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POSSIBILITIES FOR IMPROVEMENT OF ECONOMIC AND ENERGETIC EFFECTIVENESS OF SPRING BARLEY PRODUCTION DEPENDING ON NITROGEN FERTILIZATION LEVEL

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Abstract. This study compares the effectiveness of fertilization of spring barley of the cultivar Orthega relative to varied nitrogen fertilization rates in 2001, 2002 and 2004. Analysis of economic effectiveness was made on the basis of a record of measures and types of technological equipment used and outlays of labor and tractive force and material outlays, and the energy effectiveness of production on the basis of the ratio of energy contained in the obtained crops to energy outlays incurred in production. On the basis of determination of economic and energy effectiveness it was indicated that the optimal fertilization of fodder spring barley amounts to 80 kg $N \cdot ha^{-1}$. Cost analysis indicated that the main cost generator is work of tractors and machines. Additionally, growing nitrogen fertilization resulted in an increase in profitability index from an economic perspective and a decrease in value of production energy profitability index.

Key words: cost calculation, cost generators, economic analysis, energy outlays, fertilization costs

INTRODUCTION

Taking decisions in plant production is determined by many factors of economic and natural character. Preserving biodiversity is an essential element of production, and the main indicator is its profitability. Due to a large importance or barley in cereal crop production and its universal use, it is necessary to monitor the factors determining its profitability. In 1996-2006 the area of barley cultivation in Poland remained at a constant level of 1.1-1.2 m. ha. Poland is the twelfth in barley crops in the world and the sixth among the European Union countries. The value of global barley production ranged from 1219.5 m. PLN in 2002 to 2686 m. PLN in 2007, which placed barley

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second after wheat among basic cereals. Spring cultivars account for about 85% of barley crops [GUS 2008, 2009].

A serious problem in cereal production is its low economic stability. The reason for this is a small production profitability, which is most likely related to low yields and unsatisfactory grain quality. Moreover, the price level is a significant determinant of profitability in cereal production. Due to the fact that cereal prices show a downward tendency, there is the need for verification of the incurred outlays effectiveness [Nasalski et al. 2004]. Economic effectiveness of farms requires continuous profitability analysis of individual crops. Economic analysis allows drawing quick and explicit conclusions concerning the effectiveness of agricultural measures applied and outlays incurred. In recent years the profitability of cereal production has been evaluated in a simplified way with the use of the direct surplus. However, indirect costs, generally unrelated to the yield level, also determine profitability [Krasowicz 2007].

Spring barley is characterized by a higher yielding stability, as compared with other cereals. It is less sensitive to limiting weather conditions, e.g. it better tolerates the shortage of precipitation. The hight of spring barley yield depends particularly on mineral fertilization, sowing date and rate, seed quality and protection related to site factors [Noworolnik 2007, Żuk-Gołaszewska 2008]. Changes in barley production are oriented to the selection of technologies suitable to obtain high yield, with desirable grain quality parameters and low production costs [Noworolnik et al. 2004, Jurga and Dobek 2008].

The aim of this study was to indicate the effect of nitrogen fertilization on the economic and energy profitability of fodder spring barley of the cultivar Orthega under the climate and soil conditions of the north-east part of Poland.

MATERIAL AND METHODS

The study involved fodder spring barley of the cultivar Orthega. Data were worked out on the basis of a strict field experiment established at the Experimental Station in Bałcyny (53°40' N; 19°50' E), owned by the University of Warmia and Mazury in Olsztyn. The experiment was carried out in 2001, 2002 and 2004. The investigations were conducted on the soil of the good wheat complex (2), soil quality class III b, characterized by a high abundance of phosphorus and potassium and medium of magnesium, with pH 6.8. The forecrop of spring barley in each of the tested years was winter wheat. Soil under barley was prepared traditionally (plowing and cultivating measures). Phosphorus and potassium fertilizers were applied wholly preplant in an amount of 70 kg·ha^{-1} P_2O_5 (superphosphate 46%) and 100 kg·ha^{-1} K_2O in the form of potassium salt 60%. The experimental factor was differentiated level of nitrogen fertilization: 0 (the control), 40, 80 and 120 kg N·ha^{-1}. Nitrogen fertilization was applied at different plant development stages in the form of ammonium saltpeter [Żuk--Gołaszewska 2008].

