ECONOMIC EFFICIENCY EVALUATION THEORETICAL FRAMEWORK TO BIOSTIMULANTS APPLICATION ON SPRING RAPE AND OAT

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ТЕОРЕТИЧНА РАМКА ЗА ОЦЕНКА НА ИКОНОМИЧЕСКАТА ЕФЕКТИВНОСТ ОТ ПРИЛАГАНЕТО НА БИОСТИМУЛАНТИ ВЪРХУ ПРОЛЕТНА РАПИЦА И ОВЕС

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Abstract

The economic efficiency evaluation approaches of biostimulants' (BS) application in agriculture are a significant challenge. The accepted working hypothesis in the study is that the BS application can significantly increase a specific crop's yield and profit, but it couldn't rise the farm's total profit. It was made an evaluation of foliar application efficiency with biologically active substances with different concentrations. The study aims to build a theoretical framework for economic efficiency evaluation of biostimulants' application to the spring rape and oat-based on linear programming.

Key words: agriculture, biostimulants, economic efficiency

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Introduction

The economic efficiency evaluation approaches of biostimulants' (BS) application in agriculture are a significant challenge. Must be taken into consideration different factors that depend on each other. They are not only technological, experimental, or legal constraints but also the diversity of social and behavioral aspects (Belcheva, S., 1989; Brown P. and Saa S., 2015; Looney, Jackson, 2011; Rademacher, 2018; Rademacher, 2015; Izumi et. al., 1984).

The study aims to develop a theoretical evaluation framework for the economic efficiency of the BS application to the spring rape and oat.

The biostimulants' application can significantly increase the profit per specific crop (per unit area) without increasing the farm's total profit. Thus, farms' production structure and business plan can be used to evaluate BS efficiency. Efficient BS

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are those whose application increases the economic efficiency of the farm and vice versa.

Methodology

Data collection

At the beginning of 2021, in the first stage of the scientific project "Use of biostimulants in biological crop cultivation – assessment of the contributions to bioeconomy" there were set both seeds spring rape (sorte lakritz, brassica napus L.) and spring oat (sort Alexa 1). Both crop types are treated with different biostimulants with different concentrations. The BS were developed by the Institute of Cryobiology and Food Technology, Agricultural Academy, Sofia. (AA)

- BS 3 – chitosan
- BS 4 – (GA+GA) chitosan
- BS 5 – (HA) vermicompost extract
- BS 6 – (HA + HA) vermicompost extract
- BS 7 – (HA_IA) vermicompost + nature-identical growth regulator
- BS 5a – (HA_IA+ HA_IA) vermicompost + nature-identical growth regulator.

It was applied two-step treatment with different phenophases. The spring rape was treated two times – in the rosette and in the blooming stages. The spring oat was treated in stages of tillering and inflorescence fully. Harvesting was done mechanized.

The primary data was collected from The Agricultural Experimental Station (AES) in a test (experimental) field at the Institute of Agriculture and Seed Science "Obraztzov Chiflik" – Ruse, Agricultural Academy. The developed linear optimization model is based on the experimental field results, additional factors, and technical and economic norms (TEN). The model was fed up with additionally collected information from the National Statistical Institute, Bulgaria, the "Agrostatistics" department of the Ministry of Agriculture, Technical and Economic Standards for Agricultural Technology (developed by The Institute of Agrarian Economics).

Linear programming method

The economic-mathematical model is a mathematical task that reflects the essential relationships and dependencies which characterize an economic problem (Nikolov, N., et al., 1994).

Taking into consideration some constraints, the optimization model finds the optimal value (min or max) of a function. The function f is called an objective function. The system of equations and or/and inequalities are the system of constraints.

The objective function expresses the optimal criteria (min or max):

$$A_{11}X_1 + A_{12}X_2 + \cdots + A_{1n}X_n \leq B_1$$
$$A_{21}X_1 + A_{22}X_2 + \cdots + A_{2n}X_n \geq B_2$$
$$\vdots$$
$$A_{m1}X_1 + A_{m2}X_2 + \cdots + A_{mn}X_n = B_1$$

$$F = C_1X_1 + C_2X_2 + \cdots + C_nX_n \rightarrow \max\ (min), \quad (1)$$

where:

- Xj – size (magnitude) of the activities or indicators,
- Aij and Cj – the activities to be performed,
- Bi – quantity resource or activity (constrains).
- Objective function F that determines the optimal criteria.

