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ENERGY BALANCE OF POTATO GROWING IN ECOLOGICAL, LOW-INPUT AND CONVENTIONAL PRODUCTION SYSTEM

ENERGETICKÁ BILANCIA PESTOVANIA ZEMIAKOV V EKOLOGICKOM, LOW-INPUT A KONVENČNOM SYSTÉME

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During 2000–2002 the field trial was established on degraded Chernozem in a maize-barley growing region. The aim of the study was to compare the energy balance of potato growing in ecological, low-input and conventional system for incentive of agro-environmentally friendly agricultural systems.

The experimental plots were situated in water-protected zone and doses and types of chemical were used according legislative restriction.

The high and acceptable average gross energy production from hectare was obtained in all evaluated growing systems – from 89.86 GJ.ha^{-1} in ecological system, up to 106.7 GJ.ha^{-1} in conventional system. The highly significant differences between input of additional energy per hectare into evaluated systems (with average input into ecological system 34.38 GJ.ha^{-1}, low-input system 38.56 GJ.ha^{-1} and conventional system 41.11 GJ.ha^{-1}) were noted. The increase of additional energy (from chemical fertilizers) has no significant influence for gain of energy per weight unit, gain of gross energy per tone of dry matter, gross energy effectiveness, measuring consumption of gross energy and energy efficiency in conventional system with comparison to low-input system and ecological system.

Significantly lower input of additional energy into ecological and low-input system of potato growing with comparison to conventional system with simultaneous no significant differences in main characteristics of energy gains of all evaluated systems gave evidence for recommendation of agro-environmental friendly agricultural systems of potato growing in Slovakia.

Key words: energy balance, ecological system, low-input system, conventional system, growing of potatoes

Food production systems must be environmentally sustainable and their products must be accessible and safe. The yield production and input of direct and indirect fossil energy and its agro-environmental causalities is especially relevant in view of the Common Agricultural Policy of EU. An agro-industrial model relies on standardized technologies and ever-increasing fertilizer and pesticide use to provide additional food supplies for growing population. In con-

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trast, analysts propose that instead of this capital and input intensive approach, countries should favour for an agro-ecological model, which emphasizes biodiversity, recycling of nutrients, synergy among crops, animals, soil and other biological components, and regeneration and conservation of resources [1]. Present cropping technologies are energy and economical demanding with comparison to price of agricultural products. Pospišil and Macák [15] pointed out that the basic tillage systems and use of chemical have big share of total energy input into agricultural systems.

To achieve sustainable production, it is important that the natural resources are not irreversibly exhausted or destroyed. Management of ecological farming systems is based on control of complex ecological, dynamic processes. In contrast to conventional farming, an ecological farmer does not have quick-acting instruments like chemical fertilisers, pesticides, etc., to his disposal, but has to rely on more complex ones. For example, chemical fertilizer is substituted by a multifunctional crop rotation in time and space with sufficient legumes, stimulation of soil life to make nutrients available, etc. as well as these ecological aspects of ecological farming, animal welfare and an attractive landscape become more and more important with regard to marketing of ecological products [20].

Integrated farming in its various forms represents a step or several steps towards sustainability. Low-input system is one of the possibility of environmentally friendly methods of reduce energy inputs, predominantly via decreasing consumption of fossil energy (fuel, fertilizers). Integrated farming significantly reduces the use of chemical inputs through sophisticated farm management, efficient modern cultivation methods and techniques of plant protection and weed control. As with other environmentally friendly farming systems, integrated farms tend to have lower economic costs, lower yields and similar profitability as conventional farms [4].

Organic farming almost does not use any synthetic substance such as chemical pesticides and fertilizers (with a few limited exceptions), but uses natural methods such as crop rotation. In Slovakia new act no. 421/2004 [13] about ecological agriculture was released by implementing of EU law. Organic farms have significantly higher biodiversity, reduce energy consumption and cause less water pollution than intensive farms. In comparison with conventional farms, organic farms have lower costs for inputs and higher labour costs, but the total costs are usually lower by 10–25 % per hectare. Organic farms have usually lower yields, e.g. organic cereal yields are typically 60–70 % of conventional yields [11]. The same results concerning potatoes growing in ecological system with comparison to conventional one received also Jůzl et al. [10]. The main causation of lower yield is considered the insufficient protection against pests, spring deficit of nutrients and strong competition of weeds. The level of outputs and inputs of energy of crop production and individual crops is limited by particular place conditions which can be influenced by human activity (additional input of energy, farming and cropping systems) or with-

Table 1

Characteristics of the experimental site (Borovce)
Charakteristika pokusného stanovišťa (Borovce)

Parameter (1)	Value (2)
altitude (3) growing region (4) soil type (6)	167 m maize-barley (5) Luvi-haplic Chernozem (7)
content (8) N_{in} humus (Tyurin) avail. P (Mehlich II) avail. K (Mehlich II) avail. Mg (Mehlich II)	 10.5 – 16.0 $mg.kg^{-1}$ d.m. 1.8 – 2.0 % good (9) medium (10) high (11)
pH/KCl	5.5 – 7.2

N_{in} – inorganic nitrogen – anorganický dusík
avail. – available for plants
pristupný pre rastliny
d.m. – dry matter – sušina

(1) Ukazovateľ, (2) hodnota, (3) nadmorská výška, (4) výrobná oblasť, (5) kukuričnо-jačmenná, (6) pôdny typ, (7) černozem hnedozemná, (8) obsah, (9) dobrý, (10) stredný, (11) vysoký

out substantial possibility of influence by human activities as soil and climate [16].

