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Comparison of organic and conventional farming system in term of energy efficiency

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Abstract:
The aim of this study was to compare the energy use in cereal crop rotation in conventional and organic farming system in terms of additional energy inputs, gross energy production, energy profit and energy efficiency evaluation in years 2003 – 2005 in the stationary field experiment established on degraded Chernozem on loess in a maize – barley growing region in south west Slovakia (near Piešťany town). Increased energy inputs caused the increase of production in the Conventional Farming System. The Conventional System was more energy demanding (about 52.5%) in comparison with the ecological one. The most energy demanding crops were those amended by farm yard manure: maize for grain (21.31 GJ ha^{-1}in the organic system, 34.18 GJ ha^{-1}in the conventional system) and winter wheat (17.20 GJ ha^{-1}in the organic system, 24.60 GJ ha^{-1}in the conventional system). The highest energy gain provided maize for grain in both farming systems (179.22 GJ ha^{-1}in the conventional system and 177.99 GJ ha^{-1}in the organic system).

Introduction and Objectives:

Agriculture is considered to be an important segment of the world energy scheme, (fertilizers and chemicals production, soil tillage, transportation, PREININGER 1987). Today's agricultural production relies heavily on the consumption of non-renewable fossil fuels. Fossil energy consumption results in direct negative environmental effects through release of CO_2 and other greenhouse gasses.

For the implementation in agriculture of the general concept of sustainability, agronomists have proposed several solutions such as integrated arable farming systems and low input or organic farming (VEREIJKEN 1997, EDWARDS 1987).

Crop management systems need to be designed to help farmers maintain economic profitability while conserving external energy resources and farming in an environmentally responsible manner (PERVANCHON et al. 2002). In various international studies, organic agriculture shows to have lower fossil energy use and to have lower GHG emissions than conventional agriculture (BOS et al. 2006).

Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil fuels preservation and air pollution reduction (PERVANCHON et al. 2002).

The evaluation of energy producing systems and consequently the opportunity to save unnecessary expenditure in plant production are actual issues solved at different scientific workplaces in Slovakia (LEHOCKÁ et al. 2005, OTEPKA 2005, STREĎANSKÁ 1997). However the comparative studies from organic and conventional farming systems are still needed mainly for the fact that Slovakia has wide potential for organic farming development. For example, in 2003 share of organic managed land represented 2.25% of total agricultural land while in year 2005 it was 4.62%. This means an area growth 37,712 ha in two years.

Methods:

The field experiment was based on degraded Chernozem on loess (Luvi – haplic Chernozem) in a maize and barley growing region in south western Slovakia (near Piešťany). The Chernozem had a good content of potassium, normal content of phosphorus and a high content of magnesium, with the humus content 1.8% – 2.0%. The region has a continental climate with an average annual temperature of 9.2 ^{0}C and the mean annual precipitation of 593 mm.

The experiment design used a split plot arrangement in a randomized block with two replications. The harvest plot area was 78 m^{2} (3 x 26 m). The field experiment has been running eleven years. The organic system was incorporated a year later. The organic plots have been managed organically for seven years and two years was the conversion period.

(Crop rotation: spring barley, pea, winter wheat, maize for grain, spring barley, winter wheat).

Organic system: All operations were realised in compliance with Slovak Law SR 421/2004. Farm yard manure fertilisation took place twice during the crop rotation. The rate represented 40 t ha^{-1}; the N content was 0.47%. The P and K fertilisation couldn't be undertaken as there was no permit available in the Slovak Republic.

However, within the system there was mechanical weed control (harrow and finger weeder in cereal stands, hoe in maize for grain) but there was no chemical plant protection.

Conventional system: Farm yard manure fertilisation took place twice during the crop rotation to maize for grain and winter wheat after spring barley. The rate represented 40 t ha^{-1}, the N content was 0.47 % + P and K mineral fertilisation was defined by the balance method. The N fertilisation was according to the normative for planned yields; 173 kg N ha^{-1} to wheat, 180 kg N ha^{-1} to maize for grain, 130 kg N ha^{-1} to spring barley, 20 kg N ha^{-1} – starting rate for pea. Chemical protection was used against pests and diseases.

The experimental plots were situated in the ground water protection area so we had to follow appropriate norms in respect to nitrogen fertilization rates: Good agricultural practice – Law 445/2002, Water Law No. 364/2004 and No. 184/2002.

The same varieties and soil tillage practices were used in both farming systems.

