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COST-EFFECTIVENESS AND ENERGY EFFICIENCY OF FENUGREEK GROWN UNDER DIFFERENT AGRICULTURAL PRODUCTION SYSTEMS

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Abstract. The economic analysis is determined by the applied agricultural system, the response of crops to agronomic factors and environmental factors. The aim of this study was to compare the profitability of fenugreek (*Trigonella foenum-graecum* L.) production under different farming systems in north-eastern Europe. Profitability was determined mainly by the cost of farming operations and treatments. The system with the optimal sowing date (B1 - delayed by 10 days in compare to the earliest) and mechanical weed control (D0) generated the highest profits. The value of fenugreek production was determined at USD 1641.0, and the energy efficiency ratio was estimated at 0.53 to 0.60. The most profitable system was B0 – early sowing date, D1 – chemical weed control, where energy inputs reached 9814.3 MJ·ha^{-1}.

Key words: economic analysis, fenugreek cultivation, *Trigonella foenum-graecum*

INTRODUCTION

The strategic goal of agricultural producers is to optimize the cost-effectiveness of crop production. Production profitability is determined by the applied agricultural system, the response of crops to agronomic factors (sowing date, row spacing) and environmental factors (nutrient availability, susceptibility to weed infestation, disease resistance). Those factors influence cost-effectiveness, energy efficiency [Meena *et al.* 2013b] and productivity [Kumar *et al.* 2014]. Profitability and productivity are determined by all stages of the production process. Żuk-Gołaszewska *et al.* [2010] and Winnicki *et al.* [2013] demonstrated that productivity can be enhanced by optimizing the existing technologies or developing new ones.

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Changes in the global economy and surplus in agricultural output have prompted researchers and producers to search for new markets and species of crop plants. One of such plants is fenugreek (*Trigonella foenum-graecum* L.) which is farmed extensively in India and, next to wheat, rice, sugar and cotton, has attained the status of a major crop that contributes to the development of Indian agriculture [Duke 1981, Ramphul 2013]. The popularity of this herbaceous plant is also on the rise in Canada, Egypt and other countries of North Africa, as well as in Europe, including Poland. Fenugreek seeds are used in natural and modern medicine [Oncina *et al.* 2000, Amin *et al.* 2005, Żuk-Gołaszewska *et al.* 2015]. In the cosmetics industry, they are added to food (salads) and feed [Smidt and Brimer 2004]. Mazur *et al.* [1998] and Amin *et al.* [2005] demonstrated that fenugreek seed extract prevents and inhibits the development of breast cancer. Fenugreek's anticarcinogenic effects are attributed to its flavonoid content. Fenugreek also contains diosgenins that significantly reduce cholesterol levels and are used in the production of orally administered hormones and steroids [Oncina *et al.* 2000]. In traditional medicine, fenugreek can be used to make infusions, aqueous and ethanol extracts, herbal liquids, honey alcohol tinctures, tonics with anti-depressant and psychotonic activity, and herbal mixtures stimulating muscle growth.

Fenugreek, a species of the family *Fabaceae*, is an environmentally-friendly plant that enhances soil fertility. Fenugreek is a cost-effective crop that can fix atmospheric nitrogen and compensate for the loss of nitrogen leached from soil, which decreases N fertilization costs. In fenugreek production, the use of crop protection agents and greenhouse gas emissions can be effectively reduced. The analyzed species is characterized by a deep and extensive root system which loosens the soil and is a source of nutrient-rich post-harvest residues [Makai *et al.* 2004]. Fenugreek production generates profits due to higher and more stable grain yields and minimal phytosanitary risk. The yield of winter wheat grown after legumes was found to increase by 0.5-1.0 $t \cdot ha^{-1}$. Due to the break-crop effect, fenugreek minimizes weed infestation, disease incidence and harmful allelopathic effects, thus reducing the demand for crop protection agents in cereal plantations. This leguminous plant also reduces human labor during the cultivation of winter crops (tillage, preparation for sowing) [Wani *et al.* 1995, Święcicki *et al.* 2007]. The intercropping of potatoes with fenugreek increases potato yield and enhances productivity per unit area, which is an important consideration due to low potato prices. Fenugreek intercropping is particularly recommended for small agricultural producers in developing countries [Prasad *et al.* 2001].

