ENERGY BALANCE OF VARIOUS PERMANENT GRASSLAND UTILISATION SYSTEMS*

J. Ržonca, M. Svozilová, P. Mičová, M. Štýbnarová, J. Pozdíšek

Research Institute for Cattle Breeding, Ltd., Rapotín, Czech Republic

In 2003–2005 the energy analysis of the different types of permanent grassland utilisation was carried out in the Hrubý Jeseník locality. We used the following intensity of utilisation: 1. intensive – 4 cuts per year (1st cut up to 15th May, every next after 45 days), 2. medium intensive – 3 cuts per year (1st cut from 16th to 31st May, every next after 60 days), 3. low intensive – 2 cuts per year (1st cut up to 15th June, 2nd after 90 days), 4. extensive – 2 cuts per year (1st cut from 16th to 30th June, 2nd after 90 days). There were estimated values of the particular inputs of additional energy. Energy inputs moved according to the pratotechnologies from 2.17 $GJ.ha^{-1}$ to 22.70 $GJ.ha^{-1}$. The biggest share in energy inputs had fertilisers. It was 84.93% by the nitrogen fertilisation. The most energy benefit of gross and net energy was marked by a low intensive utilisation (129.64 $GJ.ha^{-1}$ gross energy and 25.93 $GJ.ha^{-1}$ NEL on average). The highest value of energy efficiency (23.74) was marked by low intensive utilisation of permanent grassland. The energy efficiency decreased using of higher doses of industrial fertilizers. From view of energy benefit and intensiveness on energy inputs it appears the most available utilisation of permanent grassland with two cuts per year (1st cut on June 15th at the latest, 2nd cut after 90 days).

net energy; energy benefit; fertilisation; pratotechnology; production of phytomass

INTRODUCTION

Withdrawal from the intensive plant production to sustainable management has fallout mainly on energy management, ecological carrying capacity and economical efficiency of new technologies. Agriculture as every other productive activity is a process of energetic transformation of raw materials and of effective change of their attributes. It differs from the other branches of human activities by the eminent transformation of solar radiation and by its purposeful accumulation to the final production (Pospišil, Vilček, 2000).

Agriculture is a complex system that is able to change inorganic substances into important organic compounds due to solar radiation. Production system is affected by various factors such as weather conditions, nutrition and fertilisation, physical and agrochemical characteristics of soil or natural characteristics of grown plants. This whole process is very complicated and it is practicable due to additional energy forms (Kotorová et al., 2004).

The issues are environmental, particularly for the control of greenhouse gas emissions and also for the evaluation of the use of scarce non-renewable resources. They also show socio-economic aspects, as fossil energy may be replaced in some cases by human resources (labour). Energy analysis can therefore play a significant role in the evaluation of sustainability of agricultural process (Boisvert, Holec, 1993).

Energy analysis provides a relevant view of the specificity of agriculture, as a user and a producer of energy simultaneously. This distinctive feature makes agriculture play a specific role in CO_2 cycles, thanks to phenomenon of photosynthesis. With forestry and some other human activities utilising renewable energies, agriculture is the only human occupation which may produce more energy than it had consumed. It is interesting therefore to check if it is true in any farming process, and to explore the causes of variations in energy results (Risoud, Chopinet, 1999).

There are various points of view of energy balance of grown plants. Most of studies about energy balance is engaged in plants grown on the arable land. It is evaluated fertilizer's effectiveness, efficiency of pesticides and various ways of soil tilling or energetic influence of preceding crops, varieties and various agro-ecological conditions (Kováč, 1998; Risoud, Bochu, 2002; Pospišil, 2002).

The aim of this study was to analyse and to quantify energy-material inputs and outputs in production process of permanent grassland on the basis of various methods of its utilisation and fertilisation and subsequently to carry out the balance from the viewpoint of additional energy sources for their optimal level assessment.

MATERIALS AND METHODS

We have carried out the observation in 2003–2005 on RICB Rapotín holdings. The locality is situated in 390–402 m above sea level and it comes under the geomorphologic division Hrubý Jeseník. Geomorphologic sub grade is deeper diluvium of mica schist. The soil is sandy-loam, type cambisol (horizons Am-Bv-B/C-C). The experimental design was a randomised complete block in four replicates. The plot size was 12.5 m^2. The years 2003–2005 were warmer than long-times average. Regarding pre-

* The paper was made with contribution of the project of the National Agency for Agricultural Research reg. n. QF 3018.