The analysis of effectiveness was made based on a record of measures and kinds of technological equipment used and determined outlays of labor and tractive force and material outlays. Maintenance costs of tractors and machines were determined on the basis of methods of the Institute of Construction, Mechanization and the Electrification of Agriculture in Warsaw [Muzalewski 2006]. Costs of mineral fertilizers and crop-protection measures were calculated as a product of use and the price per unit. Current

prices from the fourth quarter of the given year were considered in relation to all the years of the experiment. An hourly rate of pay was used according to the rates binding at the Experimental Station in Bałcyny. Calculation was carried out with reference to an area of 1 ha. The profitability index calculated as the quotient of commercial production value to the total costs incurred for its obtaining was assumed as the basic measure of the economic effectiveness of production. Calculations also considered the level of direct costs, which was used to calculate the direct surplus and the direct surplus rate.

Individual categories of costs and income were determined according to the scheme below:

– production value,
– direct costs,
– direct surplus,
– indirect costs,
– agricultural income,
– total costs,
– direct surplus rate,
– income rate,
– unit cost of production.

Apart from the assessment of economic effectiveness, individual fertilization levels were analysed in terms of energy. In order to do that, production energy effectiveness index was used as a ratio of energy contained in yields obtained to energy outlays incurred during production. This index was calculated on the basis of the following formula [Anuszewski 1987]:

$$Ee = \frac{Pe}{Ne}$$

where:

Ee – index of energy effectiveness,
Pe – energy value of yield obtained from 1 ha expressed in MJ,
Ne – value of energy outlays incurred during production (MJ) per 1 ha.

Energy provided in the form of materials was calculated by multiplying the weight of material used during production by value of energy contained. Outlays connected with the use of individual energy carriers were calculated on the basis of the following rates [Harasim 2002, 2006]:

– nitrogen mineral fertilizers (N)	70 MJ·kg^{-1}
– phosphorus mineral fertilizers (P)	14 MJ·kg^{-1}
– potassium mineral fertilizers (K)	10 MJ·kg^{-1}
– seeds of cereals and legumes	7.5 MJ·kg^{-1}
– seeds of grasses and small-seeded	30 MJ·kg^{-1}
– crop-protection preparations (active substance)	300 MJ·kg^{-1}
– engine oil	48 MJ·kg^{-1}
– use of tractors and farm machines	112 MJ·kg^{-1}
– spare parts	80 MJ·kg^{-1}
– materials for repairs	30 MJ·kg^{-1}
– greases	22 MJ·kg^{-1}
– human labor	40 MJ·kg^{-1}

Values of the unit energy outlays cumulated in tractors and farm machines were related to 1 kg of their weight. The energy outlays of machines and tractors were calculated using the following formulas [Anuszewski et al. 1979, Wójcicki 2002]:

for tractors:

$$E_{cg} = \frac{M_c \cdot W_{ec} + Z_c \cdot W_z}{T_{nc} \cdot W_{07}} \text{ MJ·ha}^{-1}$$

for machines:

$$E_m = \frac{M_m \cdot W_{em} + Z_m \cdot W_z}{T_{nm} \cdot W_{07}} \text{ MJ·ha}^{-1}$$

where:

E_{cg} – energy consumption of tractor work, MJ·ha^{-1},
M_c – summary weight of tractors used to make a given measure, kg,
W_{ec} – unit energy consumption index of tractors, MJ·kg^{-1},
Z_c – weight of used spare parts in a tractor, kg,
W_z – unit energy consumption index of spare parts, MJ·kg^{-1},
T_{nc} – standard number of tractor working hours during its use, h,
W_{07} – operating efficiency of a unit during making a given measure, ha·h^{-1},
M_m – summary weight of machine used to make a given measure, kg,
W_{em} – unit energy consumption index of a machine, MJ·kg^{-1},
Z_m – weight of used spare parts in a machine, kg,
T_{nm} – standard number of machine working hours during its use, h.

Calculations concerning economic and energy assessment were based on mean yields from the period of the study and made using the software Microsoft Excel.

RESULTS AND DISCUSSION

Nitrogen fertilization is one of the main yield-forming and cost-generating factors for cereal crops [Noworolnik et al. 2007]. In 2001 and 2002 the highest increase in yield in relation to a lower level of fertilization occurred between cultivation without fertilization and with fertilization rates of 40 kg N·ha^{-1}. An exception was the year 2004, when the greatest increase in yield was obtained after growing the nitrogen rate from 80 to 120 kg N·ha^{-1}. Moreover, it was a year of the highest yield of spring barley due to a favorable arrangement of the weather conditions, especially precipitation. In 2001, in turn, (the first year of the experiment) the lowest yield of spring barley was obtained, and the least significant difference for the years amounted to 1.143. Fertilization also significantly differentiated grain yield and $LSD_{0.05}$ was 0.787 t·ha^{-1} (Table 1).

