THE ECONOMIC AND ENERGY EFFICIENT OF SELECTED TECHNOLOGY OF SUGAR BEET PRODUCTION

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Summary. The present work is the analysis of selected costs and energy-consumption of three variants of sugar beet production engineering. The work is based on authors' own research and source materials. The economic and energy efficiency of sugar beet production has been determined, including crop and sucrose content in the yield from 1 ha.

Key words: sugar beet, production engineering, production costs, energy efficient

INTRODUCTION

The sugar beet in Poland, as well as other 38 countries, is the basic raw material for sugar production in the temperate climatic zone [Jasińska 2003, Tyburski 2004]. The sugar beet accounts for 23% of the world's sugar production with a downward tendency [Ostrowska 2002].

Changes in the home sugar industry have caused the decrease of sugar beet acreage and the increase of an average plantation area, yield harvest and sucrose content from 1 ha [Gorzelany 2010]. For the producers the most important are the production costs and the energy expenditure per 1 ha. The necessity of minimising costs and energy expenditure in sugar beet production exacts the search of low-cost methods of engineering [Zimny 2008]. The modern cultivation is connected with changing from traditional to simplified methods such as no-ploughing method - direct sowing in a stubble or mulch [Marczyńska 2011]. The arguments for simplifying the cultivation are: less fuel consumption and energy expenditure, less rides in the field, less time needed. New farming machinery is being used, which enables introducing considerable modifications in the hitherto methods of engineering within the post-harvest, basic and pre-sowing cultivation [Banasiak 1999, Findura 2004]. The conducted research shows that the method of sugar beet production engineering has a significant impact on the costs and energy-consumption of production process [Gorzelany 2010, Gorzelany et al. 2011]. Using modern technologies of harvest and improving the process of loading and delivering the yield to the sugar refinery have a positive effect on profitability, labour input during the harvest, harvest duration, loss reduction and the quality of the delivered raw material [Gorzelany, Puchalski 2008]. According to the source materials [Szeptycki 2004, Gorzelany, Puchalski 2006] the least energy-consuming technology of sugar beet harvesting is a single-stage harvest with combine harvesters. The profitability of farming is connected not only to the crop and the price of produce but also to the costs of production. Any simplification of production process allows reduction of costs with simultaneous increase of crop.

MATERIAL AND METHODS

The research was carried out on three farms in the Podkarpacie Province. On the "A" farm (Przeworsk commune) the traditional method of sugar beet production engineering was applied. The average sugar beet crop in 2010 was 63 $t \cdot ha^{-1}$. In the structure of the farm's sowing the sugar beet took 8 ha (20%). It was grown on the soils of II and III b rate. On the "B" farm (Cieszanów commune) the mulch-mustard technology was used. In the sowing structure of the farm the sugar beet took 38 ha (11%). The average sugar beet crop in 2010 came to 58 $t \cdot ha^{-1}$. It was grown on the soils of II, III a and IV b rate. On the "C" farm (Przemyśl county) the direct sowing was used. In the farm's sowing structure, the sugar beet took 17 ha (17%). The average sugar beet crop in 2010 amounted to 57 $t \cdot ha^{-1}$. It was grown on the soils of II, III a and III b rate. Within the traditional method (17 procedures) the most energy-consuming procedure was carried out - the pre-winter ploughing. The manure was used in the amount of 30 $t \cdot ha^{-1}$. Within both the mustard-mulch method and the direct sowing method 14 procedures were carried out. On the basis of the survey, the technological charts filled out in the years 2009-2010 as well as the data obtained from the farms and the source materials while applying the method of calculating the costs and the machinery energy expenditure, the analysis of the energy expenditure and costs of fuel and labour as well as the material and operational costs was conducted. The economic efficiency and the energy yield of sugar beet production was determined for the three selected methods of production engineering. In the cost accounting the IBMER method was used [Muzalewski 2006] and also the prices and technical specifications of the tractors and other farming machinery for the years 2008-2009. The energy-consumption of the sugar beet production process was calculated according to the IBMER method [Anuszewski et al. 1999, Wójcicki 2002], taking into account selected unitary indexes of energy-consumption published in the professional literature [Banasiak et al. 1999, Wójcicki 2002].

Table 1. The machinery used on particular farms and within particular methods of production engineering.

