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An optimization model for evaluating the economic effect of foliar treatment with biostimulants on spring rape

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Abstract. The aim of the study is to evaluate the economic effect of foliar treatment with biostimulants: chitosan, vermicompost and vermicompost + nature-identical growth regulator on organic production of spring rape on organic production of spring rape. Two-years field trials were conducted using a block method with foliar treatment in 2 phenological phases (in rosette and flowering phase). The biological response of the culture at different doses of the biostimulators was investigated. The obtained primary results were used as input data for the construction of an economic-mathematical model for economic evaluation The treatment of spring rape with biostimulators has a positive effect on the yield of the crop. After that, a specific agricultural holding in the region is selected, which will serve as a model on which to construct the optimization model for evaluating the economic efficiency. In this farm, along with the intended crops in the production structure, spring canola is added - controls and treated with BS. The results are optimal after using chitosan in a dose of 500 mL daa^{-1}. The results of this research show the economic benefits of using biostimulants, which are extremely important for farmers. They are an alternative to the requirements of the European Union's Green Deal At the heart of the Green Deal is the Farm to Fork (F2F) and the 'Biodiversity Strategy' (BS) strategy, which was launched by the European Commission in May 2020 to achieve a fair, healthy and sustainable food system by 2030. Under the F2F strategy, there is a need to reduce reliance on pesticides and antimicrobials, reducing excess fertilization, increasing areas for organic farming, improving animal welfare and reducing biodiversity loss. With the announcement of the goals and intentions of the Green Deal and its manifestations in agriculture, preparations also began for preliminary assessments of the consequences and impact that it will have on the entire food chain and for its transposition into the Common Agricultural Policy. At the same time, science research on alternatives to traditional conventional technologies is increasing. The results of the studies also took into account a set of assumptions for simulations of farm incomes, production and product prices.

Key words: optimization model, economic effect, biostimulants, spring rape.

INTRODUCTION

The use of biostimulants (BS) in agriculture is a significant challenge for achieving the EU's Green Deal. The implementation of the objectives set in the Green Deal are expected to significantly affect the conservation of natural resources and biodiversity. The components of the European Green Deal are the 'Farm to Fork Strategy' and the 'Biodiversity Strategy'. The objectives of the Strategies aim to reduce the environmental and climate impact on the EU food system and strengthen its sustainability. Achieving the goals of the Green Deal will require a reorientation and restructuring of Bulgarian and European agriculture to replacing technological intensity with precise and intelligent new solutions The Roadmap and the Farm to Fork and Biodiversity strategies will have a tangible impact on the European economy, the food value chain and food security. Many policy papers and research studies discuss the expected effects and trade-offs of implementing the Green Deal principles on the EU crop and livestock sector (Bremmer et al., 2021; Jongeneel et al., 2021; Wesseler, 2022; Rosegrant et al., 2022; Hurduzeu et al., 2022; Rudnicki et al., 2023.

The announcement of the goals and intentions of the Green Deal and its manifestations in agriculture and preparations began for preliminary assessments of the consequences and its impacts on the entire food chain and its transposition to the Common Agricultural Policy (CAP). The main debates before economists are whether, after biostimulants increase the yield of a certain crop, will this lead to an increase in the profit of the particular farm?

The application of biostimulants has a positive effect on bulk density, porosity soil structure, and crop yields (Belcheva, 1989; Findura et al., 2022). Studies have shown that biostimulators have a beneficial effect on the weight of the root, the number of grains of grade, weight, and seed yield (Brown et al., 2015; Szczepanek et al., 2018). Scientific publications focusing on the effect on yield, biometry and efficiency of biostimulant application in agricultural crops are available (Grabowska et al., 2012; Nemes, 2020; Woziak et al., 2020; Li et al., 2022). Additionally, the effect on plant growth and tolerance to salt stress (Gedeon et al., 2022), improves tolerance to salinity (Campobenedetto et al., 2021), under abiotic stress conditions (Bulgari et al., 2019) and biochemical and economical effect of application biostimulants (Kocira et al., 2020), vegetative, physiological and reproductive attributes of tomato crops (Sassine et al., 2022), to stress resilience in nursery production, (Di Vaio et al., 2021), the effect on the productivity and quality indicators of green mass (Chernikova et al., 2021).

The aim of the study is to evaluate the economic effect of foliar treatment with biostimulants on organic production of spring rape. An optimization model based on linear programming is applied. The analyses of the scientific team are based on the hypothesis that it is possible to apply a given biostimulator to significantly increase the yield of spring rape per unit area, but not to increase the profit of the agricultural holding as a whole. Therefore, the usefulness of biostimulants is established in the development of optimization of the production structure of a selected agricultural holding. The research team accepts that those biostimulants that increase the economic efficiency of the farm are considered useful.

Currently known that the use of biostimulants may provide benefits in the cultivation of agricultural crops, but the economic results are not fully understood. The researchers limit themselves to presenting the increase in yield. Nowadays, it is even more important to consider whether the use of biostimulants is economically effective for farmers and whether they will contribute to an increase in profit in general. Also, for the society, in addition to the economic aspects, the environmental benefits are also important.

