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ECONOMIC ANALYSIS OF TILLAGE SYSTEMS FOR CROPS GROWN IN WIDE-SPACED ROWS

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Abstract. The aim of the paper is to compare different tillage systems of sugar beet and maize grain, and to present economic considerations of the described techniques. The work included the selection of the necessary agricultural tools and machinery, and review of the economic aspects of the presented systems. The economic analysis was carried out based on operating costs of the machinery and the means of production. The production methods were compared on the basis of the data collected from two separate farms located in two rural communes of one county.

Key words: wide-spiced rows, economic analysis of tillage, no-tillage

INTRODUCTION

Agriculture is one of the oldest and most important economic activities developed by humans. It not only provides food from plant and animal agricultural products, but also raw materials for industry. Arable farming dates back thousands of years, yet it was in the previous century that rapid progress in agriculture began. In the past decade high-quality crop yields have increased due to the introduction of mineral fertilizers, pesticides and optimal crop selection. Technological advances largely contributed to the development by introducing new and efficient agricultural machines [Strużek 1996].

In order to achieve high productivity and the highest possible quality, it is necessary to provide optimal conditions for plants to grow and develop. Soil cultivation involves a number of practices improving the conditions of soil before establishing crops, including soil aeration, proper water management, weed control, mixing fertilisers and crop residue in the soil, and regulating the physical, biological and chemical properties of the soil [Piechota et. al. 2014]. The most widespread production practice these days is conventional tillage, in which ploughs are used to agitate and overturn the soil to help reduce soil compaction, control weeds and pests, and release nutrients from organic matter. The system often requires additional practices to level and smooth the field, such as dragging, rolling, harrowing and aerating, to name a few [Golka and Ptaszyński 2014].

Conventional tillage leads to negative consequences, such as disturbance of soil nutrient cycling and removing dead plant matter, which adversely affect plant growth [Księżak and Bojarszczuk 2010]. In Poland the process of gradual withdrawal of the technique has recently begun, however, due to Polish climate and soil conditions, it will probably never be withdrawn completely [Laufer and Koch 2017]. It is estimated that reduced tillage methods, namely no-till or strip-till, are used in 105 mln hectares in the World [Derpsch and Friedrich 2009]. They can

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be performed in areas where conventional cultivation is problematic and does not bring optimal yield. Alternative cultivation means using modern machinery such as chisel ploughs, cultivators, disk harrows, conditioners or power tools [Piechota et al. 2014, 2016]. What is more, agricultural operations prevent soil erosion by evenly distributing crop residue over the topsoil, which provides efficient crop cover, and also organic matter as the cover gradually decomposes [Archer and Reicosky 2009]. A reduced tillage method gaining popularity in Poland is strip-till, where narrow strips are tilled in spring or autumn, organic or mineral fertilizer is applied, and the seed is planted in the centre of the created strip. The main benefits of the method are conserving soil moisture and structure without affecting the yielding [Morris et al. 2010].

In farms where the strip-till system is used, GPS-RTK-equipped machines enhance the precision of machine operation [Pabin et al. 2008, Twardowski 2010]. Operating costs of individual machines are strictly related to the time factor, as operating costs decrease with each additional hour of machine operation on the annual basis [Kowalik and Grześ 2006, Golka and Ptaszyński 2014].

The purpose of the paper is to compare different soil cultivation systems for sugar beets and maize grain, and to present the economic considerations of the selected techniques.

MATERIAL AND METHODS

The study included the machinery and tool selection, as well as the comparison of the economic aspects of the presented systems. The economic evaluation was prepared on the basis of the calculation of machinery operating costs and agricultural input. Comparing the two systems allowed for choosing the most profitable cropping technique.

Three systems of soil cultivation for beetroots and maize grain were compared and the economic analysis of the selected methods was presented; three techniques were selected for each crop. The first and most widespread is conventional tillage (ploughing), the other two are no-till and mulch-till. For each technique tools and machines typically used in small and medium farms were carefully selected. The data analyzed in the paper had been collected in two farms in Krotoszyn County (Wielkopolska Province) in 2015: in Koźmin Wielkopolski (51° 49′ N, 17°27′ E) and Kobierno rural communes (51°43′ N, 17°29′ E). The first of the studied farms has the arable area of 45 ha; sugar beet and maize are produced using conventional tillage on the area 7 ha and 12 ha respectively. The second farm has the arable area of 65 ha; no-till system (mulch-till in 50%) is used to produce 20 ha of maize and 12 ha of sugar beet.

The data for the analysis had been obtained from two farms located in two different rural communes of one county. On the basis of the collected data the project and financial analysis were conducted focusing on the sugar beet and maize grain production. One of the studied farms used conventional tillage whereas the other one relied on no-till and mulch-till techniques. To make the comparison as realistic as possible, the same machinery and tools were taken into account for both farms.

