Biologization of potato cultivation technology

Olga Chernikova[1*], *Yuriy* Mazhayskiy[1], and *Tatyana* Seregina[2]

[1]Academy of law management of the federal penal service of Russia, 1, Sennaya street, Ryazan, 390036, Russia
[2]Federal Governmental Institution "Central Regulatory and Technical Laboratory of the Federal Penitentiary Service", 14, Zhitnaya street, Moscow, 119049, Russia

Abstract. In biologized agricultural production, along with minimized fertilizers, growth activators are widely used. The article analyzes experimental data on potato cultivation using such preparations. The purpose of this study was to study the effect of copper nanoparticles and liquid-phase biopreparation on the phenology and yield of potatoes in the conditions of lysimetric experiment. The research results showed that pre-sowing treatment of seed tubers with growth activators had a positive effect on linear indicators, heat resistance of plants, increasing it by 16.7-50.0% compared to the control, as well as yield (the increase was 8.6-54.8 t/ha). It is shown that the best effect is obtained by the combined use of copper nanoparticles and 1% liquid-phase biological product.

1 Introduction

Most of the territory of Russia is located in the zone of risky agriculture. Despite the use of the most modern technologies, organic and mineral fertilizers, the harvest may be significantly lower than planned one due to frost, drought or prolonged rains. Unfavorable environmental factors make plants experience real stress, however, growth stimulants can neutralize its effects.

Currently, more than 5000 compounds with a stimulating effect are known - these are, as a rule, substances of plant, synthetic or microbial origin [1-2] that affect various crops.

Growth stimulators, physiologically active substances that affect the intensity and direction of plant life processes, allow them to more effectively use everything that is planned by the plant genotype [3]. They have not only a stimulating, but also an adaptogenic effect on plants and are especially in demand in areas of unstable, risky farming. The use of growth activators makes it possible both to regulate the processes of plant growth and development more specifically, and to more fully use the potential of the variety.

The All-Russian Research Institute of Land Reclamation and Agriculture has developed a multifunctional liquid-phase biological product (LBP) for agriculture and crop production. Its production is based on the fermentation of a peat-manure mixture with the release of a solid-phase product, its extraction with a saline solution and further filtration. In a fresh biological product, the number of microorganisms reaches $n10^9$ – $n10^{12}$ CFU/ml

* Corresponding author: chernikova_olga@inbox.ru

(amino acid synthesizing, phosphate immobilizing, ammonifying, amylolytic, etc.). Pathogenic microflora and parasites were not detected in this biological product. It contains 0.2 – 0.5 g /l of total nitrogen, 10 and 9.5 g / l of mobile forms of phosphorus (P_2O_5) and potassium (K_2O), respectively. Also, the composition of the biological product includes metabolites of microorganisms (amino acid tryptophan, sugars, enzymes) and trace elements (manganese, iron, copper, zinc) and [2].

Metal nanoparticles (NP_S), as well as their derivatives, are among the types of biologically active substances. The use of such activators occurs in minimal doses, which makes it possible to significantly reduce the environmental burden on agricultural landscapes and agricultural production costs [4,5].

Interest in the use of NPs in agricultural practice and crop production is associated with their exceptional properties. Long-term studies have revealed the features of their biological effects:

- Metal nanoparticles are characterized by low toxicity, 7-50 times less toxicity of metals in the form of ions, 10-12 times less mineral salts, which are used in modern crop production;
- Intensify metabolic processes;
- Have a multifunctional and prolonged effect;
- Freely delivered to all organs and tissues.

In the work, scientists noted a significant increase in the yield of wheat when a solution of copper nanoparticles was introduced into the soil. No less important are the results of experiments on testing preparations on soil with worse agrochemical parameters [6].

Works on the study of the effect of presowing treatment of seeds by metal nanoparticles deserve special attention [7]. Laboratory methods have repeatedly confirmed the absence of their accumulation in the soil and crops. In addition, their use as a pre-sowing dressing of seed material has significant advantages over traditional technologies:

- Soil fertilization and spraying generate significant losses due to evaporation, runoff, leaching, that can be avoided by pre-planting;
- Carrying out during periods less loaded by agricultural work stimulate metabolic processes;
- Reduction of environmental hazard and implementation costs;
- Providing protection at the initial stage of plant development, stimulating growth and development, increasing yields.

The purpose of this study was to evaluate the effectiveness of presowing treatment of tubers by growth activators and an organic ameliorant on potato yield and quality of gray forest soil.