Rapeseed (*Brassica napus*) is a widespread agricultural crop worldwide, due to its diverse application. The development of spring rape takes place in a shorter period of time, compared to winter oilseed rape, which is limiting for the yield potential, and the generative plants are formed at rather high temperatures.

MATERIALS AND METHODS

For primary data, the results obtained from the Agricultural Experiment Station (AES) are used, in an experimental field at the Institute of Agriculture and Seed Science (ASS) 'Obraztsov Chiflik' - Ruse at the Agricultural Academy, Sofia. In the two-year period 2021–2022, 7 plots of 10 square meters each were prepared, in which seeds of spring rapeseed (*Lakritz, Brassica Napus* L.) were planted. The choice of 7 plots is consistent with the condition that there is also 1 control plot for which three repetitions of three biostimulants (BS) with different concentration of active substance (Table 1) will be made for representativeness of the results. Spring rape was treated with products developed at the Institute of Cryobiology and Food Technologies (ICFT) at the Agricultural Academy, Sofia.

Table 1. Applied biostimulants and their concentration

Biostimulants	Description
BS1_CH	(GA) chitosan 500 mL daa^{-1}
BS2_2CH	(GA+GA) chitosan 2*500 mL daa^{-1}
BS3_V	(HA) vermicompost extract 500 mL ha^{-1}
BS4_2V	(HA + HA) vermicompost extract 2*500 mL daa^{-1}
BS5_VR	(HA_IA) vermicompost + nature-identical growth regulator 500 mL daa^{-1}
BS6_2VR	(HA_IA+ HA_IA) vermicompost + nature-identical growth regulator 2*500 mL daa^{-1}

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

Spring rape was treated twice (in rosette and flowering phase). Harvesting of agricultural crops was done mechanized. Before sowing, all necessary agrotechnical measures have been observed. After obtaining the experimental results of the application of the different BS on spring rape in the experimental fields, they were automatically equated to 1 decare. After that, a specific agricultural holding in the region is selected, which will serve as a model on which to construct the optimization model for evaluating the economic efficiency. In this farm, along with the intended crops in the production structure, spring canola is added - controls and treated with BS. Based on experimental results obtained from 2021–2022 and the complex of additional factors, such as existing (available) resources: land, labor resources, mechanization, etc.; as well as the development of technical and economic standards (TES), the optimization model was developed.

Modeling is a categorical approach to studying complex problems that involves replacing the object with another similar to the original. We can construct this problem in a system of linear dependencies. Solving agricultural economic problems involves constructing a system of linear equations.

They must correspond to agronomic dependencies, restrictions on crop rotation, cultivated land, etc. (Nikolov et al., 1994). The objective function gives an answer for the previously selected optimality criteria (min, max):

$$A_{11}X_1 + A_{12}X_2 + \cdots + A_{1n}X_n \leq B_1 \quad (1)$$

$$A_{21}X_1 + A_{22}X_2 + \cdots + A_{2n}X_n \geq B_2$$

$$\frac{A_{m1}X_1 + A_{m2}X_2 + \cdots + A_{mn}X_n = B_1}{F = C_1X_1 + C_2X_2 + \cdots + C_nX_n \rightarrow \max(\min)},$$

where Xj – shows the size (magnitude) of activities or metrics; Aij and Cj – indicates the activities to be performed; Bi – means the number of resources available or the number of activities (constraints); the objective function F indicates the optimality criteria.

The economic-mathematical model (EMM) makes it possible to compare many possible solutions, from which to choose the most optimal one. In reality, however, it is quite difficult, and often even impossible, to account for the influence of the complex of all factors. Solving the present economic problem with the help of mathematical methods means to compose an economic-mathematical task. This task should be constructed according to a coordinate system that includes the most important dependencies with satisfactory accuracy.

Constructing the model

A. The unknowns are two groups:

The first group means the area of crops that are grown on the farm. These are wheat, corn, sunflower and canola. In canola, unknowns are added for the different BS and the control.

The second group includes unknowns, with the help of which the value indicators are determined. These are the so-called auxiliary unknowns and mean: gross output, variable costs, gross margin and the subsidies the farm receives.

B. Constrains

The constrains the field breeding activity block are generally divided into three groups.

I. Land use constrains

They provide the condition that the area of the crops included in the optimal production structure, which are grown on the respective land, is not more than the available area.

Mathematically, this group of restrictive conditions is formulated as follows:

$$\sum_{j \in Mi} x_{ji} \leq B_i \quad (2)$$

where Mi – set of the indices of the unknowns indicating the area of the j–th culture, on the i–th category of land, B_i – the available land category – i.

