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ENERGY EFFICIENCY OF HYBRID RYE CULTIVATION IN RELATION TO THE MANNER OF SOIL CULTIVATION

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ABSTRACT

In a one-factor field experiment, carried out in 2011-2012 in Demo Farma in Drzęczewo near Gostyń in Wielkpolskie Voivodeship, the size and structure of energy inputs incurred for cultivation of hybrid rye and index of energy efficiency were compared. The size of energy accumulated was not varied by the compared systems of field cultivation, because it depended mainly on inputs of energy accumulated brought in the form of materials (approx. 85%). The use of no-tillage cultivation reduced energy inputs brought in the form of fuel by 2.4% and in the form of aggregates (by 34.5% in comparison to tillage cultivation). The compared systems of field cultivation diversified the size of hybrid rye seed crop by 4.7%, value of the energy efficiency index by 3.9% and the size of the accumulated energy inputs by 0.9%.

Introduction

New solutions in the technology of plant cultivation are based inter alia on the reduction of intensity of field cultivation in a crop rotation, introduction of the no-tillage cultivation systems and even on the total abandonment of the mechanical impact on soil and the use of the so-called direct sowing, particularly in large-scale agricultural farms. A plough system of field cultivation, characterizes with great energy-consumption and favours water and wind erosion and causes excessive soil over drying. Introduction of the systems for the simplified cultivation systems is a response (Kordas, 2011).

Advantages from introduction of the no-tillage systems are very explicit, since they not only decrease the energy and human labour expenditures by approx. 35% (Dzienia et al., 2006) but also positively influence the soil environment and may considerably influence maintenance of balance in the natural environment (Holland, 2004; Dzienia et al., 2006; Derpsch, 2007). The aspect of the environmental protection is not without significance, because the systems of no-tillage soil cultivation are said to reduce CO_2 emission to atmosphere as a result of a slower rate of organic substance decomposition and lower fuel consumption (Derpsch, 2007).

Hybrid rye is a plant with a systematically rising economic significance. Hybrid varieties characterize with lower height of plants, better production propagation which enables obtaining a higher stock of spikes. These varieties are less susceptible to lodging, which favours greater mineral fertilization and obtaining a higher crop (Dopierała et al., 2003).

The objective of the research

The objective of the research was to analyse the size and structure of energy inputs incurred on hybrid rye cultivation in the production conditions and determination and comparison of the value of energy efficiency index of the applied cultivation systems.

Methodology and conditions of the research

A one-factor field experiment was carried out in 2011 and 2012 in Demo Farma founded in an individual farm in Drzęczewo next to Gostyń in Wielkopolskie Voivodeship. On the determined fields with 10 ha area each plough and non-plough hybrid rye cultivation of Visello variety. The soil conditions were equal on the surface of the whole experiment - soil of a granulometric composition of hard loamy sand, included to the IVa soil quality class. Winter rye was sown in the second decade of September in the amount of 60 $kg \cdot ha^{-1}$, which responded to the stock of 180 $items \cdot m^{-2}$ of germinating seeds. Each year, winter wheat was a forecrop and mineral fertilization was in total 142 $kg \cdot ha^{-1}$ N, 96 $kg \cdot ha^{-1}$ K_2O and 36 $kg \cdot ha^{-1}$ P_2O_5. According to the IOR (the Institute of Plant Protection) chemical protection and retardants were applied.

After-harvest cultivation, fertilization, sowing and plant protection were not diversified on the investigated fields. Only basic cultivation was subject to diversification. In the tillage systems, a four-furrow plough Kverneland EM80 was used and in the no-tillage system Cultus 300 unit. These machines were aggregated with a tractor of 140 KM power. Skimming was carried out with a skimming unit KOS, sowing with Rapid 300 sower, mineral fertilization with Amazone ZAF 803 spreader and application of the crop protection chemicals and leaf fertilization was carried out with Pilmet 615.

The size of the energy inputs (E_{tech}) incurred on the winter rye production was determined with the use of the accumulated energy consumption methodology (Anuszewski et al., 1979; Wójcicki, 2002).

$$E_{tech} = \sum E_{mat} + \sum E_{agr} + \sum E_{pal} + \sum E_r \quad (MJ \cdot ha^{-1}) \tag{1}$$

Because determination of the amount of energy brought in the form of human labour (ΣE_r) in field conditions was not possible for determination, this component of the accumulated energy was omitted and the formula assumed the form suggested by Piskier (Piskier, 2011):

$$E_{tech} = \sum E_{mat} + \sum E_{agr} + \sum E_{pal} \quad (MJ \cdot ha^{-1}) \tag{2}$$

ΣE_{agr} – the sum of energy consumption of the used aggregates ($MJ \cdot ha^{-1}$),
ΣE_{mat} – the sum of energy consumption of used materials ($MJ \cdot ha^{-1}$),
ΣE_{mat} – the sum of energy consumption of the consumed fuel ($MJ \cdot ha^{-1}$).