The aim of the present work was the comparison of the energy balance of potato growing in ecological, low-input and conventional system for incentive of agro-environmentally friendly agricultural systems.

MATERIAL AND METHOD

The field stationary experiment was established in 2000–2002 years on Luvi-haplic Chernozem with 1.8 – 2.0 % content of humus and neutral pH value (tab. 1) at experimental station of SCAR–RIPP in Borovce village (near Piešťany town at western part of the Slovak Republic). The site belongs to maize-barley growing region with altitude 172 m, average annual temperature 9.2 °C and annual precipitation 595 mm (tab. 2).

The experimental plots are situated in water-protected zone and doses and types of chemical were used according legislative restriction. The potato was growing under three-cropping systems in six-crop rotation sequences as follows: meadow clover – winter wheat – common pea – winter wheat – potato – spring burley with underseeding meadow clover.

Early potato variety Red Scarlett (during 2000–2001) and early potato variety Collete (in 2002) were growing. Catch crops (mustard and phacelia) after winter wheat and potatoes were incorporated.

Evaluated systems:

ES – ecological system of crop production: The direction and practices in accordance of IFOAM (International Federation of Organic Agriculture Movements) have been applied. The farmyard manure, straw and crops residues and green manure were

T a b l e 2

Weather conditions in the experimental years 2000–2002
Poveternostné podmienky v pokusných rokoch 2000–2002

Month (mesiac)	n30 (1950–1980)		2000		2001		2002	
	°C	mm	°C	mm	°C	mm	°C	mm
I.	−1.8	32	−3.3	34	−1.3	13.2	−4.0	19.8
II.	0.2	33	1.5	29.5	0.4	19.1	3.0	42.7
III.	4.2	32	4.1	79	4.7	67	7.1	20.8
IV.	9.4	43	12.8	9.7	7.7	31.8	11.1	27.8
V.	14.1	54	15.8	35.9	15.4	30.1	18.7	50.4
VI.	17.7	80	18.2	39.1	15.4	43.3	19.9	95.3
VII.	18.9	76	17.2	69.1	19.1	119	22.8	67.6
VIII.	18.4	68	20.6	20.8	20.1	10	22.4	71.7
IX.	14.5	38	13.6	42.9	11.9	115	15.6	34.5
X.	9.6	42	12.0	26.9	11.2	11.7	9.2	58.2
XI.	4.6	51	7.0	82.4	0.9	30	7.6	61.9
XII.	0.3	46	0.3	52.3	−6.9	43.3	−1.5	44.9
$\bar{x}$I.–XII.	9.2		10.0		8.2		11.0	
$\bar{x}$IV.–X.	14.7		15.7		16.8		17.1	
ΣI.–XII.		595		521.6		532.7		594.5
ΣIV.–X.		401		244.4		360.9		405.5

n30 – long-term (30-year) normal – dlhodobý (30-ročný) normál
°C – average air temperature – priemerná teplota vzduchu
mm – sum of precipitations – úhrn zrážok
$\bar{x}$I.–XII. – average temperature for year – priemerná teplota za rok
$\bar{x}$IV.–X. – average temperature for vegetation period – priemerná teplota za vegetačné obdobie
ΣI.–XII. – sum of precipitations for year – suma zrážok za rok
ΣIV.–X. – sum of precipitations for vegetation period – suma zrážok za vegetačné obdobie

used. The farmyard manure was used three-times per six-crop rotation to potatoes 40 t.ha^{-1} and to winter wheat each time 7 t.ha^{-1}. Chemical fertilizers and common chemical control were excluded. Only permitted insecticide (Novodor) and fungicide (Kuprikol) were used. Ecological protected belt (ecological infrastructure) has been also used.

LIS – low-input system (integrated system): Conventional soil cultivation was used. Straw and crop residues were incorporated into soil with supplementing of consumed PK-nutrient by chemical fertilizers. Farmyard manure was used ones per rotation to potatoes with dose 40 t.ha^{-1}. Low level of nitrogen fertilizers was used to all growing crops (to winter wheat 40 kg, to common pea 10 kg and to spring barley 30 kg nitrogen per hectare). Integrated pest management was also used.