II. Constrains related to agrotechnical requirements for crop rotation

Correct crop rotation requires the establishment of a scientifically based ratio between the areas of autumn-winter crops with a fused surface and spring trench crops. For this purpose, two limiting conditions for the given field crop rotation are included in the task. They provide, respectively, a minimum and a maximum size of the areas with autumn cereal crops, thus limiting the areas with spring trench crops. The constrains are formulated as follows:

a/ for a minimum amount of arable land with autumn cereal crops

$$\sum_{j \in M} x_j - k' \sum_{j \in N} x_j \geq 0 \tag{3}$$

b/ for maximum amount of arable land with autumn cereal crops with a combined surface

$$\sum_{j \in M} x_j - k'' \sum_{j \in N} x_j \leq 0 \tag{4}$$

where k′ – minimum relative share of the areas of autumn crops with a fused surface; k″ – maximum relative share of the areas of autumn crops with a fused surface; M – set of the indices of the unknowns x_j expressing the areas of autumn crops with a fused surface; N – set of the indices of the unknowns x_j expressing the area of all crops in the crop rotation.

c/ About the specific requirements of the sunflower for its inclusion in the crop rotation

$$x_j - k \sum_{j \in N} x_j \leq 0 \tag{5}$$

where k – coefficient denoting the maximum share of the sowing rotation area that can be occupied by the j-th crop; N – set of the indices of the unknowns x_j expressing the area of all crops in the crop rotation.

The requirement is formulated as follows: the sunflower area is less than or equal to one maximum percentage of the sowing turnover area.

III. Computational /auxiliary/ constraints

These constraints are formulated as follows:

$$\sum_{j \in M_1} f_{ij} x_j = x_i \tag{6}$$

where M_1 – a set of indices of the unknowns, denoting the activities that influence the formation of the i-th value indicator x_i; f_{ij} – coefficient denoting the contribution of the j-th activity to the formation of the i-th value indicator.

The coefficients f_{ij} in the gross production limit are calculated on the basis of average yields and current prices, or on the basis of the standard gross production determined according to the EU methodology.

Connecting block

The calculation unknowns serve to establish the value indicators for the farm as a whole. They are: gross output, variable costs, gross margin, subsidies by type.

Constraints

I. On the balance of labor resources

The farm mainly grows mechanized commodity crops; therefore, the balance of labor resources will be carried out in general for the farm all year round. In addition to the man-hours of the permanent workers, the resources also include the temporary help that the farm can provide.

The mathematical formulation is as follows:

$$\sum_{j \in J} a_{dj} X_{dj} - \sum_{d \in D} Z_d X_d \leq 0 \qquad (7)$$

where J – set of indices of the unknowns denoting cultures (activities), which require the input of the d-th category of labor; D – multiple of the category indexes permanently occupied; a_{dj} – labor cost in working days of the d-th labor category to perform the j-th activity; Z_d – number of working days that a permanently employed worker from the d-th labor category can work annually; X_d – number of people permanently employed in the d-th labor category

II. Auxiliary constraints

The constraints for the value indicators in general for the farm are:

$$\sum_{j \in M_2} x_j = x_i \qquad (8)$$

where M_2 – a set of subscripts of the auxiliary unknowns in the connecting block denoting the magnitude of the i-th metric in the j-th division; x_i – the value of the i-th value indicator in general for the farm.

Objective function

The solution of the considered problem is carried out under the optimality criterion 'max gross margin and max profit'. It is expressed as follows:

$$\sum_{j \in M_3} x_j \to max \qquad (9)$$

where M_3 – a set of the indices of the unknowns, signifying cultures and activities which contribute to the formation of the gross margin and profit; x_j – the size of the j-th activity.

The coefficients in front of the unknowns are as follows:

– commodity crops;

– the gross margin and profit per 1 area.

The assessment of the effect of biostimulants on the economic efficiency of the agricultural holding is a complex agrarian economic task. When compiling it, it is required to take into account the complex impact of many interrelated factors and conditions and the huge number of possible solutions in order to choose the best one.

Collection and processing of the necessary information for the development of an economic-mathematical task (EMT)

Conditions under which the agricultural holding functions

Those working in the relevant agricultural holding assisted in the collection of input data for the construction of the model.

The agricultural holding operates on the territory of the Ruse region. The topography of the area is predominantly low-lying and flat-hilly, which is suitable for agricultural development. The territories around the Danube River are characterized by high groundwater and alluvial-meadow soils, on which mainly vegetables, technical and fruit crops are grown, as well as deep subsoil and chernozem soils, suitable for the cultivation of cereals and technical crops, such as wheat, barley, rye, oats, corn, sunflower, canola, vines, perennials, late greens, beans, lentils, peas, etc.

The production activity of the farm mainly involves the cultivation of crop production - wheat, corn, sunflower. We are also adding the potential to grow spring canola. The farm owns 1,000 decares (daa) of its own land and can rent another 11,000 decares. Cultivable land falls into two soil types. Alluvial-meadow soil, which occupies 50%, and chernozem - 50%, respectively. This is a facilitating condition when reporting yields, because averaged data will be used. According to National Statistical Institute, Sofia, the average rent in the Ruse region for 2021 is BGN 58 daa^{-1}, but the owner has agreed with the landlord on BGN 55 daa^{-1}. There is no additional possibility of leasing land in the area because it is too limited as a productive resource. There are no hydromelioration facilities built on the land, which means that the crops are grown under non-irrigated conditions.

