	0.51	0.37	6.27	6.22	0.46	1.73	0.19	0.29
	VI	6.03	11.48	2.68	3.90	0.39	0.28	0.49	0.38	7.04	6.12	0.60	1.56	0.20	0.27
Cultivar	Rudy F_1	6.40	12.33	2.29	3.55	0.22	0.22	0.53	0.41	6.65	5.92	0.56	1.82	0.19	0.30
	ZefaFino	6.35	11.85	2.20	3.39	0.23	0.19	0.47	0.35	6.66	6.04	0.50	1.64	0.19	0.28
Year	2003	6.27	11.26	1.84	3.10	0.14	0.18	0.56	0.42	6.99	6.19	0.65	1.98	0.18	0.27
	2004	6.59	12.55	2.10	3.46	0.22	0.19	0.43	0.35	6.00	5.58	0.41	1.43	0.19	0.27
	2005	6.26	12.47	2.79	3.87	0.32	0.24	0.51	0.38	6.98	6.18	0.55	1.78	0.20	0.32
Mean		6.38	12.09	2.25	3.47	0.23	0.20	0.50	0.38	6.66	5.98	0.53	1.73	0.19	0.29
$LSD_{0.05}$ for:	coverings	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	sowing date	0.31	0.53	0.17	0.21	0.07	0.07	n.s.	n.s.	0.34	0.35	0.04	0.21	0.01	0.02
	cultivars	n.s.	0.29	0.08	0.12	n.s.	n.s.	0.02	n.s.	n.s.	n.s.	0.03	0.13	n.s.	0.01
	years	0.31	0.53	0.17	0.21	0.07	n.s.	0.03	n.s.	0.34	0.35	0.04	0.21	0.01	0.02

*Z – bulbs, L – leaves, n.s. – no significant differences

RESULTS AND DISCUSSION

The dry matter contents in the edible parts of fennel bulbs was on average 6.38% and assumed values from 4.99 to 8.54% (Tab. 1). Fennel leaves contained almost two times more dry matter than the bulbs (on average: 12.09% d.m.). Similar results were obtained by Dyduch and Najda [2005], examining leaf celery. No significant effect of covering the soil and plants upon this parameter was found. Significant differences occurred between sowing terms. In the assessment irrespective of the remaining experimental factors the bulbs of plants from May sowings were distinguished by significantly the greatest quantity of dry matter (on average: 6.97%), and the leaves from April sowings contained 12.67% of dry matter. The least dry matter was contained in the bulbs and leaves of plants sown in June (respectively 6.03 and 11.48%). The examined fennel cultivars did not differ as to the contents of dry matter in the bulbs, whereas more dry matter in leaves was determined in Rudy F_1 (12.33%).

The application of PE foil and PP50 unwoven mulch, as well as covering the plants with PP17 unwoven did not significantly affect the contents of the examined nutrients in fennel bulbs and leaves (Tab. 1). The bulbs contained on average 2.25% N-total in d.m. The content of nitrogen in the leaves was slightly higher than in the bulbs (on average: 3.47% d.m.). Similar results were obtained by Abou El-Magd et al. [2008]. The most N-total was reported in the bulbs of plants from June sowings (2.68% d.m.), and the least in those from April sowings (1.99%). In the fennel leaves the most nitrogen was also determined after sowings in June (3.90%), but the least – after sowings in May (3.12%). Bulbs and leaves of Rudy F_1 cultivar contained more total nitrogen than those of Zefa Fino.

The contents of nitrates in fennel bulbs and leaves were not very high and on average it equaled 0.23% for bulbs and 0.20% for leaves (Tab. 1). This does not confirm the charges that fennel tends to accumulate nitrates. Matthäus and Gysi [2002] determined in fennel petioles 6000-9000 ppm NO_3. More nitrates in leaves and bulbs were accumulated by plants from the last, i.e. June sowing term. Many authors confirm the fact that more nitrates were accumulated in autumn, or in poorer insolation conditions [Michałojć, 2000; Serio et al. 2004; Koudela and Petříková, 2008]. The examined cultivars did not differ in respect to nitrate contents in vegetative organs.

Fennel bulbs contained more phosphorus (on average 0.50% P in d.m.) and potassium (6.66% K in d.m.) than leaves (0.38% P and 5.98% K) (Tab. 1). In the bulbs, however, less calcium and magnesium was determined than in the leaves. Leaves contained more than three times calcium (1.73% Ca in d.m.) than bulbs (0.53%). This is confirmed by studies conducted by Özcan [2004]. However, Mahfouz and Sharaf-Eldin [2007] determined in fennel leaves only 1.04-1.1% N, 0.23% P and 3.35% K in d.m. No effect of mulching was found on the contents of P, K, Ca and Mg in fennel bulbs and leaves. The level of phosphorus did not also depend upon the sowing term, neither did the potassium level depend upon the cultivar. Significantly the most K, Ca and Mg were contained in the bulbs of plants sown in June, as compared to the earlier sowing terms. Also in the studies performed by Koudela and Petříková [2008] the bulbs of fennel grown in autumn

