Productivity and quality indicators of potato tubers using bioagents and adaptogenic drugs

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Abstract. Studies to identify the effectiveness of bioagents and adaptogenic preparations on plantings of potatoes of the Vineta variety were carried out on gray forest medium loam granulometric composition of the soil of the Zemlyaki farm in the Nizhnekamsk district of the Republic of Tatarstan. Field experiments were carried out in 2019 by employees of the Department of Plant Growing and Horticulture of Kazan State Agrarian University. The humus content in the arable layer of soil according to Tyurin is 3.35 %, pH is 5.7, easily hydrolyzable nitrogen is 112 mg/kg of soil, mobile phosphorus is 156 mg/kg, exchange potassium is 136 mg/kg of soil, molybdenum is 0.07, copper is 0.52, boron – 0.7, zinc – 4.82 mg/kg. The paper presents the results of studies on the effect of the preparation RECB-95B obtained on the basis of bacteria *Bacillus subtilis*, RECB-44 – *Pseudomonas fluorescens*, RECB-50B – *Bacillus* sp. and RECB-74B — derived from the fungus *Trichoderma viride* for antagonistic activity against pathogens. Based on the results of our preliminary studies, we selected these preparations for preplant treatment of tubers and vegetative plants. It was found that the most effective option for planting potatoes was the treatment of tubers before planting with the strain RECB-50B (2 l/t) + adaptogen in combination with three times spraying during the growing season RECB-95B, RECB-4B, RECB-50B using them together with adaptogen. Our data show that the mass of tubers does not always correspond to the number of stems and tubers, however, in variants 7 and 8 with a high mass of tubers, a larger number of stems and tubers per bush was noted. Less nitrates 73 mg/kg contained tubers from the variant when used for processing tubers of strain RECB – 50 B (2 l/t) and triple treatment of plants during the growing season with bioagents RECB – 95 B (0.5 l/ha), RECB – 44 B (0.5 l/ha), RECB – 50 B (1.0 l/ha). The use of these drugs in conjunction with the adaptogen led to an increase in the number of nitrates in the tubers. A higher starch content in tubers of 13.02 and 13.01 % was observed when treating the tubers of the drug Maxim (0.2 l/t) and strain RECB – 50 B (2 l/t) and triple treatment of plants during the growing season with bioagents RECB – 95 B (0.5 l/ha), RECB – 44 B (0.5 l/ha), RECB – 50 B (1.0 l/ha). In the dry matter, the starch content was higher when the tubers were treated with rhizoplan and amounted to 63.38 %.

1 Introduction

Potato harvest is formed during photosynthesis, meaning in the process of absorbing light and transforming its energy into the chemical potential of energy-rich organic compounds in the form of carbohydrates, fats, proteins. The productivity of potato plants largely depends on photosynthetic activity. This includes many indicators and the dynamic ratio of leaf area, the duration of their life, the intensity of the photosynthesis process itself. The most important factors affecting the growth and development of plants is solar radiation, which is the energy basis of plant life. This factor, unlike others, such as mineral nutrition, water and temperature conditions, carbon dioxide content is the most difficult to control.

Based on the data obtained, several researchers note that the optimal leaf area is 30-40 thousand m²/ha, at which the proportion of absorbed solar energy increases significantly. In the works of other researchers, the best results were obtained with leaf areas of 50 and more than

thousand m²/ha. However, they note that excessive excess of the leaf area from the optimal level leads to a decrease in crop accumulation per unit area of leaves.

Crop production, including the cultivation of potatoes in modern conditions, is carried out in conditions of global natural and man-made pressure. It is associated with significant climate change, xenobiotic pollution, and unsustainable moisture supply. As a result, there is a decrease in sown areas, a decrease in plant resistance to adverse environmental factors, and the formation of resistant strains of pathogenic microorganisms.

One of the main directions contributing to the improvement of the environmental situation is the use of biological preparations that can stimulate the immune system and increase resistance to diseases. The basis of biofungicides is composed of strains of rhizospheric bacteria *Bacillus subtilis*, which during their growth can synthesize substances that inhibit the development of phytopathogenic fungi and bacteria that are causative agents of plant diseases [1, 2].

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It has now been established that biological preparations increase plant resistance to adverse environmental factors and various fungal diseases. Along with this leads to increased crop yields [3–5].

In this regard, in the laboratory of the Kazan State Agrarian University, innovative research and production studies of biological preparations are developed and carried out, which will raise the potato industry to a higher level.

2 The purpose and objectives of research

The aim of the work is the theoretical justification and development of practical methods for pre-planting treatment of potato seeds in combination with leaf dressing of vegetative plants with bioagents and adaptogenic preparations for planting potatoes of the Vineta variety.

