Trakia Journal of Sciences, Vol. 8, No 2, pp 44-51, 2010

Available online at:
http://www.uni-sz.bg

ISSN 1313-7050 (print)
ISSN 1313-3551 (online)

Original Contribution

NUTRITIVE VALUE AND ENERGY EFFICIENCY OF WINTER PEA PRODUCTION, TREATED WITH PLANT GROWTH REGULATORS

Ts. Zhelyazkova*

Agricultural Faculty, Trakia University, Stara Zagora, Bulgaria

ABSTRACT
The influence of some plant growth regulators on the nutritive value and energy efficiency of winter pea, variety Mir was investigated. The experiment was conducted in the period 2003-2006 at Trakia University, Stara Zagora, with 3 complex preparations as followed: N-40 (naphthaleneacetic acid − NAA) – 200 and 300 cm^3/ha; HP-55 (chlorophenoxyacetic acid) – 100 and 200 cm^3/ha and G-31 (chlorophenoxyacetic acid + naphthoxyacetic acid − NOA) – 300 cm^3/ha in 300 l/ha solution.
The studies demonstrated that the application of growth regulators during the bloom period had no effect on the nutritive value of grain and straw, but had a positive effect on the energy obtained from the biomass of winter pea and the energy efficiency of the production. The highest coefficient of energy efficiency was obtained by treatment with N-40 − 200 cm^3/ha − 7.8 for GE; 3.7 for ME and 2.1 for NE, that was by 14.71%, 15.16% and 15.25%, respectively higher compared to untreated control. The combined application of N-40 at a dose 200 cm^3/ha with insecticide for control of weevil (*Bruchus pisi* L.) did not decrease the energy efficiency.

Key words: gross energy (GE), metabolizable energy (ME), net energy (NE), feed units, energy input, energy output, energy efficiency

INTRODUCTION

The energy value of forages is essential for livestock production science. It is a primary criterion for the contemporary assessment of biomass quality and is determined in feed units for milk and for growth (1). In recent years, Petkova (2) performed such studies with winter pea, but only for grain as a main production. There are no enough studies on the nutritive value of winter pea straw as additional production and promotion of it successful utilization in ruminant nutrition.

The most commonly used approach in assessing the efficiency of crop production, is the economical approach. In present times characterized with instability of market prices of raw materials and agricultural products, it however does not provide a complete idea about the efficiency of production (3, 4). Along with the traditional methods for efficiency assessment by means of economical parameters (cost prices, profitability etc.) the energy evaluation of technology is becoming more and more important on a worldwide scale. The energy approach is considered as one of the most appropriate and most precise method for efficiency evaluation in agriculture, as it compensates for the disparity of prices and permits the comparison of different production technologies in regions with various structure of costs or between periods divided by large time intervals, without complex adjustments of price indexes (5, 6, 7, 8).

Furthermore, the increasing deficiency of natural energy sources and the high prices of fuels imply the rational utilization of energy in agriculture. The evaluation of energy efficiency allows selecting scientific approaches with regard to the improvement of crop production technologies aiming at saving both energy and resources (5, 9, 10, 11, 12, 13).

The creation of conditions for complete realization of the productive potential of plants by implementation of innovative technologies is especially important for the improvement of

***Correspondence to:** *TSENKA ZHELYAZKOVA, Agricultural Faculty, Trakia University, 6000 Stara Zagora, Bulgaria, e-mail: tsenka@abv.bg*

crop production efficiency. One of the options with this connection is the utilization of plant growth regulators. In Bulgaria, experiments were performed for evaluation of the effect of growth regulators on productivity (2, 14), the chemical composition (2, 15, 16) and the economical efficacy of winter pea (2), but there are no data about the nutritive value of the biomass and the energy efficiency of winter pea production.

