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Application of environmentally safe chemical reclamation on an innovative basis in Russia

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Abstract. In the context of world food crisis, potato production and increasing its yield is an urgent topic of research. In agricultural production, one of the most basic directions of increasing production is the introduction of organic and mineral fertilizers. The purpose of the study is to develop agro-methods for the use of environmentally friendly biopolymers when applying mineral fertilizers for the effective cultivation of potato and to determine production efficiency. To end this purpose, two field experiments and one control variant without the use of biopolymers were used in our study to assess the effect of Nutricharge and Growgreen preparations on the yield of Gala potato variety. To obtain reliable experimental results, several of the following requirements were considered: representativeness, accuracy, and compliance with the principle of single difference. Experiment No. 1 - treatment of ammonium nitrate phosphate fertilizer with Nutricharge at the rate of 3 kg per 1 ha. As a result of the Nutricharge biopolymer application, the biological yield of potato increased by 83.5 c ha^{-1}. Experiment No. 2 - treatment of mineral fertilizers with Nutricharge and Growgreen, 2.5 L ha^{-1}. As a result of the biopolymers application, the biological yield of potato in this experiment exceeds the control data by 237.5 c ha^{-1}. At the same time, the yield in the second experiment turned out to be higher than the yield in the first experiment by 154 c ha^{-1}. An equally important task in conducting this study was to determine, with the help of economic assessment, the production efficiency of biopolymers application. As a result of economic analysis, we found out that the complex use of preparations allowed to reduce the cost of production of 1 ton of potato in the first experiment by 21%, in the second - by 7.7% compared with the control. Cost reduction and revenue increase in the second experiment allowed to make a profit from 1 ha of 298,020 rubles, and in the first - 221,440 rubles. The obtained research data give us reason to say that the use of biopolymers Nutricharge and Growgreen is effective and their scale should be spread throughout the entire region of the country.

Key words: potato, innovative mineral fertilizers, intensification, environmentally friendly chemical biopolymers Nutricharge and Growgreen, field experiment, potato yield and acreage, economic assessment.

INTRODUCTION

Potato (Solánum tuberósum) occupies the second place in food value after grain products. It is distinguished by its exceptional versatility in relation to its use as a product of agricultural production. The following qualities of this product should also be noted: high nutrient content and excellent taste qualities. Potato consumption is growing every year as a result of an increase in the world's population. In the conditions of the impending food crisis in the world, the increase in yields and the increase in the gross yield of potato is relevant (Kovalenko, 2019).

Recently, the government of the Moscow region has paid great attention to the development of the agricultural sector in this region. For the further development of the fruit and vegetable food sub-complex of this constitutional entity of the Russian Federation, a number of measures were taken to increase the gross yields of crop production in order to provide the population of Moscow and the Moscow Region with food products of domestic production, in accordance with medical consumption standards. It is especially important to note that the main emphasis was placed on the cultivation of such crops as: potatoes, carrots, white cabbage, table beets, which are most adapted to growing in this region according to the botanical characteristics of these crops and the combination of local natural and climatic conditions. In addition, the economic efficiency of their production is determined by the proximity to the sales market and its potential consumption volumes (Ibiev et al., 2021).

The use of biostimulators in combination with mineral fertilizers on all types of soils has an effective impact on economic fertility, and also improves the conditions for increasing soil microflora. The content of microflora (microorganisms) in well-loosened soil proves that it has a positive effect on the qualitative and quantitative composition of the soil, and this affects the increase in crop yields (Bulgakov et al., 2021).

When applying mineral fertilizers and other biological products, it is necessary to consider a number of technical and operational characteristics of machines and equipment, the efficiency of using these groups of fertilizers depends on this. In modern conditions, when almost all branches of the national economy are being converted to digital technologies, including agriculture, it is necessary to complete machines and equipment with digital installations, such as agrodrones, sensors, sensor dispensers and other digital resources that contribute to the normalized consumption of applied mineral fertilizers and biological products to provide the soil with the necessary plant nutrition elements in agriculture (Chernikova et al., 2021).

The most promising direction for increasing yields and increasing the efficiency of potato production is the use of innovative environmentally friendly mineral fertilizers - biodegradable polymers. Their main advantage is that they are capable of spontaneous destruction as a result of natural microbiological and chemical processes, without causing harm to the environment (Ushachev et al., 2017).

To successfully solve this problem in our scientific work, we conducted a study using innovative mineral fertilizers Nutricharge and Growgreen - biodegradable

polymers and environmentally friendly chemicals for plant growth and development (Volkova, 2019).

