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EFFECT OF SOIL AND PLANT COVERING AS WELL AS SOWING TERM UPON FENNEL BULB NUTRITIONAL VALUE

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Abstract. Fennel (*Foeniculum vulgare* var. *azoricum* Mill.), despite its high dietary value, is not a very popular vegetable in Poland. It bulbs constitute a low-calorie food, abundant in vitamins and mineral salts. They also contain, though in smaller amounts, the essential oil, determining the use of fennel fruit in medicine. In the field experiment with fennel growing the influence of soil mulching and flat plant shielding, as well as sowing term upon the nutritional values of two fennel cultivars, was examined. The studies covered 3 kinds of covers (covering the soil with black polyethylene film PE, covering the soil with black polypropylene unwoven PP 50 g m^{-2} and flat covering of plants with white unwoven PP 17 g m^{-2} (the controls were plots without covers), 3 sowing terms directly in the field, 2 cultivars (Rudy F_1 and Zefa Fino). The applied covers did not significantly affect the nutritional value of fennel bulbs. The bulbs of plants from June sowings contained the most protein, total nitrogen and nitrate nitrogen, as compared to earlier sowing terms. The most dry matter, vitamin C, sugars,0 phosphorus and potassium were determined in fennel bulbs from May sowings. The least protein, sugars and potassium was contained in plant bulbs from April sowings. The bulbs of Rudy F_1 cultivar were more abundant in protein, phosphorus and calcium than those of Zefa Fino cultivar. The cultivars did not differ in dry matter, nitrate, vitamin C, total sugars, fibre and potassium contents in the bulbs.

Key words: *Foeniculum vulgare* var. *azoricum* Mill., cultivar, mulching, vitamin C

INTRODUCTION

Fennel (*Foeniculum vulgare* var. *azoricum* Mill.) is not a very popular vegetable in Poland. Nevertheless, its fruit is commonly used in medicine for manufacturing preparations soothing indigestion ailments, especially for children and elderly persons. Fennel, however, is a valuable vegetable of high dietary value. Its bulbs constitute a low-calorie

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food, abundant in vitamins (C, B_1, B_2, B_6, K, PP, β-carotene) and mineral salts (potassium, calcium, magnesium, sodium and phosphorus). In 100 g of fresh bulbs protein constitutes from 1.0 to 2.4%, total sugars:1.2–3.0%, fibre 0.5–1.1%, fat ca. 0.3% [Mencarelli et al. 1996, Dobromilska 1999, Elmadfa et al. 2003]. The bulbs also contain, though in smaller amounts, essential oil, determining the use of fennel fruit in medicine.

The aim of the conducted studies was to determine the effect of soil mulching and flat plant covering, as well as sowing term upon the nutritional value of two fennel cultivars.

MATERIAL AND METHODS

The field experiment with fennel growing was performed in the years 1998–2000 in Felin Experimental Farm of the University of Life Sciences in Lublin on fawn soil, formed of medium loam. In the cultivated layer of soil (0–20 cm) the following were determined (mean values): 16.14–16.99 mg P, 25.72–29.48 mg K and 6.65–8.28 mg Mg 100 g^{-1} of soil. The experiment was established with the use of completely randomized blocks methods, in 4 replications. The surface of plot for harvest was 3.2 m^2.

The following factors were taken into account in the studies: 3 kinds of covers – covering the soil with black polyethylene film (PE), covering the soil with black polypropylene unwoven (PP 50 g m^{-2}) and flat covering of plants with white polypropylene unwoven (PP 17 g m^{-2} – Agryl P17), as well as control (without covering); 3 terms for seed sowing – April, May, June; 2 cultivars – Rudy F_1 and Zefa Fino.

Head white cabbage was the forecrop for fennel. Before winter the field underwent deep ploughing, and in spring it was harrowed. Then it underwent cultivator tillage and additional cultivations. Fertilization was applied before sowing in the following amounts: 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 nests (in twos), every 20 cm in a row. After the plants formed 2 proper leaves thinning was performed, leaving one plant in a nest. April sowings were performed as early as possible, however, in the year 1998 the spring weather course caused delay in sowings. PP17 unwoven plant covering was removed after about 4 weeks from the beginning of seedlings. The terms of sowing, removing PP17 unwoven and harvest were presented in table 1.