Table 1. Overview of rainfall and average monthly temperatures

Year	Month	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
2003	Precipitation (mm)	74.6	18.7	30.9	25.8	80.8	32.1	59.8	25.9	23.7	70.2	24.8	76.3
	Temperature (°C)	–6.0	–14.3	–3.8	6.7	15.5	18.4	18.3	19.2	12.2	5.1	5.2	–4.7
2004	Precipitation (mm)	96.9	31.8	11.9	34.3	20.9	65.4	51.5	59.3	41.0	49.8	114.1	40.9
	Temperature (°C)	–9.7	–1.4	2.2	8.93	11.6	15.4	16.93	17.5	12.1	9.4	3.43	1.1
2005	Precipitation (mm)	90.0	45.0	27.5	23.5	76.0	50.0	78.0	69.0	19.0	56	120	–
	Temperature (°C)	–1.3	–4.5	–0.7	8.9	12.7	15.6	18.3	15.7	13.4	4.9	3.1	–
Long-term mean	Precipitation (mm)	55.5	39	44.2	36.3	68.6	82.6	77.5	74.4	51.8	45.7	58.8	67.9
	Temperature (°C)	–4.9	–3.9	–0.5	4.8	10.8	14.2	14.7	13.7	9.8	5.4	2.1	–2.3

cipitations years 2003 and 2004 were dry and the year 2005 was normal. Table 1 shows temperatures and precipitations during observed period and long-term means.

On the permanent grassland these species are dominant: *Taraxacum sect. Ruderalia* (27–60%), *Poa pratentis* (23–60%), *Dactylis glomerata* (21–54%), *Elytrygia repens* (10–25%), *Trifolium repens* (3–37%), *Achillea millefolium* (3–25%), *Lolium perenne* (4–18%) and rest (0–10%, *Festuca arundinacea, F. pratensis, Bromus hordeaceus, Alopecurus pratensis, Crepis biennis*).

Intensity of utilisation:
1. intensive – 4 cuts per year (1st cut on May 15th at the latest, next after 45 days)
2. medium intensive – 3 cuts per year (1st cut on May 31st at the latest, next after 60 days)
3. low intensive – 2 cuts per year (1st cut on June 15th at the latest, 2nd cut after 90 days)
4. extensive – 2 cuts per year (1st cut on June 30th at the latest, 2nd cut after 90 days)

Nutrition and fertilisation:
A – no fertilisation
B – P:K 30:60 $kg.ha^{-1}$
C – N:P:K 90:30:60 $kg.ha^{-1}$
D – N:P:K 180:30:60 $kg.ha^{-1}$

Ammonium nitrate with pulverized limestone was used as nitrogen fertiliser, super phosphate as phosphorus fertiliser and potassium chloride as potassium fertiliser. The divide of nitrogen dosage was following: 1/3 in spring, 1/3 after first cut and 1/3 after second cut by intensive and medium intensive treatment and 1/2 in spring and 1/2 after first cut by low intensive and extensive treatment.

We used the following equation for the dry mater gross energy (BE) expression (Sommer et al., 1994):

$$BE = 0.00588*CP + 0.01918*OM \ (MJ.kg^{-1})$$

Net energy was evaluated by equation:

$$NEL = ME*/0.463 + 0.24*(ME/BE)/ \ (MJ.kg^{-1})$$

Where: CP – crude protein, OM – organic matter, ME – metabolizable energy

Metabolizable energy was evaluated by equation

$$ME = 0.00137*DCP + 0.01504*DOM$$

Where: DCP – digestible crude protein, DOM – digestible organic matter

The energy contribution quantification, the used energy equivalents and methods of the calculations were realized according to the method of Preininger (1987). For the energy balance evaluation there were included these factors to the additional energy inputs:
1. Used industrial and organic fertilisers in pure nutrients NPK ($kg.ha^{-1}$)
2. Energy in machines ($GJ.ha^{-1}$)
3. Fuel consumption ($l.ha^{-1}$)
4. Amount of the human labour ($h.ha^{-1}$)

On the basis of these energy values it was counted:
- Energy benefit:

$$EP \ (GJ.ha^{-1}) = \text{energy of phytomass} - \text{energy inputs}$$

- Energy need for production 1 t DM:

$$EN = \text{energy inputs} / \text{yield of phytomass}$$

- Coefficient of the energy efficiency:

$$CEE = \text{energy of phytomass} / \text{energy inputs}.$$

We have processed the acquired data by the statistical program SPSS 13.0 for Windows (Multifactor Analysis of Variance and LSD test).

