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Abstract: *A field stationary experiment was carried out during 2001– 2005 at the Experimental base of the SPU in Dolná Malanta. The long-term average annual temperature of the site is 9.7°C and 16.6°C during the vegetation period. The average rainfall is 561 mm, including 323 mm during the vegetation period. The aim of the study was to evaluate yield and the energy balance of common pea growing under different soil tillage and fertilization treatments. The tillage treatments were as follows: conventional tillage (to the depth of 0.25 m), reduced tillage (to the depth of 0.18 m), and minimized tillage (to the depth of 0.10 m). (EZ), additional energy input (VE), and energy of yield (EHÚ). Rational utilization of energy input (VR) and additional energy input (VE) were also significantly influenced by evaluated fertilization treatments. The lowest yield of common pea was reached by minimized technology of soil cultivation. The highest energy gain was reached by the tillage to the depth 0.18 m and the lowest by the minimized tillage.*

Rezumat*: V rokoch 2001 – 2005 bol na Experimentálnej báze Dolná Malanta založený poľný pokus. Lokalita má priemernú ročnú teplotu 9,7 °C a počas vegetačného obdobia 16,6 °C. Ročné zrážky sú 561 mm, počas vegetačného obdobia 323 mm. Bola vyhodnotená energetická bilancia hrachu siateho pri troch obrábaniach pôdy: orba do hĺbky 0,25 m, orba do hĺbky 0,18 m a minimalizačné obrábanie pôdy do hĺbky 0,10 m. Skúmali sme tri úrovne hnojenia: kontrola, hnojenie priemyselnými hnojivami bilančnou metódou, hnojenie priemyselnými hnojivami so zapracovaním pozberových zvyškov predplodiny. Stanovené boli: energetický zisk (EZ), racionálnosť využitia vkladu energie (VR), potreba energie na 1 tonu produkcie (PE), dodatková energia (VE), energie hospodárskej úrody (EHÚ). Najnižšia úroda hrachu siateho bola dosiahnutá pri minimalizačnej technológii obrábania pôdy. Najvyšší energetický zisk bol dosiahnutý pri orbe do hĺbky 0,18 m a najnižší pri minimalizačnom obrábaní pôdy.*

Key words**:** *energy balance, common peas, fertilization, primary soil tillage*
Cuvinte cheie*: energetická bilancia, hrach siaty, hnojenie, základné obrábanie pôdy*

INTRODUCTION

The yield production and input of direct and indirect fossil energy and its agro-environmental causalities is especially relevant in view of Common Agricultural Policy of EU. Legumes are crops of major importance in sustainable crop rotation patterns by increasing agrobiodiversity mainly in lowland part of arable land of Slovakia (MACÁK 2006; KOVÁČ and MACÁK, 2007a). In Slovakia 10,000 hectares are produced, for processing into frozen or canned products or for animal nutrition with average yield 2.5 t ha^{-1}. The agrienvironmental conditions and precipitation status, crop pattern, fertilization and soil tillage are the main factors of variability of crop productivity (KOVÁČ and MACÁK, 2007b). The main role of soil tillage is adjustment of physical soil properties. A major objective of soil water – management systems is to encourage water infiltration and stability of yield of peas growing in suitable crop sequences (MACÁK et al., 2006; SMATANA et al., 2006). For energy balance, different approaches are applied as fertilisation and pesticides used, efficiency of soil tillage and farming systems and energy gain of crop rotation patterns (MÉGÉON, 1996; RISOUD and CHOPINET 1999; POSPIŠIL 2002 et al.; KOVÁČ et al., 2005b; ŽÁK et al., 2006).

The aim of the study was to evaluate yield and the energy balance of common pea growing under different soil tillage and fertilization treatments.

MATERIAL AND METHOD

A field stationary experiment was carried out during 2001– 2005 at the Experimental base of the Slovak University of Agriculture in Dolná Malanta. The long-term average annual temperature of the site is 9.7°C and 16.6°C during the vegetation period. The average rainfall is 561 mm, including 323 mm during the vegetation period. The soil is classified as a medium-heavy Haplic Luvisol formed. The chemical properties of experimental site are in Table 1.

The strip-plot design with three tillage treatments in four replications and following cropping sequences of winter wheat, pea + intercrop (white mustard), grain maize, spring barley with undersowing of red clover and next year only red clover, were applied.

The tillage treatments were as follows: B-1 – conventional tillage (to the depth of 0.25 m), B-2 – reduced tillage (to the depth of 0.18 m), B-3 – minimized tillage (to the depth of 0.10 m). The fertilization methods were as follows: 0 – no fertilization; PH – balance fertilization to design yield; PZ – balance fertilization with incorporation of forecrops residues after harvest. The fertilized level was calculated on the yield level 30 t ha^{-1} according FECENKO, LOŽEK (2000).