The purpose of the present study was to assess the nutritive value of the biomass of winter pea (*Pisum arvense* L.) variety Mir, treated with growth regulators. Also, on the basis of this energy value, we aimed to determine the amount and the structure of energy costs for its production, the energy output from the grain and the straw and to perform analysis of energy efficiency of winter pea production.

MATERIAL AND METHODS

Experimental design

In the period 2003–2006 a field experiment with winter pea variety Mir was performed in the experimental base of the Department of Plant Sciences at the Trakia University, Stara Zagora. The experiment was conducted by the block design with 4 repetitions of the set, with size of experimental parcel of 10 m^2, after winter barley predecessor. The soil was a typical meadow cinnamon, with moderate humus reserve (3.42% – 4.04%), slightly acid (pH_{KCl} 5.23−5.44). The soil is slightly supplied with nitrogen (31.3–38.1 mg/1000 g soil) and phosphorus (3.1–4.3 mg/100g soil) and well supplied with potassium (42–48 mg/100 g soil).

The influence of the complex preparations: N-40 (main component naphthaleneacetic acid with auxin action) at 200 and 300 cm^3/ha; HP-55 (quarter ammonium salts, derivatives of chlorophenoxyacetic acid with auxin effect) at 100 and 200 cm^3/ha and G-31 (derivatives of chlorophenoxyacetic acid, derivatives of naphthoxyacetic acid − NOA with cytokinine effect) at dose 300 cm^3/ha, was tested. Surfactants were included in the composition of the preparations. During the second and the third year of the experiment, an additional variant for ascertaining the combined effect of the preparation that provided the highest yield during the first year and an insecticide for control of weevil (*Bruchus pisi* L.) − Nurele D at a dose of 500 cm^3/ha, was included.

The treatment of wither pea was performed in full bloom, with 300 l/ha solution. The conventional technology for winter pea cultivation was applied.

Method of nutritive value calculation

The nutritive value (gross energy: GE; metabolizable energy: ME and net energy: NE, MJ/kg dry matter; feed units for milk (FUM) and feed units for growth (FUG) in kg dry matter) was calculated on the basis of the chemical composition (15) and digestibility coefficients by using empirical equations (1). The digestibility coefficients of pea grain and straw were according to Todorov (1).

Method of energy efficiency calculation

The energy efficiency of applied plant growth regulators was determined by method of assessing the energy in agricultural crops presented in detail in literature sources (8, 12, 17, 18, 19, 20, 21, 22), evaluating both the energy accumulated in crops and the energy spent on its production.

Estimation of energy input

The real energy input was calculated on the basis of technological charts for each individual variant per 1 ha, assuming an average transportation distance of 5 km, for each experimental year.

The hourly costs for mechanization and labour were determined as per zonal norms for working shift productivity of machine and manual labour in crop breeding in Bulgaria. The hourly operating costs related to mechanization and labour was converted to energy input using the following equivalents: for mechanization − 64.80 MJ/h (23); for labour – 2.30 MJ/h (24).

The diesel fuel expenditure was determined on the basis of zonal norms for fuel consumption in mechanized field operations in Bulgaria and converted to energy units using an energy equivalent of 56.31 MJ/l (23).

The energy costs related to fertilization were calculated on the basis of energy equivalents of 60.60 MJ/kg N and 11.10 MJ/kg P_2O_5 (11).

The energy costs for seeds were determined on the basis of energy equivalent of 19.04 MJ/kg **(Table 1)**.