In European agriculture, efforts should be made to increase the area under fenugreek by deploying modern technology and decreasing agricultural inputs. Fenugreek has a broad range of practical applications, and it can be used in the production of medicinal products, food, animal feed (seeds), and in the power industry as a source of bioenergy (straw). In view of the above, the objective of this study was to compare the profitability of fenugreek production under different farming systems in north-eastern Europe.

MATERIAL AND METHODS

The field experiment was carried out in 2008-2009 at the Agricultural Experiment Station in Tomaszkowo (53°43’ N; 20°24’ E) of the University of Warmia and Mazury in Olsztyn, Poland. The experiment had a fractional factorial and completely randomized design. One-half of the complete pool of 108 combinations (54 plots) was generated according to the classification proposed by Connor and Zelen (McLean and Anderson, 1984) in the Statistica® program, in four replications. Each plot covered 10.8 m^2. In the experiment, fenugreek was cultivated in three production systems with different experimental factors.

The experimental factors were:

A – inoculation with *Rhizobium meliloti* bacteria (0: no, 1: yes),
B – sowing date (0: early, 1: delayed by 10 days, 2: delayed by 20 days),
C – row spacing (0: 15 cm, 1: 30 cm, 2: 45 cm),
D – weed control (0: mechanical, 1: chemical),
E – disease control (0: no seed dressing, chemical crop control, 1: seed dressing, no chemical crop control, 2: seed dressing and chemical crop control).

The experiment was established on brown soil developed from light loam, of quality class IVa. After the harvest of the previous crop (winter triticale), the soil was skimmed, harrowed and deep ploughed. In spring, pre-sowing treatment involved mineral fertilization with 46% granular triple superphosphate (160 kg $P \cdot ha^{-1}$) and 60% potash salt (120 kg $K \cdot ha^{-1}$). Using a cultivator, fertilizers were mixed with soil to the depth of 10-20 cm. One week before sowing, nitrogen starter fertilizer (urea) was applied at 30 kg $N \cdot ha^{-1}$ and mixed with soil by harrowing. In 2008, fenugreek was sown on 16 April, and in 2009 – on 14 April (early sowing date) in the amount of 20 kg $seeds \cdot ha^{-1}$ at the depth of 1.0-1.5 cm, after which the field was harrowed. Mechanical weed control (factor D) consisted of double manual weeding, whereas chemical weed control involved the application of the Reglone 200 SL herbicide according to the producer's recommendations. Pathogen control (factor E) involved the application of Dithane-M 45 80 WP in treatments with seed dressing and Penncozeb 80 WP in treatments with antifungal protection. The active ingredients and doses of the applied plant protection chemicals are presented in Table 1. Crops were harvested at the fully ripe stage with a combine harvester.

Table 1. Plant protection chemicals used in the experiment
Tabela 1. Charakterystyka środków ochrony roślin stosowanych w doświadczeniu

Plant protection chemicals Środki ochrony roślin	Active ingredient Substancja czynna	Active ingredient dose Dawka substancji czynnej
Reglone 200 SL	diquat	2-3 $dm^3 \cdot ha^{-1}$
Dithane–M 80 WP	Mancozeb	2 $kg \cdot ha^{-1}$
Penncozeb 80 WP	Mancozeb	2 $kg \cdot ha^{-1}$