Wheat, sunflower, corn are grown on the arable land. According to data from the National Statistical Institute in Bulgaria for 2021–2022, the average prices of soft wheat are BGN 0.40 kg^{-1}, corn - BGN 0.40 kg^{-1}, sunflower - BGN 1.00 kg^{-1}. Rapeseed - BGN 0.93 kg^{-1}. Data from the Ministry of Agriculture and Food are used for the average costs in 2021–2022 for material costs, labor costs, mechanized services. The crops are grown organically, which means there is no cost of spraying with insecticides, fungicides and pesticides. For spring rape treated with biostimulants, we add costs for two sprays. According to our expert calculations, the price for the applied biostimulators is calculated at about BGN 5.00 daa^{-1}.

The farm employs six people, including: 4 tractor drivers with a gross salary of BGN 1,500 per month (BGN 1,8000 year per person). The manager and his wife perform administrative and management functions, additionally participating in the production process. In practice, 2 more workers should be accepted with a salary of BGN 1,500 (BGN 18,000 year per person); Salary costs are included as variable costs. They depend on the volume of work performed and change depending on the size of the cultivated land. The maximum number of permanent employees on the farm is 6 people.

According to the agronomic, technological and economic requirements, the following constrains are accepted:

• Autumn cereal crops under non-irrigated conditions should occupy no less than 45% and no more than 55% of the sowing rotation area.

• Sunflower should not occupy more than 17% of the crop rotation (1/6)

Agriculture received subsidies under Pillar 1 of the CAP as follows:

• BGN 21 daa^{-1} under SEPP. And support under the so-called ‘green payments’ BGN 10 daa^{-1}, or a total of BGN 31 daa^{-1}.

According to the preliminary data on the yields of agricultural crops in 2021–2022, Department of Agrostatistics, Ministry of Agriculture and Foods, the average yields in Bulgaria for the North-East region in 2021 are: wheat - 5,902 kg ha^{-1}, corn 5,892 kg ha^{-1}, rapeseed 2,845 kg ha^{-1}, sunflower 2,378 kg ha^{-1}.

In 2021–2022, in Bulgaria, the tendency for the areas to be predominantly fertilized with nitrogen fertilizers is maintained. Phosphorous and potassium fertilizers are used to a lesser extent. The use of combined mineral fertilizers is increasing. Chemical fertilizers are not used in agriculture. Therefore, we assume that the average crop yield is as follows: wheat - 2,900 kg ha^{-1}, corn 3,400 kg ha^{-1}, sunflower 1,900 kg ha^{-1}, experimental yield of spring rapeseed 1,220 kg ha^{-1}. In the development of IMT, the yield of rape and oats from the experimental experience (control and different BS) are applied. 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.

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.

Table 2. Variables with biostimulants treatment

Crop	Biostimulants (daa)						
	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}

Source: Authors' calculations.

The variables used to evaluate the BS effect on economic efficiency are presented in Tables 2 and 3. It is worth mentioning that the spring rape were treated with different BS in different concentrations (Table 2). In addition, it was used other factors such as other crops, resources (land, labor force), and financial indicators (gross margin, costs, profit) (Table 3).

Table 3. Other variables

Other crops (daa)		Resources		Finance (BGN)	
x_1	Wheat	x_{18}	Own arable land (daa)	x_{22}	Income
x_2	Corn	x_{19}	Rented arable land (daa)	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 4); labor (Table 5); and supporting constrains (Table 6).

Table 4. First group of constrains related to the land usage (daa)

Constrains	Formula	
	Optimal production structure task (first)	Max and min area bounds task (second)
Area constrains (acres)	$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} = x_{18} + x_{19}$	$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} \leq x_{18} + x_{19}$
Constrain on rented area (daa)	$x_{19} = 11{,}000$	$x_{19} \leq 11{,}000$
Constrain on owned area (daa)	$x_{18} = 1{,}000$	
Autumn cereal crops, minimum 45% of the sowing area (daa)	$x_1 \geq 5{,}400$	
Autumn cereal crops, minimum 55% of the sowing area (daa)	$x_1 \leq 6{,}600$	
Sunflower, maximum 17% (1/6) of the sowing area (ha)	$x_3 \leq 2{,}040$	
Constrains on the land, using BS, minimum (daa)		$x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} \geq 3{,}360$
Constrains on the land, using BS, maximum (daa)		$x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} \leq 4{,}560$

Source: Authors' calculations.

Table 5. 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 6. Third group of constrains, supporting (BGN)

Constrains	Formula
Income	$116x_1 + 136x_2 + 190x_3 + 133.52x_4 + 135.48x_5 + 120.08x_6 + 118.63x_7 + 115.79x_8 + 127.12x_9 + 115.95x_{10} = x_{22}$
Variable material costs	$27x_1 + 27x_2 + 26x_3 + 24.5x_4 + 39.5x_5 + 39.5x_6 + 39.5x_7 + 39.5x_8 + 39.5x_9 + 39.5x_{10} = x_{23}$
Labor costs	$x_{24} = 18{,}000x_{20} + 18{,}000x_{21}$
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.

RESULTS AND DISCUSSION

Results from an experimental field of the Institute of Agriculture and Seed Science 'Obraztsov Chiflik' - Ruse.