Table 1. *Nutritive value of winter pea average for the period 2003 - 2005 year*

Variants Dose cm^3/ha	GE, MJ/kg DM	ME, MJ/kg DM	NE, MJ/kg DM	FUM, per kg DM	FUG, per kg DM
Nutritive value of grain					
Control, water	19.01	12.85	7.81	1.30	1.39
N-40 200	19.03	12.82	7.79	1.30	1.39
N-40 300	19.03	12.85	7.82	1.30	1.39
HP-55 100	18.99	12.87	7.83	1.31	1.40
HP-55 200	19.11	12.88	7.83	1.30	1.39
G-31 300	19.07	12.83	7.79	1.30	1.39
Average	19.04	12.85	7.81	1.30	1.39
*N-40 200 Nurele D 500	19.22	12.81	7.76	1.29	1.38
Nutritive value of straw					
Control, water	18.17	6.92	3.73	0.62	0.54
N-40 200	18.02	6.90	3.73	0.62	0.54
N-40 300	17.99	6.85	3.69	0.62	0.53
HP-55 100	18.05	6.87	3.70	0.62	0.53
HP-55 200	18.22	6.93	3.74	0.62	0.54
G-31 300	18.19	6.96	3.76	0.63	0.54
Average	18.11	6.91	3.73	0.62	0.54
*N-40 200 Nurele D 500	18.38	6.93	3.73	0.62	0.54

Legend: GE - Gross energy, ME - Metabolizable energy, NE - Net energy, FUM - Feed units for milk, FUG - Feed units for growth

* Data are for the 2004 - 2005 years crop

The energy related to used insecticides and growth regulators was determined by means of energy equivalents of 92 MJ/kg (25) and 85 MJ/kg (26), respectively.

The conversion of electric energy into heat energy was performed by multiplication of the used energy in kWh to an energy equivalent of 3.60 MJ/kWh, whereas the water expenditure – by using an energy equivalent of 0.63 MJ/m^3 (24)

Estimation of energy output and calculation of energy efficiency

The energy output was calculated on the basis of crop yields (presented as dry matter) and its energy content. The yields of the main and additional winter pea crops treated with growth regulators are obtained from a previous publication of ours (14).

The efficiency of energy input was assessed by the coefficient (R) defined by Pimentel et al. (19) as ratio of the energy value of the final product *P* (MJ/ha) and the energy spent for its production *E* (MJ/ha): (R = P / E).

Statistical analysis

Data were analysed using the standard procedures for analysis of variance (one-way ANOVA) using the packet programs for statistical processing of data − StatSoft, STATISTICA for Windows (27).

RESULTS AND DISCUSSION

The total energy value (gross energy – GE − the amount of heat liberated after combustion) of winter pea grain was 19.04 MJ/kg DM **(Table 1)**. The animals did not utilize completely the potential energy of forage crops. A considerable part is lost with non-digested fiber components, the intermediate metabolism etc. The amount of the metabolizable energy (ME, physiologically useful energy) and the net energy (NE – productive energy, i.e. for production of milk, meat etc.) in grain for ruminants is 12.85 MJ/kg DM and 7.81 MJ/kg DM respectively. On the average for all experimental years, ME amounted to 67.49%, and NE – to 40.37 % of the gross energy content of grain. On the basis of the new system for evaluation, grain contains on the average 1.30 feed units for milk (FUM) and 1.39 feed units for growth (FUG) in 1 kg DM. The values about GE, ME, FUM and FUG in winter pea grain obtained in the present study were similar with those of Petkova (2).

The average GE value of winter pea straw was 18.11 MJ/kg DM. The ME (6.91 MJ/kg DM) and NE (3.73 MJ/kg DM) were almost twice lower that those of grain. Average FUM (0.62 per kg DM) and FUG (0.54 per kg DM) in pea straw were also lower as compared to grain.

The nutritive values of grain and straw were almost equal and did not change either after the treatment with growth regulators or after the combined application with insecticide for weevil control.

The energy input for winter pea production in this study was on the average 17 862.5 MJ/ha **(Table 2)**. It was lower by 13% as compared to that reported by Ivanov (19) and Zhelyazkova and Pavlov (28) for production of spring pea, and this was due both to the reduced energy input for seeds and to the lack of need for weed control in winter pea due to its early spring development.