To achieve this goal, the following tasks were envisaged:

- conduct a comparative assessment of the effect of doses of mineral fertilizers and biological products on the yield and quality of potato tubers.

3 Research Program and Methodology

The studies were conducted on gray forest medium loam granulometric composition of the farm Zemlyaki of the Nizhnekamsk district of the Republic of Tatarstan. The humus content in the arable layer of soil according to Tyurin is 3.35 %, pH is 5.7, easily hydrolyzable nitrogen is 112 mg/kg of soil, mobile phosphorus is 156 mg/kg,

exchange potassium is 136 mg/kg of soil, molybdenum is 0.07, copper is 0.52, boron – 0.7, zinc – 4.82 mg/kg.

The predecessor of the facility was winter wheat. In the experiment, a cultivar of Vineta potato was cultivated. Mineral fertilizers (nitroammophosk 2 c/ha + ammonium nitrate 1 c/ha) were introduced during planting. An extract from millet seedlings was used as an adaptogen.

For planting, seed tubers of the first reproduction with a mass of 60...65 g were used. Aisle spacing was 75 cm, planting density was 44.33 thousand tubers per ha (30×75 cm). Planting depth 10...12 cm, the total area of the plot was 72 m², accounting 60 m². Autumn soil preparation consisted of stubble cultivation with disc cultivators to a depth of 6...8 cm after harvesting the predecessor, and after 10...12 days plowing with reversible plows. In spring, milling vertically with a milling cultivator Zirkon – 7/300. Planting was performed with a four-row potato planter Hassia SL 4 BZS.

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The studies were carried out in accordance with the methods described in the textbooks of V.F. Moseychenko, M.F. Trifonova, A.Kh. Zaveryukha, V.E. Yeshenko [6], V.V. Glukhovtseva, V.G. Kirichenko, S.N. Zudilin [7]. Statistical processing of research results was carried out by analysis of variance [8].

Table 1. Scheme of treatment of tubers before planting and plants during the growing season

Processing Option Tuber Processing	Spraying potatoes in the growing phase		
	1 treatment	2 treatment	3 treatment
1. Control	–	–	–
2. Maxim, 0.2 l/t (treatment of tubers).	–	–	–
3. Biological preparation (rhizoplan)	–	–	–
4. RECB – 50 B (2 l/t)	RECB – 95 B (0.5 L/ha)	RECB – 44 B (0.5 L/ha)	RECB – 50 B (1.0 l/ha)
5. RECB – 95 B (2 l/t)	RECB – 44 B (0.5 L/ha)	RECB – 95 B (2.0 l/ha)	RECB – 74 B (1.0 l/ha)
6. RECB – 74 B (1 l/t)	RECB – 74 B (2 l/ha)	–	–
7. RECB – 50 B (2 l/t) + adaptogen	RECB – 95 B (0.5 L/ha) + adaptogen	RECB – 44 B (0.5 L/ha) + adaptogen	RECB – 50 B (1.0 l/ha) + adaptogen
8. RECB – 95 B (2 l/t) + adaptogen	RECB – 44 B (0.5 L/ha) + adaptogen	RECB – 95 B (2.0 l/ha) + adaptogen	RECB – 74 B (1.0 l/ha) + adaptogen
9. RECB – 74 B (1 l/t) + adaptogen	RECB – 74 B (2 l/ha) + adaptogen	–	–
10. Maxim, 0.2 l/t (treatment of tubers).	RECB – 95 B (0.5 L/ha)	RECB – 44 B (0.5 L/ha)	RECB – 50 B (1.0 l/ha)
11. Maxim, 0.2 l/t (treatment of tubers).	RECB – 44 B (0.5 L/ha)	RECB – 95 B (2.0 l/ha)	RECB – 74 B (1.0 l/ha)
12. Maxim, 0.2 l/t (treatment of tubers).	RECB – 74 B (2 l/ha)	–	–

4 Results

To protect plants among microorganisms, an important place is occupied by Bacillus bacteria, which exhibit antagonistic activity against a significant number of pests and pathogens. They also have a positive effect on crop immunity. Given all this, bacteria of this genus were included in the bioagents we are studying.