CS – conventional system: Straw and crop residues were incorporated into soil with supplementing of consumed PK-nutrient by chemical fertilizers. Farmyard manure was used ones per rotation to potatoes with dose 40 t.ha^{-1}. Higher level of nitrogen fertilizers was used to all growing crops (to winter wheat 80 kg, to common pea 20 kg and to spring barley 30 kg nitrogen per hectare). Common pest management again weeds, diseases and pests was used.

In all evaluated systems the same basic tillage (conventional mouldboard plough and rotative cultivator Amazone KG-301) and management practices of organic matter (incorporation of straw and crop residues) were used. PK-fertilization in systems CS and LIS was made according to input-output balance. In the first year, the fertilization doses were applied ac-

T a b l e 3

The inputs of additional energy for potatoes growing per hectare in GJ (2000–2002)
Vstupy dodatkovej energie na hektár pri pestovaní zemiakov v GJ (2000–2002)

System (¹)	Year (²)	Human work (³)	Technological work (⁴)	Pest protection (⁵)	Fertilizers (⁶)		Seeds (⁷)	Total (⁸)
					chem.	org.		
ES	2000	0.59	15.29	1.47	–	10.8	5.68	33.21
	2001	0.61	15.29	2.69	–	10.8	6.82	35.59
	2002	0.68	15.29	3.68	–	10.8	4.50	34.33
	$\bar{x}$ES	0.63	15.29	2.61	–	10.8	5.67	34.38
LIS	2000	0.59	15.29	1.98	2.91	10.8	5.68	36.63
	2001	0.55	15.29	0.53	8.20	10.8	6.82	41.57
	2002	0.68	15.29	2.62	4.23	10.8	4.50	37.50
	$\bar{x}$LIS	0.60	15.29	1.71	5.11	10.8	5.67	38.56
CS	2000	0.59	15.29	1.98	5.42	10.8	5.68	39.14
	2001	0.55	15.29	0.53	8.46	10.8	6.82	41.83
	2002	0.68	15.29	2.62	9.10	10.8	4.50	42.37
	$\bar{x}$CS	0.60	15.29	1.71	7.66	10.8	5.67	41.11

chem. – chemical – priemyselné
org. – organic – organické
ES – ecological system – ekologický systém
LIS – low-input system – low-input systém
CS – conventional system – konvenčný systém
$\bar{x}$ES, $\bar{x}$LIS, $\bar{x}$CS – average for years within individual systems
priemer za roky v rámci jednotlivých systémov

(¹) Systém, (²) rok, (³) ľudská práca, (⁴) strojová práca, (⁵) ochrana proti škodcom, chorobám a burinám, (⁶) hnojivá, (⁷) osivá, (⁸) spolu

T a b l e 4

Determining characteristic of energy balance of potato growing
Rozhodujúce znaky energetickej bilancie pestovania zemiakov

Parameter (1)		Yield (4) (t.ha^{-1})		Input of energy (GJ) (7)			Gross energy from yield (9) (GJ.ha^{-1})
		tubers (5)	dry matter (6)	GJ.ha^{-1}	per tone of yield (8) tubers	per tone of yield (8) dry matter	
$\bar{x}$T		24.75	8.46	38.05	1.57	4.63	99.26
min.		13.91	4.76	33.21	0.44	3.41	55.78
max.		34.63	11.84	42.83	2.63	7.70	138.87
V		21.29	2.49	10.84	0.10	0.63	342.40
s		4.61	1.58	3.29	0.31	0.79	18.50
v (%)		18.65	18.69	8.87	21.05	17.67	18.65
years (Y) (2)	2000	20.57	7.02	36.33	1.81	5.29	82.46
	2001	29.86	10.21	39.75	1.33	3.89	119.72
	2002	23.84	8.15	38.07	1.57	4.71	95.59
	SS	503.07	62.77	70.18	1.36	11.79	8572.55
	F	204.51	205.45	1263.34	22.93	47.64	204.50
	$LSD_{0.05}$	1.01	0.34	0.14	0.15	0.31	4.07
	$LSD_{0.01}$	1.42	0.48	0.20	0.21	0.43	5.17
	P	1 : 2,3^{++} 2 : 3^{++}	1 : 2,3^{++} 2 : 3^{++}	1 : 2,3^{++} 2 : 3^{++}	1 : 2,3^{++} 2 : 3^{++}	1 : 2,3^{++} 2 : 3^{++}	1 : 2,3^{++} 2 : 3^{++}
systems (S) (3)	ES (a)	22.41	7.66	34.38	1.53	4.60	89.86
	LIS (b)	25.24	8.63	38.56	1.61	4.72	101.22
	CS (c)	26.61	9.08	41.11	1.56	4.57	106.70
	SS	110.22	12.65	283.94	0.04	0.15	1772.35
	F	42.28	41.41	5110.95	0.66	0.63	48.28
	$LSD_{0.05}$	1.01	0.34	0.14	0.15	0.31	4.07
	$LSD_{0.01}$	1.42	0.48	0.20	0.21	0.41	5.17
	P	a : b,c^{++} b : c^{+}	a : b,c^{++} b : c^{+}	a : b,c^{++} b : c^{++}	–	–	a : b,c^{++} b : c^{+}
Y x S	SS	77.46	8.98	22.33	0.29	3.34	1245.48
	F	14.86	14.69	20.14	2.47	6.76	14.85
	P	++	++	++	–	++	++

