Comparative evaluation of the calculated norms of mineral fertilizers interaction effectiveness with various bioagents and adaptogenic preparations on crops cruciferous oilseeds

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Abstract. Studies conducted as part of the Federal target program "Research and Development in Priority Directions for the Development of the Russian Science and Technology Complex for 2014–2020", showed high efficiency of interaction of calculated norms of mineral fertilizers with modern bioagents RECB-50B, RECB-95B and adaptogenic drugs. At the same time, the actual yield of spring rapeseed of the Gedemin variety exceeds the planned one (3 t/ha) by 9.3–12.3 %, respectively, the chemical load on the environment is reduced and the cost of production of oilseeds is reduced.

1 Introduction

The increase in the production of oilseeds due to the cultivation of spring rape, white mustard, etc., most adapted to the soil and climatic conditions of the Republic of Tatarstan, in modern conditions should be solved by the use of biological products that are environmentally and economically feasible and justify the work of farmers. Among these priorities, of course, is the implementation of a comprehensive program for the development of biotechnology, approved by the President of our country V.V. Putin on April 24, 2012. It is aimed at reducing costs in the production of competitive, environmentally friendly food products based on the widespread use of fertilizer-stimulating compounds, modern organic mineral nutrient solutions containing easily digestible amino acids, chelated forms of micronutrient fertilizers and biological preparations.

In this regard, the issues of the interaction of the calculated norms of mineral fertilizers with biological active substances in the technology of cultivating cruciferous oil crops, which are considered in this work, are not only relevant, but also significant from both theoretical and practical points of view.

2 Research Program and Methodology

The studies were conducted on the experimental field of the Chistopol State Plot of the Republic of Tatarstan. Location of the plot: latitude – 55.3768737233; Longitude – 50.7433859300.

The humus content was 5 % (according to Tyurin), mobile phosphorus 250 and exchange potassium 147 mg/kg of soil (according to Chirikov). The soil of the experimental plot was characterized by a low boron content (0.17–0.19), medium — copper (2.8–3.8), and higher than average molybdenum (0.20–0.29 mg/kg of soil). The amount of absorbed bases was at the level of 34.9–35.2 mg/equiv. Per 100 g of soil, the degree of saturation with bases is 83–85 %, the lowest moisture capacity is 28–30 %, the density of soil compaction is 1.18–1.21 g/cm^3, the content of water-resistant aggregates from 0.10 to 0.25 mm in size ranged from 44.8 to 45.1 %. The pH of the salt extract is 6.4–6.5.

Consequently, the agrochemical characteristic of the soil of the experimental plot corresponds to typical leached chernozems, which occupy 39 % of the arable land of our republic.

The precursor of the research object was pure steam. In the experiment, a cultivar of spring rape of the Belorussian selection Gedemin was cultivated. Mineral fertilizers were applied as a general background before sowing with the expectation of a planned yield of 3.0 t/ha of oilseeds of the studied crop. The repetition of the experiment is fourfold, the plot area is 32 m^2.

The following microorganism strains were used in the studies:

- RECB-95 B (Bacillus subtilis);
- RECB-50 B (Bacillus spp.).

Seed treatment with the bioagents was carried out on the day of sowing, and foliar top dressing was performed in the phase of 3-4 pairs of real spring rape leaves.

An extract from millet sprouts was used as an adaptogen. The studies were carried out with financial support from the Ministry of Education and Science of the Russian Federation in the framework of the Federal Target Program "Research and Development in Priority Directions for the Development of the Russian Science and Technology Complex for 2014–2020", agreement number 14.610.21.0017, and a unique project identification number is RFMEFI61017X0017.

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Field experiments were carried out in accordance with the methods described in the works of V.F. Moiseichenko [1] and V.M. Lukomets [2]. Statistical processing of research results was carried out by the method of variance analysis [3].

3 Results

Among the microorganisms used to protect plants, an important place is occupied by bacteria from the genus Bacillus, which were included in the composition of the studied bioagents. They, according to RI Safina [4], T.V. Zharekhina [5], R.M. Nizamova [6] exhibit antagonistic activity against a significant number of plant pathogens. Bacillus bacteria also positively affect the immunity of agricultural crops [7, 8]. In addition, the symbiosis between plants and microorganisms (plants provide them with carbohydrates) is clearly manifested in the field germination of spring rape seeds [9, 10] (Table 1).