The operating costs of tractors and machinery were calculated according to the method developed by IBMER [Muzalewski 2007]. First, for every unit the operation time (T) and annual exploitation (W_r) were adopted, with different values for the tractor and for the machinery. The equation used to calculate exploitatation in operation time was $T \cdot W_r$. In the calculations the prices of new machines including VAT were taken. Annual average machine housing and shelter ratio (k_k) accounted for 1%. Additional costs included insurance and annual circulation taxes for tractors (U). Repair expenses were as follows: tractors 90%, trailers 90%, combination drill 80%, disc harrow 90%, sprayer 60%, plough 100%, front loader 50%. Fuel pricing (C_p) for 8th

October 2013 (PLN 5.50 per dm^{-3}) was used in the calculation. Fuel consumption per hour (Z_p) *was* based on tractor specifications and the type of crop. Initially, maintenance costs included depreciation calculated as $K_a=C_m·T^1$. Housing and maintenance costs for new machines $K_k= k_k·0,01$ were multiplied by the 1% ratio. The equation used to calculate the total maintenance cost was $K_{utrz}=K_a+K_k+K_{ub,}$ whereas maintenance cost per hour was calculated as maintenance cost divided by machine exploitation per year. Exploitation expenses include: repair $K_n=k_n·C_m/T_h·100,$ fuel and lubricants $K_{ps}=1.06·Z_p·Cp$, where the adopted ratio in operation has the value of 1.06 (though it should be between 1.04 and 1.06). Another component of maintenance expenses is power consumption per unit $K_{ee}=Z_{ee}·C_{kWh},$ where Z_{ee} is the amount of electricity multiplied by the price of a kilowatt hour (kWh). Additionally, the cost of auxiliary materials needs to be included. Exploitation expenses are shown as $K_{uż}=K_n+K_{ee}+K_p+K_{mp}$. The next step was calulating the unit cost of exploitation $K_e=K_{utrz}+K_{uż}$, which indicates maintenance and exploitation expenses per one hour of operation. Farming overheads were estimated at 9% of total production costs. All the above data were transferred to relevant process charts which were the basis of the calculations and economic analysis. Additional pesticide and fertilizer expenses were also taken into account. The prices were obtained from commercial offers, which made it possible to calculate the total production cost. Finally, the economic analysis of the cultivation systems was performed for both crops, which helped determine which system was the most profitable.

RESULTS AND DISCUSSION

Table 1 shows the cost calculations for sugar beet cultivation, respectively, in three variants of crop technology. The sugar beet root yield obtained during the field experiment was in the range of 57.0 to 61.0 t·ha^{-1} depending on the cultivation technology. The smallest yield was obtained with no-tillage. Fertilizer doses and herbicides were carried out on all crops in the same way.

After careful analysis of the data and results of the calculations from the above tables, it can be stated that the lowest costs of sugar beet cultivation are generated by the no-tillage system and the highest fuel consumption and operating hours for agricultural machinery in the conventional tillage system. The largest income of 1 hectare of sugar beet growing is generated directly in the mulch-tillage and amounts to 3888.21 zł·ha$^{-1.}$

Table 2 shows the cost calculations for grain maize cultivation, respectively, in three variants of crop technology. The main yield obtained during the field trial ranged from 11.5 to 12.5 t·ha^{-1} depending on the growing technology. As in the case of sugar beet cultivation, the smallest yield was obtained with no tillage, while the largest with no tillage in the mulch. Fertilizer doses and herbicides were carried out on all crops in the same way.

After analyzing the data in the table above, it can be concluded that the lowest crop costs are generated by the mulch-tillage system and the highest fuel consumption costs and labor hours delivered to agricultural machinery in the tillage system. Total profits from individual maize cropping systems are most likely to be the same as for sugar-free beet when seed is sown directly into the mulch. The cost calculation shows that conventional tillage technology is less profitable than the no-tillage technology. The result for the mulch-tillage system for sugar beet cultivation was more than 10% more advantageous to traditional cultivation, and more than 20% for maize grain. Studies conducted by Fiszer and others [2006] in wheat cultivation indicate that the economic result of free-fall farming may be more beneficial even by more than 30% compared to conventional tillage. In the case conventional tillage system also leads to excessive soil buildup, which contributes to its over drying. As a result of plowing, a plowed sole can be

