Application of Microbiological Preparations in the Cultivation of Agricultural Crops with the Aim to Reduce the Technogenic Load of Metallurgical Plants

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Abstract. One of the ways to solve the problem of technogenic pollution is to implement biotechnologies for agricultural lands. The study aims to assess the efficiency of microbiological preparations in the cultivation of potatoes near metallurgical plants in the south of Eastern Siberia. The research was conducted in 2015-2016 on three plots located near Shelekhov aluminum production plant. The Japanese preparation EM and the Russian microbial preparations Baikal EM1 and Fitosporin-M were used. The effect of biological products on plant protection from fungal diseases was observed only in 2015. The two-year application of Fitosporin-M increased the potato yield (by 13-22%) on cultivated alkaline soils; on weakly acidic soils, an increase in the yield (by 26%) was observed only in 2016. When applying EM preparations, a stable increase in the yield (14-22%) was observed on weakly acidic soils; on alkaline soils, an increase in the yield was observed in less than 50% of cases. In general, the stable yield enhancement was observed when applying Fitosporin-M on the alkaline soils. The effectiveness of the EM preparations depended on the agrophone and weather conditions

1. Introduction

Modern urbanization causes a high concentration of settlements near industrial cities. In these settlements, people grow various agricultural products. One of the most important tasks is to develop recommendations for using biologically safe technologies that can affect the application of chemical plant protection products [1]. Preparations based on symbiotic microorganisms have been developed to maintain the natural soil fertility, reduce the anthropogenic load on the environment and improve the quality of agricultural products. Microorganisms play an important role in the adaptation of plants to external factors, including the technogenic ones. Many symbiotrophic microorganisms are highly resistant to toxic substances, participate in their transformation in the rhizosphere and in the accumulation by plants, have a positive effect on the plant growth on technogenically contaminated soils, reduce the mobility of heavy metals, thereby protecting plants from toxicants under stressful conditions of technogenic pollution [2, 3].

Currently, the most famous biological product is effective microorganisms (EM) composed of beneficial microorganisms. They do not contain synthesized or genetically modified cultures. These preparations began to be used in Japan more than 30 years ago. Now they are widely used in many countries with the aim to produce safe agricultural products [4-8] and solve biotechnology problems.
treatment of waste and sewage water; recycling of organic waste; disinfection of water in recreational reservoirs; landfill reclamation; bioremediation of contaminated soils. In Russia, these biotechnologies are used in the central chernozem zone, some southern regions and Western Siberia [16-18].

In Russia, the most famous microbiological preparation is Baikal EM1. It was developed by Irkutsk and Ulan-Ude researchers on the basis of Lake Baikal microorganisms. The main reason for the exceptional versatility of this drug is a wide range of actions of its microorganisms.

Baikal EM1 is based on more than 80 types of microorganisms. These microorganisms belong to ten orders which represent five families. EM cultures do not contain genetically modified strains. They are produced by mixing various groups of natural beneficial, non-pathogenic, aerobic and facultative anaerobic microorganisms [19].

In the Siberian region, the implementation of biotechnology is hindered by harsh natural and climatic conditions. However, they are used by farmers. Application of biological products in small areas does not yield the result promised by manufacturers, which has a negative effect on the mass implementation of biotechnology.

At the same time, an analysis of scarce data showed that in Siberia Baikal EM-1 and other microbiological preparations can be effective. The preparation has a protective and stimulating effect, improves the productivity and quality of agricultural products [20, 21].

Thus, it is necessary to study applications of these biological products in Eastern Siberia in the crop cultivation under the high anthropogenic load. The most widely and universally cultivated crop in the region is potatoes.

The aim of the present study is to assess the effectiveness of microbiological preparations in the potato cultivation near metallurgical plants of the Southern Baikal region.

2. Materials and methods

The study was conducted in the suburban area of Shelekhov, one of the largest industrial centers in the south of Eastern Siberia. The industrial profile of the town is determined by non-ferrous metallurgy. Air pollution caused by emissions of the aluminum production plant causes a high level of soil pollution in the town and surrounding areas. 0.5-8 km away from this zone, an extremely and highly dangerous hygienic contamination of agricultural soils with water-soluble fluorine (7 MPC) and B(a)P (5 MPC) was identified [22]. The category of hygienic soil contamination has not changed and remains extremely dangerous.

The studies on the effectiveness of various biological products for growing potatoes were carried out in 2015-2016 on three plots near Shelekhov. The plots were located in three different settlements, where people grow agricultural products in their gardens.