Efficiency of machines was determined with the use of simplified timing and fuel consumption during carrying out particular treatments was determined through a direct measurement. Energy brought in the form of materials was calculated through multiplication of the mass of the used material during production by the value of energy included in it assuming: for the sowing material 9 MJ·kg^{-1}, of nitrogen fertilizers 77 MJ·kg^{-1} N, potassium fertilizers 10 MJ·kg^{-1} K_2O, phosphorus fertilizers15 MJ·kg^{-1} P_2O_5, for diesel oil 48 MJ·kg^{-1}, for pesticides 300 MJ·kg^{-1} active substance (Wójcicki, 2002).

The value of the index of energy efficiency was calculated by dividing the energy value of the rye seed crop by the amount of the accumulated energy input incurred on its production. The amount of the seed crop was accepted according to the data obtained from a combine harvester. The energy inputs related to the plant collection were not included in calculations.

Research results and discussion

Tillage cultivation of hybrid rye (not related to the years of research) required the input of the accumulated energy on the level of 16.99 GJ·ha^{-1}. The use of non-tillage cultivation required a slightly lower input of the accumulated energy (by 1%) and this input was 16.84 GJ·ha^{-1} (tab. 1).

Energy brought in materials decided on the amount of inputs of energy accumulated in both cultivation systems. At the average in the investigated years it was 14.46 GJ·ha^{-1} and constituted respectively 85.1% of the incurred inputs of energy accumulated in the tillage and no-tillage cultivation 85.9%. Respectively the size of energy brought in the form of aggregates in the tillage cultivation was 0.39 GJ·ha^{-1} which constituted 2.3% of the total amount of the energy brought in the cultivation system, whereas the accumulated energy brought in the form of fuel was 2.14 GJ·ha^{-1} which constituted 12.6%. In the no-tillage cultivation, the energy brought in the form of aggregates was 0.29 GJ·ha^{-1} (1.7% of the entire input), whereas the energy brought in the form of fuel was 2.09 GJ·ha^{-1} – which constituted 12.3% of the energy accumulated consumed for hybrid rye cultivation.

Table 1
The size of the accumulated energy inputs incurred for hybrid rye cultivation in different cultivation systems (at the average in 2011-2012)

Cultivation system	Energy brought in (GJ·ha^{-1})			Accumulated energy input (GJ·ha^{-1})
	Materials	Aggregates	Fuel	
Tillage	14.46	0.39	2.14	16.99
No-tillage	14.46	0.29	2.09	16.84

When comparing the size of the accumulated energy input brought in aggregates one may assume that it is almost identical in both cultivation systems. In the non--tillage cultivation, its amount is lower by approx. 34.4% – in comparison to the tillage cultivation. Similar differences occurred in the amount of the energy brought in fuel. The use of no-tillage cultivation (in comparison to the tillage one) required by 2.4% of lower inputs incurred in this form (table 1).

Table 2
Energy efficiency of hybrid rye cultivation

Cultivation system Years	Seed crop ($dt\cdot ha^{-1}$)	Energy value of a crop ($GJ\cdot ha^{-1}$)	Accumulated energy input ($GJ\cdot ha^{-1}$)	Index of energy efficiency
		2011		
Tillage	76.70	69.03	16.69	4.13
No-tillage	66.80	60.21	16.56	3.63
		2012		
Tillage	72.70	65.45	17.32	3.78
No-tillage	75.80	68.27	17.14	3.98
		Average in 2011-2012		
Tillage	74.70	67.24	16.99	3.96
No-tillage	71.30	64.24	16.84	3.81

Two factors decide on the energy efficiency of production - energy value of a crop and the size of the accumulated energy input (table 2). Energy value of the crop differed in particular years of the research. In 2011 it was from 60.21 $GJ\cdot ha^{-1}$ in facilities with a no-tillage cultivation to 69.03 $GJ\cdot ha^{-1}$ after plough cultivation. In 2012 energy value of a crop was higher by 4.3% in the facilities cultivated in a no-tillage system was 68.27 $GJ\cdot ha^{-1}$. At the average for the years of the research, the energy value of crop obtained in the tillage system of rye production was 67.24 $GJ\cdot ha^{-1}$, whereas in the no-tillage system it was 64.24 $GJ\cdot ha^{-1}$. The obtained differences of energy value of the crop resulting from the applied systems of field cultivation were 4.7%.

