ENERGY EFFICIENCY OF BROAD BEANS GROWING FOR FORAGE PRODUCTION DEPENDING ON THE VARIETY

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Abstract

A field experiment was conducted with growing winter forage beans for grain, (fully) irrigated conditions, to determine its energy efficiency under the influence of six introduced varieties of various types of ecological origin. The experiment includes the following varieties: 1.Mearis Beaver (control-K_o); 2.Bulldog; 3.Burdon; 4.Mearis Beagle; 5.Webo; 6.Throws MS. The energy efficiency was calculated by applying a balance method (energy input/consumed and output/produced) by means of energy equivalents for all operations and biomass energy value as calculated through its chemical composition and digestibility. The energy efficiency of the winter forage beans depends on variety, varying in average from 8.84 for GE, 4.63 for ME and 2.66 for NE. The varieties Maeris Beaver and Throws MS show the most stable values of the parameters studied, regardless of the agro-meteorological conditions throughout the year. This variety contributes to the highest energy efficiency in the production of winter forage beans compared to other major factors of the agricultural technology applied, i.e. irrigation and fertilization.

Key words: winter forage beans, energy efficiency, variety

INTRODUCTION

The ever increasing shortage of proteins for feeding humans and animals worldwide, requires scientists and experts to find sources for producing larger quantities and cheaper protein per unit area. Among arable crops, the most important are leguminous forage crops, including broad beans.

The high protein content in broad beans boosted its growing as food for humans and animals in many countries. It was relatively frost-resistant crop and in the temperate regions its varieties can be sown in spring and autumn.

Broad beans are alternative crop for the production of feed grains in Bulgaria. The experimental results show that soil and climatic conditions of the country boost its productivity and it was higher than peas, beans, soybeans and chickpeas.

Variations in grain yield of crops are a result of the productive capacity of cultivated varieties, of soil and climatic conditions and the technological level of production.

Energy consumption throughout the World was permanently increasing. The use of non-renewable resources and their depletion threaten energy security. Therefore, demand management was strategically important because it leads to reduction of needs for investment in new energy sources and energy capacities, as well as reducing the costs of producing industrial and agricultural products.

Increase of energy efficiency in all spheres of economic life and in particular of agriculture was among the criteria for membership in the European Union. It requires application of the energetic approach that allows comparing different production technologies in time and space, while eliminating the influence of price conjuncture of the market and allows selecting the most effective and energy-saving technology of growing crops. [2, 3, 10, 11, 12, 13, 14]. In Bulgaria, there are studies on the reaction of broad bean varieties of various types of ecological origin, but there was no evidence of their impact on the energy efficiency of its production.

The purpose of this study was to determine the energy efficiency of winter forage beans harvested for grain under provided irrigation, depending on the crop variety.

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MATERIAL AND METHOD

A 3-year field experiment has been performed for comparing different varieties grown on leached soil type vertisols of six introduced winter forage beans, all of the same variety (Webo) from Germany while the other varieties are from England (the UK). The experiment was laid under the block method, in four replications. The soil within the test area features humus content (2.35%), neutral pH reaction (pH_{KCl} - 7.27), with low quantities of Nitrogen reserves (37,37 mg N /1000g^{-1} soil) and Phosphorus (4,3 mg P / 100g^{-1} soil) and well stocked with Potassium (27,85 mg R/100g^{-1} soil).

Sowing has been done in fall following winter wheat as predecessor, in rows spaced 70 cm apart from each other. Before the main soil treatment, 10 kg/da active substance (P_2O_5) was deposited in soil and further spring feeding of 6 kg/da N.

Through the years of study, the most favorable combination of air temperature and precipitation during the periods of fertilization, filling and ripening of broad beans were observed in the second and third years, and the most unfavorable - in the first year.

To maintain optimum soil moisture, in the first and third years three irrigations were added in, while in the second year - two irrigations.

The experiment includes the following varieties: 1.Mearis Beaver (control-K_o); 2.Bulldog; 3.Burdon; 4.Mearis Beagle; 5.Webo; 6.Throws M.S.

The chemical composition of the biomass was established through an analysis Weende [1]. The energy value - gross energy (GE); metabolizable energy (ME) and net energy (NE) in MJ kg^{-1} CB was calculated based on the chemical composition and digestibility coefficient [16].

The energy efficiency was calculated based on the balance method (energy consumed vs energy produced) based on [6, 7, 8, 17]. The energy consumed for machinery and human labor was estimated respectively based on [10, 11, 18]. The diesel fuel energy was calculated based on the local standards and by using a coefficient [10, 11]. The energy equivalent of the seeds sowed was estimated by using a coefficient [12].

The energy efficiency was established by means of a coefficient (R), defined by Pimentel [8], and the ratio between the energy P (MJ/ ha^{-1}) obtained from the total yield of biomass from the agricultural crops and E (MJ/ ha^{-1}) and the energy consumed for production: (R = P / E). All data obtained were analyzed statistically using ANOVA program.