During all the study years fennel bulbs were analyzed considering their nutritional value. Straight after harvesting the bulbs, dry matter contents were determined in the fresh material of usable parts of the plants, with the use of drier-scales method; vitamin C contents – using Tillmans's method; the contents of reducing and total sugars – using Schoorl-Regenbogen method. Also protein and total N contents were determined using Kjeldahl's method on Kjeltec System 1002 Distilling Unit apparatus; $N\text{-}NH_4$ and $N\text{-}NO_3$ – in 2% extract of CH_3COOH with the use of Bremner's distillation method in Starck's modification; phosphorus – colorimetrically; potassium and calcium – with the use of atomic absorption method (ASA); crude (raw) fibre contents – using Kürschner-Scharrer's method.

Table 1. Time-table of more important works in cultivation of fennel from sowing in the years 1998–2000

Tabela 1. Terminarz ważniejszych prac w uprawie fenkułu z siewu w latach 1998–2000

Year Rok	Sowing term Termin siewu	Removal of PP17 Zdjęcie włókniny PP17		Harvest Zbiór	
		A	B	A	B
1998	I – 6.05.	6.07.	61	7.08.	92
	II – 27.05.	21.07.	57	21.08.	87
	III – 17.06.	11.08.	55	2.09.	76
1999	I – 27.04.	8.06.	41	20.07.	83
	II – 26.05.	8.07.	41	16.08.	80
	III – 22.06.	15.08.	53	9.09.	78
2000	I – 26.04.	12.06.	46	19.07.	85
	II – 24.05.	19.07.	55	16.08.	83
	III – 21.06.	7.08.	46	5.09.	75

A – Date – Data; B – Days after sowing – Dni od siewu

The obtained results were statistically worked out with the use of variance analysis method. The significance of differences were determined with the use of Tukey's confidence intervals with significance level p = 0.05.

RESULTS

The fennel bulbs contained on average 6.37% of dry matter (tab. 2). The dry matter contents assumed values ranging from 4.96 to 8.38%. No significant effect of the applied covers upon this parameter was found. Significant differences occurred between sowing terms. Significantly the greatest dry matter contents occurred in the bulbs from May sowings (6.97% on average). The least dry matter was contained in the bulbs of plants from June sowings (6.03%). The examined fennel cultivars did not differ as to the dry matter contents in the bulbs.

In the fresh bulb weight 796 mg·100 g^{-1} protein was determined on average (tab. 2). Significantly the greatest amount of protein was reported in the bulbs of plants from June sowings (863 mg·100 g^{-1} f.w.), whereas the smallest amount was in the bulbs of plants from April sowings (688 mg). The bulbs of Rudy F_1 cultivar were more abundant in protein (822 mg·100 g^{-1} f. w.) than of Zefa Fino cultivar (770 mg).

In the fresh weight of fennel bulbs we determined on average 127.4 mg·100 g^{-1} N- total, including 13.9 mg $N\text{-}NO_3$, and the examined cultivars did not differ as to the contents of nitrates. The most total nitrogen (138.0 mg) and nitrates (23.7 mg) were contained in the bulbs of plants sown in June. The least $N\text{-}NO_3$ was determined in the bulbs from May sowings (7.3 mg).

The fennel bulbs contained on average 8.71 mg·100 g^{-1} of vitamin C in fresh weight (tab. 3). No significant effect of the experimental factors upon that feature was found. Neither the contents of raw fibre in the bulbs were modified by the factors of experiment nor it was 0.567 g·100 g^{-1} f. w. on average.