Table 1. The effect of bioagents and adaptogens on field germination of spring rape

Experience option	Field germination, pcs/m^2		Increase	
	pcs/m^2	%	pcs/m^2	%
The control	140	56	-	-
Kruiser, 15.0 l/t (seed treatment)	168	67	28	20.0
Risoplan, 1.0 l/t (seed treatment) + Risoplan, 1.0 l/ha (spraying of plants)	170	68	30	21.4
RECB-95 B, 2.0 l/t (seed treatment) + RECB-95 B, 1.0 l/t (spraying plants)	170	68	30	21.4
RECB-50 B, 2.0 l/t (seed treatment) + RECB-50 B, 1.0 l/t (spraying plants)	173	69	33	23.6
RECB-95 B, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-95 B, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	178	71	38	27.1
RECB-50 B, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-50 B, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	180	72	40	28.6
Kruiser, 15.0 l/t (seed treatment) + RECB-95 B, 1.0 l/t (spraying of plants)	175	70	45	25.0
Kruiser, 15.0 l/t (seed treatment) + RECB-50 B, 1.0 l/t (spraying plants)	175	70	45	25.0
LSD_{05}	12,1			

So, in the control variant of the experiment, 140 out of 250 sown seeds emerged (56 % field germination). Under the same conditions, under the influence of pre-sowing treatment of seeds with the studied drugs, the field germination of the object of study increased to 170–180 pcs/m^2. At the same time, the RECB-50 V + adaptogen variant with 72 % field germination was distinguished. In this experiment, the field germination rate of spring rape is increased by 28.6 % compared with the control. Such a sharp increase in field germination of this crop is apparently because the supply of nutrients in the seeds provides shoots from the soil depth of 2–3 cm. In this regard, without additional nutrients that are present in bioagents in easily digestible form to the seeds, once in a depth of more than 3 cm, there is simply not enough energy to germinate to the surface.

This explains the low field germination of the studied crop (from 56 to 72 %) compared with spring crops (82–85 %), since the adopted technology for pre-sowing cultivation of soil and modern seeders do not provide a uniform incorporation of small seeds of spring rape for optical shallow depth.

The intensity of dense stem formation depends not only on field germination, but also to a greater extent on the sprouts growth rate. The sprouts growth power is a quick transition of plants to autotrophic nutrition. It is determined by the dry mass of the studied culture in the phase of 2 pairs of true leaves of tenfold repetition (table. 2).

As the research results show, in addition to field germination, presowing treatment of seeds with the studied bioagents and adaptogenic preparations has a great influence on the sprouts growth rate. In this regard, a comparative evaluation of Risoplan, RECB-95 V and RECB-50 V shows the advantage of RECB-50 V + adaptogen. At the same time, the dry mass of spring rape in the phase of 2 pairs of true leaves increased to 0.22 g/plant versus 0.16 g/plant in the control (38 % higher than the control).

When analyzing the plant growth power, it turned out that the value of adaptogen is also significant. So, the difference between the analyzed value between the control and seed treatment with the bioagents RECB-95 V and RECB-50 V was only 0.01 g/plant, while the addition of the adaptogen to the same working solution at the rate of 1 l/t of seeds ensured an increase of 0.04 and 0.06 g/plant, respectively.

There is a direct correlation between the plant growth power and the formation of the root system of spring rape, the faster the plants switch to autotrophic nutrition, the higher the intensity of growth and development of the root system (Table 3).

Spring rape sowing was carried out in the first decade of May, May 16 – the date of the appearance of the first sprouts, after 25 days the budding phase began and after another 20 days – the flowering phase. The last phase of development is the ripening of seeds 1.5–2.0 months after flowering.

Table 2. The growth rate of sprouts of spring rape, depending on the method of seedbed preparation

Experience option	The sprouts growth rate g/plant in the phase of 2 pairs of true leaves	Increase	
		g/solution	%
The control	0.16	–	–
Kruiser, 15.0 l/t (seed treatment)	0.17	0.01	6
Risoplan, 1.0 l/t (seed treatment) + Risoplan, 1.0 l/ha (spraying of plants)	0.17	0.01	6
RECB-95 B, 2.0 l/t (seed treatment) + RECB-95 B, 1.0 l/t (spraying plants)	0.18	0.02	13
RECB-50 B, 2.0 l/t (seed treatment) + RECB-50 B, 1.0 l/t (spraying plants)	0.18	0.02	13
RECB-95 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	0.20	0.04	25
RECB-50 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	0.22	0.06	38
Kruiser, 15.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t (spraying of plants)	0.19	0.03	19
Kruiser, 15.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t (spraying plants)	0.19	0.03	19

Table 3. The effect of bioagents and adaptogenic preparations on the growth and development of the root system of spring rape (active soil layer, cm)