Nutricharge and Growgreen are the new generation biopolymers for use in industrial crops, which increases the efficiency of expensive phosphorus-containing fertilizers, increasing the time that phosphorus remains in the state accessible to plants. Nutricharge and Growgreen have appeared on the Russian market recently, but, according to the opinion and assessments of leading experts engaged in this field of research, they show good results in the process of application in the cultivation of agricultural crops (Manzhina, 2017).

As mentioned above, in the abstract of the article, one of the most promising areas for increasing yields and improving the production efficiency of potato is the introduction of organic and mineral fertilizers. Usually, in a scientifically based farming system for potato cultivation, it is recommended to apply a complex mineral ammonium nitrate phosphate fertilizer ($NH_4H_2PO_4$+NH_4NO_3+ KCL), which contains three main components necessary to ensure the normal quality of plant life at different stages - nitrogen, phosphorus, and potassium (NPK).

In agricultural practice, it has long been widely known that such an important and rather expensive plant nutrition element as phosphorus, when it enters the soil in the form of mineral fertilizers, falls into a precipitate insoluble in water and becomes inaccessible to plants precisely because of the reaction with metals. According to various data, from 75 to 95% of this element is blocked in the soil solution in an insoluble form (Lipsky, 2014).

This leads to a lack of phosphorus, which in turn manifests in a delay in the growth and development of plants - small leaves are formed, flowering and fruit ripening are late. The lower leaves acquire a dark gray or dark green shade. Over time, they curl and die prematurely. The phosphorus binding reaction in the soil occurs quickly as soon as there is enough moisture and a soil solution is formed. Calcium cations present in alkaline soils, or aluminum and iron cations in acidic soils bind phosphorus, preventing plants from taking it up (Khromov, 2017).

Nutricharge is a new generation biopolymer for use in industrial crops. This is a macromolecule with a large negative charge, which takes on the maximum amount of calcium cations (or metal cations), as far as the capacity of cation exchange allows. For comparison: chernozem has a cation exchange capacity of 40 units, and Nutricharge molecule has 1,200 units. Therefore, a protective environment is formed around the phosphorus molecule, which works for at least 10 months. Nutricharge is gradually utilized in the soil by soil bacteria, does not accumulate in plants or in the soil ('ARTEL' LLC, 2017).

The advantage of this technology is that this water-soluble polymer is a slightly viscous liquid that is simply sprayed and applied to fertilizer granules in a similar way to seed dressing. This fertilizer has no shelf life. After treatment with polymer, the fertilizer is used on the farm in the same way as usual: as a basic fertilizer scattered for the main processing, cultivation or in a seeder during sowing, and as a top dressing with embedding in the soil. That is, the application technology does not change in any way (Khromov, 2017).

Another effective tool that the Artel is engaged in is complex liquid organomineral fertilizers of the Growgreen brand.

Growgreen is a biologically active fertilizer obtained during a unique patented production process, including mixing and preparation of ammonium sulfate with trace elements with the help of beneficial microbes. The fertilizer can be used for leaf feeding without the risk of burning the leaves. This provides excellent plasticity with respect to the type and frequency of fertilization ('ARTEL' LLC, 2017).

Both with leaf feeding and with tillage, Growgreen perfectly provides crops that have a high level of demand for these two nutrients. This provides an effective alternative to other products with more than twice high level of nitrogen.

Growgreen with a lower but more effective concentration of nutrients does not acidify the soil, in the same way as traditional ammonium sulfate. Growgreen is a biologically active product obtained as a result of a specially developed microbial production process.

Due to a specially developed microbial production process that repeats natural soil processes, transforming nutrients into a form 100% accessible to plants, Growgreen fertilizers are as effective as possible with small application rates.

The special 'stickiness' of Growgreen fertilizers allows to save nitrogen by 70% of the initial fertilizer level in the fertile soil layer after experiments on 'water outwash' on the lightest - sandy soils, where conventional fertilizers are washed out by 100% ('ARTEL' LLC, 2017).

Since the appearance of Nutricharge, since 2017, 220 production experiments have been laid on the Russian market in 17 regions, 45 farms, on 16 crops, including winter wheat, rapeseed, sunflower, potato, corn, sugar beet, soy, etc.

Gala potato variety was bred by breeders in 2013, high-yielding, unpretentious in care, resistant to diseases, it is classified as early-maturing. It ripens 75–80 days after planting, with proper cultivation, the crop yields from 12 to 20 medium-sized tubers from one bush.

In this regard, the purpose of the study was to determine, with the help of agricultural techniques and field experiments, the effectiveness of the use of Nutricharge and Growgreen biopolymers in the process of growing Gala potato, and also to determine the commercial feasibility of these actions in production.