Table 2. Contents of dry matter, protein, total N and NO_3-N in fennel bulbs in years 1998–2000
Tabela 2. Zawartość suchej masy, białka, azotu ogółem i N-NO_3 w zgrubieniach fenkułu w latach 1998–2000

Factors Czynniki		Dry matter Sucha masa %	Nutrient in mg 100 g^{-1} f.w. Składnik w mg 100 g^{-1} ś.m.		
			Protein Białko	Total N N ogółem	NO_3-N N-NO_3
Kind of covering Rodzaj okrycia	Control – Kontrola	6.51	794	127.0	12.8
	PE	6.37	784	125.5	15.8
	PP50	6.24	812	129.9	14.2
	PP17	6.37	795	127.2	12.7
Term of sowing Termin siewu	I	6.13	688	110.1	10.7
	II	6.97	838	134.2	7.3
	III	6.03	863	138.0	23.7
Cultivar Odmiana	Rudy F_1	6.40	822	131.6	13.5
	Zefa Fino	6.35	770	123.3	14.3
Year Rok	1998	6.27	649	103.9	7.3
	1999	6.59	772	123.6	14.5
	2000	6.26	967	154.8	19.8
Mean – Średnia		6.37	796	127.4	13.9
$LSD_{0.05}$ for: – $NIR_{0,05}$ dla:					
coverings – osłon		n.s.	n.s.	n.s.	n.s.
sowing dates – terminów siewu		0.31	57.2	9.16	4.44
cultivars – odmian		n.s.	38.1	6.11	n.s.
years – lat		0.31	57.2	9.16	4.44

PE – black film – czarna folia; PP50 – black unwoven – czarna włóknina; PP17 – white unwoven – biała włóknina
n.s. – no significant differences – różnice nieistotnie statystycznie

The total sugars content was on average 2.65 g·100 g^{-1}, out of which 2.33 g were reducing sugars (tab. 3). No influence of covering the soil and plants upon the contents of total sugars and monosaccharides in fennel bulbs. However, significant differences occurred between sowing terms. The most total sugars were determined in the bulbs of plants from May sowings (3.01 g), and the least from the sowings performed in April (2.35 g). The bulbs of Zefa Fino cultivars contained more sugars than those of Rudy F_1 cultivar.

In the fresh weight of fennel bulbs we determined on average 31.8 mg P, 420.0 mg K and 33.6 mg Ca (tab. 4). No significant effect of the applied covers upon the contents of these nutrients in the bulbs was reported. The most phosphorus and potassium were contained in the bulbs of plants from May sowings. The contents of calcium did not depend upon the sowing term, although slightly more of that component was determined in the bulbs from June sowings. The bulbs of Rudy F_1 cultivar accumulated significantly more phosphorus and calcium than these of Zefa Fino cultivar.

The contents of nutrients in the bulbs were modified by the weather course in the subsequent study years. In the year 1999 the bulbs contained the most of dry matter, but the least vitamin C, sugars, phosphorus and calcium. In the year 2000 the bulbs were characterized by the largest contents of protein, total nitrogen, nitrates, vitamin C and total sugars, whereas in the year 1998 they accumulated the most phosphorus and calcium.

Table 3. Contents of vitamin C, reducing and total sugars and crude fibre in fennel bulbs in years 1998–2000

Tabela 3. Zawartość witaminy C, cukrów prostych, cukrów ogółem i włókna w zgrubieniach fenkułu w latach 1998–2000