The potato plant is characterized by the height of the bush, the ratio of the mass of stems and leaves, the size of the leaf surface. The symbiosis between plants and microorganisms was manifested in the growth indicators of potato plants. An analysis of the data showed that, compared to the application for the treatment of rhizoplan tubers, the use of the bio-agent RECB – 50 B (2 l/t) with the addition of adaptogen and three-fold treatment of plants during the growing season with bioagents RECB – 95 B (0.5 l/ha), RECB – 44 B (0.5 l/ha),

RECB – 50 B (1.0 l/ha) together with the adaptogen increased the height of plants compared to the control by 7.83 cm. Stem height close to this indicator – 56.67 cm was on the variant of processing seed tubers before planting with RECB – 95 B (2 l/t) simultaneously with the adaptogen and three times a during the growing season, one of the preparations: RECB – 44 B (0.5 l/ha), RECB – 95 B (2.0 l/ha) and RECB – 74 B (1.0 l/ha) together with the adaptogen. The number of stems per unit area is an equally important component of the productivity of potato plants. Although this is a varietal sign, which depends on the number of eyes on the tuber and the number of sprouts. The number of stems is determined by the number of sprouts and soil condition, and the number of seedlings is determined by the physiological state of planting material [9].

D.R. Noosey [10] notes that this factor is substantially determined by storage temperature. Storage at temperatures above 7 °C promotes early exit of tubers from dormancy and enhances apical dominance. When planting such planting material, plants quickly grow and develop, mature earlier, but have fewer stems, and therefore tubers, whose mass is relatively high. When storing planting material at lower temperatures (below 5 °C), it was accompanied by a weakening of apical dominance, delayed germination, growth and development, and an increase in the number of stems and small tubers.

In the literature, some researchers studying the structure of the crop of potato tubers note that the number of tubers depends on the number of stems. Our data show that this phenomenon does not always coincide, however, in variants 7 and 8, with a high mass of tubers, a larger number of stems and tubers per one bush was noted. On these options was the largest above-ground mass and weight of leaves per 1 bush (Table 2).

Table 2. Effect of chemical and biological preparations on potato growth indicators, 2019

Option	Plant height, cm	The number of main stems, pcs.	Mass, g/plant			Maximum leaf area, thousand m ² /ha
			tops, g	stalks	leaf, g	
1	46.13	4.00	479.6	247.6	232	34.517
2	48.90	4.00	486.9	248.9	238	35.272
3	53.00	4.40	536.7	291.7	245	36.076
4	49.73	5.33	554.0	266.0	288	42.562
5	46.33	5.13	552.2	277.2	275	40.692
6	55.13	5.33	542.6	270.6	272	40.520
7	56.73	6.00	597.2	285.2	312	46.942
8	56.67	5.53	574.8	276.8	298	44.616
9	54.07	5.53	556.0	264.0	292	43.717
10	52.47	3.93	546.7	276.7	270	39.865
11	55.27	4.20	534.6	276.6	258	38.244
12	46.33	4.00	504.8	252.8	252	37.370
LSD	2.09	0.40	22.69		14.32	

The results of the studies revealed the peculiarities of photosynthetic activity of potato plants with different variants of drug use. The leaf surface area of agroecosis depended on the method and time of application of the strain. So, plants with the RECB strain – 50 B (2 l/t) with the addition of adaptogen and triple treatment of plants

during the growing season with bioagents RECB – 95 B (0.5 l/ha) had a large leaf surface of 46.942 thousand m²/ha; RECB – 44 B (0.5 l/ha), RECB – 50 B (1.0 l/ha) together with the adaptogen.

In the formation of a high economic potato crop, several factors are crucial. These include the speed with which the assimilation apparatus is formed, the size of the active leaf surface, leaf productivity, leaf life, relative growth rate of storage organs.

However, opinions on which of the above factors of the development of a potato plant play a decisive role differ. K.H. Engel [11] notes the dominant role of the leaves, other rate of tuber formation. These differences seem to have no basis. These factors influence not fragmentedly but are in interaction with each other.

Growth duration depended on meteorological conditions of the year. If two irrigation was used in the first half of the growing season, then in the second half, when a significant amount of rainfall occurred, the leaf functioning and tuber formation duration was extended, which positively affected the potato yield (Table 3).

On all variants of the experiment, mineral fertilizers were introduced. In the control without the use of chemical and biological preparations, the actual yield was 38.72 t/ha. Processing seed tubers before planting with Maxim fungicide (0.2 l/t) increased the yield of tubers by 1.01 t/ha. The largest increase in tuber yield, 4.61 t/ha, was obtained in option 7, where the preparation RECB-50 B (2 l/t) was used together with an adaptogen to treat tubers before planting, and during the growing season, the preparation was used for the first treatment of plants – RECB-95 B (0.5 l/ha) + adaptogen, for the second treatment – RECB-44 B (0.5 l/ha) + adaptogen, third – RECB – 50 B (1.0 l/ha) + adaptogen.