Results

As it was mentioned before, the primary data was collected from AES in an experimental field at the Institute of Agriculture and Seed Science "Obraztzov Chiflik" – Ruse, Agricultural Academy. Table 1 presents the yield of spring rape in three repetitions of the biostimulants at different concentrations of dry substance and the control – 8 (K). Table 2 presents the biometric indicators after treatment with biostimulants.

Table. 1.Spring rape yield, harvest 2021

№	1st rep., kg	2nd rep., kg	3rd rep., kg	Total	Average on plot	kg/da	% moisture	Mass per 1000 grains, gr.
3	1.300	1.280	1.260	3.840	1.280	128.000	8.8	6.34
4	1.250	1.300	1.240	3.790	1.263	126.300	8.6	6.17
5	1.150	1.200	1.310	3.660	1.220	123.500	8.4	6.00
6	1.300	1.240	1.280	3.820	1.273	127.300	8.8	6.21
7	1.225	1.220	1.235	3.680	1.227	122.700	8.3	5.90
8 (K)	**1.150**	**1.200**	**1.310**	**3.660**	**1.220**	**122.000**	**8.8**	**5.88**
5a	1.245	1.220	1.270	3.735	1.245	124.500	8.7	6.03

Source: The primary data from The Agricultural Experimental Station (AES) in a test (experimental) field at the Institute of Agriculture and Seed Science "Obraztzov Chiflik" – Ruse, Agricultural Academy.

Table. 2. Biometrics – spring rape, 2021

Variant	**Plant height cm.**	**Number of branches per 1 plant**	**Number of grains in 1 plant**	**Mass of legumes in 1 plant, gr.**	**Number of seeds in 1 plant**	**Mass of seeds in 1 plant, gr.**
3	109.0	7.2	259.1	22.876	1213.2	7.691
4	110.0	6.9	246.8	22.381	1118.1	6.897
5	109.4	7.1	248.2	22.562	1265.0	7.593
6	110.8	6.9	247.9	22.231	1232.0	7.645
7	108.8	7.3	248.1	22.391	1284.3	7.581
8 (K)	**109.4**	**7.0**	**238.0**	**22.746**	**1266.2**	**7.440**
5a	111.625	7.1	248.1	22.559	1236.9	7.458

Source: The primary data from The Agricultural Experimental Station (AES) in a test (experimental) field at the Institute of Agriculture and Seed Science "Obraztzov Chiflik" – Ruse, Agricultural Academy.

Both the spring oat yields after foliar feeding with the biostimulants at different concentrations of dry substance and the control 8 (K) and the oat biometrics are presented in Tables 3 and 4.

Table. 3. Spring oat yield, harvest, 2021

№	**1st rep., kg**	**2nd rep., kg**	**3rd rep., kg**	**Total**	**Aver-age on plot**	**kg/da**	**% mois-ture**	**Mass per 1000 grains, gr.**
3	1.300	1.280	1.260	3.840	1.280	128.000	8.8	6.34
4	1.250	1.300	1.240	3.790	1.263	126.300	8.6	6.17
5	1.150	1.200	1.310	3.660	1.220	123.500	8.4	6.00
6	1.300	1.240	1.280	3.820	1.273	127.300	8.8	6.21
7	1.225	1.220	1.235	3.680	1.227	122.700	8.3	5.90
8 (K)	**1.150**	**1.200**	**1.310**	**3.660**	**1.220**	**122.000**	**8.8**	**5.88**
5a	1.245	1.220	1.270	3.735	1.245	124.500	8.7	6.03

Source: The primary data from The Agricultural Experimental Station (AES) in a test (experimental) field at the Institute of Agriculture and Seed Science "Obraztzov Chiflik" – Ruse, Agricultural Academy.

Table. 4. Biometrics – spring oat, 2021

№	1st rep., kg	2nd rep., kg	3rd rep., kg	Total	Average on plot	kg/da	% moisture	Mass per 1000 grains, gr.
3	1.105	1.300	1.203	3.608	1.203	120.267	13.4	27.32
4	1.555	1.260	1.407	4.222	1.407	140.733	14.7	26.62
5	1.560	1.350	1.455	4.365	1.455	145.500	14.6	29.66
6	1.415	1.150	1.283	3.848	1.283	128.267	14.6	25.57
7	1.370	1.300	1.335	4.005	1.335	133.500	13.3	26.69
8 (K)	**1.220**	**1.000**	**1.110**	**3.330**	**1.110**	**111.000**	**14.5**	**28.12**
5a	0.885	0.850	0.868	2.603	0.868	86.767	16.3	28.74