$^{+}P<0.05$ $^{++}P<0.01$

LSD – limit significant difference at the level α = 0.05 or α = 0.01
hraničná diferencia na hladine významnosti α = 0,05 alebo α = 0,01
P – effect significant at the level α = 0.05 or α = 0.01
preukaznosť vplyvu na hladine α = 0,05 alebo α = 0,01
min., max. – minimum and maximmum value – maximálna a minimálna hodnota
V – variance – variancia
s – standard deviation – smerodajná odchýlka
v – coefficient of variance – variačný koeficient
SS – sum of squares – suma štvorcov
F – calculated F-value – vypočítaná F-hodnota
$\bar{x}$T – total average – celkový priemer

Other symbols are identical with those of the table 3.
Ostatné symboly ako v taubľke 3.

(1) Ukazovateľ, (2) roky, (3) systémy, (4) úroda, (5) hľúz, (6) sušiny, (7) vstup energie, (8) na tonu úrody, (9) brutto energia z úrody

cording to planned yield – for winter wheat 7 tons, for spring barley 6 tons, for pea 4 tons, for potatoes 20 tons and for meadow clover up to 10 tons per hectare. The next years the fertilization doses were adjust according yield of forecrop sequence calculated according to B í z i k et al. [3], B u j n o v s k ý and L o ž e k [5]. Energy balance calculation: fundamental parameters of energy balance was calculated according to P r e i n i n g e r [17] and P o s p i š i l with V i l č e k [16]. In frame of energy balance calculation of potato growing the following parameters were calculated:

Input of additional energy (AE) comprise human and technological work, seeds, chemical fertilizers, farmyard manure and pesticides. Energy of application of fertilizers was taken into account to whole fertilizers energy items:

- energy output (energy of yield) EY = gross energy GE ($GJ.ha^{-1}$).
- gain of gross energy GGE = EY – AE ($GJ.ha^{-1}$)
- gross energy effectiveness GEEf = GGE/EY. 100 (%)
- measuring consumption of gross energy MCGE = AE/EY
- energy efficiency (output/input) EE = EY/AE

The results were tested by multifactorial analysis of variance (ANOVA test).

RESULTS AND DISCUSSION

Yield of potato (tab. 4)

The suitability of weather conditions for potato growing highly significantly influenced the average yield for all three evaluated systems. The yield of potato tubers in ecological system was highly significant lower – 22.41 $t.ha^{-1}$ with comparison to low-input system (25.24 $t.ha^{-1}$) and conventional system (26.61 $t.ha^{-1}$) in three-year average results. In conventional system, the significant higher yield than in low-input system was also reached. Interaction between systems and evaluated years was significant, it means that yield of potatoes tuber was modified by weather condition of evaluated years. The yield of tubers (tab. 6) ranged from 23.05 to 29.96 $t.ha^{-1}$ in conventional system, from 18.72 to 32.26 $t.ha^{-1}$ in low-input system and from 19.93 to 27.35 $t.ha^{-1}$ in ecological one. The biggest variability was noted in low-input system.

The average yield of dry matter of all systems was 8.46 $t.ha^{-1}$ with 7.02 – 10.21 – 8.15 $t.ha^{-1}$ in particular years. The statistical significant of yield is enumerated in table 4. The yields of dry matter in conventional (9.08 $t.ha^{-1}$) and low-input system (8.63 $t.ha^{-1}$) were highly significant higher than in ecological system (7.66 $t.ha^{-1}$) and yield in conventional system simultaneously significant with low-input system. The yield of dry matter was highly significant modified by weather condition of evaluated years.

The influence of weather to yield of potatoes stated in another papers [10, 12]. According to B á r t a and D i v i š [2] the weather condition of the years with place of growing have substantial share on total variability of yield of potatoes. The yield of potatoes in ecological growing system according many authors is lower about 20–50 %. We noted 15.8 percent less yield in ecological system with comparison to conventional one (22.41 and 26.61 $t.ha^{-1}$). R i s t [18] noted 35 percent decreasing of yield of potato in ecological system (11.4 $t.ha^{-1}$) with comparison to modern high-input system (17.6 $t.ha^{-1}$) with 80 kg nitrogen and 120 kg P_2O_5 input.