RESULTS AND DISCUSSION

Table 2 shows the values of the phytomass production and energy outputs. The highest values of phytomass production and concentration of gross energy were in the low intensive (3.) utilisation. The lowest values of these indicators were in intensive utilisation (1.). The concentration of gross energy increased with decrease of utilisation intensity. The similar tendency found Kubíčková-Hanušová et al. (2006). The content of NEL was the

Table 2. Energy and phytomass production (average of 2003–2005)

	FM[1)] ($t.ha^{-1}$)		Conc. GE[2)] ($MJ.kg^{-1}$)		Conc. NEL[3)] ($MJ.kg^{-1}$)		GE[4)] ($GJ.ha^{-1}$)		NEL[5)] ($GJ.ha^{-1}$)	
	Means	Std. dev.	Means	Std. dev.	Means	Std. dev.	Means	Std. dev.	Means	Std. dev.
Utilisation										
1	6.58	1.27	18.21	0.13	5.55	0.19	119.83	23.54	36.51	7.27
2	6.97	1.72	18.29	0.20	5.09	0.15	127.39	31.50	35.49	9.05
3	7.62	1.42	18.37	0.24	4.73	0.12	139.81	25.66	36.11	7.25
4	6.89	1.26	18.35	0.18	4.60	0.11	126.39	23.03	31.73	6.00
F-ratio	10.17	++	17.00	++	466.8	++	11.28	++	9.72	++
$HSD_{0.05}$	0.40		0.06		0.16		7.96		2.29	
$HSD_{0.001}$	0.53		0.07		0.21		10.53		3.02	
Fertilisation										
A	5.77	1.08	18.37	0.23	4.94	0.43	105.95	19.48	28.44	5.67
B	6.25	1.00	18.19	0.15	4.97	0.36	113.64	18.10	30.96	4.75
C	7.76	0.86	18.29	0.21	5.02	0.34	141.90	15.47	38.89	4.25
D	8.27	1.23	18.36	0.16	5.03	0.44	151.93	22.64	41.55	6.75
F-ratio	76.46	++	20.95	++	4.86	++	78.77	++	79.01	++
$HSD_{0.05}$	0.40		0.06		0.16		7.96		2.29	
$HSD_{0.001}$	0.53		0.07		0.21		10.53		3.02	
Year										
2003	7.42	1.36	18.21	0.10	5.02	0.37	135.11	24.90	37.28	7.66
2004	6.76	1.33	18.49	0.14	5.02	0.46	124.98	24.99	33.84	7.04
2005	6.86	1.64	18.22	0.21	4.94	0.35	124.97	29.76	33.76	7.82
F-ratio	9.13	++	103.00	++	7.00	++	7.39	++	10.85	++
$HSD_{0.05}$	0.35		0.05		0.14		6.89		1.98	
$HSD_{0.001}$	0.46		0.06		0.18		9.09		2.62	

[1)] production of phytomass dry matter, [2)] concentration of gross energy, [3)] concentration of net energy of lactation, [4)] energy output in gross energy, [5)] energy output in NEL, $^{++}$ $P < 0.01$

highest in intensive utilisation and lowest in extensive utilisation. Phytomass and energy production had increased by the fertilisation. Our results are in accordance with the results of H o l ú b e k and H o l ú b e k (2002). They found that the production of NEL in relation 22.84–30.76 $GJ.ha^{-1}$ is not affected by fertilised grassland and 43.08–52.16 $GJ.ha^{-1}$ by grassland fertilised with dosage of nitrogen 180 $kg.ha^{-1}$.

Table 3 contains energy inputs according to the particular types of utilisation and fertilisation of the permanent grasslands. Contribution of additional energy moved from 2.17 $GJ.ha^{-1}$ to 22.70 $GJ.ha^{-1}$. Similar values were found out also by M a j e r n í k et al. (2002) study of the permanent grassland. The most demanding on energy inputs was the intensive grassland utilisation (average 12.26 $GJ.ha^{-1}$), less demanding was the medium intensive (average 11.08 $GJ.ha^{-1}$) and the least demanding was the low intensive and the extensive (average 10.00 $GJ.ha^{-1}$) grassland utilisation. Energy contributions increased along with the fertilisation intensity. Fig. 1 shows percentage of the additional energy contributions for the particular components. The values for fossil fuels energy inputs moved on average from 16.17% (by the medium intensive utilisation) to 23.38% (by the intensive utilisation). Fertilizers participated the most in the energy contribution. Their share achieved up to 84.93% (1.D) by the intensive nitrogen fertilisation (dose of 180 kg $N.ha^{-1}$). Values for the human labour moved on average from 1.22% to 1.81%.