MATERIALS AND METHODS

In 2020, in the spring-summer period, the Artel organization together with the scientific staff of the RSAU-MTAA and the specialists of the Lenin Collective Farm cooperative, which is located in the Ryazan region, laid two scientific field experiments to assess the effect of Nutricharge and Growgreen preparations on the yield of Gala potato, and also, for comparison with two field experiments, a control variant was used without application of biochemical polymers.

When setting up a field experience, the requirements and conditions of conducting a similar kind of research were considered: the soil topography, the configuration and size of the experiment area, the diversity of soil fertility, vegetation, and littering, the number and size of plots on the selected planting area, the shape of plots.

The size, number, and repetition of plots are of particular importance for the accuracy and reliability of the experiment. These requirements are determined by the chosen crop for the study, the botanical and biological features of the crop, and the method of potato planting are considered, in our study the size of plots in production

conditions was 1 ha, the number of plots - 300 units, three land plots with an area of 300 hectares were chosen and selected for each experiment and control comparison option, the increase in repetition most significantly affects the accuracy of the experiment, the indicators chosen by us reduce the error of the experiment to 3%.

The shape of the plots was taken as an elongated rectangle - this is the most optimal form of efficient use of high-performance machinery and equipment. The GreenSeeker RT200 system, which is equipped with a modern Trimble FMX field computer, was used to conduct field experiment, for application and introduction of mineral fertilizers. A multifunctional device to which an autopilot or a thruster EZ-Steer, EZ-Pilot can be connected. With the help of GreenSeeker RT200, you can apply the planned fertilizer rate by GPS coordinates, 2 complexes of 6 sensors (for 2 tractors). The kit consists of 6 sensors with Trimble Recon PPC for variable speed fertilizer application. Such a system can be used with Trimble or John Deere GPS equipment (Sadykova et al., 2021).

Hereafter, let's look at the summary of the field experiment methodology:

During the field experiment in production conditions, three variants of the experiment were selected:

– control option, for comparison of experiment No. 1 and experiment No. 2, without the use of biopolymers Nutricharge and Growgreen. In the control variant, equality was observed in all the conditions that were given above, except for the studied one, known as the principle of single difference. The industrial technology of potato cultivation, scientifically-based potato farming systems by zones, the use of optimal norms of mineral fertilizers, in particular, such as: ammonium nitrate phosphate fertilizer ($NH_4H_2PO_4$+NH_4NO_3+KCL) - a complex fertilizer, which contains three main components necessary to ensure the normal quality of plant life at different stages of growth and development - nitrogen, phosphorus, and potassium (NPK), and ammonium sulfate (NH_4) $2SO_4$, mainly contains 21% nitrogen and 24% sulfur. The planting area was 300 hectares, as mentioned above.

The dose of applying ammonium nitrate phosphate fertilizer for potato was 400 kg ha per 1 ha, considering the active substance nitrogen - 20%, phosphorus - 24%, and potassium - 30%. The application rate of ammonium sulfate is 300 kg ha.

– the control option of the field experiment for comparative analysis with experiments No. 1 and No. 2 was carried out without the addition and use of biochemical polymers, the remaining parameters of the field experiment methodology were preserved and left unchanged, which were listed above. The size of the plots is 1 ha, the number of plots is 300 units, the total area of Gala variety potato planting was 300 ha, the plot shape is an elongated rectangle. The control option was carried out using industrial potato growing technology, ammonium nitrate phosphate mineral fertilizers were used for planting potatoes 400 kg ha, ammonium sulfate - 300 kg ha of working solution for leaf feeding, the method of planting tubers is a bulk bed (Dutch method) at a distance of 50–60 cm from each other, the size of tubers is on average 70–80 g, the planting rate - 4.5 t.

– experiment No. 1 - treatment of complex ammonium nitrate phosphate mineral fertilizer with Nutricharge at the rate of 3 kg per 1 ha. The experiment technology, as in the control version: industrial technology of potato cultivation, mineral fertilizers: ammonium nitrate phosphate mineral fertilizer for planting potato 400 kg ha, ammonium sulfate - 300 kg ha of working solution for leaf feeding, the method of planting tubers is a bulk bed (Dutch method) at a distance of 50–60 cm from each other, the size of tubers on average 70–80 g, the planting rate is 4.5 t, but considering the processing of the

complex ammonium nitrate phosphate mineral fertilizer with Nutricharge at the rate of 3 kg per 1 ha.

