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ORIGINAL ARTICLE

Energy-economic efficiency of growth of grain-crop cultures in conditions of right-bank forest-steppe zone of Ukraine

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The article aims to develop the theoretical framework and test the practical measures on increasing the efficiency of pea and lupine white breeding by cultivar selection, technological substantiation of basic tillage, and optimizing nutrition, in the conditions of the Forest-steppe zone. The results of the research in studying the peculiarities of growing, development and formation grain productivity of peas and lupine white depending on the pre-treatment of seeds and foliar nutrition usage are determined as well as economic, bioenergetic valuation and the evaluation of the technology on the competitiveness is given.
In addition to soil introduction of the calculated doses of mineral fertilizers, it is imperative to use highly effective fertilizers for foliar fertilization on peas and lupine, in particular and microplant. It is also advisable to conduct the treatment before sowing peas and lupine with biopreparations on the basis of nodule bacteria and also carry out the treatment of seeds with biopharmaceuticals based on phosphate-mobilizing bacteria and a bacterial preparation for the prevention of fungal disease of the root system of plants. Using the obtained theoretical and experimental data, the breeding peculiarities and the development of the assimilation apparatus and the effectiveness of the PAPs usage, functioning of the symbiotic apparatus, formation of individual, and grain productivity of peas and lupine varieties depending on the method of basic soil cultivation and feeding systems were established. The economic and energy efficiency of peas and lupine grain production using the proposed elements of the technology of growing these leguminous crops in the conditions of the Forest-steppe zone was also calculated.
Keywords: Peas; lupine white; pre-treatment of seeds; foliar nutrition; grain productivity; grain quality; economic and bioenergetic efficiency

Introduction

Leguminous crops are the most important source of plant protein, which is a fundamental part of people's diet and animal feeding. Such leguminous crops as peas and lupine white play the most important role for agricultural industry in the condition of the right-bank Forest-steppe zone (Lapinskas, 1998). Important scientific researchers results in the technology of peas and lupine growing were made by national and foreign scientists A. O. Babych, V. F. Petrychenko, A. V. Cherenkov, S. M. Kalenska, V. G. Myhailov, M. I. Bahmat, M. J. Shevnikov, O. M. Bahmat, V. V. Lyhochvor, O. V. Ovcharuk, K. Novák, B. Furseth etc (Hunt & Layzell, 1993).
Systematic researches that would promote optimizing the production process of high yielding and industrial peas varieties are currently important for increasing yields and improving grain quality (Davis & Narenda,1986). The important factors of cultivar adoption to growing technology of such peas varieties are improving ways of basic tillage, choice of optimum fertilization alternative, in particular biopreparations and modern types of fertilizers for foliar nutrition of sowing usage (Eviner & Chapin, 1997).
Leguminous crops that are studied are strategically needed high protein crops of modern crop production, and economic and bioenergetic valuation of their breeding efficiency is long-range and important issue nowadays (Bohlool, Ladha, Garrity & George, 1992). In present-day socioeconomic conditions one of the main problems of agriculture economic sector of Ukraine remains essential increasing and stabilization leguminous crops production, that are the main source of balanced in amino acid composition and content of eco-friendly protein (Bollman & Vessey, 2006).

Materials and methods

Field researches have been conducted on the basis of the Vinnytsia National Agrarian University's field in Agronomichne village Vinnytski rayon Vinnytska oblast during 2011-2017. Soil cover is represented by gray forest soils that are characterized

by low humus content – 1.97%. The amount of absorbed bases is 1.44 mg Equiv per 100 g soil. Hydrolytic gray forest soils acidity of the trial field is 3.44 mg Equiv per 100 g soil, and pH salt is 5.1. Soil moistening is provided with atmosphere precipitation, since groundwater level is situated at a depth of 10-15 m.
Hydrothermal conditions during vegetative period of lupine white in 2013-2015 were different and characterized by certain features. However right-bank Forest-steppe zone in general is quite favorable for peas, lupine white and bean growth.
In the experiment pea variety Ulus and lupine white variety Veresnevyy are studied.
The researches cover studying of effect and interaction of three factors. They are A – variety, B - foliar nutrition, C – pre-treatment of seeds.