contained more K, Ca and Mg than those from summer growing. The least potassium was contained in the leaves of plants sown in April (5.60% K in d. m.) as compared to later sowings. However, the contents of calcium and magnesium decreased with the delay of sowing term and were the most in the leaves of plants sown in April, and the least – in those from June sowings. The bulbs of Rudy F_1 cultivar accumulated significantly more phosphorus and calcium, and the leaves – more calcium and magnesium than those of Zefa Fino cultivar. The examined cultivars did not differ in their potassium and magnesium contents in the bulbs. The contents of nutrients in fennel bulbs and leaves were significantly modified by the weather course, which is proven by significant differences between study years (Tab. 1). This fact is confirmed by study results obtained by Koudela and Petříková [2008]. The most of dry matter was contained in the bulbs and leaves in the year 2004, but they accumulated the least potassium and calcium. In the year 2005 in the bulbs and leaves we determined the most N-total, nitrates and magnesium. The most P, K and Ca, and the least Mg, N-total and nitrates was contained in the bulbs collected in the year 2003. A low content of nitrates in the plants is enhanced by even distribution of precipitation and the optimum substratum humidity throughout the whole vegetation period [Sady, 2000].

Table. 2.

Content of nutrients in fennel bulbs according to harvest dates and weight of bulbs

Factors		Dry matter in %	Nutrient in % d.m.					
			Total N	NO_3-N	P	K	Ca	Mg
Harvest date	after 10 weeks	5.96	2.58	0.44	0.50	7.04	0.53	0.22
	after 12 weeks	6.30	2.28	0.23	0.52	6.24	0.52	0.20
	after 14 weeks	7.00	2.01	0.19	0.45	6.01	0.53	0.19
Bulb weight	< 200 g	6.35	2.50	0.42	0.45	6.89	0.53	0.20
	200-350 g	6.46	2.28	0.22	0.51	6.51	0.52	0.19
	> 350 g	6.46	2.11	0.21	0.51	6.30	0.53	0.19
Mean		6.38	2.25	0.23	0.50	6.65	0.53	0.19
$LSD_{0.05}$ for:								
harvest date		0.51	0.24	0.10	0.02	0.19	n.s.	0.01
bulb weight		n.s.	0.20	0.07	0.02	0.27	n.s.	n.s.

*n.s. – no significant differences

The bulb harvest term significantly affected their nutritional value (Tab. 2). Together with the harvest delay, the contents of N-total, P, K, Mg and nitrates in

the bulbs significantly decreased, whereas the dry matter contents increased. In the studies by Damato [2000] significant increase of dry matter contents was found in bulbs in the period from 112th to 125th day from sowing. The increased dry matter content in leaf celery petioles, as vegetation went on, was confirmed by Dyduch and Najda [2005]. The harvest term did not affect the calcium contents in the bulbs. The nutritional value of bulbs also depended upon the weight of bulbs (Tab. 2). The bulbs with weight < 200g contained the most N-total (2.50% d.m.), potassium (6.89% d.m.) and nitrates (0.42%). The least potassium (6.30% K in d.m.), nitrogen (2.11%) and nitrates (0.21%) was found in bulbs with weight > 350g. Quite opposite was the phosphorus content in bulbs. The tiniest bulbs contained the least of this component (0.45%). No significant differences were found in the contents of Ca and Mg in the bulbs of different weight. The bulbs weighing from 200 to 350 g and > 350g did not also differ in the contents of dry matter (6.46%), N-total, P, K and nitrates.

CONCLUSIONS

1. Applying mulch of PE foil and PP50 unwoven, as well as covering the plants with PP17 unwoven did not significantly affect the contents of examined nutrients in fennel bulbs and leaves.
2. Fennel leaves contained more dry matter, N-total, Ca and Mg than the bulbs. The bulbs were richer in P and K.
3. The bulbs of plants from June sowing contained the most N-total, nitrates, K, Ca and Mg. In the leaves the most N-total and nitrates was determined after June sowing term, and the most Ca and Mg after sowings in April. The contents of phosphorus in vegetative organs of fennel did not depend on the sowing term.
4. Bulbs and leaves of Rudy F_1 cultivar contained more total nitrogen and Ca than those of Zefa Fino. In the bulbs of the latter also more phosphorus was determined, and in the leaves – more dry matter and Mg than in Zefa Fino cultivar.
5. As the term of harvest was delayed, the contents of N-total, P, K, Mg and nitrates in the bulbs decreased, and the dry matter contents increased.
6. The bulbs of the weight < 200g contained the most N-total, potassium and nitrates, and the smallest quantity of phosphorus. The least potassium, nitrogen and nitrates were found in the bulbs of the weight > 350g.

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