The input of additional energy per hectare (tab. 4)

The average input of additional energy calculated to potatoes represents 38.05 GJ energy per hectare. The average calculated energy per particular systems was as follows: ecological system 34.38 $GJ.ha^{-1}$, low-input system 38.56 $GJ.ha^{-1}$ and conventional system 41.11 $GJ.ha^{-1}$. The structure of additional energy inputs is enumerated in the table 3. Human work has small share in all systems (1.46 – 1.83 %). The biggest share of energy input represents calculated energy input of 15.29 GJ ha^{-1} via machine work (technological work) which denotes 44.48, 39.65, 37.19 % of total energy input. The main differences between evaluated systems were noted between input of chemical fertilizers – from zero energy input in ecological system, 5.11 $GJ.ha^{-1}$ in low-input system, to 7.66 $GJ.ha^{-1}$ in conventional system. This item has crucial part on differences of input of additional energy and influenced another parameters of energy balance. F a z e k a š o v á and L í š k a [6] also pointed out to nutrient and fuel as the main part of additional energy input. On the base of energy input analysis of different cropping practices of potato M e y e r-A u r i c h et al. [14] stated also the fact, that cropping practices with reduction of the susceptibility to soil erosion by catch crops demand more energy input (by 11–17 %) due to

T a b l e 5

The gross energy balance characteristics
Znaky brutto energetickej bilancie

Parameter (1)		Gain of GE (4)			GEE (%)	Measuring consumption of GE (8) (GJ)	EE
		GJ.ha-1	per ton of yield (5)				
			tubers (6)	dry matter (7)			
$\bar{x}$T		61.23	2.43	7.10	60.51	0.39	2.60
min.		19.15	1.38	4.03	34.33	0.29	1.52
max.		97.30	2.84	8.32	70.93	0.65	3.44
V		283.80	0.07	0.63	46.23	0.004	0.17
s		16.84	0.27	0.79	3.79	0.06	0.41
v		27.13	11.03	11.04	11.05	17.67	15.61
years (Y) (2)	2000 (a)	46.14	2.20	6.44	54.89	0.45	2.27
	2001 (b)	80.04	2.68	7.83	66.80	0.33	3.02
	2002 (c)	57.53	2.40	7.02	59.84	0.40	2.50
	SS	7 141.58	1.38	11.81	859.33	0.08	3.50
	F	171.05	47.42	47.37	47.34	47.15	118.44
	$LSD_{0.05}$	4.06	0.10	0.31	2.68	0.02	0.10
	$LSD_{0.01}$	5.69	0.15	0.44	3.75	0.03	0.15
	P	1 : 2,3++ 2 : 3++	1 : 2,3++ 2 : 3++	1 : 2,3++ 2 : 3++	1 : 2,3++ 2 : 3++	1 : 2,3++ 2 : 3++	1 : 2,3++ 2 : 3++
systems (3) (S)	ES (a)	55.45	2.44	7.13	60.81	0.39	2.60
	LIS (b)	62.66	2.40	7.00	59.73	0.40	2.60
	CS (c)	65.59	2.45	7.15	61.00	0.39	2.59
	SS	653.13	0.016	0.15	11.24	0.001	0.0006
	F	15.64	0.57	0.62	0.62	0.62	0.02
	$LSD_{0.05}$	4.06	0.10	0.31	2.68	0.02	0.10
	$LSD_{0.01}$	5.69	0.15	0.44	3.75	0.03	0.15
	P	a : b,c++	–	–	–	–	–
Y x S	SS	1 057.10	0.38	3.33	243.13	0.02	0.65
	F	12.66	6.61	6.68	6.69	6.65	11.03
	P	++	++	++	++	++	++

GE – gross energy – brutto energia
EE – energy efficiency of gross energy – energetická efektívnosť brutto energie
GEE – gross energy effectiveness – energetická účinnosť brutto energie
SS – sum of squares – suma štvorcov
Other symbols are identical with tables 3 and 4.
Ostatné symboly ako v tabuľkách 3 a 4.

(1) Ukazovateľ, (2) roky, (3) systémy, (4) zisk brutto energie, (5) na tonu úrody, (6) hľúz, (7) sušiny, (8) merná spotreba brutto energie

higher nitrogen input. Their results stress the importance of relationship between energy input and global warming potential of different cropping practices.

The data about potato yield, inputs of additional energy, gross energy of yield of potato and statistical evaluation is given in the table 4. The highly significant differences between input of additional energy into evaluated systems were noted. Increasing of energy input of additional energy indicates the ecological dimension of sustainability of ecological and integrated system of growing potatoes. The coefficients for energy input and global warming potential calculated following H a a s et al. [7] adapted version of the life cycle assessment procedure can also be an important and efficient indicator for ecological weak-point analyses. Interaction between years and systems indicates the fact that weather conditions of evaluated years modified the input of energy per hectare under particular growing systems. The input of energy per ton of yield and dry mater varied insignificantly in narrow intervals from 1.53 in ecological system to 1.61 GJ in low-input one. The input of energy per one ton of dry matter has also insignificant differences. P o s p i š i l and V i l č e k [16] stated the potential input of additional energy in agro-ecological conditions of Slovakia from 30.86 to 33.4 GJ.ha^{-1}. Our result proves the higher demand for energy in conventional, low-input and even ecological (34.38 GJ.ha^{-1}) growing systems of potatoes.

