Macedonian Journal of Animal Science, Vol. **1**, No. 1, pp. 147–153 (2011)
025 ISSN 1857 – 6907
Received: June 9, 2009 UDC: 633.35–184/–185 (497.2)
Accepted: December 15, 2009

Original scientific paper

INFLUENCE OF NITROGEN, PHOSPHORUS AND MOLYBDENUM FERTILIZATION, ALONE AND IN COMBINATION ON THE WINTER FABA BEAN ENERGY EFFICIENCY OF PRODUCTION

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During three year period at the Agricultural Institute, Stara Zagora (Bulgaria), influence of fertilization with Nitrogen, Phosphorus and Molybdenum alone and in combination on the energy efficiency of winter faba bean variety Meris Bina was investigated. In the experiment the next variants were included: 1. unfertilized; 2. N_{60}; 3. P_{120}; 4. $N_{60}P_{60}$; 5. $N_{120}P_{120}$; 6. $Mo_{0,2}$; 7. $N_{120}Mo_{0,2}$; 8. $P_{120}Mo_{0,2}$; 9. $N_{120}P_{120}Mo_{0,2}$. It was established that the examined variants of mineral fertilization have positive effect on obtained biomass and energy efficiency of the production. The highest coefficient of energy efficiency was obtained from fertilization with Molybdenum ($Mo_{0,2}$) alone– 13.63 for GE; 7.49 for ME and 4.43 for NE, which was respectively with 13.,05%, 13.73% and 13.85% higher compared to the unfertilized faba bean.

Key words: winter faba; fertilization; energy input and output; energy efficiency

ВЛИЈАНИЕ НА ФЕРТИЛИЗАЦИЈАТА СО АЗОТ, ФОСФОР И МОЛИБДЕН САМИ ИЛИ ВО КОМБИНАЦИЈА ВРЗ ПРОДУКЦИЈАТА И ЕНЕРГЕТСКАТА ЕФИКАСНОСТ НА ЗИМСКИОТ СТОЧЕН ГРАВ

Во текот на тригодишен период во Земјоделскиот институт во Стара Загора (Бугарија) беше истражувано влијанието на фертилизацијата со азот, фосфор и молибден, сами или во комбинација, врз енергетската ефикасност на зимскиот сточен грав, вариетет мерис бина. Во експериментот беа вклучени следните варијанти: 1. нефертилизирана; 2. N_{60}; 3. P_{120}; 4. $N_{60}P_{60}$; 5. $N_{120}P_{120}$; 6. $Mo_{0,2}$; 7. $N_{120}Mo_{0,2}$; 8. $P_{120}Mo_{0,2}$; 9. $N_{120}P_{120}Mo_{0,2}$. Беше утврдено дека испитуваните варијанти на минерална фертилизација имаа позитивен ефект на добиената биомаса и енергетската ефикасност на продукцијата. Највисок коефициент на енергетска ефикасност беше добиен при фертилизацијата со молибден ($Mo_{0,2}$) сам – 13,63 за GE; 7,49 за ME и 4,43 за NE, кој беше, соодветно, за 13,05%, 13,73% и 13,85% повисок споредено со нефертилизираниот сточен грав.

Клучни зборови: зимски сточен грав; фертилизација; влезна и излезна енергија; енергетска ефикасност

1. INTRODUCTION

Permanent increasing the amount of agricultural production is bounded up with respective increasing of energy expenses. At the same time the lack of natural energy resources obviously decreeases. This tendency will be enlarged, which imposes introduction of the new approach of evaluation of efficiency of plant cultivation – energy efficiency. This approach allows comparing of different technologies of crop production, eliminating price variations and crises, fluctuations of inflation indices and allows selection of the high energy profitable technologies for plant cultivation (Mitova, 1996; Alam, 2006; Chamsing, 2006; Ozkan, 2004; Krasteva, et al., 2007; Jeliazkova and Pavlov, 2008).

Winter faba bean provokes the interest of the investigators recently. The new achievements of crop production and selection clacify faba bean as a high productive and effective plant in intensive conditions (Sève, B., 2004). There is some investigations in Bulgaria concerning the reaction of winter faba bean on fertilization (Kostov et al., 1987; Andreinski, 1993; Tonev, 1996), but not data for the energy efficiency of the faba bean production.

The aim of the present study is establishing of energy efficiency of winter faba bean production under the influence of fertilization with different mineral fertilizers including nitrogen, phosphorus and molybdenum fertilization alone and in combination.