On the basis of these markers we have calculated the energy balance. Value of the energy benefit, coefficients of the energy efficiency and energy need for production 1 t DM are in Table 4.

The most important factor for the energy balance is a ratio: agricultural yield energy output / input of the additional energy to production process. Coefficients of energy efficiency counted from the gross energy moved from 5.70 (1.D, 2005) to 59,50 (3.A, 2003). We found the most favourable values of this marker in low intensive utilisation. The energy effectiveness decreased by using of the higher doses of the industrial fertilisers.

The highest average value of gross and net energy benefit was noticed by low intensive utilisation (129.64 $GJ.ha^{-1}$ BE; resp. 25.93 $GJ.ha^{-1}$ NEL). The second highest energy benefit computed from gross energy was by the extensive utilisation (116.21 $GJ.ha^{-1}$). When we expressed the energy profit by NEL, we obtained the other order. The second highest value of energy profit was in medium intensive utilisation. The lowest values of energy profit were in extensive utilisation.

B a l l a (1998) found out values of energy outputs from 125.40 to 127.52 $GJ.ha^{-1}$ by growing of the clover-grass mixtures on the arable land and coefficient of energy

Table 3. Share of particular components in energy contribution (GJ.ha^{-1})

Utilisation	Fertilisation	Fuels	Human labour	Fertilisers	Machinery	Total
Extensive and low intensive	A	1.06	0.09	0.00	1.02	2.17
	B	1.30	0.09	2.27	1.27	4.94
	C	1.41	0.11	9.69	1.52	12.73
	D	1.41	0.11	17.12	1.52	20.16
	$\bar{x}$	**1.30**	**0.10**	**7.27**	**1.33**	**10.00**
Medium intensive	A	1.59	0.13	0.00	1.53	3.25
	B	1.84	0.14	2.27	1.78	6.02
	C	1.94	0.15	9.69	2.03	13.82
	D	1.94	0.15	17.12	2.03	21.24
	$\bar{x}$	**1.83**	**0.14**	**7.27**	**1.84**	**11.08**
Intensive	A	2.13	0.17	0.00	2.04	4.34
	B	2.37	0.18	2.27	2.29	7.10
	C	2.47	0.19	9.69	2.54	14.90
	D	2.58	0.21	17.12	2.79	22.70
	$\bar{x}$	**2.39**	**0.19**	**7.27**	**2.42**	**12.26**