The first plot was located two kilometers west of Shelekhov, in the floodplain of the Irkut river, 1 km from the river. The groundwater level was at a depth of three meters. Meadow soils were dominant in the adjacent areas.

The soil of the first plot was cultivated, sandy loam, light; the content of organic matter was about 3%, the soil solution reaction was alkaline (pH = 8.4).

The second plot was located in the floodplain of the Olkha river, 2.5 km east of Shelekhov near the groundwater.

On the second plot, the soil was technogenic, created by filling bog soils with conditionally fertile overburden from the sand and gravel quarries with the addition of humus. The soil was low-cultivated, sandy loam, light with a low content of organic matter (1%) and a weakly acidic reaction of the soil solution (pH = 6.2).

The third plot was located 4.5 km south of Shelekhov, on the southern slope of a gentle hill one kilometer from the floodplain of the Olkha river. In the adjacent areas, low-fertile podzolic soils were widespread. The soil was well cultivated, with a high content of organic matter (11%) and an alkaline reaction of the soil solution (pH = 8.2). By its mechanical composition, it was heavy loam, which caused poor soil aeration.
Small-plot experiments were conducted on each plot by the same scheme in three replications. The area of each plot was 3 m². Adretta potato variety was used in the study. The potato was planted at the optimal time; the cultivation technique was generally accepted in the region.

Three plots were treated with a solution of one of the biological products and one plot was watered. Three biological products were selected: Baikal EM 1 and Fitosporin-M (Russia) and an EM preparation (Japan) provided by the aquatic toxicology laboratory of the Research Biology Institute (Irkutsk State University).

The main cultures of the Japanese EM preparation are lactic acid bacteria *Lactobacillus plantarum*, *Lactobacillus casei*, *Streptococcus lactis*; phototrophic bacteria *Rhodopseudomonas palustris*, *Rhodobacter sphaeroides*; yeast *Saccharomyces cerevisiae*, *Candidautilis*; fungi *Streptomyces griseus*, *Aspergillus oryzae*, *Mucorhiemalis*. In total, the Japanese EM preparation contains about 80 different microbial cultures.

The Baikal EM1 preparation is based on the following groups of microorganisms: phototrophic bacteria *Rhodopseudomonas* and *Rhodobacter*, lactic acid sticks *Zacdobacillus* and lactic acid cocci *Zacdococcus*, yeast *Saccharomyces*. To enhance the vital activity of the microorganisms, the nitrogen-fixing free-living azotobacteria *Azotobacter* and the bacteria *Pseudomonas* were introduced.

The active substance of Fitosporin-M is living cells and spores of *Bacillus subtilis*. A composition based on chalk, fillers and powdered OD-humate was used as a carrier of the bacterial culture.

In 2015, the experiment scheme was as follows: plot 1 - watering at the rate of 10 liters per 3 m² (control). Plot 2 – treating with Japanese EM preparation (1: 1000) at the rate of 10 liters per 3 m². Plot 3 - treating with Baikal EM-1 (1: 1000) at the rate of 10 liters per 3 m². Plot 4 – treating with Fitosporin (1: 500) at the rate of 10 liters per 3 m². Differences in the concentration of the solutions were due to the manufacturers’ recommendations. Since in 2016 the Japanese EM preparation was not accessible for the population, Baikal EM-1 was used instead (1: 100, 10 l per 3 m²).

Plants were treated with biological products in the evening hours three times during the growing season with an interval of two weeks: at the beginning of the budding phase (the first decade of July), during the mass flowering and tuber ripening.

3. Results and discussions

In 2015, the meteorological conditions were close to the average long-term values. Visual observations showed that plants treated with biological products were less affected by fungal diseases, their vegetative organs developed better than in those on the control plot, and their terrestrial biomass died later (Table 1). This pattern was observed on all the plots.

| Treatment options                | Plot 1 | Plot 2 | Plot 3 |
|----------------------------------|--------|--------|--------|
| Watering (control)               | 50     | > 70   | > 50   |
| Application of the Japanese EM   | 15     | 50     | 50     |
| preparation                      |        |        |        |
| Application of Baikal EM-1       | < 50   | < 70   | 50     |
| Application of Fitosporin-M      | 15     | 50     | 50     |

The application of the EM biopreparations on plot 2 increased the potato yield by more than 20% (Table 2). A significant increase in the yield (70%) was observed when applying the Japanese biopreparation on plot 1. Fitosporin-M increased the yield on the alkaline soils of plots 1 and 3 (by 18-20%).
Table 2. Productivity of potato tubers (kg/bush) when applying biological products in 2015.