RESULTS AND DISCUSSIONS

Average for the period of the study, the energy input for growing the separate varieties vary within a narrow range, from 0.91 to 2.33 percent, compared with the control (Table 1). There is a significant difference in the energy input from year to year, almost twice greater than that in the second and third year of harvesting broad beans. The reasons for that include the agricultural meteorological conditions, the number of irrigations and obtained higher yields of grains and straw, the need for higher energy input for harvesting and transportation of products.

Table1 Energy inputin winter beans cultivation, MJ/ha

Variants	Year			Average	
	I	II	III	MJ / ha	%
Mearis Beaver	10 663,25	16 749,79	21 845,52	16 419,52	100,00
Bulldog	9 909,86	19 717,56	19 411,07	16 346,17	99,55
Bourdon	9 941,54	20 096,88	19 669,29	16 569,21	100,91
Mearis Beagale	10 345,49	19 482,40	20 207,56	16 678,49	101,57
Webo	10 748,02	19 975,11	18 859,74	16 527,63	100,65
Throws MS	9 870,39	19 493,87	21 042,44	16 802,23	102,33
Average	10 246,42	19 252,60	20 172,60	16 557,20	
LSD p< 0,05 =60,03		p<0,01 = 82,67		p<0,001 =113,89	

The diesel fuel energy - 43.16% takes a main part of the total energy input for growing the various varieties of beans (Table 2). Secondly, the share of fertilizers in energy costs reaching 28,66%, followed then by investments for seeds - 13,85% and 11.67% for pesticides. The lowest inputs are for water and electric power.

Table 2 Structure of energy input in winter beans cultivation average for the period 3 year, MJ/ha

The bearer of the energy	Variants						Average	
	Mearis Beaver	Bulldog	Bourdon	Mearis Beagle	Webo	Throws MS	MJ/ha	%
Disel-oil	7146,66	7146,66	7146,66	7146,66	7146,66	7146,66	7146,66	43,16
Fertilizers	4746,00	4746,00	4746,00	4746,00	4746,00	4746,00	4746,00	28,66
Nitrogen	3636,00	3636,00	3636,00	3636,00	3636,00	3636,00	3636,00	21,96
Phosphorus	1110,00	1110,00	1110,00	1110,00	1110,00	1110,00	1110,00	6,70
Pesticides, Total	1343,90	1343,90	1343,90	1343,90	1343,90	1343,90	1343,90	11,67
Herbicides	714,00	714,00	714,00	714,00	714,00	714,00	714,00	4,31
Insecticides	179,00	179,00	179,00	179,00	179,00	179,00	179,00	1,08
Fungicides	450,90	450,90	450,90	450,90	450,90	450,90	450,90	2,72
Human labour	83,73	83,36	84,50	85,06	84,29	85,71	84,44	0,50
Electricity	1,65	1,65	1,67	1,67	1,66	1,67	1,66	0,01
Machinery	932,46	928,29	940,96	947,17	938,60	954,45	940,32	5,67
Water	0,82	0,81	0,82	0,83	0,82	0,84	0,82	0,005
Seeds	2164,30	2095,50	2304,70	2407,20	2265,70	2523,00	2293,40	13,85
Total, MJ/ha	16419,52	16346,00	16569,21	16678,49	16527,63	16802,23	16557,20	100,00

In the process of changing the energy resulting from forage crops under the conditions of the experiment, on average, physiologically useful product for feeding animals was obtained (ME) of 77047,05 MJ/ ha^{-1} and productive energy (NE) - 44135,53 MJ/ ha^{-1} (Table 3). The metabolizable energy obtained was 52.57% of the GE.

Table 3 Energy output from the biologic mass of the winter beans. MJ/ha

Variants	Year			Average	%
	I	II	III		
Gross energy (GE) – MJ/ha					
Mearis Beaver (K0)	96 328,2	173 659,0	186 752,8	152 246,66	100%
Bulldog	81 002,9	179 996,1	147 153,0	136 050,66	89,36
Bourdon	84 552,3	171 898,3	138 300,4	131 583,66	86,42
Mearis Beagle	98 256,7	184 332,9	171 072,2	151 220,6	99,32
Webo	85 800,7	196 523,9	159 310,4	147 211,6	96,69
Throws MS	92 710,1	188 767,6	201 405,4	160 961,03	105,72
Average	89 775,15	182 529,63	167 332,36	146 545,71	
LSD p< 0,05 = 8327	p<0,01 = 11470	p<0,001 =15792			
Metabolizable energy (ME) – MJ/ha					
Mearis Beaver (K0)	50 794,8	88 703,0	94 785,2	78 094,33	100
Bulldog	42 898,8	92 865,2	92 865,2	76 209,73	97,58
Bourdon	43 677,6	88 685,6	74 852,8	69 072,03	88,44
Mearis Beagle	50 679,6	94875,2	88 393,6	77 982,8	99,85
Webo	45 481,0	99 589,5	85 533,0	76 867,8	98,43
Throws MS	48 262,0	98 510,0	105 395,0	84 055,6	107,63
Average	46 965,63	93 871,41	90 304,13	77 047,05	
LSD p< 0,05 =3470	p<0,01 = 4780	p<0,001 =6582			
Net energy (NE) – MJ/ha					
Mearis Beaver (K0)	29 453,4	50 529,9	58 368,0	46 117,1	100
Bulldog	24 943,8	53 223,0	46 662,0	41 609,6	90,22
Bourdon	24 982,8	50 689,0	43 896,8	39 856,2	86,42
Mearis Beagle	28 994,2	54 214,4	50 620,8	44 609,8	96,73
Webo	26 342,8	56 277,1	49 874,2	44 164,7	95,76
Throws MS	27 773,4	56 767,2	60 826,8	48 455,8	105,07
Average	27 081,7	53 616,76	51 708,1	44 135,53	
LSD p< 0,05 = 1750	p<0,01 = 2410	p<0,001 =3318			