Gross energy output characteristics (tab. 5)

The significantly higher production of *gross energy output from hectare* was received in conventional and low-input system with comparison to ecological one (tab. 4) with relatively high average output of 99.26 GJ.ha^{-1} in all systems. Calculation and statistical evaluation of gross energy characteristics are demonstrated in tables 5 and 6. The interaction of years with systems was highly significant. The unstable production of gross energy per hectare was found out in low-input system with interval from 75.06 GJ to 129.37 GJ.ha^{-1} (average 101.22 GJ). By A l t i e r i et al. [1], the yield stability and environmentally friendly way of production is the most important factor of sustainability. From this point of view, the low-input design of growing potatoes shall be further analyzed in site-specific condition.

The gain of gross energy per hectare was in total average 61.23 GJ. The high variability of gain of gross energy from hectare is well documented by low energy gain in 2000 (46.14 GJ) with comparison too much higher energy gain in 2001 (80.04 GJ). The gain of gross energy per hectare from ecological system was significantly lower (55.45 GJ) than in conventional (65.59 GJ) and low-input ones (62.66 GJ). No statistical differences between conventional and low-input systems have been noted. Potential gain of gross energy of potato yield per hectare varied according to P o s p i š i l and V i l č e k [16] from 34.06 to 48.47 GJ.ha^{-1} and P r e i n i n g e r [17] mentioned 50.27 GJ.ha^{-1}. We received higher gain of gross energy potential in all evaluated systems documented above.

The gain of gross energy per tone of yield was in total average 2.43 GJ without statistical differences between evaluated systems. The gain of energy per tone of yield was in extremely narrow interval 2.40 – 2.45 GJ. The increasing of additional energy has no profit for gain of energy per weight unit in conventional system and brings some detrimental effect to environment (water pollution, air pollution).

The above mentioned statement is supported by another gross energy characteristics: gain of gross energy per tone of dry matter, gross energy effectiveness, measuring consumption of gross energy and energy efficiency (output : input) showed in table 4 have no significant variability between evaluated systems. Comparison of utilization of energy inputs between different cropping systems may be an important consideration. P o s p i š i l and M a c á k [15] mentioned coefficient of efficiency r_E (output : input) as very important indicator of energy balance which expressed the rate of energy production per unit energy input. A l t i e r i [1] also mentioned that though yields are greater in chemically fertilized and machinery prepared potato fields, energy costs are higher, energy efficiency much higher and economic benefits lower than in agro-ecological system in Bolivia. Our results also show that increasing of yield of conventional and low-

T a b l e 6

Crucial characteristic of energy balance of potato growing in interaction of years and systems (2000–2002)
Rozhodujúce znaky energetickej bilancie pestovania zemiakov v interakcii rokov a systémov (2000–2002)

Interaction year x system (1)		Yield (3) (t.ha^{-1})		Input of energy (6) (GJ)			GE from yield (8) (GJ.ha^{-1})
				GJ.ha^{-1}	per ton of yield (7)		
		tubers (4)	dry matter (5)		tubers	dry matter	
2000	ES	19.93	6.82	33.21	1.68	4.92	79.92
	LIS	18.72	6.41	36.63	2.03	5.94	75.06
	CS	23.05	7.84	39.14	1.71	5.01	92.42
2001	ES	27.35	9.35	35.59	1.31	3.82	109.66
	LIS	32.26	11.03	41.57	1.29	3.78	129.37
	CS	29.96	10.25	42.08	1.40	4.08	120.15
2002	ES	19.95	6.82	34.33	1.61	5.05	79.99
	LIS	24.75	8.47	37.50	1.52	4.45	99.24
	CS	26.82	9.17	42.37	1.58	4.63	107.54

Interaction year x fertilization (2)		Gain of GE (9)			GEE (%)	Measuring consumption of GE (10) (GJ)	EE
		GJ.ha^{-1}	per ton of yield (7)				
			tubers (4)	dry matter (5)			
2000	ES	46.71	2.33	6.80	58.01	0.42	2.41
	LIS	38.43	1.98	5.79	49.36	0.51	2.05
	CS	53.28	2.30	6.72	57.30	0.43	2.37
2001	ES	73.98	2.70	7.91	67.43	0.33	3.08
	LIS	87.80	2.70	7.95	67.80	0.32	3.11
	CS	78.32	2.62	7.65	65.18	0.35	2.87
2002	ES	45.67	2.29	6.68	56.98	0.43	2.33
	LIS	61.74	2.49	7.27	62.03	0.38	2.65
	CS	65.17	2.43	7.10	60.52	0.39	2.54

GEE – gross energy effectiveness – energetická účinnosť brutto energie
GE – gross energy – brutto energia
EE – energy efficiency of gross energy – energetická efektívnosť brutto energie

(1) Interakcia rok x systém, (2) interakcia rok x hnojenie (3) úroda, (4) hľúz, (5) sušiny, (6) vstup energie, (7) na tonu úrody, (8) brutto energia úrody, (9) prírastok brutto energie, (10) merná spotreba bruto energie

input system, predominantly due to high input of chemical fertilizers with comparison to ecological system have no effect in better gross energy characteristics and may have negative influence on net income. The interaction between year and evaluated systems gave evidence about modifying of all gross energy characteristics by weather condition in particular systems.