Process	Technology		
	Traditional farm „A”	Mulch-mustard farm „B”	Direct sowing farm “C”
Manure fertilizing	Ursus 5714 + layer Tytan 7 plus	-	-
Stubble planting	John Deere 6620 + stubble aggregate Brodnica 1A U753/A/2	Fendt 716 Vario + stubble aggregate KOS 4,5 B	-
Fertilizer sowing	Ursus 5714 + fertilizer layer Motyl N031-M1	Fendt 716 Vario + fertilizer layer SIPMA N049/1	Fendt 712 + fertilizer layer Amazone ZA-M 1500
Cultivation + after-crop: mustard plant	-	Fendt 716Vario + farming aggregate Ares TL 4.0	-
Scarifying soil with cultivator	-	-	Fendt 714 + stubble cultivator Gruber KP-260 S
Ploughing	John Deere 6620 + five-furrow plough 151/8	-	-
Aggregate cultivation	John Deere 6620 + cultivation aggregate KOMBI 4,2 BH	-	-
Fertilizing	Ursus 5714 + fertilizer layer Motyl N057/1	Fendt 716 Vario + fertilizer layer SIPMA N049/1	-
Pre-sowing cultivation	John Deere 6620 + cultivation aggregate KOMBI 4,2 BH	Fendt 716Vario + cultivation aggregate Ares TL 4.0	-
Sowing	John Deere 6620 + seed drill Omega B 3.0	MTZ 82 + seed drill Kverneland Accord Monopill S	Fendt 712 + seed drill Monosem NG 6
Weed spraying	Ursus 5714 + attached sprayer 600/15/H (4 times)	MTZ 82+ sprayer Pilmet 818 (4 times)	Fendt 712 + sprayer ORP 3000/20/ PHN Goliat Plus (4 times)
Nitrogen fertilizing	Ursus 5714 + layer Motyl N057/1	-	Fendt 712 + layer MXL 1600 H
Spraying - leaf infusion	Ursus 5714 + attached sprayer 600/15/H	MTZ 82+ sprayer Pilmet 818	Self-propelled sprayer RAU-2000 l
Anti-fungal spraying - *Cercospora beticola*	Ursus 5714 + attached sprayer 600/15/H (2 times)	MTZ 82+ sprayer Pilmet 818 (2 times)	Fendt 712 + sprayer ORP 3000/20/ PHN Goliat Plus (2 times)
Harvest	Harvester Ropa Euro Tiger	Harvester Ropa Euro Tiger	Harvester Ropa Euro Tiger

RESULTS

As a result of time studies of labour input, fuel consumption measurement and source data on prices of fuel and labour, the costs of fuel and labour were determined for each method of sugar beet production engineering presenting in Table 2.

Table 2. The costs of labour input and fuel in sugar beet production engineering.

Production engineering	Labour input [h·ha^{-1}]	Fuel consumption [kg·ha^{-1}]	Labour cost [zł·ha^{-1}]	Fuel cost [zł·ha^{-1}]
Traditional	9.62	128.9	96.2	528.5
Mulch-mustard	4.11	69.4	41.1	284.5
Direct sowing	3.35	58.7	33.5	240.7

Table 3. The material costs of sugar beet production engineering.

Type of used material	Material costs of production engineering [zł·ha^{-1}]		
	Traditional	Mulch-mustard	Direct sowing
Seed	598.0	810.0	676.0
Fertilizers	1750.2	638.6	658.4
Pesticides	735.6	908.6	1174.2
∑	3083.8	2357.2	2508.6

The highest costs of labour 96.20 zł·ha^{-1} and fuel 528.50 zł·ha^{-1} were in the traditional sugar beet production engineering. According to Gorzelany [2010] these costs amounted to 136 zł·ha^{-1} and 720.7 zł·ha^{-1} respectively. The lowest costs of labour 33.50 zł·ha^{-1} and fuel 240.70 zł·ha^{-1} occurred within the direct sowing method presenting in Table 3.

A considerable part of sugar beet production costs is the cost of used materials such as seed, pesticides and fertilizers. On the basis of data on factual material-consumption within the three methods of sugar beet production engineering as well as the materials' prices, the costs of used materials were calculated (table 3). The highest material costs were carried within the traditional method and amounted to 3083.8 zł·ha^{-1}. Whereas, the lowest material costs were borne within the mulch-mustard method 2357.2 zł·ha^{-1}. By comparison, in 2007 these costs totalled up to 2144.0 zł·ha^{-1} on 99 farms [Chudoba 2008].

