INFLUENCE OF THE MINERAL FERTILIZATION AND THE INOCULATION WITH *RHIZOBIUM LEGUMINOSARUM* STRAIN ONTO THE ENERGY EFFICIENCY OF THE FORAGE WINTER PEA PRODUCTION

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Abstract

In order to determine the energy efficiency of the forage winter pea production depending on the mineral fertilization and the inoculation with Rhizobium leguminosarum, adopted is the energy approach, comprising of comparison of the total energy outgo with the amount of energy accumulated in the production and presented in comparable measurement units (kkal, MJ). For this purpose, used are the winter pea productivity results from the agrarian experiment held 1997-1999 at the Agricultural Institute, Stara Zagora, Bulgaria.

Studied is the effect of the following alternatives:

1. *Non-fertilized (water treatment);*
2. $N_{60}P_{120}$;
3. P_{12}*+Rhizobium leguminosarum*
4. *Rhizobium leguminosarum*

Grounded on the study, verified is that the mineral fertilization applied and the pre-sowing treatment of the seeds with Rhizobium leguminosarum strain using the semi-wet method do have a positive effect onto the energy obtained from the winter pea biomass and the energy efficiency of its production. The highest energy efficiency factor results from the isolated application of the inoculant – 11,9 for Gross Energy (GE); 6,06 for the Metabolizable Energy (ME) and 3,45 for the Net Energy (NE).

Key words: forage peas, inoculation, energy efficiency

INTRODUCTION

The intensified modern agriculture inevitably is accompanied by the growing rate of the total energy expenses. Along with this, growing also is the deficiency of the natural energy resources. This is why the world practice dedicates a significant role of the energy approach upon assessment of the technology. This approach allows for comparison of the production technologies in terms of time and space; it eliminates the market price formation; it allows choosing the most efficient and energy-saving technology for the production of the agricultural products. [1], [2], [7], [10], [11], [12], [14]

Determined is that upon the active legumen - rhizobium symbiosis, in order to form their yield, the leguminous plants absorb on average 2/3 atmospheric nitrogen and 1/3 of the soil.

A number of researchers believe that in future one of the possibilities for increasing the yield of the grain-legumes will be the seed inoculation with active strains of the tuber bacteria.

In contrast to the beans and the soya, where the inoculation with Rhizobium is quite common and is a part of the cultivation technology, the pea inoculation in Bulgaria is poorly studied, [8], [9], [13], [15] and there is no information on its impact over the energy efficiency of its production.

The purpose of the present study is to determine the energy efficiency upon the forage winter pea production depending on the mineral fertilization and its inoculation with *Rhizobium leguminosarum* strain.

MATERIAL AND METHOD

In 1997-1999 at the irrigated agricultural experimental station (Agricultural Institute – Stara Zagora, Bulgaria at present), an agro-technical experiment, was carried out applying the block method, 4 repetitions, crop plot of 12,8 m^2. The experimental crop was sowed following a fore-crop of winter common wheat, unirrigated. Used was "Mir" forage winter pea brand (Pisum sativum ssp. arvenseL.), Bulgarian selection. The phosphates were introduced along the main soil machining, and the nitrate fertilizer – prior to sowing. The bacteria agent Nitragin containing cultivated tuber bacteria of *Rhizobium leguminosarum*, using agar as adherant, is applied by pre-sowing seed inoculation applying the semi-wet method.

At the experimental station, the soils are grey of forest origin, humus horizon of 3,6-4,2%. They have a poor content of absorbable nitrogen (32,26 mg/1000g soil) and absorbable phosphorus (4,40 mg/100 g soil) and some significant content of absorbable potassium (27,7 mg/100g soil). The soil reaction is close to the neutral (pH_{KIE}- 7,25).

Applied was the common technology for growing forage winter peas.

Tested was the effect of the following alternatives:

1. Non-fertilized (water treatment);
2. $N_{60}P_{120}$;
3. *P_{12}+Rhizobium leguminosarum*
4. *Rhizobium leguminosarum*

For determining the energy efficiency of the mineral fertilization and the inoculation with Rhizobium of the winter peas, used is the energy analysis of the agricultural production [2], [5], [6], [7], [14], [17], [19]. The expenses for purchase of materials and carrying out the technological practices, are calculated on the grounds of technological maps that were developed as per alternatives for each year of the study, used are the zonal replacement norms and converted into energy values using the following energy equivalents: for the fertilization- 60,60 MJ/kg N, 11,10 MJ/kgP_2O_5 [3]; for the fertilization – 60, 60 MJ/kg N and 11,10 MJ/kg P_2O_5 [3]; for the diesel – 56,31 MJ/l [12]; mechanization – 64,80 MJ/h [12]; for the seeds – calculated energy equivalent average – 18,62 MJ/kg; for herbicides – 238, 0 MJ/kg [7]; insecticides – 92,0 MJ/kg [7]; Fungicides – 199,0 MJ/kg [7]; electrical power supply – 3,60 MJ/kWh [11]; labour – 2,30 MJ/h; water – 0,63 MJ/m^3 [18]; Nitragin – 57,03 MJ/l. The energy obtained from the biomass of the winter pea is calculated on the grounds of generated yield of dry matter (DM) from grain and straw and Gross Energy (GE) content, Metabolizable Energy (ME) and Net Energy (NE) content in one kg dry matter of grain (experimental facts) and straw [16].