Scheme of field pea Ulus experiment
Factor A – variety:
1. Ulus.
Factor B - pre-treatment of seeds:
1. Without treatment.
2. Ryzohumin (300 g per rate of seeds on a hectare).
3. Polymycobacterium (150 ml per rate of seeds on a hectare).
4. Ryzohumin (300 g per rate of seeds on a hectare)+Polymycobacterium (150 ml per rate of seeds on a hectare).
Factor C - foliar nutrition:
1. Without nutrition with addition of fertilization $N_{45}P_{60}K_{60}$.
2. Addition+nutrition in the budding stage CODA Fol 7-21-7 (2 l/ha).
3. Addition+nutrition in the budding stage CODA Fol 7-21-7 (2 l/ha) and in the green beans stage CODA Fol 7-21-7 (2 l/ha).
4. Addition+nutrition in the stages of budding CODA Fol 7-21-7 (2 l/ha), of green beans CODA Fol 7-21-7 (2 l/ha) and of seed filling CODA Complex (1 l/ha).
Scheme of lupine white Veresnevyy experiment
Factor A – variety:
1. Veresnevyy.
Factor B - pre-treatment of seeds:
1. Without treatment.
2. Ryzohumin (300 g per rate of seeds on a hectare).
3. Emistim C (150 ml per rate of seeds on a hectare).
4. Ryzohumin (300 g per rate of seeds on a hectare)+Emistim C (150 ml per rate of seeds on a hectare).
Factor C - foliar nutrition:
1. Without nutrition.
2. Ryzohumin+nutrition in the budding stage Emistim C (2 l/ha).
3. Emistim C+nutrition in the green beans stage Emistim C (2 l/ha).
4. Ryzohumin+nutrition in the stages of green beans Emistim C (2 l/ha) and of seed filling Emistim C (1 l/ha).
Phenological observations were conducted according to "Method of state sort testing" (2000). Mathematical treatment of the obtained results was conducted by means of dispersion and correlation-regression analyzes (Dospehov, 1985; Vergunova, 2000) using modern program pack Excel, Sigma and Statistica. Evaluation of cost efficiency of lupine white narrow-leaved breeding was conducted by means of Macybor O. K.'s methods "Agricultural economics" (1994). Calculation of lupine narrow-leaved growing technology energy efficiency was conducted using the Medevskogo O. K. and Ivanenko P. I.'s method "Energy analysis of intensive technologies in agriculture production" (1988) and the method of All-Russian Williams Fodder Research Institute (1989).

Results and discussion

The yield of grain legumes

The deficiency of vegetable protein, the orientation of agriculture to environmentally appropriate cultivation, as well as the high cost of mineral and organic fertilizers cause increased interest in legumes (Brelles-Mariño & Boiardi, 1996). These culture-an inexhaustible source of soil enrichment by nitrogen compounds nitrogen fixing nodule bacteria in symbiosis with plants, and therefore have important agronomic importance (Brevedan & Egli, 2003). Their cultivation can reduce the cost of crop production due to the inclusion in the process of agricultural production of atmospheric nitrogen, improve the phytosanitary state of crops and significantly increase the productivity of arable land (Novák, Šlajs, Biedermannová & Vondrys 2005).
The results of researches for 2011-2013 indicate the significant influence of investigated technological techniques on the size of the grain yield of pea peas of the Ulus variety (Table 1).

Table 1. Productivity of grain of lupine and pea seedlings depending on technological methods of cultivation, t/ha (2013-2015).