Within the analysed methods of production engineering, the highest costs were the material costs coming to 52%. The average costs of machinery operating amounted to 39.9%. The lowest costs were the labour costs 1.1%. The highest overall cost occurred within the traditional method and amounted to 5927.0 zł·ha^{-1}. When using manure, the cost of the traditional method is higher and comes to 5680.0 zł·ha^{-1} [Gorzelany 2010]. The lowest overall cost was found within the mustard-mulch method 4661.2 zł·ha^{-1}.

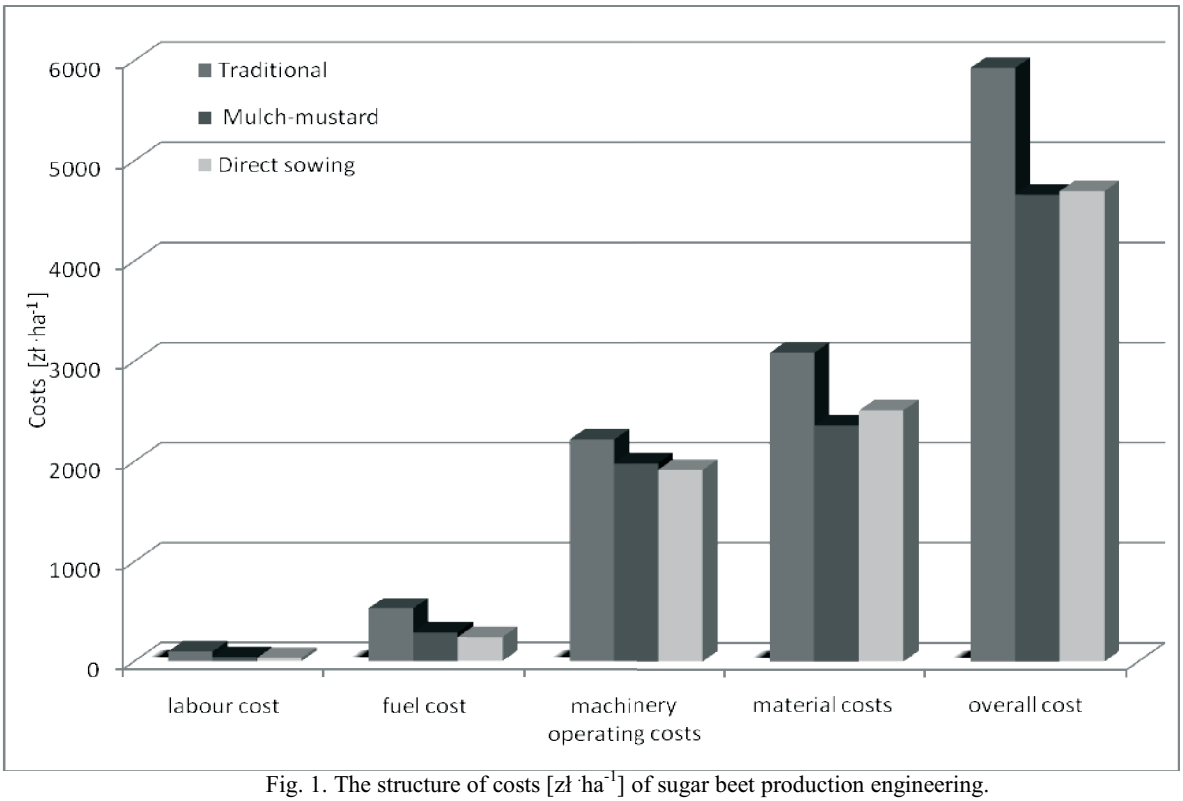

Fig. 1. The structure of costs [zł ·ha^{-1}] of sugar beet production engineering.

Table 4. The profitability of sugar beet growing depending on the method of production engineering.

Method of production engineering	Sugar beet crop [t ·ha^{-1}]	Sucrose content [%]	Value fetched for the raw material [zł ·ha^{-1}]	Overall cost [zł ·ha^{-1}]	Profit [zł ·ha^{-1}]	Economic efficiency
Traditional	63	14.8	6393.7	5927.0	466.7	1.07
Mulch-mustard	57	14.3	5559.3	4661.2	898.1	1.19
Direct sowing	58	14.6	724.6	4696.7	1027.9	1.20

Adverse climate conditions in the analysed year (lower yield crop, lower sucrose content and lower price for a tonne of raw material) have caused that the profit from growing 1ha of sugar beet was relatively low and came to 1027.9 zł ·ha^{-1} within the direct sowing method. The profit from the mulch-mustard method was 898.1 zł ·ha^{-1} and from the traditional method 466.7 zł ·ha^{-1}. According to Gorzelany [2010] the profit from the analysed methods was higher.