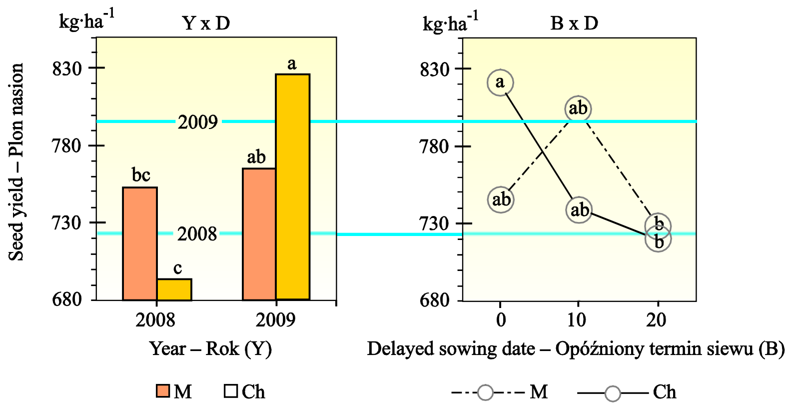
Production costs were evaluated based on the cost-effectiveness ratio and the energy efficiency ratio of fenugreek crops. Cost-effectiveness was analyzed based on experimental documentation, the applied equipment, tractor and machine performance, prices of agricultural materials in Q1-2015, average man-hour rate, average market prices of seeds and harvested crops. All calculations were performed in accordance with Polish accounting standards in agriculture [Goraj 2000]. Inputs were classified as direct and indirect costs to calculate basic cost and income categories: value of production, direct costs, gross margin, indirect costs, agricultural income, total costs, specific costs [Skarżyńska *et al.* 2008]. Gross margin, rate of agricultural income, profitability ratio and relative cost ratio were determined with the use of a developed formula. Specific costs associated with tractors, machines and treatments were calculated based on the method proposed by Muzalewski [2007]. Machine costs were broken down into tillage and treatment costs. Tillage costs involved skimming, ploughing and pre-sowing treatment. Treatment costs accounted for herbicide and fungicide application and seed harvesting. Prices and costs were expressed in USD based on the exchange rate quoted by the National Bank of Poland on 22 February 2015 (PLN 1 = USD 3.67, Rs 100 = USD 1.59). In the cost-effectiveness analysis, the main criterion was yield for the two-year experimental period. Calculations were performed in Microsoft Excel. Yield data were processed statistically by ANOVA with Tukey's test at the significance level of $p = 0.05$ in the Statistica 10.0 application.

The energy efficiency ratio was determined in treatments with various crop protection regimes. The energy efficiency ratio was calculated as the ratio of energy accumulated in crops to energy inputs during production. The consumption of various energy carriers was calculated based on the following indicators [Harasim 2006]: mineral nitrogen fertilizers (N) – 70 $MJ \cdot kg^{-1}$, mineral phosphorus fertilizers (P) – 14 $MJ \cdot kg^{-1}$, mineral potassium fertilizers (K) – 10 $MJ \cdot kg^{-1}$, seeds 7.5 $MJ \cdot kg^{-1}$, plant protection agents (active ingredient) – 300 $MJ \cdot kg^{-1}$, Diesel oil – 48 $MJ \cdot kg^{-1}$, tractor and machine wear – 112 $MJ \cdot kg^{-1}$, spare parts – 80 $MJ \cdot kg^{-1}$, repair materials – 30 $MJ \cdot kg^{-1}$, lubricant – 22 $MJ \cdot kg^{-1}$, labor – 40 $MJ \cdot kg^{-1}$. Specific energy inputs associated with tractors and machines were expressed in terms of 1 kg of machine weight. Energy inputs in machines and tractors were calculated based on a machine's weight, specific energy consumption and number of worked hours [Wójcicki 2002].

RESULTS AND DISCUSSION

In this study, minor differences in fenugreek yield were observed between treatments with different production technologies. Most treatments produced moderate fenugreek yields. Significant differences in seed yield were noted between experimental years, which could be attributed to differences in weather conditions. In the first year of the study (2008), seed yield reached 723 $kg \cdot ha^{-1}$, and it was significantly lower (by nearly 10%) than in 2009. The applied treatments (chemical control, D1) significantly differentiated yield in both years of the study (Fig. 1).