Foliar nutrition	Pre-treatment of seeds	Years			Average for years
		2011	2012	2013	

	Ulus variety				
$N_{45}P_{60}K_{60}$ (фон)	Without treatment				
	Polymycobacterium	3.47	2.8	3.19	3.15
	Risogumin	3.58	2.96	3.28	3.27
	Risogumin+	3.69	3.02	3.36	3.36
	Polymycobacterium	3.86	3.17	3.47	3.5
Addition+I*	Without treatment				
	Polymycobacterium	3.78	3.11	3.42	3.44
	Risogumin	3.95	3.24	3.54	3.58
	Risogumin+	4.07	3.32	3.63	3.67
	Polymycobacterium	4.24	3.53	3.76	3.84
Addition+I+II*	Without treatment				
	Polymycobacterium	3.99	3.32	3.58	3.63
	Risogumin	4.18	3.46	3.71	3.78
	Risogumin+	4.33	3.57	3.82	3.91
	Polymycobacterium	4.54	3.8	4	4.11
Addition+I+II+III*	Without treatment				
	Polymycobacterium	4.13	3.42	3.67	3.74
	Risogumin	4.31	3.58	3.81	3.9
	Risogumin+	4.5	3.72	3.94	4.05
	Polymycobacterium	4.74	3.99	4.2	4.31

Addition:* I-foliar nutrition in the phase of budding-Coda Fol 7-21-7; II-foliar nutrition in the phase of green beans-Coda Fol 7-21-7; III-foliar nutrition in the phase of seed infestation-Coda Complex.
LSD 0,05 t / ha; A-variety; B-pre-treatment of seeds; C-foliar nutrition.
2011 year, A-0.021; B-0.029; C-0.007; AB-0.042; AC-0.042; BC-0.059; ABC-0.083
2012 year, A-0.024; B-0.034; C-0.009; AB-0.048; AC-0.048; BC-0.068; ABC-0.096
2013 year, A-0.023; B-0.032; C-0.008; AB-0.045; AC-0.045; BC-0.064; ABC-0.091

The maximum grain yield of 4.31 t/ha seedlings in the Ulus variety was marked during growing with the use of pre-sowing seed treatment with the composition of Risoghumin+Polymycobacterium against fertilizer N45P60K60 and the three-fold, non-root crop fertilization in the flowering phases and green beans fertilized with KODA Fol 7-21-7 and pouring seeds of peas sowing fertilizer KODA Complex.
The results of research for 2013-2015 indicate the significant influence of the investigated technological methods on the grain yield of white lupine grains of Veresnevyy (Table 2).

Table 2. Productivity of grain of white lupine depending on technological methods of cultivation, t/ha (2013-2015).

Factors			**Years**			**Average for years**
variety	**Pre-treatment of seeds**	**Foliar nutrition***	**2013**	**2014**	**2015**	
Veresnevyy	Without treatment **	Without nutrition**	3.08	3.24	2.55	2.96
		1 foliar nutrition	3.13	3.35	2.59	3.02
		2 foliar nutrition	3.18	3.42	2.62	3.17
	Risogumin	Without nutrition	3.15	3.71	2.9	3.25
		1 foliar nutrition	3.31	3.88	2.94	3.38
		2 foliar nutrition	3.4	3.9	3.05	3.45
	Emistim C	Without nutrition	3.1	3.68	2.82	3.2
		1 foliar nutrition	3.2	3.74	2.86	3.27
		2 foliar nutrition	3.31	3.81	2.93	3.35
	Risogumin+Emistim C	Without nutrition	3.08	3.62	2.88	3.19
		1 foliar nutrition	3.12	3.85	3.01	3.32
		2 foliar nutrition	3.58	4.1	3.15	3.61

LSD 0.5 t/ha: A-0.07; B-0.10; C-0.08; AB-0.14; AC-0.12; BC-0.17; ABC-0.24.
2013p. LSD 0.5 t/ha: A-0.04; B-0.05; C-0.04; AB-0.07; AC-0.06; BC-0.08; ABC-0.12
2014p. LSD 0.5 t/ha: A-0.05; B-0.06; C-0.06; AB-0.09; AC-0.08; BC-0.11; ABC-0.16
2015p. LSD 0.5 t/ha: A-0.04; B-0.06; C-0.05; AB-0.08; AC-0.07; BC-0.10; ABC-0.14

Addition: *-Emistim C; **-control.