In the present study an increase in nitrogen fertilization rate resulted in a considerable growth in spring barley yield in relation to the treatment without nitrogen fertilization (Table 2). The highest yield was obtained in the case of applying a nitrogen rate of 120 kg·ha^{-1}, but the highest yield growth, amounting to 27.4%, was indicated at increasing N fertilization from 0 kg·ha^{-1} to 40 kg·ha^{-1}. Growing nitrogen rate from 40 to 80 and 120 kg·ha^{-1} resulted in an increase in yield by 14.9 and 9.4%. The highest productivity of 1 kg of nitrogen, at a level of 36.1 kg of grain, was obtained after the application of 40 kg·ha^{-1}. Within the range of higher nitrogen rates from 80 to 120

kg·ha^{-1}, in turn, a decrease in the effectiveness of nitrogen fertilization was observed. The reason for such a variety of unit effectiveness was a relatively high grain yield of the cultivar Orthega in the treatments without nitrogen fertilization.

Table 1. Spring barley yield in the years of the study [Żuk-Gołaszewska 2008]
Tabela 1. Plonowanie jęczmienia jarego w latach badań [Żuk-Gołaszewska 2008]

Year of experiment Rok badań	N rate – Dawka N, kg·ha^{-1}			
	0	40	80	120
2001	2.32	3.89	4.43	4.76
2002	4.33	6.42	7.84	8.38
2004	9.12	9.78	10.83	12.13
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:				
years – lat		1.143		
fertilization – nawożenia		0. 787		
years x fertilization – lata x nawożenie		ns – ni		

ns – ni – non-significant differences – różnice nieistotne

Table 2. Production effectiveness of spring barley fertilization with nitrogen
Tabela 2. Produkcyjna efektywność nawożenia azotem jęczmienia jarego

Specification Wyszczególnienie	N rate – Dawka N, kg·ha^{-1}			
	0	40	80	120
Mean yield – Średni plon, t·ha^{-1}	5.3	6.7	7.70	8.42
Yield difference – Różnica plonu, t·ha^{-1}		+1.44	+1.00	+0.7
Yield increase in relation to the control Przyrost plonu w stosunku do kontroli, %		27.4%	14.9%	9.4%
Effectiveness of N fertilization (1 kg grain/1 kg N) Efektywność nawożenia N (1 kg ziarna/1 kg N)		36.1	25	18

Mineral fertilization plays an essential role in the cost structure. The value of ammonium saltpeter accounted for from 17.2% of total costs incurred for 1 ha of the crop after nitrogen fertilization within the range 40-120 kg·ha^{-1} to 26.9% (Table 3). Nitrogen fertilization applied determined the economic profitability of spring barley production. Lack of nitrogen fertilization resulted in a low production economic effectiveness. A gradual increase of rates resulted in a growth of production value on average by 14.19% (Table 3), where a very strong response to nitrogen is observed again at a fertilization rate of 40 kg·ha^{-1}. Although further increasing nitrogen rates resulted in a higher yield value, this growth was not so great anymore. One PLN of costs incurred for nitrogen after the application of 120 kg·ha^{-1} of nitrogen caused an increase in production value by almost 8 PLN, and in the case of 40 kg·ha^{-1} it was over 10.5.

A growth in nitrogen fertilization increased costs of machine work and human labor by 1.2 and 2.3%, respectively. The total cost of using tractors and machines amounted to 644 and 652 PLN after applying nitrogen fertilization in two rates, which accounted for, respectively, 48.8 and 41.2% of total costs incurred per 1 ha of spring barley crop. Costs connected with sowing carried out with the cultivation unit RAPID 2 and the costs of harvest which was made with the combine harvester DEUTZ FAHR made up the largest proportion (Table 4). Applying highly efficient equipment allows reduction in the amount of measures conducted and limited use of engine oil.