The efficiency of the energy used is determined using the energy efficiency factor R, defined as a ratio between the energy P (MJ/ha) obtained from the end product and the energy E (MJ/ha) used for its production, i.e. (R=P/E) [7]

RESULTS AND DISCUSSIONS

The energy used for the production of the winter pea, determined upon the present study, as an average value for the relevant period, is 11518,72 MJ/ha (Table 1). Over the years, the highest are the energy expenses during t the second year (1999) due to an increase of the energy expenses related to harvesting and storing of the generated bigger crop. The values of the energy used during the first year (1998) for all the alternatives, are lower as the yields are lower. The differences between the energy expenses of all the alternatives are significant, except the difference between the water treatment alternative and the alternative with the isolated participation of the inoculant. The lowest energy expenses are the expenses related to the water treatment alternative, and the highest expenses are the expenses related to the nitrogen-phosphorus fertilization as a result of the increased crop and the extra energy expenses used for fertilizers. On average, for the period, those expenses are 16821,22 MJ/ha, which is 52,3% more in comparison with the alternative with the isolated participation of the P_2 in combination with the inoculant, and 85,9% in comparison with the water treatment alternative, i.e. the energy expenses have increased more than twice.

Table 1. Energy input winter peas cultivation for years and average for the period, MJ/ha

Variants	Year		Average	
	1998	1999	MJ/ha	%
Control	9184,15	8912,88	9048,52	100,00
$N_{60}P_{120}$	16647,80	16994,63	16821,22	185,90
P_{120} + Rizobium	10581,80	11494,73	11038,27	121,98
Rizobium	8842,08	9491,71	9166,90	101,30
Average	11313,95	11723,48	11518,72	

LSD $P<0,05 = 41,76$
$P<0,01 = 57,51$
$P<0,001 = 79,23$
*Differences among the parameters are statistically significant if have not equal letter.

Analyzing the structure of the energy expenses used upon cultivation of the winter peas, we find out that biggest is the share for fuel and mechanization(39,37%) (Table 2). Significant is the share of the energy invested for sowing material (33,96%). The energy expenses used for mineral fertilizers are 17,84%, and for pesticides – 8,25%. Although the Nitragin has a high energy equivalent, it is applied in very small doses and the energy expenses for it are 5,7MJ/ha and comprise as little as 0,024% on average of the total energy expenses. The energy expenses used for water are the lowest – 0,005%.

Table 2. Structure of energy input in winter peas cultivation average for the period (1998 – 1999), MJ/ha

The bearer of the energy	Variants				Average	
	Control	$N_{60}P_{120}$	P_{120} + Rizobium	Rizobium	MJ/ha	%
Diesel -oil	3623,54	4062,20	3887,0	3661,3	3808,51	33,07
Fertilizers - total	0	6708,0	1512,0	0	2055,00	17,84
Nitrogen	0	5196,0	1512,0	0	1677,00	14,56
Phosphorus	0	1512,0	0	0	378,0	3,28
Pesticides - total	950,1	950,1	950,1	950,1	950,1	8,25
Fungicides	36,8	36,8	36,8	36,8	36,8	0,32
Herbicides	714,0	714,0	714,0	714,0	714,0	6,20
Insecticides	199,3	199,3	199,3	199,3	199,3	1,73
Nitragin	0	0	5,70	5,70	2,85	0,024
Human labour	49,40	91,84	60,26	50,05	62,88	0,54
Electricity	1,53	2,85	1,87	1,55	1,95	0,017
Machinery	569,60	1058,89	694,86	577,05	725,10	6,30
Water	0,45	0,84	0,55	0,45	0,57	0,005
Seeds	3853,5	3946,11	3925,53	3920,28	3911,35	33,96
Total, MJ/ha	9048,12	16820,83	11037,87	9166,48	11518,32	100,00

Table 3 suggests that the Gross Energy obtained from the biomass of the winter pea, on average for the period, is 110 544,9 MJ/ha. The Metabolizable Energy obtained, which is useful for the animals in terms of physiology, is 56 529,7 MJ/ha, while the Net Energy – the productive energy, is 32 212,0 MJ/ha. Also with those indicators, higher are the values during the second year (1999) when the yields from the biomass are higher.

Considering all the alternatives, highest are the yields of Gross Energy, Metabolizable Energy and Net Energy with the combined nitrogen-phosphorus fertilization, where the increase compared to the water treatment alternative reaches up to 20,13% for the Gross Energy; 20,62% for the Metabolizable Energy and up to 20, 94% for the Net Energy. High is the energy income also with the isolated participation of the inoculant, however it is lower compared to the participation of the phosphorus fertilization in combination with the inoculant. The lowest energy yield comes from the water treatment alternative. The differences in the energy yields are statistically determined at ($p<0,05$).