– experiment No. 2 - in addition to the Nutrichardge treatment, potato leaf fertilization was carried out in the phase of 5–7 leaves with micro-fertilizer Growgreen, 2.5 L ha^{-1} for a working solution of 300 L ha^{-1}. When conducting experiment No. 2, the conditions and requirements were considered, as in experiment No. 1, but in addition to the Nutrichardge treatment, potato leaf fertilization was carried out in the phase of 5–7 leaves with microfertilizer Grwgreen, 2.5 L ha^{-1} for a working solution of 300 L ha^{-1}.

RESULTS AND DISCUSSION

When conducting the experiment, it is necessary, first of all, to take into account indicators in physical units such as: gross harvest, biological and production yields, they are the basis for calculating the main results in our study. Biological yield is the potential yield based on selective sampling prior to harvest, when the crop is at its optimum ripeness. It is calculated according to the formula:

$$\text{У} = \frac{P \times A}{10{,}000}$$

where, P – number of plants per 1 hectare before harvest; A – mass of tubers from 1 bush, centner per hectare.

Production yield - the amount of products received after harvesting, according to the actual threshing, losses during harvesting and transportation to the place of its storage.

In the control option of the field experiment, the following production results were obtained:

– the gross yield amounted to 112,955 hundredweights from the potato planting area of 300 hectares;

– the production yield of potatoes was:

$$\text{Уі}_{sown\ area} = \frac{Bulk\ yield, \text{c}}{\text{S}^2_{\text{sowing}}} = \frac{112{,}955\ \text{c}}{300\ \text{ha}} = 376.56\ \text{c ha}^{-1}$$

– biological yield - 554.5 c ha^{-1}, production yield - 376.56 c ha^{-1}.

Production indicators during experiment No. 1 - treatment of complex ammonium nitrate phosphate mineral fertilizer with Nutricharge at the rate of 3 kg per 1 ha.

– biological yield - 638 c ha^{-1}, production yield - 418.31 c ha^{-1}, the difference was 83.5 c ha^{-1} and 41.75 c ha^{-1}, respectively.

After conducting experiment No. 2, we obtained the following results:

– biological yield - 792 c ha^{-1}, production yield - 495.31 c ha^{-1}. The difference is significant compared to both the control variant and experiment No. 1, the obtained biological yield in the second experiment exceeds the control data by 237.5 c ha^{-1}, and in experiment No. 1 - by 154 c ha^{-1}, the difference in production yield was 118.75 c ha^{-1} and 77 c ha^{-1}, respectively.

Further, for the purpose of economic assessment and identification of potato production growth reserves and the potential of the selected potato variety ‘Gala’, the actual costs of the grown potato crop were calculated.

Table 1 shows the actual costs of growing potato in 2020 by experiments.

Table 1. The actual costs of growing potato in the agricultural complex Collective Farm n.a. Lenin in 2020, rubles

Name	Total	per 1 c	per 1 ha	as a % of the total
Salary	12,300,026	102.07	38,438	18.45
Fuel and lubricants	1,926,109	15.98	6,019	2.89
Seeds	6,967,967	57.83	21,775	10.45
Mineral fertilizers	7,530,272	62.49	23,532	11.29
Means of protection	12,231,455	101.51	38,223	18.35
Costs of previous years	1,495,354	12.41	4,673	2.24
Tractor services	7,959,235	66.05	24,873	11.94
Motor transport	2,038,888	16.92	6,372	3.06
General expenses of production	4,321,268	35.86	13,504	6.48
Work of collective agricultural enterprise	2,583,760	21.44	8,074	3.88
Depreciation	5,255,964	43.62	16,425	7.88
Implementation costs	1,960,654	16.27	6,127	2.94
Other	102,746	0.85	321	0.15
TOTAL	62,653,598	53.31	208,355	100.00

The cost of production of 1 c of potato is:

$$C_{potato} = \frac{\sum costs}{Bulk\ yield} = \frac{62{,}653{,}598\ rubles}{112{,}955\ c} = 553.31\ rubles\ c^{-1}$$

The cost of production of 1 ton of potato, respectively, is 5,533.09 rubles per ton.

Let's calculate performance indicators separately for each experiment and compare them.

Results of experiment No. 1 with the treatment with Nutricharge fertilizers

At the first stage of the analysis, we will determine the indicators of the production efficiency of potato cultivation in physical units, which are the basis for calculating the cost indicators of potato production. However, indicators of production efficiency in physical units reflect only one side of the achieved result. To identify the full economic effect of the experiment, we will determine and calculate the cost indicators of the effectiveness of fertilizer application.

We will calculate the values of indicators that will allow to compare the effect of using fertilizers treated with Nutricharge according to experiment No. 1 (Table 2).