Table 7. Spring rape yield, harvest 2021–2022 (Average)

	Spring rape yield, harvest 2021					Spring rape yield, harvest 2022					Average 2021–2022
Biostimulant	1 rep (kg)	2 reps (kg)	3 reps (kg)	Av. (kg)	kg daa^{-1}	1 rep (kg)	2 reps (kg)	3 reps (kg)	Av. (kg)	kg daa^{-1}	kg daa^{-1}
Chitosan 500 mL daa^{-1}	1.30	1.28	1.26	1.28	128.0	1.45	1.40	1.38	1.45	141.0	134.50
Chitosan-2*500 mL daa^{-1}	1.25	1.30	1.24	1.26	126.3	1.35	1.25	1.29	1.35	129.7	127.98
Vermi compost extract 500 mL daa^{-1}	1.15	1.20	1.31	1.22	123.5	1.27	1.32	1.28	1.27	129.0	126.25
Vermicompost + nature-identical growth regulator 2*500 mL daa^{-1}	1.25	1.22	1.27	1.25	124.5	1.24	1.34	1.30	1.24	129.3	126.92
vermicompost extract 2*500 mL daa^{-1}	1.30	1.24	1.28	1.27	127.3	1.37	1.35	1.34	1.37	135.3	131.32
Vermicompost + nature-identical stretch regulator 500 mL daa^{-1}	1.23	1.22	1.24	1.23	122.7	1.30	1.27	1.28	1.30	128.3	125.52
Control	1.15	1.20	1.31	1.22	122.0	1.24	1.28	1.27	1.24	126.3	124.17

Source: The primary data from The Agricultural Experimental Station (AES) in a test (experimental) field at the Institute of Agriculture and Seed Science ‘Obraztsov Chiflik’ – Ruse, Agricultural Academy, 2021–2022.

Table 8. Biometrics - spring rape, 2021–2022

BS	Biometrics - spring rape, 2021						Biometrics - spring rape, 2022					
	plant height, cm	branches per 1 plant, no.	Beans in 1 plan, no.	weight of beans in 1 plant, gr.	seeds in 1 plan, no.	weight of seeds in 1 plant, gr.	plant height, cm	branches per 1 plant, no.	beans in 1 plan, no.	weight of beans in 1 plant, gr.	seeds in 1 plan, no.	weight of seeds in 1 plant, gr.
Chitosan 500 mL daa^{-1}	109.0	7.2	259.1	22.9	1,213.2	7.7	106.9	7.6	246.2	23.3	1,267.2	7.9
Chitosan - 2*500 mL daa^{-1}	110.0	6.9	246.8	22.4	1,118.1	6.9	110.4	7.2	260.8	23.4	1,220.7	7.5
Control	109.4	7.0	238.0	22.7	1,266.2	7.4	110.4	7.1	264.1	23.6	1,272.8	7.5
Vermi compost extract 500 mL daa^{-1}	109.4	7.1	248.2	22.6	1,265.0	7.6	110.5	7.2	252.3	23.5	1,256.3	7.5
Vermicompost + nature-identical growth regulator 2*500 mL daa^{-1}	111.6	7.1	248.1	22.6	1,236.9	7.5	110.2	6.8	243.8	22.1	1,244.7	7.5
Vermicompost + nature-identical stretch regulator 500 mL daa^{-1}	108.8	7.3	248.1	22.4	1,284.3	7.6	109.6	6.9	236.7	22.4	1,128.6	6.8
Vermicompost extract 2*500 mL daa^{-1}	110.8	6.9	247.9	22.2	1,232.0	7.6	107.6	6.8	264.7	24.3	1,316.9	8.2

Source: The primary data from The Agricultural Experimental Station (AES) in a test (experimental) field at the Institute of Agriculture and Seed Science 'Obraztsov Chiflik' – Ruse, Agricultural Academy, 2021–2022.

The primary data were collected from an experimental field of the Institute of Agriculture and Seed Science 'Obraztsov Chiflik' - Ruse, Agricultural Academy. Table 7 presents the yields of spring canola in three replications of the biostimulants at different concentrations of dry matter and the control for 2021–2022. Table 8 presents the biometric indicators after treatment with biostimulants, for 2021 and 2022, respectively.

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.

$$F = 80x_1 + 102x_2 + 155x_3 + 100.02x_4 + 86.98x_5 + 71.58x_6 + 70.13x_7 + 67.29x_8 + 78.62x_9 + 71.05x_{10} - 18{,}000x_{20} - 18{,}000x_{21} \rightarrow \textbf{Max gross margin}, \quad (10)$$

$$F = 80x_1 + 102x_2 + 155x_3 + 100.02x_4 + 86.98x_5 + 71.58x_6 + 70.13x_7 + 67.29x_8 + 78.62x_9 + 71.05x_{10} - 18{,}000x_{20} - 18{,}000x_{21} - 55x_{19} + 31x_{18} + 31x_{19} \rightarrow \textbf{Max profit} \quad (11)$$

Task solution

Making a management decision is an extremely important and responsible task for agrarian entrepreneurs. The results obtained from the optimization are shown in tabular form as follows:

First option. In Table 9, the parameters of the solution of the objective function with optimization and maximum gross margin and maximum profit can be traced. The decision presents an option for crop rotation of the included agricultural crops with the use of different biostimulants, and with different concentration of active substance, with/without included CAP subsidy for the farm. The optimal solution of the task also includes the set precondition for dropping the requirement for the maximum size of cultivated land.