2. MATERIAL AND METHODS

In the experimental field of Pastren – Experimental Station of Irrigation Agriculture (Agricultural Institute, Stara Zagora), a three year field experiment by the block method in four repetitions with the experimental parcel size of 14 m^2 was conducted with winter faba bean after the predecessor winter wheat. The applied crop density was – 25 g.s./m^2 with row spacing 70 cm between. The crop was established by the Faba bean (*Faba vulgaris* var. *equinal*) variety Meris Bina.

Phosphorus fertilizer was incorporated into the soil before ploughing during autumn and nitrogen fertilization during early spring. Molybdenum by the form of sodium molybdate, 0.2 kg/ha was applied by wet seeds treatment before seeding.

The soil in the region is leached smolnitza with a massive humus layer with 3.6–4.2% humus. The soil is low reserved with available nitrogen and phosphorus and well with potassium. Soil acidity is moderate.

Irrigation was applied by seasonal stationary installation with perforated plastic tubes with taps, by furrows.

All other operations for cultivation of winter faba bean were applied in accordance with the conventional technology for cultivation of this plant.

The following variants were tested: 1. unfertilized; 2. N_{60}; 3. P_{120}; 4. $N_{60}P_{60}$; 5. $N_{120}P_{120}$; 6. $Mo_{0,2}$; 7. $N_{120}Mo_{0,2}$; 8. $P_{120}Mo_{0,2}$; 9. $N_{120}P_{120}Mo_{0,2}$.

Energy efficiency of the cultivated faba bean was established by the ratio of energy input and energy output used for common energy analyses of cultivated agricultural crops (Ivanov, 1998, 1999; Tokarev et al.., 1989; Chamsing et al., 2006; Pimentel et al., 1973; Jeliazkova and Pavlov, 2008). As for the energy input, all expenses for the respective agricultural operations included in the technology by the norms and transformed in energy equivalents are the following: for fertilization – 60.60 MJ/kg N, 11.10 MJ/kg P_2O_5 (Chaudhary et al., 2006), Mo – 0.037 MJ/kg; – for diesel fuel – 56.31 MJ/l (Ozkan et al., 2004b); – for mechanization – 64.80 MJ/h (Ozkan et al., 2004b); for seeds – calculated energy equivalent – 19.12 MJ/kg (Petkova and Pavlov, 2009); – for herbicides – 238.0 MJ/kg (Helsel, 1992); – insecticides – 92.0 MJ/kg (Helsel, 1992); – for electricity – 3.60 MJ/kWh (Ozkan et al., 2004a); – for water – 0.63 MJ/m^3 (Yaldiz, 1993, Jeliazkova 2008). The energy output from the biomass of winter faba bean was calculated on the base of the yield of dry matter (DM) from grain and straw, energy value – Gross energy (GE), Metabolizable energy (ME) Net energy (NE) in kg DM of grain (Petkova and Pavlov, 2009) and for straw (Todorov et al., 2007).

The efficiency of the input energy was determined by the coefficient of energy efficiency R, defined as a ratio between the energy P (MJ/ha) obtained from the final whole productivity and the energy E (MJ/ha) input for the production (R = P/E) (Pimentel et al., 1973; Jeliazkova and Pavlov, 2008).

3. RESULTS AND DISCUSSIONS

For cultivation of winter faba bean energy input was average 22010.01 MJ/ha (Tab. 1). Energy input varies during the years depending on the productivity and agroecological conditions during separate years. The highest energy input was obtained in the first year and the lowest in the third year.

Energy input was lowest in the unfertilized (control) variant. Differences in the energy input by the variants are significant due to the energy expenses for the fertilizer and also increased additional expenses for harvesting and storage of the higher yield of biomass. The highest value of energy input – 35114.96 MJ/ha was obtained when fertilization with $N_{120}P_{120}$ $Mo_{0,2}$ was applied. The energy expenses with fertilization were three times higher compared to the control. The differences were not statistically significant for the application of $N_{120}P_{120}Mo_{0,20}$ with$N_{120}P_{120}$ and P_{120} with $P_{120}Mo_{0,20}$. The molybdenum treatment has not a significant effect on the energy expenses. There are statistically significant differences in energy input between the control and fertilization with N_{60}; $N_{60}P_{60}$; $Mo_{0,20}$ and $N_{120}Mo_{0,20}$.