2 Methods

The lysimetric experiment on gray forest soil. Potato crop was grown as an experimental crop. The seeding rate was 30 c/ha. The variety is Red Scarlett. The scheme of the lysimetric experiment included the use of an organic ameliorant (cattle manure 90% and chicken manure 10%), as well as growth activators (a liquid-phase biological product and a suspension of copper nanoparticles).

- Control variant (0);
- Suspension of copper nanoparticles at a dose of 0.01 g per hectare seeding rate (Cu 0.01);
- Compost 40 t/ha (K);

• Compost 40 t/ha + suspension of copper nanoparticles at a dose of 0.01 g per hectare seeding rate (K+ Cu 0.01);

• Compost 40 t/ha + liquid-phase biopreparation at a concentration of 1% (K + LPB 1%);

• Compost 40 t/ha + liquid-phase biopreparation at a concentration of 2% (K+LPB 2%);

• Compost 40 t/ha + liquid-phase biopreparation at a concentration of 1% + suspension of copper nanoparticles at a concentration of 0.01 g per hectare seeding rate (K + LPB 1% + Cu 0.01);

• Compost 40 t/ha + liquid-phase biopreparation at a concentration of 2% + suspension of copper nanoparticles at a concentration of 0.01 g per hectare seeding rate (K + LPB 2% + Cu 0.01).

The studies were carried out in stationary field lysimeters of the NRIHEA design with an undisturbed soil profile, the area of which is 1.13 m^2. At the beginning of the experiment, soil samples were taken from a depth of 0 – 25 cm, which characterized it with a low humus content on average 4.6 % (3.8 % – 5.4 %). The reaction of the soil solution medium was slightly acidic, the pH averaged 5.7 (5.3 – 6.4). The content of mobile forms of nutrients on average was as follows: the content of total nitrogen – 0.12%, potassium – 833.5 mg / kg, phosphorus – 128 mg / kg, which refers it to the average degree of cultivation of soils (medium provided with macronutrients).

In the autumn of 2020, after harvesting the previous crop - spring barley, an organic ameliorant was introduced at a dose of 40 t/ha, consisting of cattle manure (90%) and bird droppings (10%), with a moisture content of 85%. This organic norm was plowed (buried) to a depth of 25 cm.

To impart biological activity, the copper suspension was subjected to ultrasonic treatment in an aqueous medium. The average size of the nanoparticles was 40-60 Nm, with a phase composition of 100% copper. LPB is a dark brown liquid with a specific odor, the acidity of which is 6.5 – 7.5. It contains N, C, K, P, Mg, Ca, beneficial microflora and amino acids. The seeds were soaked before sowing in an aqueous solution of the preparations for 30 minutes. The optimal concentration of copper nanoparticles was used – 0.01 g per hectare seeding rate. LPB was used in concentrations of 1% and 2%. In the control, the seeds were soaked in distilled water for 30 minutes before sowing.

Potatoes were grown on gray forest soils in lysimeters according to the technology generally accepted for this region. Sowing was carried out according to the technology recommended for the cultivation of this crop, taking into account weather conditions. The predecessor is spring barley.

3 Results and Discussion

The intensity of plant growth processes is an important environmental indicator that indirectly characterizes the activity of stretching or cell division. Observations of phenological indicators: the development and growth of plants were carried out throughout the growing season. The results of plant growth intensity are presented in the 1st table.

At the beginning of the growing season, the highest intensity of growth processes was observed in the variant with the use of compost and 1% liquid-phase biological product (table 1). The differences with the control variant were significant and amounted to 5.57 cm or 47.85%.

In case of the second measurement on July, in the variant with the combined use of compost, LPB 1% and Cu 0.01, the maximum excess over the control was 6.77 cm or 14.83%. Probably, pre-sowing treatment of seeds with copper nanoparticles led to an increase in the adaptive potential of potatoes, which favorably affected the regulation of growth processes and increased resistance to high ambient temperatures and drought.

The resistance of plants to high temperatures (heat resistance) is their ability to adapt to adverse environmental influences, while maintaining the stability of all physiological processes. Heat resistance is one of the indicators of drought resistance, which reflects the ability of plants to tolerate high soil and air temperatures. The temperature above 40 ^{0}C is unfavorable for a large number of plants in the temperate zone and in the case of prolonged exposure to the plant leads to its death [8].

The degree of heat resistance of plants can be determined by the rate of appearance of pheophytin spots, as well as by the intensity of browning of leaves, which occurs as a result of the destruction of chlorophyll. When exposed to a high temperature on a leaf, followed by its immersion in a dilute hydrochloric acid solution, dead and damaged cells will turn brown due to the free penetration of acid into them, which will lead to the transformation of chlorophyll into pheophytin, while intact and living cells will remain green [9].