In the group of the analyzed agronomic factors, fenugreek was most sensitive to sowing date (date 0) and weed control. The highest yield was noted in treatments with the earliest sowing date and chemical weed control. When sowing was delayed by 20 days, seed yield was significantly lowered regardless of the applied weed control method. In a study by Boutfirass [2006-2007], yield was more influenced by sowing date and mechanical weed control than by herbicide application. The highest seed yield was noted when seeds were sown early (535 $kg \cdot ha^{-1}$) and when weeds were controlled mechanically (417 $kg \cdot ha^{-1}$). The corresponding increase in yield reached 67% to 110% and 46% to 73%, respectively. In treatments where herbicides were applied, weeds accounted for approximately 5% of the total dry matter content of the crop, and fenugreek yields were not reduced in comparison with hand-weeded treatments [Moyer *et al.* 2002]. Fungicides had no significant impact on fenugreek yield due to low levels of infection and low effectiveness of the applied product. Kołodziej and Zejdan [2000] and Acharya *et al.* [2006] also reported low levels of pathogenic infections, weeds and pests, probably because the analyzed fenugreek treatments covered a very small area. In large fenugreek plantations [Dhruj *et al.* 2000], fungicides significantly reduced disease incidence in comparison with control. In treatments that were least affected by plant diseases (19.38%), fenugreek yield reached 2132 kg·ha^{-1}. In cases where 23.77% plants were colonized by pathogenic fungi, seed yield was reduced by 5.2%. The highest net profit (USD 73.5) was noted in treatments controlled with hexaconazole, followed by wettable sulfur (USD 63.2) which was also the most cost-effective fungicide. In a study by Meena *et al.* [2013b], the value of production was calculated at 402.2 USD·ha^{-1} after treatment with the Mancozeb fungicide and the Dimethoate 30 EC pesticide, in comparison with 84.8 USD·ha^{-1} under control conditions. The resulting income was higher by USD 299.1 in optimally fertilized and managed treatments. Net profit was determined at USD 654.9 in optimally managed plots and at USD 439.1 in plots managed in line with standard farming practice. The benefit-cost ratio reached 2.08-‑3.12 in demonstration treatments and 1.80-1.95 in control. Front line demonstrations (FLDs) of proven agricultural technologies can significantly increase yield and profits from fenugreek production, thus increasing income levels in farming communities.



means for years and production factors marked with the same letter do not differ significantly according to Tukey's test – średnie dla lat i czynników agrotechnicznych oznaczone taką samą literą nie różnią się istotnie według testu T Tukeya

Fig. 1. Significant main effect of year (Y) and interaction effects of year × weeding (Y × D) and sowing date × weeding (B × D) for the seed yield of fenugreek (weed treatment: M – mechanical, Ch – chemical)

Rys. 1. Istotny efekt główny lat (Y) oraz interakcji lata × odchwaszczanie (Y × D) i termin siewu × odchwaszczanie (B × D) plonu nasion kozieradki (odchwaszczanie: M – mechaniczne, Ch – chemiczne)

Production costs in this study are presented in Table 2. The value of fenugreek production was determined at USD 1760 and USD 1966.6·ha^{-1}.

The lowest values were observed in treatments with delayed sowing and chemical weed control (B2, D1), whereas the highest values were noted in early sown treatments and in treatments where plants were protected with the Reglone 200 SL herbicide during the growing season. A minor difference in production costs (40 USD·ha^{-1}) was observed between treatments with mechanical and chemical weed control. In other studies of legumes, the total value of production reached 172.8 USD·ha^{-1} for fodder peas, 760.2 USD·ha^{-1} for yellow lupine and 1076.7 USD·ha^{-1} for blue lupine [Czerwińska-Kayzer and Florek 2012].