The maximum value of the grain yield of white lupine varieties was obtained on variants of the experiment with pre-sowing seed treatment with an inoculum Risogumin and growth stimulator Emistim C in combination with two non-root nutrients Emistim C. In this case, the grain yield was 3.61 t/ha, and exceeded the control variant on 0.65 t/ha, and in percents, respectively, 18%.

The economic efficiency of the technology of growing leguminous crops

Grain economy develops due to increased economic efficiency of production, with an increase in gross and marketable products (Djekoun & Planchon). In the calculations of the economic efficiency of growing peas for grain, the indicators of grain yield, grain yield, material costs for its cultivation, labor remuneration, depreciation, repair, and others were taken into account (Dorcinvil, Sotomayor-Ramírez, & Beaver, 2010). The complexity of the calculations of economic efficiency consists in instability and disparity of prices for industrial (agricultural machinery, mineral fertilizers, pesticides, fuel and lubricants) and agricultural products (Duke & Collins, 1985).

The basis of the analysis of the economic efficiency of the estimation of the technology of cultivation of seedlings of pea has been laid the variants of pre-seed treatment of the seeds with the composition Polymiksobacterin+Risogumin and foliar fertilization with KODA fertilizers in the phases of budding, green beans and seed filling (Table 3).

Table 3. Economic efficiency of cultivating pea sown on grain of the Ulus variety (average for 2011-2013).

Foliar nutrition	Pre-treatment of seeds	Expenditure on cultivation thousand UAH/ha	Cost of production thousand UAH/ha	Cost of 1 t thousand UAH	Conditionally net profit thousand UAH/ha	The level of profitability, %
$N_{45}P_{60}K_{60}$ (фон)	Without treatment	6905	11.4	2.2	4.4	64.4
	Polymycobacterium	6911	11.8	2.1	4.9	70.5
	Risogumin	6920	12.1	2.1	5.2	74.6
	Risogumin+ Polymycobacterium	6927	12.6	2	5.7	81.9
Addition+I*	Without treatment	7056	12.4	2.1	5.3	75.3
	Polymycobacterium	7062	12.9	2	5.8	82.3
	Risogumin	7072	13.2	1.9	6.2	87
	Risogumin+ Polymycobacterium	7078	13.8	1.8	6.8	95.5
Addition +I+II*	Without treatment	7197	13.1	2	5.9	81.6
	Polymycobacterium	7204	13.6	1.9	6.4	89.1
	Risogumin	7213	14.1	1.8	6.9	95
	Risogumin+ Polymycobacterium	7220	14.1	1.8	6.9	95.4
Addition +I+II+III*	Without treatment	7403	13.5	2	6.1	81.9
	Polymycobacterium	7410	14	1.9	6.6	89.5
	Risogumin	7419	14.6	1.8	7.2	96.7
	Risogumin+ Polymycobacterium	7426	15.5	1.7	8.1	108.9

Addition:* I-foliar nutrition in the phase of budding-Coda Fol 7-21-7; II-foliar nutrition in the phase of green beans-Coda Fol 7-21-7; III-foliar nutrition in the phase of seed infestation-Coda Complex.

This model of cultivation technology of pea seed yielded a contingent net income of 8.1 thousand UAH / ha in the Ulus variety, while the cost of grain was 1.7 thousand UAH / ton. At the same option, the maximum profitability level was 108.9% for the Ulus variety.

It was established that the studied elements of cultivation technology significantly influenced the economic efficiency of growing lupine white (Table 4).

Table 4. Economic efficiency of growing lupine white (average for 2013-2015).

Factors			Grain yield, t/ha	Expenditure on cultivation	Cost of production	Cost of 1 t	Conditionally net profit	The level of profitability,
Variety	Pre-treatment of seeds	Foliar nutrition*		thousand UAH/ha	thousand UAH/ha	thousand UAH	thousand UAH/ha	%
Veresnevyy	Without treatment **	Without nutrition**	2.96	23680	12000	4054	11680	97
		1 foliar nutrition	3.02	24160	12300	4073	11860	96
		2 foliar nutrition	3.17	25360	12600	3975	12760	101
	Risogumin	Without nutrition	3.25	26000	12400	3815	13600	109
		1 foliar nutrition	3.38	27040	12700	3757	14340	113
		2 foliar nutrition	3.45	27600	13000	3768	14600	112
	Emistim C	Without nutrition	3.2	25600	12200	3813	13400	110
		1 foliar nutrition	3.27	26160	12500	3823	13660	109
		2 foliar nutrition	3.35	26800	12800	3821	14000	109
	Risogumin+Emistim C	Without nutrition	3.19	25520	12600	3950	12820	102
		1 foliar nutrition	3.32	26560	12900	3886	13660	106
		2 foliar nutrition	3.61	28880	13200	3657	15680	119

