Biotechnologic farming: an innovative approach to sustainable agriculture

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Abstract. The symbiotic relationship between agriculture and the environment has undergone a profound shift with the advent of extensive chemicalization. While this approach initially bolstered yields, it simultaneously disrupted the delicate equilibrium of nature. The repercussions have been felt across the spectrum, from weakened natural defenses in plants and animals to human health concerns. The efficacy of traditional agricultural techniques has dwindled in the face of these mounting challenges. The urgency of the situation calls for an exploration of innovative farming methods that can reconcile productivity with ecological integrity. This article presents a foray into a novel biotechnological approach to farming, a transformative endeavor that champions environmental friendliness, resource conservation, cost-effectiveness, and innovation. The crux of this endeavor is the cultivation of agricultural crops on soil marred by salinity and heavy metal degradation - a locale perilously poised on the brink of desertification in the arid expanse of Uzbekistan. This research encapsulates an intensive investigation, delving into the intricate mechanics of this newfangled bio-agrotechnology. Through painstaking experimentation and strategic implementation, the innovative methodology triumphs over the adversities posed by challenging soil conditions. The results are not only heartening but transformative. The application of this bio-agrotechnology rejuvenates saline soils, heralding a resurgence in fertility that ripples across the ecosystem. This reinvigoration is evidenced in elevated crop yields and heightened product quality, illustrating the synergistic harmony between nature and innovation.
Keywords. Saline soils, biological fertilizers, bioagrotechnology, soil fertility, crops, sustainable agriculture, food security.

1 Introduction

In recent years, agriculture, using intensive technologies, is everywhere facing the problems of land degradation, a drop in the quantity and quality of products and, as a result, a

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decrease in the economic performance of all economic activities in the agricultural sector. There is a need for a deep critical analysis of the development of intensive production methods, when even elementary environmental requirements were ignored in the pursuit of volume, quantity and quick profit [1, 2].

The ever-increasing population of the planet, the constant decline in crop yields, an annual average of 30% yield loss due to pests, plant diseases and weeds were the basis for the total chemicalization of agriculture [3]. However, such an approach provoked a global ecological crisis, putting, on the one hand, endangered the life of mankind, and on the other hand, caused serious violations in agricultural activities [4]. As a result of chemicalization, mechanization and melioration, the chemical and physical load on the components of the agricultural landscape grew exponentially [5]. A significant increase in the use of nitrogen, phosphorus fertilizers and pesticides (seed protectants, herbicides, fungicides, insecticides, chemical growth stimulants and pollinators) has led to the suppression of beneficial soil microflora - the basis of fertility and the activation of harmful microflora that destroys soil humus, as a result of [6]:

- soil properties have deteriorated - structure, water permeability, aeration;
- the number of mobile forms of nitrogen, phosphorus, potassium, macro-microelements decreased;
- the level of soil fertility is catastrophically reduced;
- pathogenic microflora develops in the soil, causing various plant diseases;
- the development of the aerial parts of plants is enhanced, root formation is inhibited;
- metabolic processes in plants are disturbed, which leads to a decrease yield and quality of agricultural products in connection with the accumulation of nitrates, nitrites, pesticide residues in it;
- the environment is polluted with toxic substances as a result of the accumulation of chemicals in the soil, groundwater, plant and livestock products, causing contamination of feed and food products;
- the imbalance of the microflora of the gastrointestinal tract of the body is disturbed, which leads to the formation of many diseases (gastritis, peptic ulcer of the stomach and duodenum, liver damage, rheumatoid arthritis, joint damage, urolithiasis, bronchial asthma, dermatitis, allergic, oncological and other diseases).

Thus, chemicalization violated self-regulation in living nature, weakened the defenses of plants, animals and humans. Old, proven agricultural technologies are no longer able to cope with these problems [7]. Mankind faced the problem of finding alternative ways of farming, maintaining its high productivity and environmental safety [8]. Under these conditions, old technologies should be replaced by biotechnology, and at the present stage only with its help it is possible to solve the environmental, energy and food problems facing humanity.