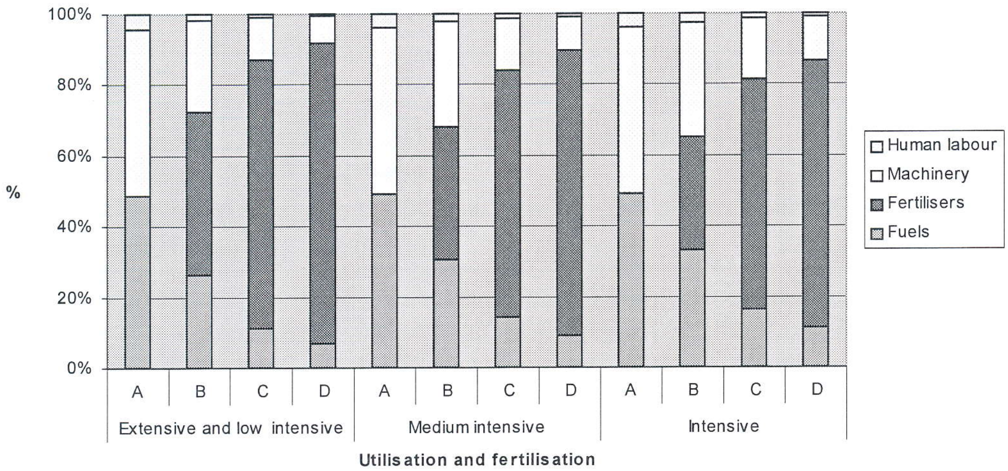

Fig. 1. Share of particular components in energy contribution in per cent

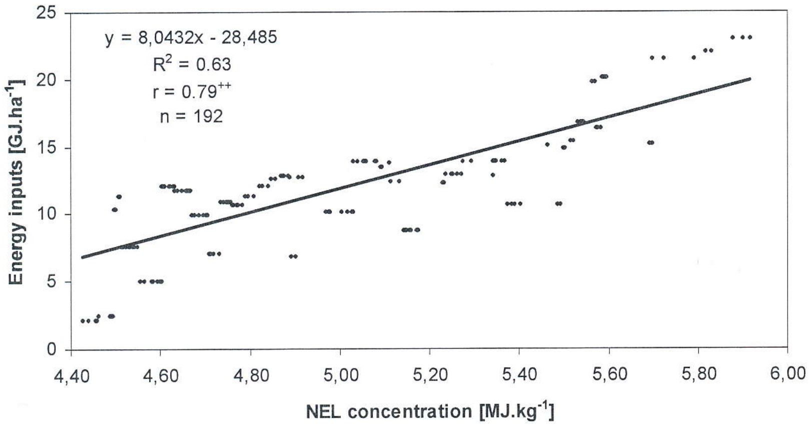

Fig. 2. Comparison between increase of additional energy inputs and NEL concentration in DM

efficiency was 5.71–6.62 commensurate with the growing technologies. P o r v a z and J a n č o v i č (2001) were engaged in growing of alfalfa. They found out energy inputs on the level of 22.27 GJ.ha^{-1}, outputs were 622.18 GJ.ha^{-1} (total phytomass) and coefficient of energy efficiency was 28.77. Comparing with our results and with results of M a j e r n í k et al. (2002) we can conclude that production of feedstuffs is more energy demanding on the arable land, assuming that nitrogen fertiliser doses will not be higher than 100 kg. Nitrogen dose of 180 kg.ha^{-1} causes increasing of the energy intensiveness above level of cereals grown on arable land.

Table 4. Markers of the energy balance (average of 2003–2005)

	EP (GE)[1)] (GJ.ha^{-1})		EP (NEL)[2)] (GJ.ha^{-1})		CEE (GE)[3)]		CEE (NEL)[4)]		EN[5)] (GJ.t^{-1})	
	Means	Std. dev.	Means	Std. dev.	Means	Std. dev.	Means	Std. dev.	Means	Std. dev.
Utilisation										
1	107.39	18.54	24.08	4.84	12.84	6.47	3.91	1.99	1.80	0.86
2	116.13	27.25	24.23	6.77	16.43	10.10	4.55	2.80	1.54	0.81
3	129.64	21.20	25.93	5.50	23.74	17.67	6.07	4.51	1.26	0.78
4	116.21	18.12	21.56	4.88	21.21	15.16	5.30	3.72	1.38	0.86
F-ratio	13.66	++	6.57	++	33.66	++	20.20	++	50.49	++
$HSD_{0.05}$	7.61		2.18		3.07		0.66		0.12	
$HSD_{0.001}$	10.05		2.88		4.05		0.87		0.16	
Fertilisation										
A	102.79	19.80	25.28	5.65	36.83	13.66	9.69	3.21	0.57	0.22
B	107.71	18.52	25.03	4.84	19.80	5.05	5.34	1.14	0.98	0.26
C	128.18	15.82	25.17	4.15	10.41	1.52	2.84	0.33	1.79	0.27
D	130.69	22.90	20.31	6.53	7.18	1.19	1.96	0.31	2.63	0.45
F-ratio	32.41	++	11.92	++	251.37	++	279.97	++	766.79	++
$HSD_{0.05}$	7.61		2.18		3.07		0.66		0.12	
$HSD_{0.001}$	10.05		2.88		4.05		0.87		0.16	
Year										
2003	124.27	21.79	26.44	7.31	20.94	16.41	5.71	4.32	1.41	0.86
2004	113.89	19.38	22.74	3.26	17.30	11.69	4.59	2.87	1.53	0.81
2005	113.87	25.69	22.66	5.09	17.42	12.29	4.57	2.92	1.54	0.89
F-ratio	7.77	++	12.56	++	8.10	++	13.22	++	6.50	++
$HSD_{0.05}$	6.59		1.89		2.66		0.57		0.10	
$HSD_{0.001}$	8.70		2.49		3.51		0.75		0.14	

[1)] energy benefit counted from gross energy, [2)] energy benefit counted from NEL, [3)] coefficient of the energy efficiency counted from gross energy, [4)] coefficient of the energy efficiency counted from NEL, [5)] energy need for production 1 t DM, $^{++}$ $P < 0.01$

Then it follows, that the most participate in energy inputs and in energy benefit are industrial fertilisers. Machinery has an indispensable share on the energy inputs. Its extent of contribution is equal as energy provided in fuel form. Energy production increased by the fertilisation with industrial fertilisers, but coefficient of energy efficiency obviously decreased. M a j e r n í k et al. (2002) published the similar conclusion.

