Evaluation of the economic efficiency of introducing the biostimulant chitosan into biological production of spring rapeseed[1]

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Abstract: The purpose of the research is to evaluate the economic effect of the application of biostimulator chitosan in the biological production of spring rapeseed. Two-year field trials were conducted using a block method with foliar treatment in 2 phenological phases. The biological response of the culture at different doses of the biostimulator was studied. The obtained primary results were used as input data for the construction of an economic-mathematical model for economic evaluation.

According to the obtained data, the application of the biostimulator chitosan has a positive effect on biometric indicators and increases the yield of rapeseed. Better results were observed after using chitosan 500 ml/ha. The results of this research show the economic benefits of using biostimulants, which are extremely important for farmers. They are an alternative to farmers according to the European Union's Green Deal priorities. Recommendations to farmers have been made.

Key words: biostimulant chitosan, growth regulator, spring rapeseed, biometrics, technological indicators, economic efficiency

1. INTRODUCTION

The use of biostimulants (BS) in agriculture is a significant challenge for achieving the EU's Green Deal. The goals set in the Green Deal are expected to impact significantly on the development of agriculture in the medium and long term and it raises both research and practical questions. Components of the European Green Deal are “Farm to Fork Strategy” and “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 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), etc.

This study aims to evaluate the economic efficiency of the application of biostimulant chitosan in spring rapeseed. An optimization model based on linear programming is applied.

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. All of these challenges have many possible solutions that differ depending on the goals set.

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

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potential, and the generative plants are formed at rather high temperatures.

2. MATERIAL AND METHODS

For primary data, the results obtained from the Agricultural Experiment Station (AES) are used, in a experimental field at the Institute of Agriculture and Seed Science (IZS) "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 (*sorte Lakritz, brassica napus L.*) were planted. The choice of 2 plots is consistent with the condition that there is also 1 control plot for which three repetitions of biostimulant (BS) chitosan will be made (table 1). Spring rape was treated with products developed at the Institute of Cryobiology and Food Technologies (ICHT) at the Agricultural Academy. There were used biostimulant chitosan with different concentrations (table 1). Spring rapeseed 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 rapeseed 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. They should reflect the conditions that must be taken into account when solving the task (Nikolov et al., 1994).

The objective function expresses the optimality criteria (min, max):

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

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

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$$A_{m1}X_1 + A_{m2}X_2 + \cdots + A_{mn}X_n = B_1$$

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$$F = C_1X_1 + C_2X_2 + \cdots + C_nX_n \to \max\ (min)$$

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Where:

- Xj - shows the size (magnitude) of activities or metrics,

- Aij и 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 problem. The economic-mathematical model is a mathematical task that reflects with satisfactory accuracy the most important, most essential connections and dependencies characterizing the economic problem.

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 groundwater and black earth soils (cereal and technical crops). Climatic conditions create prerequisites for growing the following crops: barley, wheat, corn, sunflower, rapeseed, rye, vines, fruit trees, late vegetables, soybeans, chickpeas, 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 rapeseed. The farm owns 1,000 decares 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/dca, but the owner has agreed with the landlord on BGN 55/dca. 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, corn – BGN 0.40/kg, sunflower – BGN 1.00/kg. Rapeseed - BGN 0.93/kg. 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 biostimulator is calculated at about BGN 5.00/dca.

Six people work permanently on the farm, distributed as follows: 4 mechanics with a gross salary of BGN 1500/month (BGN 18000/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 1500 (BGN 18000/year per person); These labor costs will be accepted as variable costs because they depend on the volume of activity performed and may vary in practice. The maximum number of permanent employees on the farm cannot exceed 6 people. The number of days during which it is possible to perform field work in the months with increased labor pressure is respectively: m. July – 26 working days; August – 26 working days; m. September - 24. When the operators do not perform mechanized activities, they perform general work on the farm.

According to the technological requirements, the following restrictions must be observed:

• 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/dca under SEPP. And support under the so-called "green payments" BGN 10/ dca, or a total of BGN 31/dca.