When constructing the production structure in the farm's crop rotation, the assumption is made that the own land of 1,000 decares (daa), and the leased land -11,000 decares, are used to their full capacity.

Solving the task gives an answer to the set parameters including the area of cultivated land, which agricultural crops will be included in the optimal solution (wheat, maize and sunflower, spring oats - control and spring canola - control, spring oats and spring rape - treated with biostimulants, with admissibility for distribution of different concentration of active substance).

The optimality criterion of the objective function, the constructed constraints and the set price values influence the results. Linear equations maximize profitable crops and minimize production costs.

Due to the listed reasons and imposed restrictive conditions in the optimization, wheat is planned to cover a minimum of 5,400 decares. This is the minimum restrictive condition for autumn cereal crops for crop rotation according to agronomic requirements (min. 45% of the crop rotation area). The entire amount of wheat is distributed over the minimum area set for autumn cereal crops. The stipulated maximum of 55% of the crop rotation area, or up to 6,600 decares, is not included in the solution of the task, because the mandatory inclusion of sunflower in the crop rotation is taken into account in the restrictive condition for the minimum size of the areas. In the optimal solution, he enters with 3,240 decares. In the remaining area of 3,360 decares, spring rape is included -

treated with chitosan - 500 mL daa^{-1}. A leading role in the distribution of these crops is played by those with a higher economic benefit for the farm. The optimization matrix does not include the distribution of the other spring rape treated with the other biostimulants.

Table 9. Production structure and economic results of application of biostimulants

Unknown	Name	daa	Number	BGN
x_1	Wheat (daa)	5,400		
x_2	Maize, (daa)	0		
x_3	Sunflower, (daa)	3,240		
x_4	Spring rape - control (daa)	0		
x_5	Spring rape - BS 1 Chitosan 500 mL daa^{-1}	3,360		
x_6	Spring rape - BS 2 Chitosan-2*500 mL daa^{-1}	0		
x_7	Spring rape - BS 3 Vermi compost extract 500 mL daa^{-1}	0		
x_8	Spring rape - BS 4 Vermi compost extract 2*500 mL daa^{-1}	0		
x_9	Spring rape - BS 5 Vermicomposting + nature-identical stretch regulator 500 mL daa^{-1}	0		
x_{10}	Spring rape BS 6 Vermicomposting + nature-identical stretch regulator 2*500 mL daa^{-1}	0		
x_{18}	Own arable land (daa)	1,000		
x_{19}	Leased arable land (daa)	11,000		
x_{20}	Permanently employed mechanics (no.)		4	
x_{21}	Permanently employed workers (no.)		2	
x_{22}	Income (BGN)			1,675,204.8
x_{23}	Material costs (BGN)			362,760
x_{24}	Labor costs (BGN)			108,000
x_{25}	Income (BGN)			1,312,444.8
x_{26}	Gross margin (BGN)			1,204,444.8
x_{27}	Fixed costs (BGN)			605,000
x_{28}	Profit (BGN)			599,444.8
x_{29}	Profit with subsidy (BGN)			971,444.8

Source: Authors' calculations, 2023.

The optimization model includes the maximum amount of land with sunflower, because it is economically profitable, and corn is dropped from the crop rotation.

During the development of the technical and economic regulations (TER), yields of agricultural crops were set, in accordance with biological production, depending on the region, the type of soil, with/without the presence of biostimulants, and different market prices of commodity crops. All this reflects on the income, income, gross margin and, accordingly, the profit of the various crops on the one hand, as well as on the agricultural economy as a whole, on the other.

In the solution of the task, it is possible to trace how the minimum and maximum limits are distributed, such as the restrictive condition for the area on which the use of biostimulants is allowed - min 3,360 decares and maximum 4,560 decares. The solution to the task only includes the spring rapeseed treated with chitosan 500 mL daa^{-1} in the minimum size of 3,360 daa of land, as economically the most profitable for the farm.

As a result, in the optimization model, all set restrictive conditions for achieving maximum economic effect - maximum gross margin and maximum profit - are fulfilled. In the solution of the problem, the optimal economic efficiency is achieved with a

Gross margin of BGN 1,204,444.8 or BGN 100.37 daa^{-1}, the realized profit without subsidy of BGN 599,444.8 (BGN 49.95 daa^{-1}) and with subsidy BGN 971,444.8, which is BGN 80.95 daa^{-1}.

Solution of the task, when the optimality criterion is set in the objective function as maximum profit (Table 10). When including fixed costs and the amount of subsidies per unit of planted area in the amount of BGN 31 ha^{-1}, the optimal solution does not change.

As a result of the subsidies, an increase in profit was generated from BGN 599,444.8 to BGN 971,444.8. The other attributes of the model remain unchanged.

Second option. Table 10 presents the results of the optimization, according to which a limit is set for minimum limits in which the cultivated land varies, but with maximum inclusion of the permissible area with the presence of crops treated with biostimulants.