In order to determine the structure of energy expenditure (table 5), the operational and material machinery data were used as well as unitary energy indexes [Banasiak et al. 1999, Wójcicki 2002] and the results of authors' own research.

Table 5. The structure of energy expenditure within sugar beet production process

Method of production engineering	Labour input [MJ·ha^{-1}]	Fuel [MJ·ha^{-1}]	Direct energy expenditure [MJ·ha^{-1}]	Energy expenditure on production and machinery repairs [MJ·ha^{-1}]	Energy expenditure on materials [MJ·ha^{-1}]	Overall energy expenditure [MJ·ha^{-1}]
Traditional	769.6	6187.2	6956.8	3641.6	34083.5	44681.9
Mulch-mustard	328.8	3331.2	3660.0	2808.4	22028.5	28469.9
Direct sowing	268.0	2817.6	3085.6	2377.3	23059.0	28521.9

Table 6. The energy yield of sugar beet production engineering.

Method of production engineering	Yield [t ·ha^{-1}]	Sucrose content [%]	Sugar crop [kg ·ha^{-1}]	Sugar/obtained food energy [MJ ·ha^{-1}]*	Overall energy expenditure [MJ ·ha $^{-1}$]	Energy efficiency
Traditional	63	14.8	9324.0	148251.6	44681.9	3.3
Mulch-mustard	57	14.3	8151.1	129600.0	28469.0	4.6
Direct sowing	58	14.6	8468.0	134641.0	28521.9	4.7

* food energy of 1 kg of sugar - 15.9 MJ.

As far as the analysed methods of sugar beet production engineering are concerned, the highest direct energy expenditure was found within the traditional method 6956.8 MJ·ha^{-1}, while the lowest within the direct sowing method 3085.6 MJ·ha^{-1}.

The traditional method required the highest energy expenditure on production and machinery repairs as well as materials used, and amounted to 3641.6 MJ·ha^{-1} and 34083.5 MJ·ha^{-1}, respectively, and considering that the manure was used (10000 MJ·ha^{-1}). Relatively low energy expenditure on materials was noted within the mulch-mustard method 22028.5 MJ·ha^{-1}. On these farms, a low mineral fertilizer was used on the basis of soil analysis.

The highest overall energy expenditure of 44681.9 MJ·ha^{-1} was marked for the traditional method. The overall energy expenditure for the mulch-mustard method was 28469.9 MJ·ha^{-1} and for the direct sowing method 28521.9 MJ·ha^{-1}.

The highest energy efficiency was obtained within the direct sowing and it came up to 4.7. In the other methods of sugar beet production engineering the values were respectively: mulch-mustard method 4.6, and traditional method 3.3.

CONCLUSIONS

1. The highest labour and fuel costs were borne within the traditional method of sugar beet production engineering: fuel 528.50 zł ·ha^{-1} and labour 96.20 zł ·ha^{-1}.
2. The material costs varied among the three methods:
   - traditional method 3083.8 zł ·ha^{-1}
   - mulch-mustard 2357.2 zł ·ha^{-1}
   - direct sowing 2508.6 zł ·ha^{-1}.
3. The economic efficiency of sugar beet production ranged from 1.07 for traditional method to 1.2 for direct sowing.
4. Within the analysed methods of sugar beet production engineering, the overall costs of sugar beet production varied and totalled up to: traditional method 44681.9 MJ·ha^{-1}, direct sowing 28521.9 MJ·ha^{-1}, mulch-mustard 28469.0 MJ·ha^{-1}.
5. The energy affectivity of sugar beet production within the analysed methods ranged from 3.3 for traditional method to 4.7 for direct sowing.

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ЭКОНОМИЧЕСКАЯ И ЭНЕРГЕТИЧЕСКАЯ ЭФФЕКТИВНОСТЬ ПРИ ВЫБОРЕ ТЕХНОЛОГИ ПРОИЗВОДСТВА САХАРНОЙ СВЕКЛЫ.

Аннотация. В работе выполнен анализ приведеннях затрат и энергопотребления для трех вариантов производства сахарной свеклы. Работа основана на собственных исследованиях и исходных материалах авторов. В результате определена экономическая и энергетическая эффективность производства сахарной свеклы, в том числе урожайность, содержание сахарозы полученное с 1 га.

Ключевые слова: сахарная свекла, производство, затраты на производства, энергозатраты.