Processing of fertilizers with Nutricharge led to an increase in the biological yield of potato from 554.5 c ha^{-1} to 638 c ha^{-1}, which is equal to 15% in percentage terms.

Since the actual yield was not measured at the site, it was assumed that the increase in production yield was 50% of the increase in production yield, that is, 41.75 c ha^{-1} (the change in production yield to control is 11%). According to experiment, the production yield was determined as the sum of the increase in production yield and the yield of the sown area, i.e.:

$$Yi_{prod.} = Increase\ Yi_{prod.} + Yi_{sown\ area} = 41.75\ c\ ha^{-1} + 376.56\ c\ ha^{-1} = 418.31\ c\ ha^{-1}$$

The actual experiment costs per 1 ha increased by the cost of Nutricharge per 1 ha, i.e. by 5,250 rubles/ha or 2.5% to the control, i.e. the amount is relatively small. At the same time, the cost of production of 1 ton of potato in the experiment decreased to 5,106.36 rubles/ton, i.e. 7.71%.

The proceeds from the sale of potato from 1 ha at a price of 10,400 rubles per ton amounted to 391,625 rubles according to control, 435,045 rubles according to experiment. The profit calculated as the difference between revenue and actual costs, according to experiment, showed an increase of 38,170 rubles/ha, which amounted to 20.83%.

Table 2. Data from experiment No. 1 with the processing of ammonium nitrate phosphate fertilizers with Nutricharge for sowing potato in the agricultural complex Collective Farm n.a. Lenin in 2020

Indicators	Agricultural complex Collective Farm n.a. Lenin, Kasimovsky district	
	Potato	
	control	experiment
Applied on 1 ha on the experimental plot, kg	700	700
Actual costs per 1 ha, rubles	208,355	213,605
including: actual cost of fertilizers applied for the crop, including work in progress, rubles	23,532	23,532
Of these: cost of fertilizers per 1 ha in experiment, rubles	14,000	14,000
The cost of Nutricharge per 1 ha, rubles	0	5,250
Total: including the cost of fertilizers and Nutricharge per 1 ha in the experiment	14,000	19,250
Biological yield, c ha^{-1} (Gala variety) (Act)	554.5	638
The difference in the yield of experiments in comparison with the control, (+,-), c ha^{-1}		83.5
Change in biological yield in % to control, %		115,06
Production yield (adjusted in the experiment by 50% of the increase in biological yield)	376.56	418.31
Increase in production yield, c ha^{-1}		41.75
Change in production yield in % to control, %		111.09
Change in costs per 1 ha to the control variant, rubles		5,250
Change in costs per 1 ha to the control variant, in %		102.52
Cost of 1t of production yield, rubles	5,533.09	5,106.36
Change in the cost of 1 t to control, rubles		-426.73
Change in the cost of 1 t to control, %		-7.71
Actual selling price of potato, rubles/t	10,400	10,400
Estimated revenue from 1 ha, rubles	391,625	435,045
Profit from 1 ha, rubles	183,270	221,440
Increase in profit from 1 ha in comparison with control, %		20.83
Increase in profit from 1 ha in comparison with the control, rubles		38,170
Profitability, %	87.96	103.67
Change in profitability to control, % (+, -)		15.71

Profitability, calculated as the ratio of profit to actual costs, according to control was 87.96%, according to experiment - 103.67%, showing an increase of 15.71%.

We will calculate the indicators of economic efficiency, with the condition that the entire sown area of 300 hectares was sown with potato, and fertilizers were treated with Nutricharge.

Let's determine the volume of additional products that could be obtained by using the entire sown area, having previously transferred the increase in yield from c ha^{-1} to t ha^{-1}:

$$Add.products = Selling\ price \cdot S^2_{sowing} \cdot Increase\ Yi_{prod.}$$
$$= 10{,}400 \text{ rubles} \cdot 300 \text{ ha} \cdot 4{,}175\ t\ ha^{-1} = 13{,}894{,}400 \text{ rubles}$$

We will calculate the additional costs of processing fertilizers for 300 hectares:

$$Add.\text{costs} = \text{Cost of Nitricharge per 1 ha, rubles} \cdot S^2_{sowing} = 5{,}250 \text{ rubles} \cdot 300 \text{ ha}$$
$$= 1{,}680{,}000 \text{ rubles}$$

Additional costs to the total cost as a percentage will amount to 2.52%.