Addition: *-Emistim C; **- control.

The best indicators of economic efficiency, namely the profitability rate-119%, were noted for the technology of growing lupine of the white variety of In Veresnevyy, the lowest yield of gross (49526 MJ/ha) and exchange energy(27918 MJ/ha) in the Veresnevyy variety on the control version, where the bactericidal preparation Risogumin and the growth stimulator Emistim C in combination with two non-root nutrients Emistim C. were used in pre-planting seed treatment. Cost and profit were thus respectively-3657 UAH/t and 15680 UAH/ha.

Bioenergetic efficiency of technologies for growing leguminous crops

Widespread use of intensive technologies has led to an increase in the volume of fuel, electricity, chemicals and protection and, as a result, energy costs (Elkins, Hamilton, Chan, Briskovich & Vandeventer, 1976). The newly created technologies should be more plastic, which will allow them to adapt to the conditions of various resource-technological support (Mateos et al., 2001). They should provide for the maximum realization of the potential of cultural productivity (Furseth, Conley & Ané, 2011). The scientific substantiation of the technological process of cultivating crops will help to optimize the flow of energy through agrotechnical measures with the purpose of purposeful formation of highly productive agrocenoses (Furseth, Conley & Ané, 2012).

According to energy estimation, the technology of cultivating seedlings was the most effective, which included pre-planting of seed with the composition of Polymycobacterium+Risoguminum and the use of frozen fertilizers of KODA in the phases of budding, green beans and seeding on the background of fertilizer N45P60K60, which ensured a gross energy output of 76.24 GJ/ha, net energy gain-58.12 GJ/ha in the Ulus variety (Table 5).

Table 5. Energy efficiency of growing peas for grain of the Ulus variety, depending on the effect of pre-seed treatment and extra-root crops (average for 2011-2013).

Foliar nutrition	Pre-treatment of seeds	Output of gross energy, MJ/ha	Exit of exchange energy, MJ/ha	Energy costs, MJ/ha	Bionergic coefficient	Energy efficiency
$N_{45}P_{60}K_{60}$ (фон)	Without treatment	16.9	55.78	38.88	5.36	2.3
	Polymycobacterium	17.08	57.91	40.83	5.22	2.39
	Risogumin	17.67	59.38	41.71	5.26	2.36

	Risogumin+ Polymycobacterium	17.84	61.92	44.07	5.1	2.47
Addition+I*	Without treatment	16.95	60.8	43.85	4.93	2.59
	Polymycobacterium	17.12	63.27	46.15	4.79	2.7
	Risogumin	17.71	64.98	47.27	4.82	2.67
	Risogumin+ Polymycobacterium	17.88	67.99	50.11	4.65	2.8
Addition+I+II*	Without treatment	16.99	64.22	47.23	4.68	2.78
	Polymycobacterium	17.16	66.93	49.76	4.54	2.9
	Risogumin	17.75	69.11	51.36	4.54	2.89
	Risogumin+ Polymycobacterium	17.93	72.77	54.84	4.36	3.06
Addition+I+II+III*	Without treatment	17.18	66.16	48.98	4.59	2.85
	Polymycobacterium	17.36	68.99	51.63	4.45	2.97
	Risogumin	17.95	71.7	53.76	4.43	3
	Risogumin+ Polymycobacterium	18.12	76.24	58.12	4.2	3.21

Addition:* I-foliar nutrition in the phase of budding-Coda Fol 7-21-7; II-foliar nutrition in the phase of green beans-Coda Fol 7-21-7; III-foliar nutrition in the phase of seed infestation-Coda Complex.