LSD test confirmed that the nitrogen fertilisation has more influence in energy production than only the phosphorus and potassium fertilisation. We noticed the significant differences between the treatments with nitrogen fertilisation and the treatments without nitrogen fertilisation ($P < 0.01$). The statistically significant differences were between low intensive utilisation and the rests treatments ($P < 0.05$). The utilisation and fertilisation mode had influence on energy concentration. We noticed significant differences between every mode of treatment.

Fig. 2 shows the evolution and relation between inputs of additional energy and the concentration of NEL in dry mater of growth. Pozdíšek (2006) hold the NEL concentration of forage lower as 5.2 MJ.kg^{-1} as forage of bad quality. From this figure caused that for forage production with NEL concentration higher than 5.2 MJ.kg^{-1} we need provide 13.34 GJ.ha^{-1} of additional energy.

CONCLUSION

On the basis of our results we can conclude:

1. Energy inputs increased in this way: 4. (extensive) = 3. (low intensive) < 2. (medium intensive) < 1.(intensive).
2. From the viewpoint of energy benefit and of intensiveness on energy inputs it appears the most available grassland utilisation by 2 cuts per year (1st cut on June 15th at the latest, 2nd cut after 90 days).
3. From the viewpoint of forage quality and the rational utilisation of non recoverable energy we can consider the medium intensive utilisation and the fertilisation with 90 kg of nitrogen per ha as the most suitable.
4. Decreasing of inputs in form of the additional energy is necessary to search in decrease of fuel consumption and in rational nitrogen nutrition.

REFERENCES

BOISVERT, V. – HOLEC, N.: À la recherche d'indicateurs de développement soutenable. Centre Pierre Mendès France, Université de Paris I. Cahier METIS, *21*, 1993. 163 pp.

DZIENIA, S. – WERESZCZAKA, J.: Energy-effectiveness of varied winter wheat cultivation systems under varied soil conditions. Electronic Journal of Polish Agricultural Universities, 2002, Agronomy, Volume 5, Issue 1. Available online. http://www.ejpau.media.pl/series/volume5/issue1/agronomy/art-03.html.

HOLÚBEK, I. – HOLÚBEK, R.: Economics of grassland utilisation in dependence on the system of their cultivation and fertilisation. Agrochemistry, 2002: 9–13.

KOTOROVÁ, D. et al.: Comparison of energy balance of cultivation of thick-sown cereals on gleyic fluvisol and cultisol luvisol. Collection of scientific papers OVUA Michalovce. Michalovce, OVUA, *20*, 2004: 119–127.

KOVÁČ, L.: Energy analysis of differentiated systems of clover-grass mixtures. Collection of scientific papers OVUA Michalovce. Michalovce, OVUA, *14*, 1998: 154–167.

KUBÍČKOVÁ-HANUŠOVÁ, A. – ŠINDL, P. – SLIVKOVSKÁ-HRUŠKOVÁ, Š. – KOLÁŘ, L. – KUŽEL, S.: Energy woody species compared with energy stem species and effect of fertilisation on the quality of biomass in view of energy technologies. In: Agroregion 2006. Increase of competitiveness in agriculture. České Budějovice, JCU 2006: 65–69.

MAJERNÍK F. – ZMETÁKOVÁ Z. – PROKSOVÁ E.: Energy analysis of different types of grasslands. Modern Machinery in Agriculture, 2002 (6): 18–20.

POSPIŠIL, R.: Energy analysis of cost-saving systems of soil cultivation and fertilisation in different systems of plant production. Agriculture, *48*, 2002: 374–379.

POSPIŠIL, R. – VILČEK, J.: Energy systems of soil management. Bratislava, VÚPOP 2000. 108 pp.

POZDÍŠEK, J.: To cattle nutrition in the breeding system withouth market milk production. Veterinářství, 2006 (2): 105–111.