Table 2. *Energy input in winter pea cultivation for the years and average for the period 2003 - 2006 year, MJ/ha*

Variants Dose cm^3/ha	Year			Average	
	2003 - 2004	2004 - 2005	2005 - 2006	MJ/ha	%
Control, water	17856.2	17714.0	17641.7	17737.3	100.00
N-40 200	18100.3	17936.7	17846.0	17961.0	101.26
N-40 300	18031.3	17892.1	17791.6	17905.0	100.95
HP-55 100	18060.1	17897.0	17812.1	17923.1	101.05
HP-55 200	17980.4	17834.0	17732.8	17849.0	100.63
G-31 300	17916.5	17782.8	17700.2	17799.8	100.35
Average	17990.8	17842.7	17754.1	17862.5	
*N-40 200 Nurele D 500	-	17830.9	17740.9		

*Data are for the 2004 - 2005 and 2005 - 2006 years crop

The energy input varies during the separate years of the experiment. The highest costs were in 2003-2004 because of the higher input related to the harvesting and storage of the larger production in this season. The lowest energy input for all tested variants was in 2005-2006, when the crop yields were the lowest as well. In general, the differences between energy inputs among the variants were low. Minimum energy costs were obtained with controls. In variants treated with growth regulators, energy input increased both because of the additional energy for growth regulators and due to higher expenditure related to larger crops. The maximum values of energy input were observed in the treatment with H-40 at a dose of 200 cm^3/ha – 17.961 MJ/ha on the average, that represented an increase only by 1.26% vs the conventional technology for winter pea grain production. The combined introduction of the preparation H-40 at 200 cm^3/ha and an insecticide for weevil control, resulted in reduction of energy input by 105.1–105.8 MJ/ha as compared to its independent application.

The analysis of the structure of energy input in the production of winter pea for the period 2003–2006 on the average **(Table 3)** showed that the highest share of total energy input was that of fertilizers (48.8%). The costs for production and utilization of fertilizers are studies in numerous investigations and the various studies reported a share of 40 to 55% from the total energy input in agriculture in developed countries (7, 12, 25, 29, 30).

The shares of the energy for machinery and fuels (28,7%) and seeds (21,3%) in the total energy input were also considerable. The energy costs related to pesticides and labour were 0.6% and 0.5% of all spent energy. Despite the relatively high energy equivalent of growth regulators, the energy costs related to their use varied from 8.5 to 25.5 MJ/ha for the different variants and were only 0.09% of the total costs.

Table 3. *Structure of energy input in winter pea cultivation average for the period 2003 - 2006 year, MJ/ha*

Energy input for the materials and activities applied in pea cultivation	Variants							Average	
	Control, Water	N-40 200 cm^3/ha	N-40 300 cm^3/ha	HP-55 100 cm^3/ha	HP-55 200 cm^3/ha	G-31 300 cm^3/ha	*N-40 (200) Nurele D (500)	MJ/ha	%
Diesel-oil	4026.9	4118.0	4088.3	4104.4	4067.8	4043.8	4000.3	4064.2	22.767
Fertilizers, total	8715.0	8715.0	8715.0	8715.0	8715.0	8715.0	8715.0	8715.0	48.819
- Nitrogen	7272.0	7272.0	7272,0	7272.0	7272.0	7272.0	7272.0	7272.0	40.736
- Phosphorus	1443.0	1443.0	1443.0	1443.0	1443.0	1443.0	1443.0	1443.0	8.083
Pesticides, total	92.0	109.0	117.5	100.5	109.0	117.5	109.0	107.8	0.604
- Insecticides	92.0	92.0	92.0	92.0	92.0	92.0	92.0	92.0	0.515
- Plant growth regulators	0.0	17.0	25.5	8.5	17.0	25.5	17.0	15.8	0.088
Human labour	82.2	93.7	90.6	92.2	87.8	84.5	89.1	88.6	0.496
Electricity	2.4	2,4	2.4	2.4	2.4	2.4	1.7	2.3	0.013
Machinery	1008.2	1112.4	1080.6	1097.9	1056.5	1026.0	1060.5	1063.2	5.956
Water	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.5	0.003
Seeds	3810.0	3810.0	3810.0	3810.0	3810.0	3810.0	3810.0	3810.0	21.343
Total, MJ/ha	17737.3	17961.0	17905.0	17923.1	17849.0	17799.8	17785.9	17851.6	100.000