Table 10. Variant when including only cultures treated in different concentrations of biostimulants. Production structure and economic results of application of biostimulants

Unknown	Name	daa	Number	BGN
x_1	Wheat (daa)	0		
x_2	Maize (daa)	0		
x_3	Sunflower (daa)	0		
x_4	Spring rape - control (daa)	0		
x_5	Spring rape - BS 1 Chitosan 500 mL daa^{-1}	12,000		
x_6	Spring rape - BS 2 Chitosan-2*500 mL daa^{-1}	0		
x_7	Spring rape - BS 3 Vermi compost extract 500 mL daa^{-1}	0		
x_8	Spring rape - BS 4 Vermi compost extract 2*500 mL daa^{-1}	0		
x_9	Spring rape - BS 5 Vermicomposting + nature-identical stretch regulator 500 mL daa^{-1}	0		
x_{10}	Spring rape BS 6 Vermicomposting + nature-identical stretch regulator 2*500 mL daa^{-1}	0		
x_{18}	Own arable land (daa)	1,000		
x_{19}	Leased arable land (daa)	11,000		
x_{20}	Permanently employed mechanics (no.)		4	
x_{21}	Permanently employed workers (no.)		2	
x_{22}	Income (BGN)			1,547,160
x_{23}	Material costs (BGN)			474,000
x_{24}	Labor costs (BGN)			108,000
x_{25}	Income (BGN)			1,073,160
x_{26}	Gross margin (BGN)			965,160
x_{27}	Fixed costs (BGN)			605,000
x_{28}	Profit (BGN)			360,160
x_{29}	Profit with subsidy (BGN)			732,160

Source: Authors' calculations, 2023.

Based on the set limiting conditions in the optimization, it is planned that the entire distribution of the sowing turnover area of 12,000 decares will be occupied by spring rape treated with chitosan 500 mL daa^{-1}. It is this solution that shows the variety of possible solutions of the proposed economic-mathematical model. The optimization model selects the most optimal solution according to the set parameters in the objective function and offers such a distribution of the production structure, consistent with the restrictive conditions, different yield, market price, and the different economic efficiency of it.

In the optimization model, all set restrictive conditions are met to achieve maximum economic effect - maximum gross margin and maximum profit.

In the solution of the task, the optimal economic efficiency is achieved with a Gross margin of BGN 965,160, realized profit without subsidy of BGN 360,160 and with subsidy - in the amount of BGN 732,160.

In this option, the material costs increase from BGN 362,760 to BGN 474,000, due to the need to spray the rapeseed on the entire 12,000 decares area. Betting on this production in the agricultural economy, a decrease in income by BGN 128,044.80 is reported, or from BGN 1,675,204.8 it shrinks to BGN 1,547,160. This is a clear sign that treating crops with biostimulants in order to a good economic result is obtained, an increase in yield should be achieved in larger quantities. Apparently, the positive effect on yield, which is in the range (1–5% for 2021–2022) Theoretically, if their values are changed in the condition of the task, and this is completely possible and feasible, then the model after several iterations will give another optimization.

The working hypothesis that the applied BS significantly increases the production efficiency of the treated agricultural crops, but they do not have an analogous impact on the economic efficiency of the agricultural holding as a whole, was verified.

CONCLUSIONS

The influence of biostimulators on the economic efficiency of spring rape, as well as on the production structure of the agricultural holding, was carried out with an economic-mathematical model based on linear programming. The following conclusions can be drawn from the obtained results: On the one hand, the use of biostimulators in agriculture increases material costs and contributes to a higher yield and biometrics of spring rape. On the other hand, the proposed optimization model showed that the foliar treatment of agricultural crops with biostimulants is able to influence the production structure and the economic efficiency of the agricultural holding. And thirdly, the positive impact of biostimulants on yield does not always have a positive economic effect on the farm as a whole.

The resulting optimization is a kind of new approach for studying the economic efficiency in the use of biostimulants in agriculture. The proposed optimization model is a useful tool for accounting the economic efficiency of the effect of biostimulants not only for farmers, but also for politicians and management decision makers following the objectives of the Green Deal.

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REFERENCES

Belcheva, S. 1989. *Effect of biologically active substances on the seed productivity of alfalfa.* Dissertation thesis, Agricultural Academy, Sofia, Bulgaria (BG), 182 pp.

Bremmer, J., Gonzalez-Martinez, A., Jongeneel, R., Huiting, H., Stokkers, R. & Ruijs, M. 2021. Impact Assessment of EC 2030 Green Deal Targets for Sustainable Crop Production. *Wageningen, Wageningen Economic Research, Report* 2021–150. 70 pp.

Brown, P. & Saa, S. 2015. Biostimulants in agriculture. *Front. Plant Sci*. **6**, 671. doi: 10.3389/fpls.2015.00671

Bulgari, R., Franzoni, G. & Ferrante, A. 2019. Biostimulants application in horticultural crops under abiotic stress conditions. *Agronomy* **9**(6), 306.