Table 2. Costs of fenugreek production
Tabela 2. Koszty produkcji kozieradki

Specification Wyszczególnienie	Agronomic factors – Czynniki agrotechniczne					
	B0, D0	B0, D1	B1D0	B1,D1	B2, D0	B2, D1
Yield – Plon, kg·ha^{-1}	745.0	821.0	803.0	739.0	729.0	720.0
Yield value –Wartość plonu	1522.5	1677.8	1641.0	1510.2	1489.8	1471.4
Subsidies – Dopłaty	288.8	288.8	288.8	288.8	288.8	288.8
Production value Wartość produkcji	1811.3	1966.6	1929.8	1799.0	1778.6	1760.2
Total direct costs Całkowity koszt bezpośredni	242.4	309.2	242.4	309.2	242.4	309.2
Seeds – Nasiona	54.5	54.5	54.5	54.5	54.5	54.5
Mineral fertilization Nawożenie mineralne	174.3	174.3	174.3	174.3	174.3	174.3
60% urea – mocznik	20.7	20.7	20.7	20.7	20.7	20.7
46% triple superphosphate superfosfat potrójny	84.6	84.6	84.6	84.6	84.6	84.6
Inoculum - *Rhizobium meliloti*	10.6	10.6	10.6	10.6	10.6	10.6
60% potash salt sole potasowe	69.0	69.0	69.0	69.0	69.0	69.0
Plant protection Ochrona roślin	13.6	80.4	13.6	80.4	13.6	80.4
- Dithane M 45	3.0	3.0	3.0	3.0	3.0	3.0
- Reglone 200 SL	0.0	66.8	0.0	66.8	0.0	66.8
Total indirect costs Całkowity koszt pośredni	359.8	332.8	359.8	332.8	359.8	332.8
Tractor and machine performance – Wydajność ciągników i maszyn	268.4	247.1	268.4	247.1	268.4	247.1
Labor – Nakład pracy	26.3	23.0	26.3	23.0	26.3	23.0
Agricultural tax – Podatek rolny	32.4	32.4	32.4	32.4	32.4	32.4
Other indirect costs Inne koszty pośrednie (+10%)	32.7	30.3	32.7	30.3	32.7	30.3
Total costs – Koszty ogółem	602.3	642.0	602.3	642.0	602.3	642.0

The highest cost-effectiveness ratio (3.20) was noted when fenugreek plants were sown with a 10-day delay and were weeded mechanically (B1, D0) (Table 3). The treatment where sowing was delayed by 20 days and weeds were controlled chemically (B2, D1) was characterized by the lowest value of the cost-effectiveness ratio (0.74). In the treatment where fenugreek plants were sown early and weeds were controlled chemically (B0, D1), the cost-effectiveness ratio was relatively high (3.06), and gross margin reached 84.6%, which was a satisfactory result in comparison with the remaining treatments. The cost-benefit ratio was significantly higher in demonstration plots than in control plots. The cost-benefit ratio in demonstration and control treatments ranged from 1.94 to 3.12 and differed across experimental years [Meena *et al.* 2013b]. Similar results were reported by Sharma [2003] in moth beans. A comparison of various agricultural systems revealed the highest net return rate (0.61 USD·ha^{-1}) in the production system of rice-fenugreek-okra. The return per every dollar invested was highest for the rice-fenugreek–okra sequence, and a return of USD 2.74--3.20 was reported for every dollar invested in technology [Jat *et al.* 2012]. In a study by Lal (2014), the cost ratio was calculated at 6.41. The investment of 22.3 USD·ha^{-1} combined with the recommended fertilization, water management, plant protection, scientific monitoring and non-monetary factors resulted in additional mean returns of 142.6 USD·ha^{-1}.