* Data are for the 2004 - 2005 and 2005 - 2006 years crop

For the period of the study, winter pea biomass yielded on the average 131 579.0 MJ/ha GE, 61 383.5 MJ/ha ME and 34 873.4 MJ/ha NE (Table 4). The lowest values of GE, ME and NE were established in 2005−2006 when the dry matter yield from both grain and straw were the lowest.

The yields of GE, ME and NE after the different treatments showed highest values after treatment with H-40 at a dose of 200 cm^3/ha, with values higher than controls by 16.17% for GE, by 16.62% for ME and by 16.71% for NE. When the dose of this preparation was increased to 300 cm^3/ha, the energy output was also high, but lower compared to the smaller dose applied. The lowest energy output for the separate years of the experiment and for the entire period on the average was established with the growth regulator G-31. The differences between variants treated with growth regulators and controls were statistically significant at P<0.001. The combined application of the preparation N-40 at 200 cm^3/ha and an insecticide for weevil control resulted in reducing energy output values compared to its independent application.

The analysis of data of energy outputs from the primary crop and residues showed that winter pea cultivation occurred in conditions of positive energy balance because the amount of obtained energy was higher than that spent on its production. This resulted in high average coefficients of energy efficiency (Table 5) – 7.4 for GE, 3.4 for ME and 2.0 for NE. The highest energy efficiency coefficients were obtained in 2003–2004, due to the highest biological yields during that period.

From an energy point of view, the treatment of winter pea with H-40 (200 cm^3/ha) was the most efficient, and within the period 2003−2006, that resulted in increasing the coefficient of energy efficiency as compared to the water control by 14.71% for GE, 15.16% for ME and 15.25% for NE, respectively. The differences were also statistically significant (P<0.001). The application of higher doses of preparations HP-55 and N-40 was less effective, and the trends followed the same direction for all three years of the experiment. The lowest energy efficiency was obtained with the growth regulator G-31, and this was primarily due to the lower energy output. The combined application of N-40 at a dose of 200 cm^3/ha and an insecticide for weevil control did not results in reducing efficiency as compared to its independent application.

Table 4. *Energy output from the whole biological mass of the winter pea for the years and average for the period 2003 - 2006 year, MJ/ha*

Variants Dose cm³/ha	Type of energy	Year			Average	
		2003 - 2004	2004 - 2005	2005 - 2006	MJ/ha	%
Control, water	GE	131113.1	120705.5	111305.6	121041.4	100.00
	ME	61853.5	55845.3	51752.7	56483.8	100.00
	NE	35211.0	31694.2	29339.7	32081.6	100.00
N-40 200	GE	152921.3	139891.3	129026.0	140612.8 a**	116.17
	ME	72354.1	65114.5	60141.8	65870.1	116.62
	NE	41195.0	36957.1	34179.7	37443.9	116.71
N-40 300	GE	145213.7	134390.7	122708.9	134104.4 b	110.79
	ME	68512.7	61876.9	56868.5	62419.4	110.51
	NE	39021.0	35081.6	32259.7	35454.1	110.51
HP-55 100	GE	149733.9	136938.3	126593.3	137755.2 c	113.81
	ME	70898.0	63273.7	58819.9	64330.6	113.89
	NE	40377.4	35941.4	33372.9	36563.9	113.97
HP-55 200	GE	142390.0	130973.0	119005.4	130789.5 d	108.05
	ME	66940.7	60395.5	55095.2	60810.5	107.66
	NE	38071.1	34266.2	31273.7	34537.0	107.65
G-31 300	GE	135616.8	125031.4	114810.2	125152.8 e	103.40
	ME	63889.8	57936.8	53333.4	58386.7	103.37
	NE	36345.5	32861.5	30271.9	33159.6	103.36
Average	GE	142831.5	131321.7	120574.9	131576.0	
	ME	67408.1	60740.5	56001.9	61383.5	
	NE	38370.2	34467.0	31782.9	34873.4	
*N-40 200 Nurele D 500	GE	-	140679.7	131132.7		
	ME	-	65161.0	60255.7		
	NE	-	36956.9	34113.6		