Campobenedetto, C., Mannino, G., Beekwilder, J., Contartese, V., Karlova, R. & Bertea, C.M. 2021. The application of a biostimulant based on tannins affects root architecture and improves tolerance to salinity in tomato plants. *Sci. Rep.* **11**(1), 354. doi: 10.1038/s41598-020-79770-5

Chernikova, O., Mazhaysky, Yu., Buryak, S., Seregina, T. & Ampleeva, L. 2021. Comparative analysis of the use of biostimulants on the main types of soil. *Agronomy Research* **19**(S1), 711–720. doi: 10.15159/AR.21.075

Di Vaio, C., Testa, A., Cirillo, A. & Conti, S. 2021. Slow-release fertilization and Trichoderma harzianum-based biostimulant for the nursery production of young olive trees (Olea Europaea L.) *Agronomy Research* **19**(3), 1396–1405. doi: 10.15159/AR.21.143

Findura, P., Šindelková, I., Rusinek, R., Karami, H., Gancarz, M. & Bartoš, P. 2022. Determination of the influence of biostimulants on soil properties and field crop yields. *Int. Agrophys.* **36**, 351–359. doi: 10.31545/intagr/155955

Gedeon, S., Ioannou, A., Balestrini, R., Fotopoulos, V. & Antoniou, C. 2022. Application of Biostimulants in Tomato Plants (*Solanum lycopersicum*) to Enhance Plant Growth and Salt Stress Tolerance. *Plants* **11**(22), 3082. doi: 10.3390/plants11223082

Grabowska, A., Kunicki, E., Sekara, A., Kalisz, A. & Wojciechowska, R. 2012. The effect of cultivar and biostimulant treatment on the carrot yield and its quality. *Veg. Crops Res. Bull.* **77**, 37–48. doi: 10.2478/v10032-012-0014-1

Hurduzeu, G., Pânzaru, R.L., Medelete, D.M., Ciobanu, A. & Enea, C. 2022. The Development of Sustainable Agriculture in EU Countries and the Potential Achievement of Sustainable Development Goals Specific Targets (SDG 2). *Sustainability* **14**, 15798. doi: 10.3390/su142315798

Jongeneel, R.A., Silvis, H.J, Gonzalez-Martinez, A.R., Jager, J. 2021. The Green Deal: An assessment of impacts of the Farm to Fork and Biodiversity Strategies on the EU livestock sector. *Wageningen, Wageningen Economic Research, Report* 2021–130. 68 pp.

Kocira, S., Agnieszka Szparaga, A., Hara, P., Treder, K., Findura, P., Bartoš, P. & Filip. M. 2020. Biochemical and economical effect of application biostimulants containing seaweed extracts and amino acids as an element of agroecological management of bean cultivation. *Sci. Rep.* **10**, 17759. doi: 10.1038/s41598-020-74959-0

Li, J., Van Gerrewey, T. & Geelen, D. 2022. A Meta-Analysis of Biostimulant Yield Effectiveness in Field Trials. Front. *Plant Science* **13**, 836702. doi: 10.3389/fpls.2022.836702

Nemes, N. 2020. Comparative analysis of organic and non-organic farming systems: A critical assessment of farm profitability. *FAO Web side*. [cited May2020]. *https://www.fao.org/tempref/docrep/fao/011/ak355e/ak355e00.pdf*.

Nikolov, N., Ivanov, G. & Stefanov, L. 1994. Economic and mathematical modeling of agricultural production. *Sofia: Zemizdat.* (BG). Николов, Н., Иванов, Г., Стефанов, Л. 1994. Икономико-математическо моделиране на селскостопанското производство. *София: Земиздат* (in Bulgarian).

Rosegrant, M.W., Sulser, T.B. & Wiebe, K. 2022. Global investment gap in agricultural research and innovation to meet Sustainable Development Goals for hunger and Paris Agreement climate change mitigation. Front. *Sustain. Food Syst. Sec. Land, Livelihoods and Food Security*. Volume **6**, 965767. doi: 10.3389/fsufs.2022.965767

Rudnicki, R., Biczkowski, M., Wi´sniewski, Ł., Wi´sniewski, P., Bielski, S. & Marks-Bielska, R. 2023. Towards Green Agriculture and Sustainable Development: Pro-Environmental Activity of Farms under the Common Agricultural Policy. *Energies* **16**, 1770. doi: 10.3390/en16041770

Sassine, Y.N., Sajyan, T.K., El Zarzour, A., Abdelmawgoud, A.M.R., Germanos, M. & Alturki, S.M. 2022. Integrative effects of biostimulants and salinity on vegetables: Contribution of bioumik and Lithovit®-urea50 to improve salt-tolerance of tomato. *Agronomy Research* **20**(4), 793–804. doi: 10.15159/AR.22.074

Szczepanek, M., Jaśkiewicz, B. & Kotwica, K. 2018. Response of barley on seaweed biostimulant application. *Research For Rural Development* **2**, 49–54. doi: 10.22616/rrd.24.2018.050

Wesseler, J. 2022. The EU's farm-to-fork strategy: An assessment from the perspective of agricultural economics. *Applied Economic Perspectives and Policy*, 1–18. doi: 10.1002/aepp.13239

Woziak, E., Blaszczak, A., Wiatrak, P. & Canady, M. 2020. Biostimulant mode of action: Impact of biostimulant on whole-plant. *In The Chemical Biology of Plant Biostimulants* (eds Geelen, D. & Xu, L.), 207–227 (Wiley, Hoboken, 2020).

https://www.mzh.government.bg/media/filer_public/2022/04/27/ra400_publicationcrops2021_preliminarydata.pdf