Source: The primary data from The Agricultural Experimental Station (AES) in a test (experimental) field at the Institute of Agriculture and Seed Science "Obraztzov Chiflik" – Ruse, Agricultural Academy

The construction of the model uses two criteria – max gross margin and max profit. There were build two economic-mathematical models based on these criteria:

First task. A task with optimized production structure of a farm, considering the agrotechnical requirements for crop rotation. The solution gives the most optimal production structure under both criteria of *max gross margin and max profit*. It will allow obtaining a decision on how to optimally combine available resources (land, labor force, size of arable land) and farm constraints; what crops to produce; agrotechnical requirements; which biostimulants to apply; on which cultures and in what concentration to be applied BS; in which phase to treat them to achieve the highest economic effect.

Second task. There were set bounds for the minimal and maximum size of the arable land, including crops treated with biostimulants. The aim is to find an optimal solution, achieving *max gross margin* and *max profit*. The solution gives the optimal combination of the most economically effective productions. The result is the best combination of the available resources (land, labor resources, and various biostimulants), giving specific constraints. Also, what crop to produce and what agrotechnical requirements? All this achieves the highest economic effect.

It was worked on the following hypothesis: Biostimulants, applied in the critical phases of vegetation in the appropriate dose, stimulate the productivity of crops to an extent dependent on the species and variety belonging and increase the economic efficiency of agricultural holdings.

Defined variables and constrains

The subjective restrictions shrink the possible solutions. This is because including more and more different group criteria in the model (e.g., land, crops, BS, land constraints, labor force, etc.) searches for a balance between the defined constraints and often leads to compromise solutions to the task.

There were used three types of biostimulants in different combinations with different concentrations (table 5).

Table 5. Applied biostimulants and their concentration

Biostimulants	Description
BS1_CH	(GA) chitosan 500 ml/ha
BS2_2CH	(GA+GA) chitosan 2*500 ml/ha
BS3_V	(HA) vermicompost extract 500 ml/ha
BS4_2V	(HA + HA) vermicompost extract 2*500 ml/ha
BS5_VR	(HA_IA) vermicompost + nature-identical growth regulator 500 ml/ha
BS6_2VR	((HA_IA+ HA_IA) vermicompost + nature-identical growth regulator 2*500 ml/ha

Source: Institute of Cryobiology and Food Technology, Agricultural Academy, Sofia.

The variables used to evaluate the BS effect on economic efficiency are presented in Tables 6 and 7. It is worth mentioning that the spring rape and spring oat were treated with different BS in different concentrations (table 6). In addition, it was used other factors such as other crops, resources (land, labor force), and financial indicators (gross margin, costs, profit) (table 7).

Table. 6. Variables with biostimulants treatment

Crop	Biostimulants (ha)						
	Control	BS1_CH	BS2_2CH	BS3_V	BS4_2V	BS5_VR	BS6_2VR
spring rape	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
spring oat	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}

Source: Authors' calculations

Table. 7. Other variables

Other crops (ha)		Resources		Finance (BGN)	
x_1	Wheat	x_{18}	Own arable land (ha)	x_{22}	Income
x_2	Corn	x_{19}	Rented arable land (ha)	x_{23}	Material costs
x_3	Sunflower	x_{20}	Permanently employed mechanics (number)	x_{24}	Labor costs
		x_{21}	Permanent employees (number)	x_{25}	Margin
				x_{26}	Gross margin
				x_{27}	Fixed costs
				x_{28}	Profit
				x_{29}	Profit with subsidies

Source: Authors' calculations

Constrains

The constraints of the optimal plan are divided into three groups: land usage (table 8); labor (table 9); and supporting constrains (table 10).