PREININGER, M.: Energy evaluation of production process in plant production. Praha, ÚVTIZ 1987. 29 pp.

RISOUD, B. – BOCHU, J. L.: Bilan énergétique et émission de gaz à effet de serre à l'échelle de la ferme. Alter Agri. ITAB, *55*, 2002: 10–13.

RISOUD, B. – CHOPINET, B.: Efficacité énergétique et diversité des systèmes de production agricole. Application à des exploitations bourguignonnes. Ingénieries EAT, 1999 (20): 17–25.

SOMMER A. et al.: Demand of nutrients and nutritive values of feedstuffs for cattle, sheep and goats. Nitra, VÚŽV 1994. 113 pp.

Received for publication on September 24, 2006
Accepted for publication on October 25, 2006

RŽONCA, J. – SVOZILOVÁ, M. – MIČOVÁ, P. – ŠTÝBNAROVÁ, M. – POZDÍŠEK, J. (Výzkumný ústav pro chov skotu, s. r. o., Rapotín, Česká republika):

Energetická bilance různých způsobů využívání trvalých travních porostů.

Scientia Agric. Bohem., *38*, 2007: 58–63.

V letech 2003–2005 jsme se v podmínkách Hrubého Jeseníku zabývali energetickou analýzou různých způsobů využívání TTP. V pokusu byly uplatněny tyto způsoby využívání: 1. intenzivní – čtyři seče za rok (první seč do 15. 5., následující po 45 dnech), 2. středně intenzivní – tři seče za rok (1. seč od 16. do 31. 5., další po 60 dnech), 3. málo intenzivní – dvě seče za rok (1. seč do 15. 6., druhá po 90 dnech), 4. extenzivní – dvě seče za rok (první seč od 16. do 30. 6., druhá po 90 dnech). Varianty hnojení byly následující: A – bez hnojení, B – P : K 30 : 60 $kg.ha^{-1}$, C – N : P : K 90 : 30 : 60 $kg.ha^{-1}$, D – N : P : K 180 : 30 : 60 $kg.ha^{-1}$. Kvantifikace energetických vkladů, použité energetické ekvivalenty a způsoby výpočtů a vyjádření výstupů energie byly uskutečněny podle metodiky Preiningera (1987). Výstupy energie jsme vyjádřili jednak prostřednictvím brutto energie, kterou jsme vypočítali podle vzorce BE = 0,00588*NL + 0,01918*OH ($MJ.kg^{-1}$) a net energie laktace, kterou jsme vypočítali podle vzorce NEL = ME*/0,463 + 0,24*(ME/BE)/ ($MJ.kg^{-1}$). Vypočítali jsme hodnoty jednotlivých vstupů dodatkové energie. Podle jednotlivých pratotechnik se vstupy energie pohybovaly od 2,17 $GJ.ha^{-1}$ do 22,70 $GJ.ha^{-1}$. Největší částí energetických vkladů byla hnojiva, která se na nich, při intenzivním hnojení dusíkatými hnojivy, podílela až do výšky 84,93 %. Nejvyšší průměrný energetický zisk brutto i net energie jsme zaznamenali u málo intenzivního využívání (průměr 129,64 $GJ.ha^{-1}$ BE a 25,93 $GJ.ha^{-1}$ NEL). Nejvyšší koeficient energetické účinnosti (23,74) jsme zaznamenali rovněž u málo intenzivního využívání TTP. Používáním vyšších dávek průmyslových hnojiv se energetická efektivnost snižovala. Z hlediska energetického zisku a náročnosti na vstupy energie se ukazuje nejvhodnější využívání trvalých travních porostů dvěma sečemi za rok (v termínu 1. seč do 15. 6., druhá po 90 dnech). Z hlediska kvality píce v kombinaci s využitím neobnovitelných zdrojů energie můžeme považovat středně intenzivní využívaní a dávku dusíku v množství 90 kg na hektar za nejvhodnější. Pěstitelský ročník, hnojení a využívání TTP se na výnosu i energetických ukazatelích projevil významně.

net energie; energetický zisk; hnojení; pratotechnika; produkce fytomasy

Contact Address:

Ing. Jozef Ržonca, Výzkumný ústav pro chov skotu, s. r. o., Rapotín, Výzkumníků 267, 788 13 Vikýřovice, Česká republika, e-mail: jozef.rzonca@vuchs.cz