| Treatment options                        | Plot 1       | Plot 2       | Plot 3       |
|------------------------------------------|--------------|--------------|--------------|
| Watering (control)                       | 1.03 ± 0.07  | 0.38 ± 0.03  | 0.78 ± 0.05  |
| Application of the Japanese EM preparation (1:1000) | 1.74 ± 0.08  | 0.48 ± 0.04  | 0.76 ± 0.06  |
| Application of Baikal EM-1 (1:1000)      | 1.07 ± 0.11  | 0.49 ± 0.05  | 0.80 ± 0.08  |
| Application of Fitosporin-M              | 1.29 ± 0.08  | 0.40 ± 0.05  | 0.95 ± 0.06  |

In 2016, the moisture values differed from the average long-term ones. In the first ten days of August, atmospheric precipitation exceeded the average long-term level. At the beginning of the second decade of August, the floodplain of the Olkha River was partially flooded. Plot 2 was in the flooded zone, which killed the terrestrial biomass of plants; potato tubers were harvested three weeks earlier than usual. The effect of plant protection from fungal diseases was not observed.

A significant increase in the yield with Fitosporin-M was observed on all the plots (13-26%).

Table 3. Productivity of potato tubers (kg / bush) when applying biological products in 2016.

| Treatment options                        | Plot 1       | Plot 2       | Plot 3       |
|------------------------------------------|--------------|--------------|--------------|
| Watering (control)                       | 1.10 ± 0.02  | 0.36 ± 0.02  | 0.85 ± 0.09  |
| Application of Baikal EM-1 (1: 1000)     | 1.43 ± 0.04  | 0.42 ± 0.03  | 0.90 ± 0.20  |
| Application of Baikal EM-1 (1:100)       | 1.02 ± 0.03  | 0.45 ± 0.02  | 1.12 ± 0.22  |
| Application of Fitosporin-M              | 1.27 ± 0.08  | 0.49 ± 0.02  | 1.09 ± 0.10  |

The application of Baikal EM-1 provided an increase in the yield on plot 2 (by 14-20%) at different concentrations of the solution and on plot 1 (by 23%) at 1: 1000. It was not possible to establish any regularities caused by various concentrations. The inefficiency of Baikal EM1 on plot 3 was due to unfavorable aeration conditions that developed on the heavy loamy soils in 2016 due to the waterlogging.

According to [23], the most favorable conditions for microorganisms can be found on slightly acidic soils at pH = 6.5, where the number of bacteria is high. EM preparations contain microbiological cultures adapted to lower reactions of the environment [24]. Therefore, a stable effect from the EM preparations was observed only on low fertile, weakly acidic soils of plot 2. Unfavorable conditions may develop on alkaline soils. As a result, the EM preparations do not always realize their potential.

4. Conclusion

The 2015-2016 research results showed that in the suburban area of the Southern Baikal region, near the large metallurgical plant, the effectiveness of biological products in the potato cultivation was determined by the hydrothermal conditions of the growing season and agricultural background.

A more stable yield gain was observed when using Fitosporin-M.

The effect of EM preparations was stable only on technogenic soils with a weakly acidic reaction of the soil solution. On alkaline soils with a high content of organic matter, an increase in the potato yield was in less than 50% of cases. It was not possible to identify any regularities.

On alkaline soils, which are common near aluminum production plants, it is most appropriate to apply Fitosporin-M, whose effectiveness depends on the agrophone, aeration and moisture.

EM preparations can be applied along with measures aimed to restore technogenically disturbed light soils with neutral and acidic reactions of the soil solution.
5. Reference

[1] Sokolova M G, Belogolova G A, Akimova G P and Verkhoturov V V 2015 Bacterial technologies in plant physiology during technogenesis *Evvestiya vuzov Applied chemistry and biotechnology* vol 2 (13) pp 76–80

[2] Belimov A A and Tikhonovich I A 2011 Microbiological aspects of resistance and accumulation of heavy metals in plants (review) *Agricultural biology* vol 3 pp 10–15

[3] Belogolova G A Sokolova M G and Gordeeva O N 2013 Migration and bioavailability of heavy metals, arsenic and phosphorus under the influence of rhizosphere bacteria in technogenic ecosystems *Agrochemistry* vol 6 pp 83–92

[4] Kour D, Rana K L, Yadav A N,… and Saxena A. K 2020 Microbial biofertilizers: Bioresources and eco-friendly technologies for agricultural and environmental sustainability *Biocatalysis and Agricultural Biotechnology* vol 23 101487