Factors Czynniki		Vitamin C in mg 100 g^{-1} f.w. Witamina C w mg 100 g^{-1} ś.m	Nutrient in g 100 g^{-1} f.w. Składnik w g 100 g^{-1} ś.m.		
			Reducing sugars Cukry redukujące	Total sugars Cukry ogółem	Fibre Włókno
	Control – Kontrola	8.86	2.32	2.64	0.585
Kind of covering Rodzaj okrycia	PE	8.66	2.30	2.62	0.572
	PP50	8.02	2.35	2.64	0.569
	PP17	9.28	2.31	2.68	0.545
Term of sowing Termin siewu	I	8.77	1.97	2.35	0.570
	II	8.88	2.63	3.01	0.608
	III	8.47	2.35	2.57	0.525
Cultivar Odmiana	Rudy F_1	8.87	2.24	2.56	0.558
	Zefa Fino	8.54	2.40	2.73	0.577
Year Rok	1998	8.67	2.48	2.73	0.563
	1999	7.91	2.14	2.49	0.575
	2000	9.54	2.40	2.69	0.564
Mean – Średnia		8.71	2.33	2.65	0.567
$LSD_{0.05}$ for: – $NIR_{0,05}$ dla:					
coverings – osłon		n.s.	n.s.	n.s.	n.s.
sowing dates – terminów siewu		n.s.	0.17	0.23	n.s.
cultivars – odmian		n.s.	0.12	n.s.	n.s.
years – lat		n.s.	0.17	0.23	n.s.

* Denotations as in table 2 – Oznaczenia jak w tabeli 2

Table 4. Contents of P, K and Ca in fennel bulbs in years 1998–2000

Tabela 4. Zawartość P, K i Ca w zgrubieniach fenkułu w latach 1998–2000

Factors Czynniki		Nutrient in mg 100 g^{-1} f.w. Składnik w mg 100 g^{-1} ś.m.		
		P	K	Ca
	Control Kontrola	32.3	418.9	35.0
Kind of covering Rodzaj okrycia	PE	31.6	421.4	33.1
	PP50	31.2	414.7	32.1
	PP17	31.9	424.8	34.3
Term of sowing Termin siewu	I	30.0	404.9	32.5
	II	35.8	434.6	32.5
	III	29.4	420.5	35.9
Cultivar Odmiana	Rudy F_1	33.4	420.9	35.6
	Zefa Fino	30.1	419.0	31.7
Year Rok	1998	34.8	404.9	40.0
	1999	28.5	434.6	26.8
	2000	32.0	420.5	34.1
Mean – Średnia		31.8	420.0	33.6
$LSD_{0.05}$ for: – $NIR_{0,05}$ dla:				
coverings – osłon		n.s.	n.s.	n.s.
sowing dates – terminów siewu		2.23	13.7	n.s.
cultivars – odmian		1.48	n.s.	2.5
years – lat		2.23	13.7	3.7

* Denotations as in table 2 – Oznaczenia jak w tabeli 2

DISCUSSION

The bulbs of fennel obtained from field crops in the years 1998–2000 contained on average 6.37% of dry matter and 127.4 mg N-total, 31.8 mg phosphorus, 420.0 mg potassium, 33.6 mg calcium and 0.567 g raw fibre in 100 g fresh weight. The determined values are confirmed in literature [Koudela and Petříková 2000, Wierzbicka and Kuskowska 2002, Elmadfa et al. 2003]. In 100 g edible part of the bulbs we determined on average 8.71 mg vitamin C, 2.65 g total sugars, 2.33 g reducing sugars and 796 mg protein. In the assessment of vitamin C level there occur differences between authors, and even in different works of the same authors. Koudela and Petříková determined in fennel bulbs 147–157 mg·kg^{-1} [2000] and 87–347 mg·kg^{-1} [2008] vitamin C w in fresh weight, Wierzbicka and Kuskowska [2002] 8.6 mg·100 g^{-1}, Dobromilska [1996, 1999], 3.18–4.40 mg·100 g^{-1}, and Lipska-Szpunar [1992] 12.75 mg·100 g^{-1}. According to Elmadfa et al. [2003] in 100 g of fresh bulb weight there are 93 mg ascorbic acid, 2.4 g protein and 2.8 g assimilable carbohydrates, as well as more dry matter (14%) and calcium (109 mg).

The applied covers did not significantly affect the contents of dry matter, vitamin C, nitrates, potassium, calcium, total sugars, monosaccharides and fibre in fennel bulbs. The bulbs of plants grown without covers contained a little more dry matter (6.51%) and fibre (0.585 g 100 g^{-1}) than those from covered objects. Also in the studies conducted by Dyduch and Najda [2005] the celery plants grown on plots mulched with black PE foil and black PP unwoven contained less dry matter than on the uncovered control. According to Siwek [2002], the plants growing on mulched plots contain smaller amounts of certain active substances, due to greater tissue hydration.