Table 3. Economic effectiveness of spring barley fertilization with nitrogen
Tabela 3. Ekonomiczna efektywność nawożenia azotem jęczmienia jarego

Specification Wyszczególnienie	N rate – Dawka N, kg·ha^{-1}				Mean Średnia
	0	40	80	120	
Mean yield value – Średnia wartość plonu, zł·ha^{-1}	2 489.4	3 148.2	3 617.6	3 961.1	3 304.0
Yield value difference – Różnica wartości plonu, zł·ha^{-1}		658.8	469.4	343.5	490.6
Yield value increrase in relation to the control Przyrost wartości plonu w stosunku do kontroli, %		20.9	13.0	8.7	14.2
Effectiveness of N fertilization (increase in yield value/ increase in costs of N fertilization) Efektywność nawożenia N (wzrost wartości plonu/wzrost kosztów nawożenia N)		10.6	9.0	7.9	9.2

Table 4. Cost calculation of tractor and machine work at cultivation, protection and harvest in spring barley production
Tabela 4. Kalkulacja kosztów pracy ciągnika i maszyn przy uprawie, ochronie i zbiorze w produkcji jęczmienia jarego

Type of activities Rodzaj wykonywanych czynności	Unit cost of tractor work, PLN·h^{-1} Jednostkowy koszt pracy ciągnika, zł·h^{-1}	Unit cost of machine work, PLN·h^{-1} Jednostkowy koszt pracy maszyny, zł·h^{-1}	Number of working hours Liczba godzin pracy	Value, PLN Wartość, zł
Plowing – Orka	123.0	48.0	0.5	80.7
Harrowing – Bronowanie	64.2	6.8	0.2	13.5
Fertilizer application Wysiew nawozów	64.2	24.5	0.1	8.0
Sowing – Siew	123.0	206.1	0.6	200.8
N fertilization Nawożenie N	64.2	18.0	0.1	7.4
Plant protection Ochrona roślin	64.2	49.4	0.2	26.1
Harvest – Zbiór	344.7	–	0.8	258.5
Transport	64.2	2.0	0.8	49.7
Total – Razem			3.2	644.3

An increase in rates of N mineral fertilization influenced the improvement of profitability index, although production costs increased (unit cost of 1 kg of ammonium saltpeter) The present study strictly correspond to the study by Koziara et al. [2007]. This index was the highest in a rate of 120 kg N·ha^{-1} and amounted to 2.50 (Table 5). Costs of mineral fertilizers increased from 238.89 PLN·ha^{-1} on the control treatment to 426.51 PLN·ha^{-1} – application of 120 kg N·ha^{-1}. This caused a growth in costs of mineral fertilizers, as compared with cultivation without nitrogen fertilization, by 20.7; 34.4 and by 44.0%, respectively, after applying 40, 80 and 120 kg N·ha^{-1}. Looking for the optimal rates of nitrogen fertilization from the point of view of yield height is the subject of many scientific publications. Kraska and Pałys [2004] shows a relation between an increase in mineral fertilization and a growth in spring barley yield. The results of the present study confirmed the earlier studies by Koziara et al. [2006] and Szempliński [2003]. The authors indicated that an increase in spring barley grain yield occurred up to 60 and 90 kg N·ha^{-1}, respectively.

Table 5. Cost calculations of spring barley cultivation
Tabela 5. Obliczenia kosztów uprawy jęczmienia jarego

Specification Wyszczególnienie	N rate – Dawka N, kg·ha^{-1}			
	0	40	80	120
Total production value Wartość produkcji ogółem	2 489.4	3 148.2	3 617.6	3 961.1
Production costs per 1 ha of crops, PLN – Koszty produkcji na 1 ha uprawy, zł·ha^{-1}				
Total direct costs – Koszty bezpośrednie ogółem	509.1	571.6	634.1	696.7
Seed – Materiał siewny	146.7	146.7	146.7	146.7
Mineral fertilization – Nawożenie mineralne:	238.9	301.4	364.0	426.5
ammonium saltpeter – saletra amonowa	0.00	62.5	125.1	187.6
superphosphate – superfosfat	140.8	140.8	140.8	140.8
potassium salt – sól potasowa	98.0	98.0	98.0	98.0
Plant protection – Ochrona roślin:	123.5	123.5	123.5	123.5
Granstar 75 WG	27.7	27.7	27.7	27.7
Cerelux Plus 535 EC	44.9	44.9	44.9	44.9
Amistar 250 SC	50.8	50.8	50.8	50.8
Direct surplus – Nadwyżka bezpośrednia	1980.3	2576.6	2983.4	3264.4
Indirect costs – Koszty pośrednie	811.3	820.7	838.5	888.4
Work of tractors and equipment Praca ciągników i sprzętu	644.3	644.3	652.3*	652.3*
Work outlays – Nakłady pracy	21.9	21.9	22.4	22.4
Agricultural tax – Podatek rolny	86.0	86.0	86.0	86.0
Other indirect costs – Pozostałe koszty pośrednie	59.0	68.4	77.8	127.7
Total costs per 1 ha – Ogółem koszty na 1 ha	1320.3	1392.3	1472.7	1585.1
Measures of economic efficiency – Mierniki sprawności ekonomicznej				
Agricultural income, PLN – Dochód rolniczy, zł	1169.1	1755.9	2144.9	2376.0
Direct surplus rate, % Stopa nadwyżki bezpośredniej	79.5	81.8	82.4	82.4
Agricultural income rate, % Stopa dochodu rolniczego	47.0	55.8	59.3	60.0
Unit costs, PLN·dt^{-1} – Koszty jednostkowe, zł·dt^{-1}	25.1	20.8	19.1	18.8
Profitability index – Wskaźnik opłacalności	1.9	2.3	2.5	2.5