Quantification of the energy contribution, the used energy equivalents and methods of calculation were calculated according to Preininger's method (1987). For the energy balance evaluation, the following factors of the additional energy inputs were calculated:

1. mineral and organic fertilizers in pure NPK nutrients used [kg ha^{-1}]
2. energy in machines [GJ ha^{-1}]
3. energy in seeds [GJ ha^{-1}]
4. fuel consumption [l ha^{-1}]
5. pesticides [kg ha^{-1}]
6. labour consumption [h ha^{-1}].

The statistical program Statistica 6.0 for Windows was used for data analysis (analysis of variance, multiple range tests).

RESULTS AND DISCUSSION

The experimental site is characterized with the high average temperature and the lower rainfall. A weather condition in the individual year of cultivation is presented in figure 1.

The precipitation status of evaluated year strongly influences the variability in soil moisture. The extremely dry June (6.5mm) 2003 has the influence on soil moisture scenario. The highest precipitation doses were noted in 2002 and 2005. In assessment of soil humidity balance and soil moisture dynamic the high influence tillage systems have to be keeping in mind (KOVÁČ et al., 2005a). In our trial during period of seeds formation (Mai–June) the warmest conditions were noted in 2001-2003.

During elongation period of peas plant optimal temperature (day-night) for peas crop in vegetative period are in interval 16-20 °C and 10-16 °C in generative phase of peas crop (LAHOLA et al.,1990). Similarly LEHMANN and BLIXT (1994) referred 18 °C as optimal temperature with higher temperature in vegetative phase and lower in generative phase.

For common pea are suitable sandy-loam soils with the depth of the topsoil 180-350 mm, with the content of humus 2 %, pH 6-7 (POSPIŠIL, CANDRÁKOVÁ, 2004). The nutrient content in soil is presented in table 1.

The highest grain yield of common pea was reached at the treatment with mineral fertilizers at every method of soil cultivation in an average. According the five years results disk tools, as a part of minimized technology, was the less suitable for primary tillage of common peas (tab. 2).

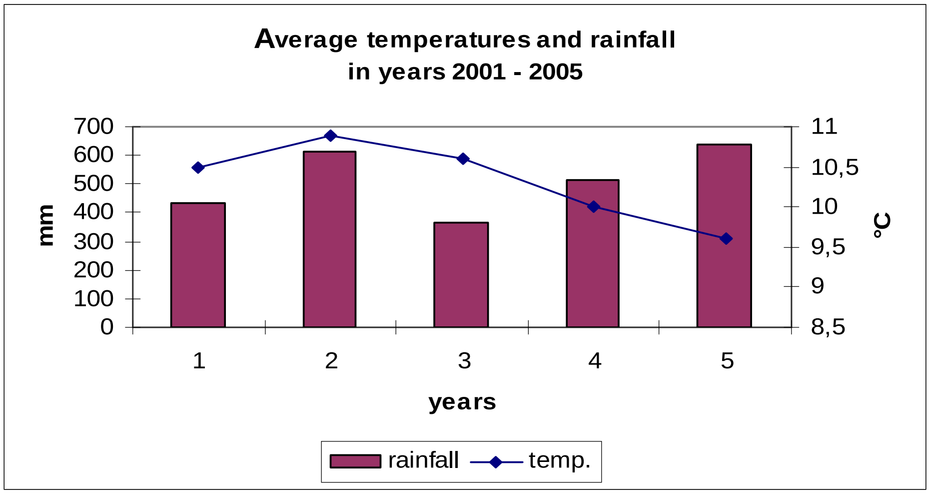

Figure 1

Table 1

The agrochemical soil characteristics before sowing

Year	Nutrient content (mg kg^{-1})					Humus %	pH / KCl
	N_{an}	P	K	Ca	Mg		
2001	3.95	55	260	2110	270	2,41	5.69
2002	4.11	58	246	1890	235	2.40	5.63
2003	3.78	56	220	1560	215	2.43	5.60
2004	4.05	69	304	1750	230	2.42	5.65
2005	3.87	69	296	1600	221	2.40	6.39

Energy outputs from growing of peas varied from 51.53 GJ ha^{-1} in minimize tillage system with incorporation of forecrop residues (B3 PZ, 2003) to 348.68 GJ ha^{-1} in reduced tillage (B2, PH, 2002). The soil tillage system strongly differs in energy balance evaluation. KOVÁČ et al. (2005b) noted highest brutto energy output by conventional tillage (216 GJ h^{-1}) with comparison to no till system (202 GJ h^{-1}) The placement of the postharvest residues was negative on energy production, what can be caused by the influence of postharvest residues of preceding crop – winter wheat. Postharvest residues of winter wheat showed the least values of microbial activities, least speed of mineralization and the high immobilization of nitrogen after their placement in the plough-land (ZAUJEC, 1994).