In the analyzed experiment, slightly more total nitrogen, plants from objects mulched by PP50 unwoven accumulated protein and reducing sugars, and more vitamin C was accumulated by plants from those covered by PP17 unwoven. More total protein and sugars after soil mulching with black PP unwoven and PE foil was accumulated by celery petioles in Najda's studies [2004], whereas effect upon vitamin C contents was ambiguous. Rekowska and Słodkowski [2005] reported lower vitamin C contents in the leaves of European corn salad covered with unwoven, as compared to that grown in open field. The salad covered with unwoven accumulated the least vitamin C, and the most – that mulched with black foil [Wierzbicka and Kuskowska 2002]. Siti i in. [1994] found the increased contents of N, P, K and Ca w in the leaves of peppers grown on plots mulched with black foil. The greater contents of dry matter, total sugars and L-ascorbic acid are related to high temperatures during the period of gaining harvest ripeness [Wierzbicka 1999]. Gajc-Wolska et al. [2005] reported higher level of vitamin C in the fruit of peppers mulched with straw than in those mulched with unwoven. As Kalisz and Cebula [2001] report, the factor with the strongest effect upon the accumulation of nutrients in Chinese cabbage heads was the kind of cover, which, however, was strongly related to the grown cultivar. In the conducted studies the Rudy F_1 cultivar conducted in its bulbs more protein, total nitrogen, phosphorus and calcium than the Zefa Fino cultivar. No differences between cultivars were found, regarding the contents of dry matter, nitrates, vitamin C, total sugars, fibre and potassium in the bulbs. Greater

contents of dry matter and vitamin C in the bulbs of Zefa Fino cultivar than in these of Rudy F_1 cultivar were reported by Koudela and Petříková [2000].

In the case of vegetables whose edible parts are leaves, or their thickened bases, the term of growing gains special importance. In autumn, as a consequence of worse light conditions and lower temperatures, the plants accumulate more nitrates [Jaworska and Kmiecik 1999, Serio et al. 2004]. The decreased light intensity, or shortening of the day increase their accumulation in the plants [Lisiewska and Kmiecik 1991, Koudela and Petříková 2000, Sady 2000]. On the basis of the obtained results it was found that the level of nitrates in the bulbs was not very high and it did not exceed the allowable standards. Similar results were obtained by Dobromilska [1999], who determined in fennel bulbs 101–275 mg $NO_3 \cdot kg^{-1}$ f.w., and in another series of studies: 752–798 mg $NO_3 \cdot kg^{-1}$. Santamaria et al.[1999] determined in fennel bulbs from 107 to 769 mg $NO_3 \cdot kg^{-1}$ f. w. According to Koudela and Petříková [2000] the bulbs contain 1515–1632 mg nitrates$\cdot kg^{-1}$ f. w.

In the conducted experiment the most total nitrogen (138.0 mg 100 g^{-1}) and nitrates (23.7 mg 100 g^{-1}) was contained in the bulbs of plants sown in June (harvest in September). The least N-NO_3 was determined in the bulbs of fennel from May sowings (7.3 mg 100 g^{-1}). Many authors confirm that the level of nitrates in plants grows as the growing term is delayed [Michałojć 1994, 2000; Šebečić and Vedrina-Dragojević 1999; Sady 2000; Krężel and Kołota 2003]. A similar relationship was reported by Dobromilska [1999], but in her studies the level of nitrates in fennel bulbs from June sowings was higher (1527–1709 mg $NO_3 \cdot kg^{-1}$). The increase of nitrate level in fennel petioles with the delay of growing term was demonstrated by Matthäus and Gysi [2001]. The least N-total and protein was found in the bulbs of plants sown in April, and the least nitrates – from May sowings (harvest until the 3rd decade of August). Similar results were obtained by Kmiecik et al. [2002] in growing dill.