The investigation of the structure of the input energy for cultivation of winter faba bean demonstrates that the expenses for fertilizers occupy the highest amount of all energy input (44.164%, Tab. 2). Expenses for fuel and seeds occupy 25.605% and 19.605%, respectively. This shows that each technological decision which leads to optimization of amount of chemical products applied in plant cultivation is a good manner to improve the energy balance of the production. Energy expenses for application with Molybdenum are 0,010% for the chemical and for labour 0.472%.

For the period of the investigation the average amount of the obtained total energy was 141607.5 MJ/ha gross energy (GE, Tab. 3). The obtained metabolizable energy (ME) was 77450.6 MJ/ha, and pure productive net energy (NE) was 45761.7 MJ/ha.

Table 1

Energy input in faba bean cultivation for three years and average for the same period, MJ/ha

Variants	Year			Average	
	I	II	III	MJ/ha	%
Control	10971.96	10577.62	10471.71	10673.76	100.00
N_{60}	21985.46	21705.45	21557.18	21749.36	203.76
P_{120}	14185.68	13867.49	13709.91	13921.03**b***	130.42
$N_{60}P_{60}$	25091.69	24685.60	24543.04	24773.44	232.10
$N_{120}P_{120}$	35347.90	35015.03	34842.50	35068.48**a**	328.55
$Mo_{0,20}$	11160.85	10721.88	10648.49	10843.74	101.59
$N_{120}Mo_{0,20}$	32352.06	32058.65	31872.69	32094.47	300.69
$P_{120}Mo_{0,20}$	14167.65	13747.12	13637.75	13850.84**b**	129.77
$N_{120}P_{120}Mo_{0,20}$	35342.81	35158.02	34844.04	35114.96**a**	328.98
Average	22289.56	21948.54	21791.92	22010.01	

LSD $P < 0,05 = 79.8$; $P < 0.01 = 109.9$; $P < 0.001 = 151.4$
*Differences between the parameters are statistically significant if they have not the equal letter.

Table 2

Structure of energy input in faba bean cultivation average for three year period, MJ/ha

Source of energy input	Variants									Average	
	Control	N_{60}	P_{120}	N_{60}" P_{60}	N_{120} P_{120}	$Mo_{0,20}$	N_{120} $Mo_{0,20}$	P_{120} $Mo_{0,20}$	N_{120} P_{120} $Mo_{0,20}$	MJ/ha	%
Diesel fuel	4853.36	4968.61	5064.90	5071.09	5069.96	4937.07	4984.75	5029.23	5089.11	4994.17	25.605
Fertilizers	0.00	10908.00	2886.00	13794.00	24096.00	0.74	21210.74	2886.74	24096.74	8614.12	44.164
Nitrogen	0.00	10908.00	0.00	10908.00	21210.00	0.00	21210.00	0.00	21210.00	7171.00	36.765
Phosphorus	0.00	0.00	2886.00	2886.00	2886.00	0.00	0.00	2886.00	2886.00	1443.00	7.398
Molybdenum	0.00	0.00	0.00	0.00	0.00	0.74	0.74	0.74	0.74	0.12	0.001
Pesticides	353.28	353.28	353.28	353.28	353.28	353.28	353.28	353.28	353.28	353.28	1.811
Insecticides	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	26.68	0.137
Fungicides	326.60	326.60	326.60	326.60	326.60	326.60	326.60	326.60	326.60	326.60	1.674
Human labour	87.46	90.14	97.87	92.47	90.08	93.93	92.81	95.87	93.35	91.99	0.472
Electricity	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	2.03	0.010
Machinery	1045.22	1094.90	1184.54	1128.17	1124.71	1124.28	1118.45	1151.28	1148.04	1116.97	5.727
Water	508.41	508.41	508.41	508.41	508.41	508.41	508.41	508.41	508.41	508.41	2.607
Seeds	3824.00	3824.00	3824.00	3824.00	3824.00	3824.00	3824.00	3824.00	3824.00	3824.00	19.605
Total, MJ/ha	10673.76	21749.36	13921.03	24773.44	35068.48	10843.74	32094.47	13850.84	35114.96	19504.97	100.00

T a b l e 3

Energy output from the whole biologic mass of the faba bean for three years and average for the same period, MJ/ha