Experience option	Sowing – sprouts	Sprouts – budding	Budding – Flowering	Flowering – ripening
The control	5.3	20.3	23.8	24.6
Kruiser, 15.0 l/t (seed treatment)	5.6	21.8	24.1	25.0
Risoplan, 1.0 l/t (seed treatment) + Risoplan, 1.0 l/ha (spraying plants)	5.7	22.1	24.6	25.4
RECB-95 V, 2.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t (spraying plants)	6.0	22.7	24.9	26.1
RECB-50 V, 2.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t (spraying plants)	6.1	22.9	25.0	26.6
RECB-95 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	6.8	24.4	26.6	27.0
RECB-50 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	7.2	25.1	27.8	28.2
Kruiser, 15.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t (spraying plants)	6.2	24.7	26.4	27.0
Kruiser, 15.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t (spraying plants)	6.4	24.8	26.7	27.2

In each development phase, the depth of the active soil layer (the soil layer in which the bulk of the roots are located) was determined. During the measurements, it was revealed that the root system of spring rape in the initial stage develops extremely slowly. In the “sowing-sprouts” phase, roots occupy from 5.3 in the control, up to 7.8 cm of the soil layer in the variant with seed treatment RECB-50 B + adaptogen.

More intensive root growth occurs during the budding and flowering phases of spring rape. Without presowing seed treatment, the increase is 15–18.5 cm, and in the variants using bioagents and adaptogens in 2 doses, the active soil layer increases to 26.6–27.8 cm. Moreover, the individual roots of spring rape penetrate to a depth of more than 100 cm, extracting additional nutrients and moisture.

The accelerated transition of plants to autotrophic nutrition of a large number of sprouts obtained, the formation of a deeply penetrating root system due to pre-sowing seed treatment and additional non-root top dressing with biological preparations contributed to the formation of up to 42–48 thousand m^2/ha of leaf rape spring rape plants with a height of 117–125 cm.

As a result, spring rape fruit elements, depending on the studied methods of using biologics, differed both from control (without presowing seed treatment) and traditional seed inlay (Kruizer 15 l/t) according to the following features (Table 4):

- the number of productive pods increased from 30 pcs/plant in the control to 40 on the variant RECB-50 V (2.0 l/t of seeds) + adaptogen (1.0 l/t) + RECB-50 V (1.0 l/ha);
- the number of seeds in the pod in this experiment exceeded the control by 23 %;
- the density of the grass stand before harvesting reached a maximum value of 152 pcs/m^2;
- the mass of 1000 seeds were 3.22 g against 3.15 in the control;
- biological yield from the use of RECB-50 V in two doses (pre-sowing treatment in combination with an adaptogen and foliar application) exceeded the control by 86 % (5.20 against 2.8 t/ha in the control).

Before proceeding with the analysis of the gross yield of rapeseed oilseeds (actual yield), three factors should be noted:

- firstly, in May 2019, precipitation fell 86 % more than the average long-term indicators. During the formation of pods (July), the moisture supply was within normal limits (95 mm), and during oilseed loading a record amount of precipitation fell (103 % higher than normal);
- secondly, the average daily air temperature in July and August was 1 ниже lower, which became the main factor in restraining the growth of many pests of spring rape.

And, finally, the formation of a dense tall agrocenosis contributed to the displacement of weeds from the herbage.

As a result of the merger of the above 3 favorable factors, it led to the formation of yields of oilseeds of spring rape higher than planned (Table 5).

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Table 4. Structure and biological productivity of spring rape

Experience option	Number of products pods, pcs\sol	The number of seeds in the pod, pcs.	Number of plants before harvesting, pcs/m^2	The mass of 1000 seeds, g	Biological productivity, t/ha
The control	30	22	129	3.15	2.80
Kruiser, 15.0 l/t (seed treatment)	30	23	135	3.18	2.96
Risoplan, 1.0 l/t (seed treatment) + Risoplan, 1.0 l/ha (spraying plants)	31	23	136	3.18	3.01
RECB-95 V, 2.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t (spraying plants)	33	24	149	3.20	3.77
RECB-50 V, 2.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t (spraying plants)	34	24	158	3.20	4.12
RECB-95 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	38	26	151	3.21	4.78
RECB-50 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	40	27	150	3.21	5.20
Kruiser, 15.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t (spraying plants)	34	25	150	3.19	4.06
Kruiser, 15.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t (spraying plants)	34	25	150	3.20	4.24

Table 5. The effectiveness of the use of bioagents and adaptogenic drugs in crops of spring rape