The cost of the potato harvest at the selling price of all products made will be:

$$V_{act} = Bulk\ yield, \text{t} \cdot Selling\ price\ 1 \text{ t} = 12{,}050 \text{ t} \cdot 10{,}400\ rubles = 125{,}320{,}000 \text{ rubles}$$

Let's determine the actual amount of profit as the difference between revenue and costs:

$$Pr = V - C = 125{,}320{,}000 \text{ rubles} - 62{,}653{,}598 \text{ rubles} = 58{,}646{,}302 \text{ rubles}$$

Let's determine the estimated cost of the crop when processing fertilizers with Nutricharge as the sum of the volume of additional products and the cost of the crop at the selling price, we get 13,894,400 rubles + 125,320,000 rubles = 139,214,400 rubles.

We will find a profit when using Nutricharge for the entire sown area of potato:

$$Pr = V - C = 139{,}214{,}400 \text{ rubles} - 62{,}653{,}598 \text{ rubles} - 1{,}680{,}000 \text{ rubles}$$
$$= 70{,}860{,}702 \text{ rubles}$$

The increase in profit as a percentage of the original variant will be (70,860,702 rubles / 58,646,302 rubles) * 100 - 100 = 20.83%

The estimated additional profit will be equal to 13,894,400 rubles - 1,680,000 rubles = 12,214,400 rubles.

Results of experiment No. 2 with the treatment of fertilizers with Nutricharge and Growgreen

We will carry out the same calculation of indicators as in the previous paragraph. The results are presented in Table 3. Let's determine how the processing of fertilizers with Nutricharge and Growgreen will affect the economic results.

The difference in actual costs per 1 hectare of sown area between control and experiment amounted to 8,750 rubles, of which the cost of Nutricharge amounted to 5,250 rubles, the cost of Growgreen - 3,500 rubles. The change in costs in percentage terms increased by 4.2%.

According to the second experiment, the obtained biological yield exceeds the control data by 237.5 c ha^{-1}, increasing from 554.5 c ha^{-1} to 792 c ha^{-1} (42.83%). At the same time, the yield in the second experiment turned out to be higher than the yield in the first experiment by 154 c ha^{-1}, i.e. by 24.13%.

The conducted field experiment No. 2 and the analysis of the experimental data obtained, gives us reason to say that the use of Nutricharge and Growgreen biopolymers are effective and their scale needs to be increased and distributed throughout the Non-Chernozem zone of Russia.

The production yield in the second experiment was also adjusted by 50% of the biological yield increase, since no measurement was made on the site. The change in the production yield according to experiment in comparison with the control shows an increase of 118.75 c ha^{-1}, which is 31.54%.

Table 3. Data from experiment No. 2 with the processing of ammonium nitrate phosphate fertilizers with Nutricharge and Growgreen for sowing potato in the agricultural complex Collective Farm n.a. Lenin (Ryazan region) in 2020

Indicators	Agricultural complex Collective Farm n.a. Lenin Kasimovsky district	
	Potato	
	control	experiment
Applied on 1 ha on the experimental plot, kg	700	700
Actual costs per 1 ha, rubles	208,355	217,105
Including: Actual cost of fertilizers applied for the crop, including work in progress, rubles	23,532	23,532
Of these: The cost of fertilizers per 1 ha in experiment, rubles	14,000	14,000
The cost of Nutricharge per 1 ha, rubles	0	5,250
The cost of Growgreen per 1 ha, rubles	0	3,500
Total: including the cost of fertilizers, Nutricharge and Growgreen per 1 ha in the experiment	14,000	22,750
Biological yield, c ha^{-1} (Gala variety) (Act)	554.5	792
The difference in the yield of experiments in comparison with the control, (+,-), c ha^{-1}	-	237.5
Change in biological yield in % to control, %	-	142.83
Production yield (adjusted in the experiment by 50% of the increase in biological yield)	376.56	495.31
Increase in production yield, c ha^{-1}	-	118.75
Change in production yield in % to control, %	-	131.54
Change in costs per 1 ha to the control variant, rubles	-	8,750
Change in costs per 1 ha to the control variant, in %	-	104.20
Cost of 1t of production yield, rubles	5,533.09	4,383.20
Change in the cost of 1 t to control, rubles	-	-1,149.89
Change in the cost of 1 t to control, %	-	-20.78
Actual selling price of potato, rubles t^{-1}	10,400	10,400
Estimated revenue from 1 ha, rubles	391,625	515,125
Profit from 1 ha, rubles	183,270	298,020
Increase in profit from 1 ha in comparison with control, %	-	62.61
Increase in profit from 1 ha in comparison with the control, rubles	-	114,750
Profitability, %	87.96	137.27
Change in profitability to control, % (+, -)	-	49.31

The cost of production of 1 ton of potato using Nutricharge and Growgreen decreased by 1,149.89 rubles, which amounted to 20.78%.