Table 3. The effect of chemical and biological preparations on the formation of potato tubers productivity, 2019

Option	From the bush		The mass of one tuber, g	Biological productivity, t/ha	Productivity, t/ha	Deviation from control, ±
	the number of tubers, pcs.	the mass of tubers, g				
1	11.2	936	83.57	40.24	38.72	–
2	11.8	956	81.01	41.27	39.76	+ 1.04
3	12.8	978	76.41	41.73	40.25	+ 1.53
4	14.4	1012	70.27	43.35	41.86	+ 3.14
5	12.4	1009	81.37	43.48	41.89	+ 3.17
6	12.4	998	80.48	42.91	41.43	+ 2.71
7	14.6	1036	70.96	44.89	43.33	+ 4.61
8	14.4	1025	71.68	44.25	42.77	+ 4.05
9	11.8	1014	85.93	43.77	42.20	+ 3.48
10	12.6	987	78.33	42.11	40.58	+ 1.86
11	13.0	995	76.54	42.62	41.05	+ 2.33
12	12.0	964	80.33	41.29	39.78	+ 1.06
LSD	1.38	23.74		1.09	1.11	

An analysis of the crop structure showed that the mass of tubers per bush in the early ripening variety Vineta, depending on the type of experiment, ranged from 936 to 1036 g/bush. In the structure of the crop, tubers of a large fraction mainly prevailed, their share in the crop was 65 %. The average fraction (40–80 g) of the studied variants for the studied variety was 28.3 %.

Table 4. Vineta potato crop structure, 2019

Option	The structure of the harvest of tubers from 1 bush					
	0–40 g		40–80 g		more than 80 g	
	the number of tubers, pcs.	the mass of tubers, g	the number of tubers, pcs.	the mass of tubers, g	the number of tubers, pcs.	the mass of tubers, g
1	2.8	95	4.4	316	4.0	525
2	2.8	50	5.0	399	5.0	507
3	2.6	88	4.2	290	6.0	600
4	3.4	97	3.0	181	8.0	734
5	1.4	39	3.8	276	7.2	694
6	1.0	31	3.0	177	8.4	791
7	3.2	87	2.8	144	8.6	805
8	2.0	67	5.4	345	7.0	613
9	2.6	88	4.8	265	4.4	661
10	1.8	68	4.0	284	6.8	635
11	2.0	72	4.8	326	6.2	597
12	1.6	58	5.2	369	5.2	537

Potato tubers, depending on the experimental options, differed in starch content. The analysis of table 4 showed that a smaller amount of nitrates 73 mg/kg contained tubers with the option when used for processing tubers of strain RECB – 50 B (2 l/t) and triple treatment of plants during the growing season with bioagents RECB – 95 B (0.5 l/ha), RECB – 44 B (0.5 l/ha), RECB – 50 B (1.0 l/ha). The use of these drugs in conjunction with the adaptogen led to an increase in the number of nitrates in the tubers. A similar picture was observed in other variants with the use of adaptogen. It should be noted that in all experimental variants the content of nitrates in tubers did not exceed the MAC.

Table 5. Quality indicators of Vineta potato tubers, depending on the method and doses of the use of chemical and biological preparations, 2019

Option	The content of nitrates, mg/kg	The starch content, %	
		in nat. substance	in dry matter
1	160	11.74	57.79
2	88	13.02	57.93
3	113	12.14	63.38
4	73	13.01	60.69
5	92	11.76	54.56
6	146	10.66	58.99
7	139	11.71	56.39
8	216	10.90	58.24
9	183	10.15	53.48
10	153	10.15	55.35
11	167	11.33	58.28
12	108	12.12	56.51
MAC	250		

A higher starch content in tubers 13.02 and 13.01 % was observed when Maxim (0.2 l/t) and RECB strain – 50 B (2 l/t) were used for treatment of tubers and triple treatment of plants during the growing season with RECB – 95 B bioagents (0.5 l/ha), RECB – 44 B (0.5 l/ha), RECB – 50 B (1.0 l/ha). In the dry matter, the

starch content was higher when the tubers were treated with rhizoplan and amounted to 63.38 %.

5 Conclusion

A higher yield at the level of 43.33 t/ha was formed when RECB strain – 50 B (2 l/t) was applied for tuber treatment and triple treatment of plants during the growing season with the bioagents RECB – 95 B (0.5 l/ha), RECB – 44 B (0.5 l/ha), RECB – 50 B (1.0 l/ha). In order to reduce the pesticidal load on the environment and improve the quality of tubers, this option should be used without adaptogen.

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