Table 8. First group of constrains related to the land usage (in ha)

Constrains	Formula	
	Optimal production structure task (first)	**Max and min area bounds task (second)**
Area constrains (acres)	$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} = x_{18} + x_{19}$	$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} \leq x_{18} + x_{19}$
Constrain on rented area (ha)	$x_{19} = 11\ 000$	$x_{19} \leq 11\ 000$
Constrain on owned area (ha)	$x_{18} = 1\ 000$	
Autumn cereal crops, minimum 45% of the sowing area (ha)	$x_1 \geq 5\ 400$	
Autumn cereal crops, minimum 55% of the sowing area (ha)	$x_1 \leq 6\ 600$	
Sunflower, maximum 17% (1/6) of the sowing area (ha)	$x_3 \leq 2\ 040$	
Constrains on the land, using BS, minimum (ha)		$x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} \geq 3360$
Constrains on the land, using BS, maximum (ha)		$x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} \leq 4560$

Source: Authors' calculations

Table 9. Second group of constrains related to the labor (number)

Constrains	Formula
Permanently employed mechanics (number)	$x_{20} = 4$
Permanent employees (number)	$x_{21} = 2$

Source: Authors' calculations

Table 10. Third group of constrains, supporting (BGN)

Constrains	Formula
Income	$116x_1 + 136x_2 + 190x_3 + 113{,}46x_4 + 128{,}93x_5 + 117{,}46x_6 + 114{,}86x_7 + 115{,}79x_8 + 118{,}39x_9 + 114{,}11x_{10} + 42{,}18x_{11} + 45{,}70x_{12} + 53{,}48x_{13} + 55{,}29x_{14} + 32{,}97x_{15} + 48{,}74x_{16} + 50{,}73x_{17} = x_{22}$
Variable material costs	$27x_1 + 27x_2 + 26x_3 + 24{,}5x_4 + 39{,}5x_5 + 39{,}5x_6 + 39{,}5x_7 + 39{,}5x_8 + 39{,}5x_9 + 39{,}5x_{10} + 31x_{11} + 46x_{12} + 46x_{13} + 46x_{14} + 46x_{15} + 46x_{16} + 46x_{17} = x_{23}$
Labor costs	$x_{24} = 18000x_{20} + 18000x_{21}$
Fixed costs	$x_{27} = 55x_{19}$
Margin	$x_{25} = x_{22} - x_{23}$
Gross margin	$x_{26} = x_{22} - x_{23} - x_{24}$
Profit	$x_{28} = x_{22} - x_{23} - x_{24} - x_{27}$

Source: Authors' calculations

Objective function

The objective function and the constrained values were added in the following linear programming model, using two optimal criteria – max gross margin and max profit.

$$F = 80x_1 + 102x_2 + 155x_3 + 79{,}96x_4 + 80{,}43x_5 + 68{,}96x_6 + 66{,}36x_7 + 67{,}29x_8 + 69{,}89x_9 + 65{,}61x_{10} + 2{,}18x_{11} - 9{,}30x_{12} - 1{,}52x_{13} + 0{,}29x_{14} - 22{,}03x_{15} - 6{,}26x_{16} - 4{,}27x_{17} - 18000x_{20} - 18000x_{21} \rightarrow \textbf{Max gross margin,} \quad (2)$$

$$F = 80x_1 + 102x_2 + 155x_3 + 79{,}96x_4 + 80{,}43x_5 + 68{,}96x_6 + 66{,}36x_7 + 67{,}29x_8 + 69{,}89x_9 + 65{,}61x_{10} + 2{,}18x_{11} - 9{,}30x_{12} - 1{,}52x_{13} + 0{,}29x_{14} - 22{,}03x_{15} - 6{,}26x_{16} - 4{,}27x_{17} - 18000x_{20} - 18000x_{21} - 55x_{19} + 31x_{18} + 31x_{19} \rightarrow \textbf{Max profit} \quad (3)$$

Conclusion

Based on the results of the empirical test collected from AES in the experimental field at the Institute of Agriculture and Seed Science "Obratzov Chiflik" – Ruse, Agricultural Academy, there was collected and analyzed primary data related to the impact of experimentally developed biostimulants at the Institute of Cryobiology and Food Technology, Agricultural Academy, Sofia, on spring rape and spring oat. On this basis and additionally collected information, it was developed production optimization model.

The construction of the model uses two criteria – max gross margin and max profit. There were build two economic-mathematical models based on these criteria. The first model allows obtaining a decision on how to optimally combine available resources (land, labor force, size of arable land) and farm constraints; what crops to produce; agrotechnical requirements; which biostimulants to apply; on which cultures and in what concentration to be applied BS; in which phase to treat them to achieve the highest economic effect. The second model gives the optimal combination of the most economically effective productions. The result is the best combination of the available resources.

The applied approach is widely used in solving optimization problems. The next step will be to verify constructed methodology in other farms in Bulgaria. Also, to derive conclusions related to the biostimulants' effect on the economic efficiency of the farm.

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