With the potato selling price of 10,400 rubles per 1 ton, the estimated revenue from 1 ha for control amounted to 391,625 rubles, according to experiment - 515,125 rubles. The excess in revenue amounted to 123,500 rubles per 1 ha or 31.5%.

In terms of profit, the difference between control and experiment amounted to 114,750 rubles per 1 ha of area, or 62.61%.

The profitability of production showed an increase from 87.96% by control to 137.27% by experiment, i.e. the difference is 49.31%.

The use of Nutricharge and Growgreen drugs showed greater effectiveness in comparison with the use of Nutricharge alone.

For example, the complex use of drugs allowed to reduce the cost of production of 1 ton of potato: in the first experiment it amounted to 5,106.36 rubles, in the second - 4,383.20 rubles (change of 723.16 rubles). The revenue received from the sale of potato according to experiment No. 1 amounted to 435,045 rubles per 1 ha, whereas in experiment No. 2 - 515,125 rubles. The difference is 80,080 rubles per 1 ha. Cost reduction and revenue increase in the second experiment allowed to make a profit from 1 ha of 298,020 rubles, and in the first - 221,440 rubles, i.e. 34.5% more. The difference in profitability is significant: experiment No. 1 - 103.67%, experiment No. 2 - 137.27%, i.e. 33.6%.

We will calculate the economic efficiency indicators of the results of the use of Nutricharge and Growgreen for the entire potato planting area and compare them with the indicators from the first experiment (Table 4).

Table 4. Calculation of the expected results of the use of Nutricharge and Growgreen for the entire area of potato planting and comparison with experiment No. 1

Indicator	Experiment No. 1	Experiment No. 2	Change of indicators
The use of drugs for the entire area of potato planting would allow to obtain additional products, rubles	13,894,400	39,520,000	25,625,600
Additional costs for processing fertilizers for 320 ha (estimated calculation), rubles	1,680,000	2,800,000	1,120,000
As a % of total costs	2.52	4.20	1.7
Calculated cost of the crop when processing fertilizers with drugs, rubles	139,214,400	164,840, 000	25,625,600
Cost of the crop increase, rubles	13,894,400	39,520,000	25,625,600
Calculated net profit when using drugs for the entire planting area, potato, rubles	70,860,702	95,366,302	24,505,600
Net profit increase in % to the original variant	20.83	62.61	41.78
Calculated additional net profit, rubles	12,214,400	36,720,000	24,505,600

Higher yields and lower cost of production according to the second experiment allowed to obtain high indicators of economic efficiency. Thus, the cost of additional potato production according to experiment No. 2 exceeded the additional production volume according to experiment No. 1 by 25,625,600 rubles (almost 3 times). The volume of additional costs in the second experiment increased by 1,120,000 rubles in comparison with the first experiment, which is approximately 67%. Net profit is higher according to experiment No. 2 by 24,505,600 rubles in comparison with the first experiment. The increase in net profit in the second experiment is 41.78% more than in the experiment No. 1.

As is known in the scientific world, as a criterion of the truth and falsity of scientific knowledge, a scientific statement or phenomenon is determined by two positivism principles. The first is the principle of verification (verifiability) of a hypothesis, theory, and the second is the principle of falsification (refutation) of a hypothesis, theory. Everything must be confirmed by economic practice. Following this statement, we decided to check, by conducting scientific field experiments, how promising and effective the actions we are conducting are, as a result of the use of biochemical polymers Nutricharge and Growgreen to increase yields and production efficiency of potato crops in production conditions.

Treatment of ammonium nitrate phosphate fertilizer with Nutricharge during potato cultivation provides a significant improvement in production and economic indicators: potato yield increased from 554.5 c ha^{-1} to 638 c ha^{-1}, which is 15% in percentage terms. There was a decrease in cost by 1,149.89 rubles, which amounted to 20.78%, the excess in revenue was 123,500 rubles from 1 ha or 31.5%, in profit terms, the difference between control and experiment was 114,750 rubles from 1 ha of area or 62.61%. An even more tangible result is obtained with the combined use of processed fertilizers and leaf dressing Growgreen.

In modern conditions, the entire mechanism of agricultural production is aimed at ensuring the economic efficiency of production, often neglecting product quality and environmental safety. In their studies, agricultural scientists I. Ushachev, I. Trubilin, E. Ogloblin, and a number of other authors note that the most promising direction for solving this problem is the use of environmentally friendly mineral fertilizers (Ushachev et al., 2017). These statements cause certain discussions, disputes and discussions of the designated problem. The use of new generation biopolymers 'Nutricharge' and 'Growgreen' in the process of potato production confirms the correctness of this direction.