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, corn 5,892 kg/ha, rapeseed 2,845 kg/ha, sunflower 2,378 kg/ha.

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, corn 3,400 kg/ha, sunflower 1,900 kg/ha, experimental yield of spring rapeseed 1,220 kg/ha. 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; 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.

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Table 1: Applied biostimulant chitosan and concentration

Biostimulants	Description
BS1_CH	(GA) chitosan 500 ml/ha
BS2_2CH	(GA+GA) chitosan 2*500 ml/ha

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

3. RESULTS AND DISCUSSION

Results from an experimental field of the Institute of Agriculture and Seed Science "Obraztsov Chiflik" – Ruse

The primary data were collected from an experimental field of the Institute of Agriculture and Seed Science "Obraztsov Chiflik" – Ruse, Agricultural Academy. Table 2 presents the yields of spring rape in three replications of the biostimulants at different concentrations of dry matter and the control for 2021-2022. Table 3 presents the biometric indicators after treatment with biostimulants, for 2021 and 2022, respectively.

Table 2: Spring rape yield, harvest 2021-2022 (Average)

	Spring rape yield, harvest 2021					Spring rape yield, harvest 2022					Average 2021-2022
Biostimulant	1 reps (kg)	2 reps (kg)	3 reps (kg)	Av. (kg)	kg/dca	1 reps (kg)	2 reps (kg)	3 reps (kg)	Av. (kg)	kg/dca	kg/dca
Chitosan 500 ml/ dca	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/ dca	1,25	1,30	1,24	1,26	126,3	1,35	1,25	1,29	1,35	129,7	127,98
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 "Obraztzov Chiflik" – Ruse, Agricultural Academy, 2021-2022

Table 3: Biometrics – spring rape, 2021-2022

	Biometrics – spring rape, 2021						Biometrics – spring rape, 2022					
BS	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/ dca	109,0	7,2	259,1	22,9	1213,2	7,7	106,9	7,6	246,2	23,3	1267,2	7,9
Chitosan-2*500 ml/ dca	110,0	6,9	246,8	22,4	1118,1	6,9	110,4	7,2	260,8	23,4	1220,7	7,5
Control	**109,4**	**7,0**	**238,0**	**22,7**	**1266,2**	**7,4**	**110,4**	**7,1**	**264,1**	**23,6**	**1272,8**	**7,5**

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, 2021- 2022

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:

Table 4. Production structure and economic results of application of biostimulant Chitosan

unknown	name	dca	Number	BGN
x_1	Wheat (dca)	5400		
x_2	Maize, (dca)	0		
x_3	Sunflower, (dca)	3240		
x_4	Spring rape – control (dca)	0		
x_5	Spring rape - BS 1 Chitosan 500 ml/ dca	3360		
x_6	Spring rape – BS 2 Chitosan-2*500 ml/ dca	0		

x_{18}	Own arable land (dca)	1000		
x_{19}	Leased arable land (dca)	11000		
x_{20}	Permanently employed mechanics (no.)		4	
x_{21}	Permanently employed workers (no.)		2	
x_{22}	Income (BGN)			1675204,8
x_{23}	Material costs (BGN)			362760
x_{24}	Labor costs (BGN)			108000
x_{25}	Income (BGN)			1312444,8
x_{26}	Gross margin (BGN)			1204444,8
x_{27}	Fixed costs (BGN)			605000
x_{28}	Profit (BGN)			599444,8
x_{29}	Profit with subsidy (BGN)			971444,8