Variants	Year			Average	
	I	II	III	MJ/ha	%
Gross energy (GE)					
Control	116536.20	140137.20	128904.60	128526.00	100.00
N_{60}	117766.70	153625.00	137863.60	136418.43**a**	106.14
P_{120}	140559.60	171934.10	155670.20	156054.63	121.42
$N_{60}P_{60}$	130771.00	153660.50	138407.00	140946.**17a,b**	109.66
$N_{120}P_{120}$	122531.50	152658.80	134419.60	136536.63**a,b**	106.23
$Mo_{0,20}$	137433.50	156925.00	148543.00	147633.83**b,c**	114.87
$N_{120}Mo_{0,20}$	122840.50	157087.90	137559.10	139162.50**b**	108.28
$P_{120}Mo_{0,20}$	137960.00	159126.00	147205.50	148097.17**c**	115.23
$N_{120}P_{120}Mo_{0,20}$	121891.00	166849.00	134535.50	141091.83**b,c**	109.78
Average	127587.8	156889.3	140345.3	141607.5	

LSD $P < 0.05 = 8047$
$P < 0.01 = 11084$
$P < 0.001 = 15260$
*Differences between the parameters are statistically significant if they have not the equal letter

Variants	I	II	III	MJ/ha	%
Metabolizable energy (ME)					
Control	63629.60	76427.60	70424.30	70160.50	100.00
N_{60}	64530.40	83984.00	75537.20	74683.87**a**	106.45
P_{120}	78061.60	93995.60	86425.20	86160.80	122.81
$N_{60}P_{60}$	70712.90	83892.30	75728.50	76777.90**a**	109.43
$N_{120}P_{120}$	67406.00	83293.00	73892.00	74863.67**a**	106.70
$Mo_{0,20}$	75159.20	86813.20	81253.20	81075.20**b**	115.56
$N_{120}Mo_{0,20}$	66861.50	84699.50	74876.00	75479.00**a**	107.58
$P_{120}Mo_{0,20}$	75111.70	86873.70	80127.30	80704.23**b**	115.03
$N_{120}P_{120}Mo_{0,20}$	67492.20	89442.40	74516.60	77150.40**a**	109.96
Average	69885.0	85491.3	76975.6	77450.6	

LSD $P<0,05 = 3489$
$P<0,01 = 4806$
$P<0,001 = 6617$
*Differences between the parameters are statistically significant if they have not the equal letter

Variants	I	II	III	MJ/ha	%
Net energy (NE)					
Control	37644.40	45188.80	41677.00	41503.40	100.00
N_{60}	38172.60	49621.20	44682.00	44158.60**a**	106.40
P_{120}	46602.60	55664.40	51587.10	51284.70	123.57
$N_{60}P_{60}$	41449.80	49418.40	44658.60	45175.60**a**	108.85
$N_{120}P_{120}$	39940.60	49147.50	43767.60	44285.23**a**	106.70
$Mo_{0,20}$	44412.20	51600.40	48018.80	48010.47**b**	115.68
$N_{120}Mo_{0,20}$	39490.40	49778.80	44225.00	44498.07**a**	107.22
$P_{120}Mo_{0,20}$	44100.00	51076.80	47039.40	47405.40**b**	114.22
$N_{120}P_{120}Mo_{0,20}$	40087.00	52247.60	44266.00	45533.53**a**	109.71
Average	41322.2	50416.0	45546.8	45761.7	

LSD $P<0,05 = 1815$
$P<0,01 = 2499$
$P<0,001 = 3441$
*Differences between the parameters are statistically significant if they have not the equal letter

Table 4

Coefficient of the energy efficiency from the whole biologic mass of the faba bean for three years and average for the same period

Variants	Year I	Year II	Year III	Average	%
Gross energy (GE)					
Control	10.62	13.25	12.31	12.06	100.00
N_{60}	5.36	7.08	6.40	6.28**b**	52.04
P_{120}	9.91	12.40	11.35	11.22**a**	93.04
$N_{60}P_{60}$	5.21	6.22	5.64	5.69**b**	47.20
$N_{120}P_{120}$	3.47	4.36	3.86	3.89**c**	32.29
$Mo_{0,20}$	12.31	14.64	13.95	13.63	113.05
$N_{120}Mo_{0,20}$	3.80	4.90	4.32	4.3**c**	35.97
$P_{120}Mo_{0,20}$	9.74	11.58	10.79	10.70**a**	88.74
$N_{120}P_{120}Mo_{0,20}$	3.45	4.75	3.86	4.02c	33.32
Average	7.10	8.80	8.05	7.98	

LSD $P < 0.05 = 0.61$
$P < 0.01 = 0.85$
$P < 0.001 = 1.17$
*Differences between the parameters are statistically significant if they have not the equal letter