Legend: GE - Gross energy, ME - Metabolizable energy, NE - Net energy
* Data are for the 2004 - 2005 and 2005 - 2006 years crop
** Differences between variants are statistically significant at P < 0.05 if not equal letters

Average for:	for GE, MJ/ha;	for ME, MJ/ha;	for NE, MJ/ha;
LSD, P<0.05	1631.5	876.6	492.6
LSD, P<0.01	2319.2	1246.1	700.2
LSD, P<0.001	3358.0	1804.3	1013.9

CONCLUSIONS

The treatment of winter pea with growth regulators did not result in considerable differences in the specific nutritive and energy values of both grain and straw as feed sources in ruminant nutrition.

The energy input for winter pea production in this study was on the average 17 862.5 MJ/ha. The structure of average energy costs was as followed: 8 715.0 MJ/ha (48.8%) for fertilizers; 5 127.4 MJ/ha (28.7%) for machinery and diesel fuel; 3 810.0 MJ/ha (21.3%) for seeds; 107.8 MJ/ha (0.6%) for pesticides; 88.6 MJ/ha (0.5%) for labour costs; 2.8 MJ/ha (0.10%) – other costs (electricity, water supply).

The energy output of winter pea biomass was on the average 131 579.0 MJ/ha gross energy, 61 383.5 MJ/ha metabolizable energy and 34 873.4 MJ/ha net energy.

The growth regulators applied at the bloom stage increased the energy output of winter pea biomass and the energy efficiency of the plants cultivation. The highest coefficient of energy efficiency was obtained from the treatment with N-40 at a dose of 200 cm^3/ha – 7.8 for GE; 3.7 for ME and 2.1 for NE. The combined application of N-40 at a dose of 200 cm³/ha and an insecticide for weevil control did not results in reduced efficiency as compared to its separate application.

Table 5. *Coefficient of the energy efficiency from the whole biological mass of the winter pea for years and average for the period 2003 - 2006 year*

Variants Dose cm³/ha	Type of energy	Year			Average	%
		2003 - 2004	2004 - 2005	2005 - 2006		
Control, water	GE	7.34	6.81	6.31	6.82	100.00
	ME	3.46	3.15	2.93	3.18	100.00
	NE	1.97	1.79	1.66	1.81	100.00
N-40 200	GE	8.45	7.80	7.23	7.83 a**	114.71
	ME	4.00	3.63	3.37	3.67	115.16
	NE	2.28	2.06	1.92	2.08	115.25
N-40 300	GE	8.05	7.51	6.90	7.49 b	109.75
	ME	3.80	3.46	3.20	3.48	109.47
	NE	2.16	1.96	1.81	1.98	109.47
HP-55 100	GE	8.29	7.65	7.11	7.68 c	112.62
	ME	3.93	3.54	3.30	3.59	112.70
	NE	2.24	2.01	1.87	2.04	112.78
HP-55 200	GE	7.92	7.34	6.71	7.32 d	107.37
	ME	3.72	3.39	3.11	3.41	106.98
	NE	2.12	1.92	1.76	1.93	106.97
G-31 300	GE	7.57	7.03	6.49	7.03 e	103.03
	ME	3.57	3.26	3.01	3.28	103.01
	NE	2.03	1.85	1.71	1.86	103.00
Average	GE	7.94	7.36	6.79	7.36	
	ME	3.75	3.40	3.15	3.43	
	NE	2.13	1.93	1.79	1.95	
*N-40 200 Nurele D 500	GE		7.89	7.39		
	ME		3.65	3.40		
	NE		2.07	1.92		