Literature data about energy balance characteristics are very different and difficult to compare because of different natural and production conditions, farming practices and usied technologies and systems. Information about production of gross energy from hectare also vary substantially according to growing conditions. Vilček and Gutteková [19] likewise Pospišil with Vilček [16] recorded range of production of gross energy in interval 64.92 – 81.87 GJ.ha^{-1}, Preininger [17] 88.62 GJ.ha^{-1}, Hruška and Janíček [8] 103.52 GJ.ha^{-1}. In our trial output of gross energy production in all evaluated systems varied from 75.06 to 129.37 GJ.ha^{-1}, in average 99.26 GJ.ha^{-1}. Vilček and Gutteková [19] recorded energy efficiency in range 2.1 – 2.45 GJ, Hruška with Janíček [8] from 1.1 to 3.44 GJ. According to design of field trial we received energy efficiency of evaluated systems in narrow interval 2.59 – 2.60 GJ in conventional, low-input and also ecological system.

CONCLUSION

According to results of three-years field trials on Luvi-haplic Chernozem in maize-barley growing region in south-western Slovakia we can make next conclusion:

1. The high and acceptable gross energy production from hectare in all evaluated growing systems from 89.86GJ.ha^{-1} (ecological system), 101.22 GJ.ha^{-1} (low-input system) to 106.7 GJ.ha^{-1} (conventional system) in average was obtained.
2. Highly significant lower input of additional energy into ecological system of potato growing with comparison to low-input and conventional system and highly significant lower input of additional energy into low-input system with comparison to conventional system were ascertained by average input 34.38 GJ.ha^{-1} of additional energy into ecological system, 38.56 GJ.ha^{-1} into low-input system and 41.11 GJ.ha^{-1} into conventional system.
3. Increased yield of conventional and low-input system with comparison to ecological system, predominantly due to high input of chemical fertilizers have no effect on better energy characteristics. The increasing of additional energy has no profit for gaining of energy per weight unit, gaining of gross energy per tone of dry matter, gross energy effectiveness, measuring consumption of gross energy and energy efficiency in conventional system with comparison to low-input and ecological system but it brings some detrimental effect to environment (water pollution, air pollution, consumption of fossil energy).
4. Decreasing of energy input per hectare and non-significant change of another energy characteristics between evaluated cropping systems indicates the ecological dimension of sustainability of ecological and integrated system of growing potatoes.
5. Energy balance of growing potatoes is one of the important tools for evaluation of environmentally friendly growing practices in particular agro-environmental conditions. Significant differences in input of additional energy of evaluated systems and simultaneous no significant differences in main characteristics of energy gains gave evidence for recommendation of agro-environmental friendly agricultural systems in frame of Common Agricultural Policy of EU for better fulfilment of cross-compliance in Slovakia.

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SÚHRN

V rokoch 2000–2002 sa v poľnom stacionárnom pokuse v Borovciach pri Piešťanoch hodnotila energetická bilancia pestovania zemiakov v ekologickom, low-input a konvenčnom systéme hospodárenia v kukuričnо-jačmennej výrobnej oblasti, v pásme ochrany vôd. Vo všetkých systémoch hospodárenia sa zemiaky pestovali v rovnakom šesťhonovom osevnom postupe v nasledujúcom poradí: jačmeň jarný s podsevom ďateliny lúčnej – ďatelina lúčna – pšenica ozimná – hrach siaty – pšenica ozimná – zemiaky.

Ekologický systém bol manažovaný v zmysle zásad IFOAM a v súlade zo zákonom o ekologickom poľnohospodárstve. Sadivo bolo morené biomoridlami. Maštaľný hnoj bol aplikovaný trikrát za rotáciu (dávka 40 t.ha^{-1} k zemiakom a 7 t.ha^{-1} k pšenici ozimnej).

Pri low-input systéme bola aplikovaná nižšia dávka dusíka z priemyselných hnojív: k pšenici 40 kg, k hrachu 10 kg, k jačmeňu 30 kg.ha^{-1}. Maštaľný hnoj sa aplikoval raz za rotáciu k zemiakom v dávke 40 t.ha^{-1}. Bola použitá integrovaná ochrana rastlín.