Variants	Year I	Year II	Year III	Average	%
Metabolizable energy (ME)					
Control	5.80	7.23	6.73	6.58	100.00
N_{60}	2.94	3.87	3.50	3.44**b**	52.19
P_{120}	5.50	6.78	6.30	6.19**a**	94.10
$N_{60}P_{60}$	2.82	3.40	3.09	3.10**b**	47.10
$N_{120}P_{120}$	1.91	2.38	2.12	2.14**c**	32.44
$Mo_{0,20}$	6.73	8.10	7.63	7.49	113.73
$N_{120}Mo_{0,20}$	2.07	2.64	2.35	2.35**c**	35.74
$P_{120}Mo_{0,20}$	5.30	6.32	5.88	5.83**a**	88.59
$N_{120}P_{120}Mo_{0,20}$	1.91	2.54	2.14	2.20**c**	33.38
Average	3.89	4.81	4.41	4.37	

LSD $P < 0.05 = 0.36$
$P < 0.01 = 0.50$
$P < 0.001 = 0.68$
*Differences between the parameters are statistically significant if they have not the equal letter

Variants	Year I	Year II	Year III	Average	%
Net energy (NE)					
Control	3.43	4.27	3.98	3.89**a**	100.00
N_{60}	1.74	2.29	2.07	2.03**d**	52.17
P_{120}	3.29	4.01	3.76	3.69**ab**	94.68
$N_{60}P_{60}$	1.65	2.00	1.82	1.82**d**	46.85
$N_{120}P_{120}$	1.13	1.40	1.26	1.26**c**	32.44
$Mo_{0,20}$	3.98	4.81	4.51	4.43	113.85
$N_{120}Mo_{0,20}$	1.22	1.55	1.39	1.39**c**	35.62
$P_{120}Mo_{0,20}$	3.11	3.72	3.45	3.43**b**	87.97
$N_{120}P_{120}Mo_{0,20}$	1.13	1.49	1.27	1.30**c**	33.30
Average	2.30	2.84	2.61	2.58	

LSD $P < 0.05 = 0.38$
$P < 0.01 = 0.53$
$P < 0.001 = 0.72$
*Differences between the parameters are statistically significant if they have not the equal letter

The highest values of GE, ME and NE were obtained during the second year, when the yield of grain and straw were the highest. Fertilization increases the energy output of faba bean. The highest output of GE, ME and NE was obtained from fertilization with P_{120}, which is 21.42% for GE; 22.81% for ME and 23.57% for NE compared to the control. The difference is statistically significant at $P < 0.05$ with other fertilization levels. The energy input was also higher with application of $Mo_{0,2}$, $P_{120}Mo_{0,2}$. Nitrogen fertilization alone or in combination leads to lower energy output.

In dry years such as the first and the third one higher ME and NE output were obtained from $Mo_{0,2,}$ while in a wet year the respective energy output was obtained from – $N_{120}P_{120}Mo_{0,2}$.

The coefficient of energy efficiency of faba bean average cultivation for three years was: 7.98 for GE; 4.37 for ME and 2.58 for NE (Tab. 4). The energy efficiency coefficient was the highest during the second year. From the energy point of view the most effective is fertilization with $Mo_{0,20}$ which increases the coefficient of energy efficiency with 13.05% for BE; 13.73% for ME and 13.85% for NE compared to the control. The differences between the application of Molybdenum and other fertilization levels and combinations are statistically significant at $P < 0.05$. High energy efficiency was also obtained from P_{120} and $P_{120}Mo_{0,2}$, which do not exceeded the control. Nitrogen N_{60}, N_{120} alone or in combination has lower energy efficiency. The lowest energy efficiency was obtained when fertilization with $N_{120}P_{120}$, was applied due to very high energy expenses but it did not receive enough high energy output.

4. CONCLUSSION

- Fertilization increases the productivity of winter faba bean, but also increases the amount of energy input, which was average about 22010.01 MJ/ha GE. Fertilization – 44.164% and fuel – 31.32% occupy the highest amount of energy input in faba bean cultivation.
- Energy output from faba bean cultivation was average 141607.5 MJ/ha GE; 77450.6 MJ/ha ME and 45761.7 MJ/ha NE.
- The highest amount of energy output was obtained from fertilization with P_{120}. Because of higher energy input phosphorus fertilization is less effective compared to molybdenum.
- The highest coefficient of energy efficiency for faba bean cultivation in irrigation conditions was obtained from fertilization with ($Mo_{0.2}$) – 13.63 for GE; 7.49 for ME and 4.43 for NE, which was with 13.05%; 13.73% and 13.85% higher compared to unfertilized faba bean.

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