Table 3. Cost-effectiveness ratio in fenugreek production
Tabela 3. Wskaźniki efektywności produkcji kozieradki

Specification Wyszczególnienie	Agronomic factors – Czynniki agrotechnniczne					
	B0, D0	B0, D1	B1, D0	B1, D1	B2, D0	B2, D1
Gross margin, USD·ha^{-1} Nadwyżka bezpośrednia	1568.9	1657.4	1687.4	1489.8	1536.2	1451.0
Agricultural income, USD·ha^{-1} Dochód rolny	1209.1	1324.7	1327.6	1157.1	1176.4	1118.3
Gross margin ratio, % Wskaźnik nadwyżki bezpośredniej	86.6	84.3	87.4	82.8	86.4	82.4
Rate of agricultural income, % Wskaźnik dochodu rolnego	66.8	67.4	68.8	64.3	66.1	63.5
Specific costs – Koszty bezpośrednie, USD·kg^{-1}	0.81	0.78	0.75	0.87	0.83	0.89
Profitability ratio Współczynnik opłacalności	3.01	3.06	3.20	2.80	2.95	2.74
Relative costs ratio – Współczynnik kosztów względnych	0.33	0.33	0.31	0.36	0.34	0.36

The analyzed fenugreek treatments were characterized by similar energy inputs. Tractors and machines were the most energy-intensive inputs (Table 4). Seed harvesting was the most energy-demanding farming operation (approx. 646 MJ·ha^{-1}) that accounted for nearly 50% of total energy expenditures. Barley production costs associated with harvest and sowing were highest in spring at 1012 and 725 USD·ha^{-1}, respectively. Ploughing and transportation costs were also considerable. Total machinery costs ranged between USD 2359.4 and 2442.7, depending on the number of chemical protection treatments [Winnicki *et al.* 2013].

Total energy inputs per hectare were estimated at 10000 MJ·ha^{-1} (Table 5). Energy expenditure was 437 MJ·ha^{-1} higher in mechanically weeded treatments than in plots with chemical weed control. The energy value of fenugreek yield was low, ranging from 5400 MJ·ha^{-1} to 6022 MJ·ha^{-1}. Dubis *et al.* [2015] estimated the total cost of winter triticale production at USD 8074-9542. Direct costs accounted for 60-65% of total costs. Regardless of the applied production technology, the predominant cost items were mineral fertilizers (30-39%), followed by the costs of tractor and machine operation (26-30%), crop protection (11-19%) and labor (3%).

The lowest level of energy accumulated in yield was observed when sowing was delayed by 20 days and weeds were controlled chemically (B2, D1), and the highest – when sowing was delayed by 10 days and weeds were controlled mechanically (B1, D0). The lowest specific energy consumption and the highest energy efficiency ratio were noted in the system with an early sowing date and chemical weed control (B0, D1) – the energy efficiency ratio reached 0.6 and specific energy consumption was determined at 12 MJ·kg^{-1}. For other agricultural crops, the costs associated with fossil fuel use in conventional and organic farming systems were determined at 12220 and 4950 MJ·ha^{-1}, respectively [Haas *et al.* 2005].

Table 4. Energy inputs – tractors and farm machinery
Tabela 4. Nakłady energetyczne ciągników i maszyn

Farming operations Zabiegi rolnicze	Specific costs associated with tractors Koszty bezpośrednie związane z ciągnikami MJ·h^{-1}	Specific costs associated with machines Koszty bezpośrednie związane z maszynami MJ·h^{-1}	Specific costs associated with tractors and machines Koszty bezpośrednie związane z ciągnikami i maszynami MJ·h^{-1}	Working time Czas pracy h	Inputs Nakłady MJ·h^{-1}
Skimming – Podorywka	63.0	44.9	107.9	0.8	86.3
Harrowing – Bronowanie	63.0	29.2	92.2	0.3	27.7
Ploughing – Uprawa płużna	63.0	90.1	153.0	0.5	76.5
PK fertilization Nawożenie PK	63.0	25.4	88.2	0.3	26.5
Cultivator tillage Gruberowanie	63.0	15.5	78.5	0.5	39.2
N fertilization – Nawożenie N	63.0	25.2	88.2	0.3	26.5
Sowing – Siew	63.0	71.7	134.7	1	134.7
Post-sowing harrowing Bronowanie posiewne	44.9	17	61.9	0.3	18.6
Harvest – Zbiór	0	807.1	807.1	0.8	645.7
Transport – Transport	44.9	108.2	153	1	153
Total – Ogółem	63.0	44.9	107.8	0.8	86.3
Plant protection – Ochrona roślin					
Chemical protection Ochrona chemiczna	44.9	12.1	19.2	0.2	8.6
Mechanical cultivation Uprawa mechaniczna	44.9	56.8	28.8	1	101.7