The bulbs from May sowings contained the most dry matter, vitamin C, sugars, phosphorus, potassium and fibre. Majkowska-Gadomska and Wierzbicka [2005] explain higher contents of sugars in lettuce by lighter overcast. Also Bin and Royal [1997] report that not only temperature is important for accumulating sugars, but also solar radiation. It is confirmed by other authors, whereas the views on accumulation of vitamin C, as well as P, K, Ca and Mg in vegetables, related to growing terms, are varied [Michałojć 1994, 2000; Jaworska and Kmiecik 1999; Kozik and Ruprik 2000; Krężel and Kołota 2003]. In the studies conducted by Kmiecik et al. [2002], the most fibre was contained in the petioled leaves of dill sown in May (harvest in June), and the least – in those from August sowings (harvest in September). The case was similar with nitrogen and protein contents. The increase of dry matter and protein contents, as well as the decrease of L-ascorbic acid level in the petioles of leaf celery, as the vegetation went on, were confirmed by Najda [2004], as well as Dyduch and Najda [2005].

CONCLUSIONS

1. The applied covers did not significantly affect the nutritional value of fennel bulbs.

2. Bulbs of plants from June sowings contained the most protein, total nitrogen and nitrate nitrogen as compared to earlier sowing terms.

3. The most of dry matter, sugars, phosphorus and potassium was determined in bulbs of May sowings fennel.

4. The least protein, sugars and potassium was contained in the bulbs of plants sown in the first term.

5. The bulbs of Rudy F_1 cultivar were more abundant in protein, phosphorus and calcium than those of Zefa Fino cultivar. The cultivars did not differ as far as dry matter, nitrates, vitamin C, total sugars, fibre and potassium contents in the bulbs were concerned.

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WPŁYW OSŁANIANIA GLEBY I ROŚLIN ORAZ TERMINU SIEWU NA WARTOŚĆ ODŻYWCZĄ ZGRUBIEŃ KOPRU WŁOSKIEGO

Streszczenie. Koper włoski (*Foeniculum vulgare* var. *azoricum* Mill.), pomimo wysokiej wartości dietetycznej jest w Polsce mało popularnym warzywem. Jego zgrubienia są pokarmem niskokalorycznym bogatym w witaminy i sole mineralne. Zawierają również, chociaż w mniejszej ilości, olejek eteryczny, który decyduje o wykorzystaniu w lecznictwie owoców fenkułu. W doświadczeniu polowym z uprawą kopru włoskiego badano wpływ ściółkowania gleby i płaskiego osłaniania roślin oraz terminu siewu na wartość odżywczą dwóch odmian kopru włoskiego. W badaniach uwzględniono 3 rodzaje osłon (okrycie gleby czarną folią polietylenową PE, okrycie gleby czarną włókniną polipropylenową PP 50 g m^{-2} i płaskie okrycie roślin białą włókniną polipropylenową PP 17 g m^{-2} (kontrolę stanowiły poletka bez osłon), 3 terminy siewu wprost na polu, 2 odmiany (Rudy F_1 i Zefa Fino). Zastosowane osłony nie wpłynęły znacząco na wartość odżywczą zgrubień kopru włoskiego. Zgrubienia roślin z siewów czerwcowych zawierały najwięcej białka, azotu ogółem i azotu azotanowego w porównaniu z wcześniejszymi terminami siewu. Najwięcej suchej masy, witaminy C, cukrów, fosforu i potasu oznaczono w zgrubieniach fenkułu z siewów majowych. Najmniej białka, cukrów i potasu zawierały zgrubienia roślin z siewów w kwietniu. Zgrubienia odmiany Rudy F_1 były bogatsze w białko, fosfor i wapń niż odmiany Zefa Fino. Odmiany nie różniły się pod względem zawartości suchej masy, azotanów, witaminy C, cukrów ogółem, włókna i potasu w zgrubieniach.

Słowa kluczowe: *Foeniculum vulgare* var. *azoricum* Mill., odmiana, ściółkowanie, witamina C

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