Table 2

The influence soil cultivation and fertilization on the seed yield of common pea

Soil cultivation	Fertilization	Seed yield (t ha^{-1})					
		2001	2002	2003	2004	2005	Average
B 1	0	5.47	5.53	1.32	3.26	3.08	3.73
	PH	5.65	5.76	1.36	3.65	3.74	4.03
	PZ	5.09	5.08	1.13	3.29	4.90	3.90
	Average	**5.40**	**5.46**	**1.27**	**3.40**	**3.91**	**3.89**
B 2	0	5.66	5.67	1.53	3.52	3.44	3.96
	PH	5.69	5.80	1.45	3.58	3.55	4.01
	PZ	5.27	5.35	1.51	3.48	4.01	3.92
	Average	**5.54**	**5.61**	**1.50**	**3.53**	**3.67**	**3.97**
B 3	0	4.52	4.59	1.02	3.52	3.82	3.49
	PH	4.50	4.52	1.35	3.75	3.86	3.60
	PZ	4.67	4.76	1.00	3.12	3.18	3.35
	Average	**4.56**	**4.62**	**1.12**	**3.46**	**3.62**	**3.48**

Table 3

Energy balance of growing of common pea (average of year 2001-2005).

Tillage and fertilization treatments		Energy gain [GJ ha^{-1}]	Energy efficacy [%]	Need of energy per ton of main product [GJ t^{-1}]	Rational utilization of energy input [%]
B1	0	59.41	7.37	3.67	90.23
	PH	61.89	6.94	3.76	87.04
	PZ	54.35	6.47	4.35	79.05
	$\overline{x}$	58.55	6.93	3.93	85.39
B2	0	63.16	7.90	3.21	90.30
	PH	62.52	7.10	3.51	88.32
	PZ	59.08	7.05	3.62	85.29
	$\overline{x}$	61.59	7.35	3.44	87.98
B3	0	51.43	6.88	4.24	83.52
	PH	52.36	6.31	4.01	82.54
	PZ	49.76	6.32	4.56	84.98
	$\overline{x}$	51.18	6.50	4.27	83.64

The energy inputs of the soil tillage were in intervals from 8.57 GJ ha^{-1} (B1 - in the year 2003) to 14.62 GJ ha^{-1} (B2 - in the year 2005). Comparable high of the energy inputs stated Pospišil (2002). In our experiments the highest demand energy inputs from fossil fuels was by tillage (B1) to the depth 0.25m (10.47 GJ ha^{-1}) and the least demand (9.29 GJ ha^{-1}) was noted by minimized tillage soil cultivation (B3). The energy from fossil fuels was sharing on additive energy inputs by minimized tillage 27.71 % (B1). 25.78 % (B2) and 24.41% (B3). The highest energy gain was in the treatment B2 with mineral fertilization (PH) in 2002 (91.82 GJ ha^{-1}) and the lowest in the treatment B3 with incorporation of post harvest residues (PZ) in 2003 (5.61 GJ ha^{-1}). This data indicates that common pea has expressive variability of yields in the individual years. The highest energy gain was reached at the tillage to the depth 0.18 m and the lowest at minimal tillage (tab.3). We noted statistically significant differences at the $P > 0.05$ between these two methods of cultivation.

All evaluated indicators were influenced by year condition (tab. 4). Primary soil tillage significantly influenced energy gain (EZ), additional energy input (VE), and energy of yield (EHÚ). Rational utilization of energy input (VR) and additional energy input (VE) were also significantly influenced by evaluated fertilization treatments.

Table 4

Analysis of variance of main indicators of energy balance of common pea production

Indicator	Year	Soil cultivation	Fertilization
	degree of freedom 4	Degree of freedom 2	degree of freedom 2
Energy of grain yield - EHÚ	113.25^{+++}	5.23^{+}	0.61^{-}
Energy gain - EZ	115.30^{+++}	4.60^{++}	0.40^{-}
Rational utilization of energy - VR	123.50^{+++}	2.10^{-}	5.80^{++}
Need of energy per 1 tonne of production - PE	79.55^{+++}	1.75^{-}	1.22^{-}
Additional energy - VE	60.83^{+++}	73.26^{+++}	9.62^{+++}

Significance $^{+++}$ $\alpha<0.001$; $^{++}$ $\alpha<0.01$; $^{+}$ $\alpha<0.05$

CONCLUSIONS

According to the five years evaluation period of common pea field trials during 2001-2005 we can suggest the following conclusion:

- Primary soil tillage significantly influenced energy gain (EZ), additional energy input (VE), and energy of yield (EHÚ).
- Rational utilization of energy input (VR) and additional energy input (VE) were also significantly influenced by evaluated fertilization treatments.
- The least accepted technology from point of view of yield was minimize soil cultivation.
- The highest level of production energy of yield of common pea was achieved at the tillage to the depth 0.18m.

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