Table 5. Energy inputs, MJ·ha^{-1}
Tabela 5. Nakłady energetyczne, MJ·ha^{-1}

Specification Wyszczególnienie	Agronomic factors – Czynniki agrotechniczne					
	B0, D0	B0, D1	B1D0	B1,D1	B2, D0	B2, D1
Tractors and equipment Ciągniki i sprzęt	1336.1	1243.0	1336.1	1240.0	1336.1	1243.0
Labor – Nakład pracy	272.0	238.0	272.0	238.0	272.0	238.0
Diesel oil – Olej napędowy	4291.6	3831.8	4291.6	3831.8	4291.6	3831.8
Mineral fertilization Nawożenie mineralne	4080.0	4080.0	4080.0	4080.0	4080.0	4080.0
Plant protection products Środki ochrony roślin	121.0	271.5	121.5	271.5	121.5	271.5
Seeds – Nasiona	150.0	150.0	150.0	150.0	150.0	150.0
Total energy inputs Całkowite nakłady energii	10251.2	9814.3	10251.2	9814.3	10251.2	9814.3
Energy value of yield Wartość energetyczna plonu	5587.5	6157.5	6022.5	5542.5	5467.5	5400.0
Energy efficiency ratio – Współczynnik wydajności energetycznej	0.55	0.60	0.59	0.56	0.53	0.55
Specific energy consumption Bezpośrednie nakłady energii	13.8	12.0	12.8	13.3	14.1	13.6

CONCLUSIONS

1. Fenugreek production can be recommended not only for agricultural, environmental or medical reasons, but also due to economic considerations in various farming systems in Central Europe.
2. In the present study, the profitability of fenugreek production was determined mainly by the cost of farming operations and treatments. The system with the optimal sowing date and mechanical weed control (B1, D0) generated the highest profits.
3. The value of fenugreek production was determined at USD 1641.0, and the energy efficiency ratio was estimated at 0.53 to 0.60. The most profitable system was B0, D1 where energy inputs reached 9814.3 $MJ \cdot ha^{-1}$.

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EKONOMICZNO-ENERGETYCZNA EFEKTYWNOŚĆ KOZIERADKI POSPOLITEJ UPRAWIANEJ W ZRÓŻNICOWANYCH WARUNKACH AGROTECHNICZNYCH

Streszczenie. Ekonomiczna analiza zastosowanego systemu rolniczego uwarunkowana jest czynnikami agrotechnicznymi i środowiskowymi. Celem badań było porównanie opłacalności uprawy kozieradki pospolitej w warunkach zróżnicowanej agrotechniki północno-wschodniej Europy. Wykazano, że czynnikami warunkującymi opłacalność produkcji tego gatunku były koszty zabiegów agrotechnicznych. Najkorzystniejszą pod względem opłacalności okazała się technologia z optymalnym terminem siewu (B1 – opóźnionym o 10 dni w porównaniu z kontrolą) i mechaniczną regulacją zachwaszczenia (D0). Wartość produkcji kształtowała się na poziomie 1641,0 USD. Wskaźniki efektywności energetycznej wynosiły od 0,53 do 0,60. Najkorzystniejsza była technologia

B0 – wczesny termin siewu, D1 – chemiczna ochrona roślin, a poniesione nakłady energii na tę technologię wynosiły 9814,3 $MJ \cdot ha^{-1}$.

Słowa kluczowe: analiza ekonomiczna, *Trigonella foenum-graecum*, uprawa kozieradki pospolitej

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