The energy balance was calculated according to our own results. We used the real raw yields converted to 14% of dry matter content and recalculating coefficients by PREININGER (1987). We calculated direct and indirect energy inputs. Direct energy inputs consisted of human labour energy – energy equivalent was 25.65 MJ h^{-1}, fossil energy like the sum of diesel – oil consumption, electric energy and heat energy. Indirect energy inputs consisted of machinery, chemical fertilizers, farm yard manure, and seed energy. Direct energy is used at the farm and on fields for crops, but indirect energy is not consumed at the farm. However, both direct and indirect forms of energy are required for agricultural production in terms of its development and growth. The yields were evaluated by variance analysis.

Results and Discussion:

Energy input–output analysis is used to evaluate the efficiency and environmental impacts of production systems (GUNDOGMUS 2006). Energy balance is a vital tool to evaluate the efficiency on how production systems use energy (THIAGO & MARCOS 2004). Energy balance makes it possible to compare different farming systems in terms of energy efficiency. Energy efficiency is closely associated with economical but also ecological aspect of agricultural production. According to PREININGER (1987) each production activity, is a process of energy transformation and its changing characteristics (PREININGER 1987). The aim of our study was to compare different farming systems (organic and conventional) in terms of energy input, energy profit and energy efficiency from 2003 – 2005.

Tab. 1: Energy balance in cereal crop rotation in two farming systems.

Crop	***System***	***Yields ($t\ ha^{-1}$)***	***Additional Energy Input ($GJ\ ha^{-1}$)***	***Gross Energy Production ($GJ\ ha^{-1}$)***	***Energy Profit ($GJ\ ha^{-1}$)***	***Energy efficiency***
Spring barley	*Organic*	4.67	12.63	137.7	125.07	0.91
	Conventional	5.77	16.56	164.9	148.34	0.90
	LSD at the level $\alpha=0.05$	0,75				
Pea	*Organic*	2.66	7.39	94.9	87.50	0.92
	Conventional	2.98	10.36	97.9	87.56	0.89
	LSD at the level $\alpha=0.05$	0.53				
Winter wheat	*Organic*	4.70	9.20	150.5	141.30	0.94
	Conventional	5.45	20.26	165.4	145.14	0.88
	LSD at the level $\alpha=0.05$	0.85				
Maize for grain	*Organic*	6.95	21.31	199.3	177.99	0.89
	Conventional	6.96	34.18	213.4	179.22	0.84
	LSD at the level $\alpha=0.05$	1.59				
Spring barley	*Organic*	4.76	12.63	132.0	119.37	0.90
	Conventional	5.96	16.56	169.3	152.74	0.90
	LSD at the level $\alpha=0.05$	0.80				
Winter wheat	*Organic*	4.21	17.20	135.0	117.80	0.87
	Conventional	4.61	24.60	140.1	115.50	0.82
	LSD at the level $\alpha=0.05$	0.98				
Average			13.39	141.6	128.21	0.91
			20.42	158.5	138.08	0.87

The yields obtained in organic farming were comparable with the yields from conventional production. Statistically significant differences in grain yields were only found in spring barley. In the soil climatic conditions (soils with high soil fertility) in south west Slovakia it is also possible to cultivate pea, winter wheat and maize for grain successfully by using farming systems with lower inputs.

The Conventional Farming System was more energy demanding than the Organic Farming System (the difference represented 52.5%). The results were in lines with OTEPKA'S results (2005) which showed that Organic Farming System had lower energy demands than these required by the Conventional Farming System.

The crops that demanded the most energy were those that used the farm yard manure (maize for grain and winter wheat). Pea was the least energy consuming crop in our project. Our results were in lines with the results of STREDANSKA (1997) who found that the most energy demanding plant was maize for grain.

The energy profit was higher in the Conventional Farming System (the difference represented 7.69%).

The farming system energy efficiency, so called the net energy profit, represents the difference between gained and delivered energy. Energy efficiency was higher in the Organic Farming system than in the Conventional Farming System. Major differences in energy efficiency between organic and conventional farming system were discovered at winter wheat after pea.

Conclusions:

The yields obtained in organic farming were comparable with the yields from conventional production. The research results revealed that the energy input use on organic production was 52.5% lower than that of conventional production.

Energy balance makes it possible to compare different farming systems in terms of energy efficiency. More energy from embedded energy units was produced in the organic farming system (about 4.4% on average).

Combining renewable energies and organic agriculture offers tremendous synergies for sustainable development.

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