Table 3. Energy output from the whole biologic mass of the winter peas for years and average for the 2 years period, MJ/ha

Gross energy				
Variants	Year		Average	
	1998	1999	MJ/ha	%
Control	94117,4	107320,6	100719,0	100,00
$N_{60}P_{120}$	114059,0	127940,4	120999,7	120,13
P_{120} + Rizobium	105963,5	116998,9	111481,2	110,68
Rizobium	110762,4	107197,6	108980,0	108,20
Average	106225,5	114864,3	110544,9	
LSD p < 0,05 = 6021,8	p < 0,01 = 8652,6		p < 0,001 = 11912,6	
Metabolizable energy				
Control	48926,4	53968,8	51447,6	100,00
$N_{60}P_{120}$	59244,0	64873,2	62058,6	120,62
P_{120} + Rizobium	54376,5	59791,1	57083,8	110,95
Rizobium	55717,2	55340,4	55528,8	107,93
Average	54566,0	58493,3	56529,7	
LSD p < 0,05 = 2546,5	p < 0,01 = 3507,8		p < 0,001 = 4829,6	
Net energy				
Control	28189,9	30377,4	29283,6	100,00
$N_{60}P_{120}$	34039,4	36794,5	35416,9	120,94
P_{120} + Rizobium	31053,6	34069,4	32561,5	111,19
Rizobium	31470,6	31701,7	31586,1	107,86
Average	31188,3	33235,7	32212,0	
LSD p < 0,05 = 1277,5	p < 0,01 = 1759,0		p < 0,001 = 2422,1	

A pre-condition for the high energy efficiency of the production, is the balance of the energy used and the energy generated from the main and additional crop, which in the case of the winter pea is positive (Table 4). On average for the study period, the energy efficiency factor is 10,8 for the Gross Energy; 5,15 for the Metabolizable Energy and 2,94 for the Net Energy. Its values are higher during the second year resulting from the higher yields.

Table 4. Coefficient of the energy efficiency from the whole biologic mass of the winter peas for years and average for the 2 years period

Gross energy				
Variants	Year		Average	%
	1998	1999		
Control	10,24	12,04	11,14	100,00
$N_{60}P_{120}$	6,85	7,52	7,19	64,54
P_{120} + Rizobium	10,01	10,17	10,09	90,57
Rizobium	12,52	11,29	11,90	106,82
Average	9,91	10,26	10,08	
LSD p < 0,05 = 0,77	p < 0,01 = 1,07		p < 0,001 = 1,47	
Metabolizable energy				
Control	5,32	6,06	5,69	100,00
$N_{60}P_{120}$	3,56	3,82	3,69	64,85
P_{120} + Rizobium	5,13	5,20	5,16	90,68
Rizobium	6,30	5,83	6,06	106,50
Average	5,08	5,22	5,15	
LSD p < 0,05 = 0,42	p < 0,01 = 0,58		p < 0,001 = 0,80	
Net energy				
Control	3,07	3,41	3,24	100,00
$N_{60}P_{120}$	2,04	2,16	2,10	64,81
P_{120} + Rizobium	2,93	2,96	2,95	91,04
Rizobium	3,56	3,34	3,45	106,48
Average	2,90	2,97	2,94	
LSD p < 0,05 = 0,43	p < 0,01 = 0,60		p < 0,001 = 0,82	

Most effective, in terms of energy point of view, is the isolated application of the inoculant which increases the energy efficiency factor compared to the water treated alternative with 6,82% for the Gross Energy; 6,5 % for the Metabolizable Energy and 6,48% for the Net Energy on average for the experimental period. Less effective technological solution is the application of the inoculant in combination with the phosphorus fertilization (P_{120}+Rhizobium leguminosarum), a trend specific for the two years of the study. The lowest energy efficiency comes from the application of the nitrogen-phosphorus fertilization ($N_{60}P_{120}$) mainly because of the invested energy expenses for fertilizers and harvesting of the bigger crop of the forage winter pea.

CONCLUSIONS:

⇒ The energy expenses used for the production of the forage winter pea on average are: 11 518,72 MJ/ha, and the energy yield is: 110 544, 9 MJ/ha for the Gross Energy; 56 529,7 MJ/ha for the Metabolizable Energy and 32 212,0 MJ/ha for the Net Energy;

⇒ The applied mineral fertilization and inoculation of the seeds with Rhizobium leguminosarum, isolated or in combination, have a positive effect on the energy efficiency upon the cultivation of winter pea, “Mir” brand.

⇒ The highest energy efficiency factor results from the isolated participation of the inoculant, which is 11,9 for the Gross Energy; 6,06 for the Metabolizable Energy and 3,45 for the Net Energy, allowing for its use as an element of the energy-saving and eco-friendly technology of the cultivation of winter pea in the conditions of grey soils of forest origin.

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