Table 1. Indicators of linear growth of potatoes.

Experiment options	**Plant height, cm**					
	June			**July**		
	Average	**Changes**		**Average**	**Changes**	
		cm ±	**%**		**cm ±**	**%**
0	11.64	-	-	45.64	-	-
Cu 0.01	11.89	+0.25	2.15	45.43	-0.21	-0.46
K	13.55	+1.91	16.41	46.97	+1.33	2.91
K+ Cu 0.01	12.86	+1.22	10.48	47.67	+2.03	4.45
K+LPB 1 %	17.21	+5.57	47.85	49.72	+4.08	8.94
K+ LPB 2 %	14.19	+2.55	21.91	48.08	+2.44	5.35
K+ LPB 1 % + Cu 0.01	16.14	+4.50	38.66	52.41	+6.77	14.83
K+ LPB 2 % + Cu 0.01	15.02	+3.38	29.04	49.22	+3.58	7.84
$LSD_{05\ cm}$	1.2			3.6		

Therefore, the indicators of heat resistance of plants act as criteria for assessing their resistance to adverse environmental factors.

Almost all of the leaf copper is concentrated in chloroplasts and is closely related to the processes of photosynthesis, stabilizing chlorophyll, protecting it from destruction. Copper is a part of the copper protein, forming an oxidizing enzyme, and promotes the synthesis of iron-containing enzymes in plants [10]. It has a positive effect on the synthesis of proteins in plants, which provide the water-retaining capacity of plant tissues, as a result, copper in the form of a fertilizer is important for giving plants drought and frost resistance and protection against bacterial diseases. Copper is involved in the process of nitrogen fixation by plants, increases resistance to lodging.

The adaptive properties of copper also appeared when it was used in pre-sowing treatment in the form of a suspension of nanoparticles (table 2).

Table 2. Heat resistance of potato plants.

No.	**Experiment option**	**Heat resistance, number of pheophytin spots**
1	0	12
2	Cu 0.01	8
3	K	10
4	K+ Cu 0.01	8
5	K+LPB 1 %	10
6	K+ LPB 2 %	10

7	К+ LPB 1 %+ Cu 0.01	6
8	К+ LPB 2 %+ Cu 0.01	7

Thus, the number of pheophytin spots on potato leaves in the variant with the use of an organic ameliorant and presowing treatment of tubers with copper nanoparticles and 1% LPB decreased by 6 compared to the control. In the variants where only Cu NPs and together compost with Cu NPs - by 4, for K + LPB 2% + Cu 0.01 - by 5.

Productivity is a very important performance indicator in the cultivation of agricultural crops and agricultural production in general. The size of the harvest allows us to judge the quality of the activities carried out, reflects the impact of the conditions in which the cultivation of plants was carried out. The indicators of plant growth and development and yield in our experiment were directly dependent on each other (table 3).

Pre-sowing treatment of tubers with NPs Cu and 1% and 2% LPB against the background of compost application had a positive effect on potato yield (table 3). The smallest increase was noted in the Cu 0.01 and K variants, the increase in yield was 8.6% and 9.6%, respectively, in relation to the control. Within the same limits, there was an increase in productivity on the variants K+ Cu 0.01 and K+ LPB 2% + Cu 0.01: 22.8% and 26.9%. The increase in yield on the variants K + LPB 1% and K+ LPB 2% and amounted to 26.5 t/ ha.

Table 3. Effect of organic ameliorant and presowing treatment of potato seeds on yield (t/ha).

Experiment options	**Mass of products**		
	Average, t/ha	**Changes**	
		t/ha	**%**
0	19.7	-	-
Cu 0.01	21.4	+1.7	+8.6
К	21.6	+1.9	+9.6
К+ Cu 0.01	24.2	+4.5	+22.8
К+LPB 1 %	26.5	+6.8	+34.5
К+ LPB 2 %	26.5	+6.8	+34.5
К+ LPB 1 % + Cu 0.01	30.5	+10.8	+54.8
К+ LPB 2 % + Cu 0.01	25.0	+5.3	+26.9
$LSD_{05\ t/ha}$	2.03		

Studies have shown that the use of 1% of LPB and copper nanoparticles as a pre-sowing treatment of tubers maximized potato productivity. Thus, the yield increased by 54.8% and amounted to 30.5 t/ha.