Legend: GE - Gross energy, ME - Metabolizable energy, NE - Net energy
* Data are for the 2004 - 2005 and 2005 - 2006 years crop
** Differences between variants are statistically significant at $P < 0.05$ if not equal letters

Average for:	for GE, MJ/ha;	for ME, MJ/ha;	for NE, MJ/ha;
LSD, $P<0.05$	0.08	0.04	0.02
LSD, $P<0.01$	0.11	0.06	0.04
LSD, $P<0.001$	0.16	0.09	0.05

REFERENCES

1. Todorov, N., Standarts for nutrition and nutritive value on forages for cattle and buffalo. Sofia, Phare, PENSOFT, 236 p., 1997 (Bg)
2. Petkova, R. A., Productivity and qality of winter forage pea – resource for protein problem resolving. *Dissertation*, Agricultural Academy – Bulgaria, 167 p., 2006 (Bg)
3. Mandal, K. G., Sahap, K. P., Ghosh, P. K., Hati, K. M., Bandyopadhyay, K. K., Bioenergy and economic analysis of soybean-based crop production systems in central India. *Biomass and Bioenergy,* 23, 5: 337-345, 2002
4. Pimentel, D., Economics and energetics of organic and conventional farming. Journal of *Agricultural and Environmental Ethics*, 6, 1: 53–59, 1993
5. Hatirli, S. A., Ozkan, B., Fert, C., An econometric analysis of energy input–output in Turkish agriculture. *Renewable and Sustainable Energy Reviews*, 9, 6: 608-623, 2005
6. Mitova, T., Essence and value on energy analysis for an estimation on different link from system on agriculture on an example on fertilizers. *Soil Science, Agrochemistry and Ecology,* Sofia, Bulgaria, 31, 5: 14-17, 1996 (Bg)
7. McLaughlin, N. B., Hiba, A., Wall, G. J., King, D. J., Comparison of energy inputs for inorganic fertilizer and manure based corn production. *Canadian Journal Agricultural Engineering*, 42, 1: 2.1–2.14, 2000
8. Pimentel, D., Hurd, L. E., Belloti, A. C., Forster, M. J., Oka, J. N., Sholes, O. D.,