V konvenčnom systéme hospodárenia bola aplikovaná dávka 40 ton maštaľného hnoja pod zemiaky a vyššia hladina dusíka v súlade s obmedzeniami platnými pre pásmo hygienickej ochrany vôd, tzn. k pšenici 80 kg, k hrachu 20 kg, k jačmeňu 30 kg dusíka na hektár. Súčasne sa použila konvenčná ochrana proti burinám, chorobám a škodcom.

Pri všetkých systémoch hospodárenia bolo rovnaké základné obrábanie pôdy a mechanické zásahy počas vegetácie, zapravenie pozberových zvyškov a slamy. Medziplodiny na zelené hnojenie (facélia a horčica) sa pestovali po ozimnej pšenici a zemiakoch. Dávka prvého hnojenia fosforom a draslikom v low-input a v konvenčnom systéme bola na plánovanú úrodu pšenice 7 ton, jarného jačmeňa 6 ton, hrachu 4 tony, zemiakov 20 ton a ďateliny lúčnej 10 ton z hektára.

V rámci energetickej analýzy sa hodnotili vstupy dodatkovej energie, energia úrody, zisk brutto energie, brutto energetická účinnosť, merná spotreba brutto energie a energetická efektívnosť. Výsledky vyhodnotenia energetickej analýzy vstupov a výstupov pestovania zemiakov v jednotlivých systémoch hospodárenia dovoľujú urobiť nasledovné závery:

- V hodnotených systémoch sa získala vysoká brutto energia úrody z hektára – v priemere od 89,86 GJ.ha^{-1} v ekologickom systéme do 106,7 GJ.ha^{-1} v konvenčnom systéme hospodárenia.
- Vstupy dodatkovej energie boli preukazne najnižšie do

ekologického systému (34,38 GJ.ha^{-1} v porovnaní s 38,56 GJ ha^{-1} v low-input systéme, resp. s 41,2 GJ. ha^{-1} v konvenčnom systéme).

- Zvýšenie úrody a energetického výstupu v low-input a konvenčnom systéme v porovnaní s ekologickým (v dôsledku vyšších vstupov energie z priemyselných hnojív) nemalo pozitívny prínos na sledované energetické vlastnosti, teda zvýšenie vstupu dodatkovej energie nemalo preukazný vplyv na energetické parametre brutto energie (zisk energie na tonu produktu, energetická účinnosť energie, merná spotreba energie a energetická efektívnosť).

Získané výsledky trojročného pokusu sú podkladom pre odporučenie pestovania zemiakov v ekologicky priateľných systémoch v rámci Spoločnej poľnohospodárskej politiky EÚ a napomôžu napĺňať podmienky cross-compliance v podmienkach Slovenska.

Kľúčové slová: energetická bilancia, ekologický systém, low-input systém, konvenčný systém, pestovanie zemiakov

ANOTÁCIA

Dňa 27. mája 2005 pred komisiou z vedného odboru 41-02-9 Špeciálna rastlinná výroba na Fakulte agrobiológie a potravinových zdrojov Slovenskej poľnohospodárskej univerzity v Nitre obhájila doktorandskú dizertačnú prácu Ing. Jana F e c k o v á na tému

PRODUKCIA A KVALITA CUKROVEJ REPY V ZÁVISLOSTI NA VYBRANÝCH ANTROPOGÉNNYCH FAKTOROCH

Cieľom práce bolo:

- porovnať produkčné schopnosti odrôd tolerantných a citlivých na BNYVV v podmienkach bez výskytu BNYVV
- zhodnotiť vplyv listových preparátov na báze bioaktívnych látok (Avit-35 a Humix univerzál plus) na ukazovatele produkčného procesu cukrovej repy, na úrodu a technologickú kvalitu cukrovej repy a na výživový stav cukrovej repy počas vegetácie
- zhodnotiť vplyv testovaných preparátov v interakcii s odrodami a podmienkami počasia na uvedené parametre
- zistiť podiel vplyvu jednotlivých faktorov (odroda, listový preparát) a poveternostných podmienok na sledované parametre
- zhodnotiť použitie listových preparátov z ekonomického hľadiska.

Z výsledkov vyplýva, že v podmienkach bez výskytu rizománie prejavili odrody odolné voči BNYVV lepšie produkčné schopnosti ako na rizomániu náchylná odroda. Listové preparáty (Avit-35 a Humix univerzál plus) štatisticky preukazne zvýšili úrodu buliev a úrodu rafinády a preukazne znížili cukornatosť buliev. Avit-35 zhoršil technologickú kvalitu buliev štatisticky preukazným zvýšením obsahu Na^+. Listové preparáty neovplyvnili obsah K^+ a αN v buľvách. Fotosyntetickú aktivitu rastlín ovplyvnili len čiastočne. V suchom roku zvýšili listovú pokryvnosť (Avit-35 v najsuchšom období znížil čistý výkon fotosyntézy), v normálnom roku fotosyntetickú aktivitu neovplyvnili. Neovplyvnili ani koncentráciu živín v listoch cukrovej repy. Aplikácia oboch preparátov bola z ekonomického hľadiska rentabilná.

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