Table 1. Cost calculation for sugar beet cultivation

A	Value of sugar beet production			
	Item:	conventional tillage	no-tillage	mulch-tillage
		value (PLN)		
1	Main crop	7980.00	7581.00	8113.00
2	Area payment	830.80	830.80	830.80
	Production value:	8810.80	8411.80	8943.80
B	Direct costs			
1	Seed material	595.00	595.00	595.00
2	Potassium salt	408.00	408.00	408.00
	Superfos	290.00	290.00	290.00
	Nitro-chalk	264.00	264.00	264.00
	Ammonium nitrate	272.00	272.00	272.00
	Cost of mineral fertilizers	1234.00	1234.00	1234.00
3	Betanal Elite 274 EC	292.50	292.50	292.50
	Goltix 700SC	324.00	324.00	324.00
	Duet Ultra 497 SC	174.96	174.96	174.96
	Agil	73.26	73.26	73.26
	Cost of pesticides	864.72	864.72	864.72
4	Plonwit Opty	38.32	38.32	38.32
	Cost of foliar fertilizers	38.32	38.32	38.32
B	Direct costs (total B)	2732.04	2732.04	2732.04
C	Direct surplus (A-B)	6078.76	5679.76	6211.76
D	Indirect costs			
1	Combine harvesting	800.00	800.00	800.00
	Liming	110.00	110.00	110.00
2	Variable machinery cost – farmer's own machines	776.91	441.51	572.16
3	Taxes and insurance	250.00	250.00	250.00
4	Other	70.00	70.00	70.00
5	Farming overheads	441.00	396.00	423.00
6	Water cost	4.59	4.59	4.59
7	Manhour per hectare	112.60	90.40	93.80
D	Indirect costs (total D)	2565.10	2162.50	2323.55
	Total cost (B+D)	5297.14	4894.54	5055.59
E	Agricultural income per hectare (A-(B+D)	3513.66	3517.26	3888.21

Table 2. Calculation in the maize for grain

A	Corn production value			
	Item	conventional tillage	no-tillage	mulch-tillage
		value (PLN)		
1	Main crop	6240.00	5980.00	6500.00
2	Compensatory area payment	139.00	139.00	139.00
3	Single area payment	830.80	830.80	830.80
	Production value	7209.80	6949.80	7469.80
B	Direct costs			
1	Seed material	455.00	455.00	455.00
2	Potassium salt	272.00	272.00	272.00
	Superfos	290.00	290.00	290.00
	Nitro-chalk	264.00	264.00	264.00
	Ammonium nitrate	272.00	272.00	272.00
	Cost of mineral fertilizers	1098.00	1098.00	1098.00
3	Mocarz	42.36	42.36	42.36
	Nikosz 040 SC	112.50	112.50	112.50
	Cost of pesticides	154.86	154.86	154.86
4	Plonwit Opty	38.32	38.32	38.32
	Cost of foliar fertilizers	38.32	38.32	38.32
B	Direct costs (total B)	1746.18	1746.18	1746.18
C	Direct surplus (A-B)	5463.62	5203.62	5723.62
D	Indirect costs			
1	Combine harvesting	400.00	400.00	400.00
2	Variable machinery cost – farmer's own machines	1090.86	864.20	857.27
4	Other	180.00	250.00	70.00
5	Farming overheads	351.00	333.00	333.00
6	Water cost	4.32	4.32	4.59
7	Manhour per hectare	164.80	136.20	140.80
D	Indirect costs (total D)	2440.98	2057.72	2055.66
	Total cost (B+D)	4187.16	3803.90	3801.84
E	Agricultural income per hectare (A-(B+D)	3022.64	3145.90	3667.96

formed that limits the flow of water and gases [Golka and Ptaszyński 2014]. It should be added that simplified crops significantly reduce the labor input to the yield [Klikocka et al. 2011]. The use of simplification allows to reduce energy expenditure while increasing the yield [Czarnocki et al. 2008].

CONCLUSIONS

1. Conventional tillage generates the highest production costs of both maize grain and sugar beet. Ploughing appears to be the most energy-intensive agro-technical practice.
2. The highest profit and the highest yield per unit for maize grain and sugar beet production can be achieved using the mulch-till system, with production costs lower than in the conventional tillage system.
3. A relatively small number of agro-technical practices generates the lowest production costs in the no-till system.

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ANALIZA EKONOMICZNA SYSTEMÓW UPRAWY ROLI DLA ROŚLIN UPRAWIANYCH W SZEROKICH MIĘDZYRZĘDZIACH

Synopsis. Celem pracy jest porównanie różnych wariantów systemów uprawy roli dla buraków cukrowych i kukurydzy na ziarno oraz dokonanie analizy ekonomicznej zaprojektowanych technologii. Praca obejmuje dobór maszyn i narzędzi do uprawy roli z łącznym porównaniem ekonomicznych aspektów przedstawionych systemów. Ocena ekonomiczna danych technologii została wykonana na podstawie obliczeń kosztów eksploatacji maszyn i użytych środków produkcji. Scharakteryzowane systemy uprawy zostały porównane w oparciu o dane uzyskane z dwóch różnych gospodarstw rolnych zlokalizowanych na terenie dwóch gmin w jednym powiecie.

Słowa kluczowe: szerokie międzyrzędzia, analiza ekonomiczna uprawy roli, uprawa bezorkowa

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