* in the case of rate 80 and 120 kg – values of tractors and equipment costs were increased by an additional measure, which is fertilizer application – w przypadku dawki 80 i 120 kg wartości kosztów ciągników i sprzętu zostały podwyższone o dodatkowy zabieg, jakim jest wysiew nawozów

Yield level and differences in prices are important reasons for selecting plants cultivated and technologies applied [Krasowicz 2007]. Cost-generating character of nitrogen fertilization is essential [Nasalski et al. 2004]. In the present study the cost of mineral fertilizers ranged from 10.9 to 27% of direct costs. In plant production the percentage of costs of mineral fertilizers can amounted to even 64% [Kołoszko-Chomentowska 2006].

In production costs structure the costs of the operation of machines ranged from 48.8% on the control treatment (without nitrogen fertilization) to 41.13% on the treatment where the highest nitrogen rate was applied (120 kg·ha^{-1}). A similar relation was indicated also in the study by Jurga and Dobek [2008] concerning the estimation of plant production costs. Reduction of costs of cultivation measures by means of simplifying production technologies and using efficient equipment is economically justified especially on farms of large areas.

Among measures of economic efficiency, unit costs should also be considered, which after the application of 40 kg N·ha^{-1} decreased by 17.21%. Higher N rates affected also favorable changes in the unit cost, but not so large as those mentioned above. Similar tendencies are shown in the case of agricultural income rate and direct surplus rate, although a rate of 120 kg N·ha^{-1} caused a decrease in the latter.

Currently energy efficiency, which is a reflection of yield height and energy outlays, is an important element in plant production. Costs of machines and tractors play an essential role in the determination of energy outlays. Agricultural machines used for sowing and harvesting constitute the highest percentage. Their total value accounts for almost 85% of energy outlays incurred for technical measures (Table 6).

Table 6. Energy outlays of tractor and machine work at cultivation, protection and harvest in spring barley production

Tabela 6. Nakłady energetyczne pracy ciągnika i maszyn przy uprawie, ochronie i zbiorze w produkcji jęczmienia jarego

Type of activities Rodzaj wykonywanych czynności	Unit cost of tractor work – Jednostkowy koszt pracy ciągnika MJ·godz.$^{-1}$	Unit cost of machine work – Jednostkowy koszt pracy maszyny MJ·godz.$^{-1}$	Number of working hours Liczba godzin pracy	Value Wartość MJ
Plowing – Orka	58.7	49.6	0.5	50.9
Harrowing Bronowanie	42.4	46.5	0.2	16.9
Fertilizer application Wysiew nawozów	42.4	30.5	0.1	6.6
Sowing – Siew	58.7	524.0	0.6	355.5
N fertilization Nawożenie N	42.4	30.5	0.1	6.5
Plant protection Ochrona roślin	42.4	57.0	0.2	22.9
Harvest – Zbiór	807.1	0.0	0.7	605.3
Transport	42.4	48.0	0.7	67.8
	Total – Razem		3.2	1132.4

Analysis of energy outlays presented in Table 7 allows us to find that the highest index of energy efficiency is obtained at zero nitrogen fertilization. This situation occurs due to a very high energy value of fertilizers introduced into soil, especially nitrogen ones. In spite of the high yield and economic profitability of using higher nitrogen rates the energy assessment is unfavorable. A similar relation was observed in the study by Szempliński and Kisiel [1998], where energy effectiveness indexes show very similar values. In the study conducted by Wielicki [1989] in average conditions per one unit of energy outlay about one unit should be obtained in the main yield. In this study, each variant of nitrogen fertilization met this condition, and the relation was even much more favorable. A comparison of production and economic effects of various technology of spring barley production proved to be the most favorable after using an economical technology [Nieróbca et al. 2008].