Whitman, R. J, Food production and the energy crisis. *Science*, 182:443-449, 1973
9. Alam, M. S., Alam M. R., Islam, K. K., Energy Flow in Agriculture: Bangladesh. *American Journal of Environmental Sciences*, 3: 213-220, 2005
10. Chamsing, A., Salokhe, V., Singh G., Energy Consumption Analysis for Selected Crops in Different Regions of Thailand. *Agricultural Engineering International: the CIGR Ejournal,* Vol. 8., 2006, http://cigr-ejournal.tamu.edu/submissions/volume8/EE%2006%20013%20Salokhe%20final%206Nov2006.pdf
11. Chaudhary, V., Gangwar, B., Pandey D, Auditing of Energy Use and Output of Different Cropping Systems in India. *Agricultural Engineering International: the CIGR Ejournal,* Vol. 8, 2006, http://cigr-ejournal.tamu.edu/submissions/volume8/EE%2005%20001%20Chaudhary%20final%2028June2006.pdf
12. Hülsbergen, K. J., Feil, B., Biermann, S., Rathke, G. W., Kalk, W. D., Diepenbrock, W., A method of energy balancing in crop production and its application in a long-term fertilizer trial. *Agriculture, Ecosystems and Environment*, 86, 3: 303-321, 2001
13. Ozkan, B., Akcaoz, H., Fert, C., Energy input-output analysis in Turkish agriculture. *Renewable Energy*, 29: 39-51, 2004
14. Zhelyazkova, Ts., Pavlov, D., Ivanova, I., Nenkova, D., Influence of some plant growth regulators on winter pea (*Pisum arvense* L.) productivity. *Journal of mountain agriculture on the Balkans*, Ttoyan, Bulgaria, 10, 3: 499-511, 2007
15. Zhelyazkova, Ts., Pavlov, D., Toskov, K., Influence of some plant growth regulators on winter pea (*Pisum arvense L.*) chemical composition. *Plant Sciense*, Sofia, Bulgaria, 44, 6: 547-550, 2007 (Bg)
16. Zhelyazkova, Ts., Pavlov, D., Uzunova, K., Content of mineral elements in the grain of winter pea, treated with plant growth regulators. *Journal of mountain agriculture on the Balkans*, Ttoyan, Bulgaria, 10, 3: 512-524, 2007
17. Ivanov, D., A general methodical approach to the power consumption analysis of the grain and forage production. *Agricultural Engineering*, Sofia, Bulgaria, 35, 5: 26-29, 1998 (Bg)
18. Ivanov, D., Energy efficiency of the grain and forage production by regions in the Republic of Bulgaria. *Agricultural Science*, Sofia, Bulgaria, 37, 2: 30-34, 1999 (Bg)
19. Ivanov, D., A structural analysis of the energy consumption in the Bulgarian grain production. *Agricultural economics and management*, Sofia, Bulgaria, 44, 4: 13-20, 1999 (Bg)
20. Tokarev, V., Bratushkin, V., Nikiforov, A., Methodical recommendations by a fuel and energy estimation of agricultural machinery, technological processes and technologies in plantgrowing. Moscow, VIM, 59 p., 1989 (Ru)
21. Tyulin, V., Petrova, L., Salihov, P., Ivanov, D., Biopower estimation of cultivation of forage crops in agrolandscapes. *Forage production,* 11: 4-7, 1999 (Ru)
22. Pimentel, D., Berardi, G., Fast, S., Energy efficiency of farming systems: organic and conventional agriculture. *Agriculture, Ecosystems and Environment*, 9: 359-372, 1983
23. Ozkan, B., Kurklu, A., Akcaoz, H., An input–output energy analysis in greenhouse vegetable production:a case study for Antalya region of Turkey. *Biomass and Bioenergy*, 26: 89–95, 2004
24. Yaldiz, O., Ozturk, H., Zeren, Y., Bascetincelik, A., Energy usage in production of field crops in Turkey. *5th Int. Cong. on Mechanization and Energy Use in Agriculture*, 11-14-Oct 1993, Kusadasi, Turkey (cited by Hatirli et al., 2006).
25. Helsel, Z. R., Energy and alternatives for fertilizer and pesticide use. *In Energy in Farm Production,* ed. Fluck R. C., New York: Elsevier, 1992
26. Green, M. B., Energy in pesticide manufacture, distribution and use. *In Energy in Plant Nutrition and Pest Control*, ed. Z. R. Helsel, Amsterdam, The Netherlands, 165-177, 1987
27. StatSoft, Inc. STATISTICA for Windows [Computer program manual], 2000
28. Zhelyazkova, Ts. and Pavlov, D., Energy efficiency of spring pea production, treated with plant growth regulators. *Journal of mountain agriculture on the Balkans*, Ttoyan, Bulgaria, 11, 5: 866-878, 2008
29. Rathke, G. W., Körschens, M., Diepenbrock, W., Substance and energy balances in the static fertilisation experiment bad Lauchstädt. *Archiv für Acker- und Pflanzenbau und Bodenkunde*, 48: 423–433, 2002
30. Hülsbergen, K. J., Feil, B., Diepenbrock, W., Rates of nitrogen application required to achieve maximum energy efficiency for various crops: results of a long-term experiment. *Field Crops Research*, 77: 61–76, 2002