Experience option	Actual oilseed productivity, t/ha	Increase	
		t/ha	%
The control	2.24	–	–
Kruiser, 15.0 l/t (seed treatment)	2.40	0.16	7.1
Risoplan, 1.0 l/t (seed treatment) + Risoplan, 1.0 l/ha (spraying plants)	2.46	0.22	9.8
RECB-95 V, 2.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t (spraying plants)	2.82	0.58	25.9
RECB-50 V, 2.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t (spraying plants)	3.15	0.91	40.6
RECB-95 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	3.28	1.04	46.4
RECB-50 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	3.37	1.13	50.4
Kruiser, 15.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t (spraying plants)	3.06	0.82	36.6
Kruiser, 15.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t (spraying plants)	3.19	0.96	42.4
LSD05	0.16		

Table 6. Economic efficiency of the interaction of calculated norms of mineral fertilizers with bioagents from the RECB group and adaptogenic preparations in the production of rapeseed oilseeds

Experience option	The cost of gross output, thousand rubles/ha	Total costs, thousand rubles/ha	Net profit, thousand rubles/ha	Profitability, %	Cost of 1-ton oilseeds, thousand rubles
The control	44.8	31.6	13.2	41.8	14.1
Kruiser, 15.0 l/t (seed treatment)	48.0	33.2	14.8	44.5	13.8
Risoplan, 1.0 l/t (seed treatment) + Risoplan, 1.0 l/ha (spraying plants)	49.2	33.9	15.3	45.1	13.8
RECB-95 V, 2.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t (spraying plants)	56.4	38.1	18.3	46.8	13.5
RECB-50 V, 2.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t (spraying plants)	63.0	40.3	22.7	56.3	12.8
RECB-95 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	65.6	40.5	25.1	62.0	12.3
RECB-50 V, 2.0 l/t + adaptogen, 1.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t + adaptogen, 1.0 l/ha (spraying plants)	67.4	41.0	26.4	64.4	12.2
Kruiser, 15.0 l/t (seed treatment) + RECB-95 V, 1.0 l/t (spraying plants)	61.2	39.7	21.5	54.2	13.0
Kruiser, 15.0 l/t (seed treatment) + RECB-50 V, 1.0 l/t (spraying plants)	63.8	40.1	23.7	59.1	12.6

So, pre-sowing seed treatment with RECB-50 V + working solution adaptogen and foliar application with the same preparations provided the yield of spring rape 3.37 t/ha, which is 12.3 percent higher than the estimated yield. The yield increase to the control experiment was 1.13 t/ha (50.4 %).

At the same time, a significant decrease in the effectiveness of the classic seed dresser of Kruizer cruciferous oilseeds should be emphasized, which is associated with an increase in the resistance of cruciferous fleas, cabbage moths, rapeseed beetle, stalked secretive hunter, cruciferous sawfly and many others. etc.

It is precisely for this reason that the efficiency of pre-sowing seed treatment by Kruiser at the rate of 15 l/t of seeds in relation to the control is only 7.1 % versus 36.6–42.4 % with the addition of RECB-95 V or RECB-50 V.

Reducing the costs of protecting plants from diseases and pests, increasing the efficiency of applying the calculated norms of mineral fertilizers undoubtedly had a great influence on the economic indicators of the production of rapeseed oilseeds (Table 6).

Of particular note is the high profitability of the production of rapeseed oilseeds in the soil-climatic conditions of the Republic of Tatarstan (from 41.8 to 64.4 %), which is associated with the price of its sale (20 thousand rubles/t) against 8-10 thousand rubles/tons of spring wheat grain).

Even under such favorable conditions for cultivating this crop, the difference in net profit from using RECB – 50 V in combination with the adaptogen in two doses increases to 26.4 thousand rubles/ha against 14.8 thousand rubles/ha Kruiser seed treatment at the rate of 15 l/t (78.4 % increase).

However, the difference in the cost of production of 1 ton of oilseed between the above compared options is reduced and amounts to only 15.6 %, which is associated with the costs of cleaning, transportation, sorting and drying of additional crops.

Nevertheless, from the sale of each ton of products to the cash register of the economy, from 5.9 to 7.8 thousand rubles of cash.

4 Conclusion

In order to reduce the chemical load on the environment, save money, fully realize the potential possibility of calculated norms of mineral fertilizers on leached chernozems of the Republic of Tatarstan in order to obtain 3.28–3.37 t/ha of oilseeds of spring rape, it is recommended to pre-sow seeds with strains of RECB-50 V (2.0 l/t) or RECB-95 V (2.0 l/t) in combination with leaf dressing in the phase of 3–4 pairs of real leaves with the same strains (norm 1.0 l/ha consumption) with the addition of an adaptogenic preparation .

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