The energy efficiency factor at the same time in the Ulus variety was 3.21.

The energy analysis of white lupine growing technologies, which included pre-sowing seed treatment and root-grown nutrition, had different energy saturations and unequal values of the energy coefficient and bioenergy efficiency (Table 6).

The largest yield of gross (60.402 MJ/ha) and the exchange (3.8098 MJ/ha) of energy in the Veresnevyy variety was obtained in the version where the bacterial preparation Risogumin and the growth stimulator Emistim C in combination with two non-root nutrients Emistim C were used in pre-sowing seed treatment.

In Veresnevyy, the lowest yield of gross (49526 MJ/ha) and exchange energy(27918 MJ/ha) in the Veresnevyy variety on the control version.

Table 6. Bioenergy efficiency of lupine growing technologies (average for 2013-2015).

Factors			Output of gross energy, MJ/ha	Exit of exchange energy, MJ/ha	Energy costs, MJ/ha	Bionergic coefficient	Energy efficiency
variety	Pre-treatment of seeds	Foliar nutrition*					
Veresnevyy	Without treatment **	Without nutrition**	49526	27918	11468	4.31	2.43
		1 foliar nutrition	50531	28086	12404	4.07	2.27
		2 foliar nutrition	53040	30190	13340	3.97	2.26
	Risogumin	Without nutrition	54379	31505	14323	3.79	2.2
		1 foliar nutrition	56554	32765	15259	3.7	2.15
		2 foliar nutrition	57725	33489	16195	3.56	2.07
	Emistim C	Without nutrition	53542	31188	13790	3.88	2.26
		1 foliar nutrition	54714	32127	14726	3.71	2.18

	2 foliar nutrition	56052	33045	15662	3.57	2.11
Risogumin+Emistim C	Without nutrition	53375	32720	16345	3.27	1.97
	1 foliar nutrition	55550	34250	17281	3.21	1.98
	2 foliar nutrition	60402	38098	18217	3.31	2.09

Addition: * – Emistim C; ** – control.

Consequently, pre-sowing seed treatment with a bacterial drug and a growth stimulator in combination with two non-root nutrients in the cultivation of white lupine contributed to the formation of maximum gross and metabolism.

Conclusions

In the article the processes of yield growth, development and formation of leguminous crops and influence of organized factors in view of hydrothermal conditions of right-bank Forest-steppe zone of Ukraine made on them are theoretically founded and practically proved. Researches were aimed at solution of set scientific problem. It helped to make next conclusions:

Top yield 4.31 t/ha of field pea variety Ulus developed owing to seed inoculation with Ryzohumin and Polymycobacterium and to arranging foliar nutrition with fertilizers CODA Fol 7-21-7 in the stages of budding and green beans and CODA Complex in the stage of seed filling, that is relatively more on 1.16 t/ha comparing to control.

Seeds pre-treatment with the bacterial fertilizer Ryzohumin and the growth stimulator Emistim C in combination with two foliar nourishments with Emistim C conduced to development of the highest of lupine white seeds productivity. Therewith the productivity of the variety Veresnevyy was 3.61 t/ha that is more on 0.65 than without seeds pre-treatment.

Evaluation of cost efficiency shows that the highest operating profit 8.1 thousand grn/ha, the level of profitability 108.9 % and the lowest prime cost 1.7 thousand grn/t were obtained owing to seed inoculation with Ryzohumin and Polymycobacterium and to arranging foliar nutrition with fertilizers CODA Fol 7-21-7 in the stages of budding and green beans and CODA Complex in the stage of seed filling. The same production methods provided the best energy measures and turned out to be competitive. So energy coefficient was 3.21.

Economic and energy analyses of growing technology shows that the lowest prime cost 3657 grn/t and the highest level of profitability of the variety Veresnevyy 119% were obtained owing to seeds pre-treatment with the bacterial fertilizer Ryzohumin and the growth stimulator Emistim C in combination with two foliar nourishments with Emistim C. In this case energy coefficient was 2.09.

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