[5] Jaffri Sh B, Shahzad K and Jabeen A A 2021 Biofertilizers’ functionality in organic agriculture entrenching sustainability and ecological protection *Biofertilizers* vol 1 pp 211-219

[6] Gautam K, Sirohi Ch, Singh N R,… and Parihar M 2021 Microbial biofertilizer: Types, applications, and current challenges for sustainable agricultural production *Biofertilizers* vol 1 pp 3-19

[7] Mayera J, Scheida S, Widmera F, Fließbach A and Oberholzer H-R 2010 How effective are ‘Effective microorganisms® (EM)’? Results from a field study in temperate climate *Applied Soil Ecology* vol 46(2) pp 230-239

[8] Hu Ch and Qi Y 2013 Long-term effective microorganisms application promote growth and increase yields and nutrition of wheat in China *European Journal of Agronomy* vol 46 pp 63-67

[9] Quintella C M, Mata A M T and Lima L C P 2019 Overview of bioremediation with technology assessment and emphasis on fungal bioremediation of oil contaminated soils *Journal of Environmental Management* vol 241 pp 156-166

[10] Fana Y V, Lee Ch T, Klemes J J… and Leow Ch W 2017 Evaluation of Effective Microorganisms on home scale organic waste composting *Journal of Environmental Management* vol 216 pp 41-48

[11] Talaat N B 2019 Effective microorganisms: An innovative tool for inducing common bean (Phaseolus vulgaris L) salt-tolerance by regulating photosynthetic rate and endogenous phytohormones production *Scientia Horticulturae* vol 250 pp 254-265

[12] Shalaby E A 2011 Prospects of effective microorganisms technology in wastes treatment in Egypt *Asian Pacific Journal of Tropical Biomedicine* vol 1, Issue 3 pp 243-248

[13] Megharaj M and Naidu R 2017 Soil and brownfield bioremediation *Microbial Biotechnology* vol 10(5) pp1244-1249 doi:10.1111/1751-7915.12840

[14] Kuppusamy S, Palanisami T, Megharaj M, Venkateswarlu K, and Naidu R 2016 Ex situ remediation technologies for environmental pollutants: a critical perspective *Rev Environ Contam Toxicol* vol 236 pp 117–192

[15] Kuppusamy S, Palanisami T, Megharaj M, Venkateswarlu K, and Naidu R 2016 In situ remediation approaches for the management of contaminated sites: a comprehensive overview *Rev Environ Contam Toxicol* vol 236 pp 1–115

[16] Blinov VA and Ivanov A B 2011 Study of the use of effective microorganisms for the purification of wastewater from ions of heavy metals *Water and ecology: problems and solutions* vol 2 (46) pp 57-60

[17] Chachina S B, Boltunova S V and Cherkashina N V 2015 Destruction of oil hydrocarbons using microbiological preparations Baikal EM, Tamir, Vostok. *Omsk Scientific Bulletin* vol 1 pp 221-225

[18] Tumanyan A F, Tyutyma N V and Sheherbakova N A 2014 The influence of growth stimulants on the yield and fractional composition of potato grown on light chestnut soils of the Lower Volga region *Bulletin of RUDN* vol 4 pp 38-45
[19] Abbasova Z I, Allakhverdiev S R… and Khalilova Kh D 2012 EM-technology - the hope of the XXI century Problems of agrochemistry and ecology vol 12 pp 390-394

[20] Kim E I and Rykova LM 2002 Materials of the II International scientific-practical conference "EM-technology. Reality and Prospects” (Ulan-Ude Ivanovo: Publishing house of Ivanovo State Agricultural Academy) pp 29–30

[21] Ivanova S V and Ivanina O Yu 2006 Reports of regional scientific and practical. Conference "Food technologies, food quality and safety" (Irkutsk: ISTU) pp 134–138

[22] Belykh L I, Ryabchikova I A, Seryshev V A et al 2006 Assessment of the degree of chemical pollution of the soil and vegetation cover of the agroecosystems of the Southern Baikal region Agrochemistry vol 5 pp 78-89

[23] Koltsova O M and Maraeva O B 2001 Materials of the 1st International Conference "Effective microorganisms - reality and prospects" (November 1-3 2000 Voronezh) pp 56-58

[24] Bulgadaeva R V, Nechesov I A, Dranishnikova A I and Shablin P A 2001 Materials of the 1st International Conference "Effective microorganisms - reality and prospects" (November 1-3 2000 Voronezh) pp 14-16