To identify the dynamics of changes in soil processes and agrochemical characteristics from the use of the studied preparations against the background of compost, long-term studies are needed, since organic fertilizers exhibit a cumulative effect: with prolonged use of compost together with microbial biological preparations, organic substances that are resistant to decomposition, microorganisms accumulate in the soil, improving its structure and enriching the soil with useful elements.

Studies of the agrochemical characteristics of gray forest medium loamy soil in the experimental variants are shown in the 4th Table.

Table 4. Agrochemical properties of gray forest medium loamy soil on variants of the lysimetric experiment.

Experiment options	**pH, units**	**Total nitrogen, %**	**Phosphorus mob., mg/kg**	**Potassium mob., mg/kg**
0	5.4	0.10	116	120
Cu 0.01	5.3	0.10	118	124

K	6.0	0.12	124	134
K+ Cu 0.01	5.9	0.12	125	136
K+LPB 1 %	6.2	0.14	130	138
K+ LPB 2 %	6.0	0.13	129	138
K+ LPB 1 % + Cu 0.01	6.4	0.16	133	140
K+ LPB 2 % + Cu 0.01	6.1	0.15	130	140

Considering that for every 100 kg of tubers, potatoes remove from the soil an average of 50 kg of nitrogen, 20 kg of phosphorus and 90 kg of potassium, it should be noted that the use of all fertilizer systems had a positive effect not only on potato yields, but also on soil fertility indicators. The greatest improvement in agrochemical parameters was recorded with the combined use of three components: the content of total nitrogen increased by 50.0–60.0%, mobile phosphorus by 14–17 mg/kg, mobile potassium by 20 mg/kg in comparison with the control. The acidity of the soil became close to neutral increased from 5.4 (acidic) to 6.4.

4 Conclusion

Field lysimetric studies have shown that copper nanoparticles and liquid-phase biopreparation have biological activity. Their use as micro-fertilizer stimulants in the pre-sowing treatment of seeds contributed to an increase in the growth, development, yield of potatoes and agrochemical properties of gray forest soil. The greatest effect on the sum of the indicators was observed when used in potato cultivation technology with joint pre-sowing treatment with copper nanoparticles with a 1% solution of a liquid-phase biological product.

References

1. G. Yu. Rabinovich, N. G. Kovalev, Yu. D. Smirnova. Application of new biofertilizers and biological preparations in the cultivation of spring wheat (Triticum aestivum L.) and potato (Solanum tuberosum L.). Agricultural Biology. 50(5), 665-672 (2015)
2. Yu. D. Smirnova, G. Yu. Rabinovich. Cultivation of spring wheat with the use of the biological preparation LPB. Proceedings of the III International Scientific and Practical Conference "Methods and Technologies in Plant Breeding and Crop Production" Kirov 291-295 (2017)
3. A. V. Goryntsev, I. N. Bondareva. The effectiveness of the use of growth stimulants in the cultivation of potatoes. Bulletin of the Perm State Humanitarian and Pedagogical University Series No. 2 Physical, mathematical and natural sciences. 2, 27-33 (2017)
4. O. V. Chernikova, L. E. Ampleeva, Yu. A. Mazhaisky. Formation of corn yield during seed treatment by selenium nanoparticles. Russian Agricultural Science. 2, 24-27 (2019)
5. O. V. Chernikova, L. E. Ampleeva, Yu. A. Mazhaisky. Effect of selenium nanoparticles on the formation of corn yield. Russian Agricultural Sciences. 45(3), 256-259 (2019)
6. O. Chernikova, T. Seregina, Y. Mazhaysky, S. Buryak, L. Ampleeva. Comparative analysis of the use of biostimulants on the main types of soil. Agronomy Research. 19(1), 711-720 (2021)
7. O. N. Tsapovskaya, A. V. Kozlov, A. A. Pyatova. Ecological assessment of the impact of copper on the growth and development of spring wheat plants. Agroecoinfo. 4 (2022)

https://doi.org/10.1051/bioconf/20237101047

8. E. A. Arestova, S. V. Arestova. Heat resistance of plants of the genus Fraxinus L. in the Saratov Volga region (on the example of the arboretum of the Research Institute of Agriculture of the South-East). International scientific journal "Innovative Science". 11-3, 31-33 (2016)
9. Zh. E. Mazets, S. V. Sudeinaya, E. R. Gritskevich. Plant Physiology: Practicum (Minsk: BSPU) 71 (2010)
10. R. A. Afanasiev, A. S. Samotoenko, V. V. Galitsky. Efficiency of foliar top dressing of winter wheat with microelements in the conditions of the Central Chernobyl. Fertility. 4(55), 13-15 (2010)