Source: Authors' calculations, 2023

Table 5. Variant when including only cultures treated in different concentrations of biostimulants. Production structure and economic results of application of biostimulants

unknown	name	dca	Number	BGN
x_1	Wheat (dca)	0		
x_2	Maize (dca)	0		
x_3	Sunflower (dca)	0		
x_4	Spring rape – control (dca)	0		
x_5	Spring rape - BS 1 Chitosan 500 ml/ dca	12 000		
x_6	Spring rape – BS 2 Chitosan-2*500 ml/ dca	0		
x_{18}	Own arable land (dca)	1000		
x_{19}	Leased arable land (dca)	11000		
x_{20}	Permanently employed mechanics (no.)		4	
x_{21}	Permanently employed workers (no.)		2	
x_{22}	Income (BGN)			1547160
x_{23}	Material costs (BGN)			474000
x_{24}	Labor costs (BGN)			108000
x_{25}	Income (BGN)			1073160
x_{26}	Gross margin (BGN)			965160
x_{27}	Fixed costs (BGN)			605000
x_{28}	Profit (BGN)			360160
x_{29}	Profit with subsidy (BGN)			732160

Source: Authors' calculations, 2023

First option. In Table 4, 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 biostimulant Chitosan, 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, and the leased land -11,000 decares, are used to their full capacity.

Solving the optimization equation is expected to give us an answer to the questions concerning the area of cultivated land to be sown with certain agricultural crops (wheat, maize and sunflower, and spring rapeseed – control - treated with biostimulant Chitosan, with admissibility for distribution of different concentration of active substance).

The main influence on the results is the type of the objective function, the constraints and the set price parameters. The type of the objective function is linear, as are the constraints. Linearity affects the results in 2 ways:

1. Maximizes cost-effective crops produced, on the one hand;

2. On the other hand, it minimizes the price disadvantages to the size of their set minimum.

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 3240 decares. In the remaining area of 3360 decares, spring rape is included - treated with chitosan - 500 ml/decare. A leading role in the distribution of these crops is played by those with a higher economic benefit for the farm.

The optimization has taken into account all the limiting conditions and has included in the solution other crops that are more economically profitable. In the same way, the result should be interpreted for the inclusion of the maximum amount of land under sunflower, and corn is dropped from the crop rotation. This is because no precondition has been set for its mandatory inclusion in the solution of the task. That is, 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 of the crop rotation, presence of biostimulants, different yield, market price, and the different economic efficiency, consequence of these conditions.

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 3360 decares and maximum 4560 decares. The solution to the task only includes the spring rapeseed treated with chitosan 500 ml/ha in the minimum size of 3360 ha 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/decare, the realized profit without subsidy of BGN 599,444.8 (BGN 49.95/decare) and with subsidy BGN 971,444.8, which is BGN 80.95/decare.

Table 4 present the results when profit is included as the objective function. The results of the optimization confirm the conclusions made so far. Adding fixed costs to the model does not change the final result for the optimal ratio of planted areas.

Of interest is whether the presence of subsidies will change the optimization results. The influence of the subsidies in the model is reflected by the subsidies per unit of sown area in the amount of BGN 31/ decare. The main result of the use of subsidies is the increase in profit from BGN 599,444.8 to BGN 971,444.8. All other parameters of the model - in terms of the structure of the areas for cultivation of the various crops and labor costs remain unchanged regardless of whether they are subsidies included or not.

Second option. Table 5 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.

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/decare. 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) 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.

CONCLUSIONS

Based on the results of the empirical test collected from AES in the experimental field at the Institute of Agriculture and Seed Science "Obraztsov Chiflik" – Ruse, Agricultural Academy, there was collected and analyzed primary data related to the impact of experimentally developed biostimulant chitosan at the Institute of Cryobiology and Food Technology, Agricultural Academy, Sofia, on spring rape. 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 and in what concentration to be applied biostimulant chitosan; 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 influence of biostimulant chitosan on the economic efficiency of spring rapeseed, as well as on the production structure of the agricultural holding, was carried out with an economic model based on linear programming. On the other hand, the proposed optimization model showed that the foliar treatment of spring rapeseed with biostimulant chitosan is able to influence the production structure and the economic efficiency of the agricultural holding. And thirdly, the positive influence of biostimulant chitosan on crop 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 to account for the economic efficiency of the effect of biostimulants, not only for farmers, but for policy makers involved in policy making and management decision makers.

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