The value of the energy efficiency index (table 2) did not differ in particular years of research and was at the level of 3.88. According to Wielicki (1989) per one unit of the energy inputs incurred in production there should be four energy units of the produced product. Data presented in table 2 show that the index of the energy efficiency of rye production was varied by the applied systems of field cultivation and difference concerning its value was 3.9%. Also Czarnocki (2013) points out differences of the energy efficiency index between the applied systems of field cultivation, stating that often savings of the energy input obtained due to simplifications are reduced by values of crop losses and may exceed even 50%. On the other hand, Kordas' research (1999) shows that considerably higher effectiveness was obtained after the use of direct sowing.

In the author's own research which was carried out, differences in the amount of inputs of the energy accumulated between the analysed cultivation systems were respectively 0.8% in 2011 and 1.05% in 2012 and at the average 0.9%. Czarnocki (2013) using a no-tillage cultivation obtained 6% reduction of the size of the accumualted energy inputs in winter barley cultivation. Similar savings at the level of 6.1% on energy inputs incurred on no-tillage cultivation and 5.6% in direct sowing was proved by Orzech et al. (2004). The no-tillage cultivation causes decrease of the amount of fuel consumption, this relation was confirmed in the author's own research (Piskier, 2011; Piskier and Majchrzak, 2013). Also Jaskulski et al. (2013) replacing a classic tillage non-plough cultivation reported limitation of fuel consumption in winter rape and winter wheat by 3.9 to 4.6 $l\cdot ha^{-1}$. The highest participation in the accumulated energy inputs is reported in materials including nitrogen fertilizers (Starczewski et al., 2008; Klikocka et al., 2012; Czarnocki, 2013). According to

Nasalski (2004) fertilization constitutes a basic factor which decides on economic efficiency of agricultural production. It is a considerable crop-shaping factor and at the same time it has a significant participation in the structure of inputs and the production costs. The systems of field cultivation, applied in the author's own research, differentiated the size of the winter rye seed crop. Moreover, Weber and Podolska (2008), Jug et al. (2011) as well as Halinairz et al. (2013) inform on the reduction of the winter wheat seed crop in the field experiments influenced by simplifications in the field cultivation. On the other hand Piskier and Sławiński did not report significant differences in yielding hybrid rye between the plough and no-tillage system. Whereas in the research carried out by Entrup and Schneider (2003) and Fiszet et al. (2006) a positive impact of non-plough soil cultivation on the size of the winter wheat crop, which was significantly higher than the one obtained in the plough system of field cultivation, was reported.

Conclusions

1. Inputs brought in the form of materials decide on the size of the incurred energy inputs, independent from the field cultivation system. They constitute 85.1% of the size of energy inputs incurred in the tillage cultivation and 85.9% in the no-tillage cultivation.
2. The use of the no-tillage cultivation system allows reduction of the inputs of the energy brought in the form of fuel by approx. 2.4% and in the form of aggregates by 34.5%.
3. The application of the no-tillage cultivation system in 2011 caused decrease of the hybrid rye seed crop by 12.9%, value of the energy efficiency index by 11.1% and the size of the accumulated energy inputs by 0.8%. These different values were reported in 2012. Non-plough field cultivation caused the increase of the seed crop by 4.3%, the value of the energy effectiveness index by 5.3% and the decrease of the amounts of the acummulated energy inputs by 1%.

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EFEKTYWNOŚĆ ENERGETYCZNA UPRAWY ŻYTA HYBRYDOWEGO W ZALEŻNOŚCI OD SPOSOBU UPRAWY GLEBY

Streszczenie. W jednoczynnikowym doświadczeniu łanowym, prowadzonym w latach 2011-2012 w Demo Farmie w Drzęczewie koło Gostynia w województwie wielkopolskim porównywano wielkość i strukturę nakładów energetycznych poniesionych na uprawę żyta hybrydowego oraz wartość wskaźnika efektywności energetycznej. Wielkość nakładu energii skumulowanej nie była zróżnicowana przez porównywane systemy uprawy roli, zależała ona bowiem w głównej mierze od nakładów energii skumulowanej wniesionej w formie materiałów (około 85%). Zastosowanie uprawy bezorkowej zmniejszyło nakład energii wniesionej w formie paliwa o 2,4%, a w formie agregatów o 34,5% (w porównaniu do uprawy orkowej). Porównywane systemy uprawy roli różnicowały wielkość plonu ziarna żyta hybrydowego o 4,7%, wartość wskaźnika efektywności energetycznej o 3,9%, a wielkość skumulowanych nakładów energetycznych o 0,9%.

Słowa kluczowe: system uprawy, plon ziarna, wskaźnik efektywności energetycznej, żyto hybrydowe