The lowest values of gross and metabolizable energy obtained in the first year of the study when the lowest yield of dry grain and straw was received, while the highest values were in the second year. Average for the period of the experiment, the highest values of gross, metabolizable and net energy were derived from varieties Throws M.S. and Maeris Beaver (control). The lowest energy outputs were from Bourdon variety, with 11.56 up to 13.58 % compared to the control.

An indication for a high energy efficiency of the production of winter forage beans is the positive balance of energy inputs and outputs expressed by the energy efficiency ratio (Table 4). Average for the period of the study, coefficients of -8.84 were obtained for GE; 4,63 for ME and 2.66 for NE. The highest levels of energy efficiency were obtained in the second year of the experiment, due to obtaining higher yields with less energy input, as opposed to the third year, when the highest yields were gathered, but with the greatest investments.

Table 4 Coefficient of energu efficiency from the biologic mass if the winter beans

Variants	Year			Average	%
	I	II	III		
Gross energy (GE) – MJ/ha					
Mearis Beaver (K0)	9,03	10,36	8,54	9,31	100%
Bulldog	8,17	9,12	7,58	8,29	89,04
Bourdon	8,50	8,55	7,03	8,02	86,14
Mearis Beagle	9,49	9,46	8,46	9,13	98.06
Webo	7,98	9,83	8,44	8,75	93,98
Throws MS	9,39	9,68	9,57	9,55	102,58
Average	8,76	9,50	8,27	8,84	
LSD p< 0,05 = 0,67				p<0,01 = 0,94	p<0,001 =1,29
Metabolizable energy (ME) – MJ/ha					
Mearis Beaver (K0)	4,76	5,29	4,33	4,79	100%
Bulldog	4,32	4,7	4,78	4,6	96,03
Bourdon	4,36	4,41	3,80	4,19	87,47
Mearis Beagle	4,89	4,86	4,37	4,70	98,12
Webo	4,23	4,98	4,53	4,58	95,61
Throws MS	4,88	5,05	5,00	4,97	103,89
Average	4,57	4,88	4,47	4,63	
LSD p< 0,05 = 0,66				p<0,01 = 0,53	p<0,001 =0,72
Net energy (NE) – MJ/ha					
Mearis Beaver (K0)	2,76	3,01	2,67	2,81	100%
Bulldog	2,51	2,69	2,40	2,53	90,03
Bourdon	2,51	2,52	2,23	2,42	86,12
Mearis Beagle	2,80	2,78	2,50	2,69	95,72
Webo	2,45	2,81	2,64	2,63	93,59
Throws MS	2,81	2,91	2,89	2,87	102,13
Average	2,64	2,78	2,55	2,66	
LSD p< 0,05 = 0,39				p<0,01 = 0,55	p<0,001 =0,74

Proceeding from an energy point of view, the most effective cultivation was that of varieties Maeris Beaver (control) and Throws M.S. Their efficiency ratios are higher than the ones for the other varieties, correspondingly by GE of 1.98 to 13.86, ME of 1.88 to 12,53, and NE 4.28 to 13.88 for the variety Maeris Beaver, and for the variety Throws M.S. they are 4.52 to 16.44 GE; 7.80 to 16.42 ME, and 8.54 to 16.01 NE.

Comparing the energy efficiency of production of winter forage beans, depending on the variety, irrigation and fertilization, we find that the energy input was the highest for fertilization - 22010,01 MJ/ ha^{-1} [13] followed by that for irrigation -18607,73 MJ/ ha^{-1} [14] while the least (energy input) was for the variety- 16 419,23 MJ/ ha^{-1}. The resulting GE, ME and NE was the highest for the irrigation factor, while being the lowest or nearly equal with the other two factors.

With regard to the energy efficiency ratio, the highest values were for the factor "variety", while the lowest – for the factor "fertilization". Irrigation occupies an intermediate position on this indicator.

CONCLUSIONS

- The energy efficiency of winter forage beans depending on the variety grown on leached Vertisols for grain, is average 8.84 for GE, 4.63 for ME and 2.66 for NE;

- The varieties Maeris Beaver and Throws M.S. showed the most stable values of the parameters studied, regardless of the agro-meteorological conditions of the year.

- Variety contributes to the highest energy efficiency in the production of winter forage beans compared to other major factors of its agricultural technology - irrigation and fertilization.

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