The structure of energy outlays was dominated by those which were connected with mineral fertilizers; they accounted for even 68% in the case of the higher rate (Table 8). Other essential elements were technical measures (work of tractors and machines and engine oil), the whole share noticeably decreased along with growing nitrogen rates.

Table 7. Energy outlays per 1 ha of crop
Tabela 7. Nakłady energetyczne w przeliczeniu na 1 ha uprawy

Specification Wyszczególnienie	Energy outlays – Nakłady energetyczne, MJ·ha^{-1}			
	0 kg N	40 kg N	80 kg N	120 kg N
Work of tractor and equipment Praca ciągnika i sprzętu	1132.4	1132.4	1139.0	1139.0
Work outlays – Nakłady pracy	127.2	127.2	127.2	127.2
Engine oil – Olej napędowy	2213.3	2213.3	2213.3	2213.3
Mineral fertilization Nawożenie mineralne	1980	4780	7580	10380
Plant protection – Ochrona roślin	207.9	207.9	207.9	207.9
Seed – Materiał siewny	1200	1200	1200	1200
Total energy outlays Nakłady energetyczne razem	6860.8	9660.8	12467.3	15267.3
Energy value of yield Wartość energetyczna plonu	39450	50250	57750	63150
Energy effectiveness index Wskaźnik efektywności energetycznej	5.7	5.2	4.6	4.14
Unit energy consumption Energochłonność jednostkowa, MJ·dt^{-1}	130.4	144.2	161.9	181.3

Table 8. Structure of energy outlays
Tabela 8. Struktura nakładów energetycznych

Specification Wyszczególnienie	Energy outlays – Nakłady energetyczne, %			
	0 kg N	40 kg N	80 kg N	120 kg N
Work of tractor and equipment Praca ciągnika i sprzętu	16.5	11.7	9.1	7.5
Work outlays – Nakłady pracy	1,8	1,3	1,0	0,7
Engine oil – Olej napędowy	323	22,9	17,8	14,5
Mineral fertilization Nawożenie mineralne	28.9	49.5	60.8	68.0
Plant protection – Ochrona roślin	3.0	2.2	1.7	1.4
Seed – Materiał siewny	17.5	12.4	9.6	7.9
Sum – Suma	100.0	100.0	100.0	100.0

CONCLUSIONS

1. The highest economic effectiveness in barley production was obtained after the application of the highest nitrogen rate – 120 kg·ha^{-1}, but increasing the rate over 80 kg N·ha^{-1} became economically unjustified.
2. Calculations made based on the results of the field study showed that energy effectiveness decreases with each supplied unit of nitrogen fertilizer.
3. From the point of view of energy and economy, in spring barley cultivation costs related to the work of machines and tools should be considered, since they are the basic cost generators.
4. Nitrogen fertilization causes an increase in profitability index from an economical perspective and a decrease in the value of production energy profitability index.

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MOŻLIWOŚCI POPRAWY EFEKTYWNOŚCI EKONOMICZNEJ ORAZ ENERGETYCZNEJ PRODUKCJI JĘCZMIENIA JAREGO W ZALEŻNOŚCI OD POZIOMU NAWOŻENIA AZOTEM

Streszczenie. W pracy porównano efektywność nawożenia jęczmienia jarego odmiany Orthega w odniesieniu do zróżnicowanych dawek nawożenia azotem w latach 2001, 2002 i 2004. Analizę efektywności ekonomicznej określono w oparciu o ewidencję zabiegów i rodzajów wykorzystanego sprzętu technologicznego oraz nakładów siły roboczej, pociągowej i nakładów materiałowych, a efektywności energetycznej produkcji na podstawie stosunku energii zawartej w uzyskanych plonach do nakładów energetycznych poniesionych w produkcji. Na podstawie określenia efektywności ekonomicznej oraz energetycznej wykazano, że optymalne nawożenie paszowego jęczmienia jarego wynosi 80 kg $N \cdot ha^{-1}$. Analiza kosztów wykazała, że głównym generatorem kosztów jest praca ciągników i maszyn. Zwiększanie nawożenia azotem powodowało ponadto wzrost wskaźnika opłacalności w ujęciu ekonomicznym i spadek wartości wskaźnika energetycznej opłacalności produkcji.

Słowa kluczowe: analiza ekonomiczna, generatory kosztów, kalkulacja kosztów, koszty nawożenia, nakłady energetyczne

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