S. Khromov, R. Lipsky, S. Manzhina, and a number of other specialists involved in the study of the effect of mineral fertilizers on the soil environment, in their studies argue and prove that such an important and rather expensive element of plant nutrition as phosphorus, when it enters the soil in the form of mineral fertilizers, it precipitates into a water-insoluble precipitate and becomes inaccessible to plants. According to various sources, from 75 to 95% of this element is blocked in the soil solution in an insoluble form for the growth and development of crops, and the introduction of ammonium sulfate, a much-needed mineral fertilizer for plants, also causes problems in the digestibility and availability of such elements as nitrogen and sulfur. Processing of mineral fertilizers with biopolymers 'Nutricharge' and 'Growgreen' due to a specially developed microbial production process that repeats natural soil processes, transforms nutrients into a 100% available form for crops (Khromov, 2017; Lipsky, 2014; Manzhina, 2017; 'ARTEL' LLC, 2017). Thus, we can conclude that the treatment of mineral fertilizers with biopolymers 'Nutricharge' and 'Growgreen' increases the productivity of crops, which was proved in the course of our experiments No. 1 and No. 2.

The authors represented by V. Bulgakov, O. Adamchuk, S. Pascuzzi in their studies suggest that the use of biological products based on living beneficial microorganisms, in combination with mineral fertilizers, has a positive effect on the absorption and availability of such an important element of phosphorus for growth and development of plants, increase the beneficial micro flora in the soil (Bulgakov et al., 2021).

Also noteworthy are the studies by O. Chernikova, T. Seregina, Yu. Mozhaisky, S. Buryak, who argue that when using mineral fertilizers and other biological products, it is necessary to take into account a number of technical and operational characteristics of machines and equipment, their acquisition, paying attention to the possibility of using digital settings. These conditions will contribute to the normative-dosed consumption of the applied mineral fertilizers and biological products, to provide the soil environment with the necessary plant nutrients. (Chernikova et al., 2021).

After a comprehensive review and analysis of a scientific statement or phenomenon, everything must be confirmed by economic practice. Following this statement, we decided to check, by conducting scientific field experiments, how promising and

effective is the use of biochemical polymers 'Nutricharge' and 'Growgreen' in terms of increasing yields and increasing the production efficiency of potato crops under production conditions.

The results obtained during the study proved that the scientific hypothesis put forward by us, the theory (the use of biochemical polymers Nutricharge and Growgreen for the effective cultivation of Gala potato variety) was true and correct. It has been proven by production and economic practice, by conducting a number of scientific field experiments. This is clearly evidenced by the obtained production and economic indicators of the Gala potato variety cultivation.

CONCLUSIONS

During the research, we determined that the use of biodegradable polymers to improve the absorption of minerals and fertilizers by plants is one of the promising areas. So far, in the agriculture of the Russian Federation, they have not yet been widely introduced and used in the production of agricultural products.

The use and implementation of biochemical polymers, as we see from application technology and the experiments carried out, will contribute to the production of environmentally friendly products, without negative environmental consequences, primarily on the soil and the environment. It is also necessary to note the economic component of the experiment, from economic calculations we see that the use of biochemical polymers will contribute to the growth and increase in crop production, and this affects the indicators of increasing the efficiency of potato production.

According to the obtained economic indicators, using the monographic method of economic research, it can be concluded that the profitability of potato production increases when fertilizers are processed with Nutrichage and Growgreen. If in the first case, the use of only Nutricharge made it possible to obtain an increase in profitability by 15.71%, then in the second case, the increase was already 49.31% compared to the control.

The next conclusion to be noted from our study is that Nutricharge and Growgreen appeared on the Russian market relatively recently - only 4 years; now, after receiving verified data on the effectiveness of their use, the question of promoting this product and introducing the use of a new technology for processing mineral fertilizers for other agricultural producers arises. As it was defined in the introduction, the main feature in agriculture when spreading innovations is that this innovation needs to be spread to hundreds and even thousands of producers

Based on the study, the following directions for the effective development of agribusiness can be outlined:

– distribution and implementation of this innovative tool among agricultural producers, considering the peculiarities of their agro-climatic conditions;

– prospects for the use of Nutricharge and Growgreen in the Non-Chernozem zone of Russia;

– the use of biochemical polymers, together with legumes in the crop rotation system, which will increase the production efficiency of other agricultural crops, and in particular such demanded crops as cereals (winter and spring wheat), grain products, which play a crucial role in the world grain market.

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