Undoubtedly, today the soil is involved in all the most important processes of the functioning of terrestrial ecosystems and the biosphere as a whole - from providing resources and space for terrestrial vegetation to maintaining the parameters of the atmosphere and hydrosphere, including the problems of greenhouse gases, the purity of surface and ground waters, and the elimination of xenobiotics [9].

An exceptional role in the formation of soil quality or "soil health" is played by soil microorganisms, which perform all the main ecosystem functions. Modern intensive technologies in agriculture, aimed at maximizing yields and quick profits, are essentially waging a costly battle with the soil microbial system - the foundation of ecosystem resilience [10].

The way out of the situation is the emphasis on " soil health " in the broadest sense and its sustainable maintenance with the possibility of an acceptable livelihood for the current and future generations. That is why soil microorganisms are the main element of a sustainable and efficient life support system.

A decrease in the composition and abundance of useful soil microflora, which is involved in the circulation of important macro- and microelements, suppresses the processes of restoring soil fertility and structure, which leads to the process of soil degradation - erosion, phosphatization, salinization and desertification . As a result, greenhouse gases such as carbon dioxide (CO_2), nitrous oxide (N_2O) and methane are released from the soil into the atmosphere, which seems to be a powerful factor in climate change on the planet.

2 Materials and methods

Plants do not feed on fertilizers applied to the soil, but on the products of their processing by soil microorganisms. Therefore, the growth, development of plants and the value of yields are determined by the soil microflora, especially those living in the rhizosphere, i.e. in the root zone of plants. Consequently, all agricultural technologies should ensure the development of the microflora of the rhizosphere, taking into account the genetic characteristics of plants.

Now all over the world there is a revision of the concept of development of agricultural production and a gradual transition from intensive technogenic methods of agricultural production to biological methods.

In recent years, in a number of developed countries, in particular in Europe, the USA, Canada, Japan, China and Russia, cheap production methods have been used that bring a high effect at relatively low costs. Main point biological farming technologies consists in applying to the soil effective microorganisms, which enrich it with readily available nutrients, make it fertile and supply plants with the necessary products of their vital activity (vitamins, enzymes, amino acids, etc.). At the same time, mineral fertilizers (only in combination with organic ones), pesticides and other chemical plant protection products are not used, the products become environmentally friendly and completely safe for humans.

Restoring degraded soils lies in the efficient and rational use of the biological potential of the soil, in optimizing the plant-microbial interaction in agrophytocenoses and improving the ecosystem as a whole.

One of the components of ecological farming is the use of new biotechnologies based on the use of biofertilizers (bacterial fertilizers, biological products, biocomposts, biofungicides, etc.). One of the urgent problems of farming in the world is the problem of soil phosphatization, which arose as a result of the annual introduction of a large amount of phosphate fertilizers into soils for agricultural crops. The utilization rate of phosphorus from fertilizers is low and amounts to only 10-20% of the applied amount, while the rest of it, reacting with soil complexes, turns into compounds that are insoluble in water and inaccessible to plants. At the same time, the phosphate regime of soils is disturbed, which leads to a deficiency of available phosphorus and as a result:

- the activity of beneficial microorganisms in the soil is reduced (especially the nitrogen cycle - nitrifiers, azotobacter, cellulose-decomposing);
- the balance of nutrient biogenic (nitrogen, potassium) and other macro-microelements (Ca, Mg, Zn) is disturbed;
- the efficiency of photosynthesis, respiration decreases, root formation, growth and development of plants;

- favorable conditions are created for the development of microscopic fungi in the soil, including phytopathogens;
- the intake of heavy metals into plants increases;
- soil fertility decreases, because there is a direct correlation between soil fertility and phosphate regime;
- the ability of soil and plants to retain water is deteriorating;
- the productivity of agricultural crops and their quality is reduced.

Improving the phosphate regime of soils and phosphorus nutrition of plants is extremely necessary due to the fact that during phosphorus starvation, the effectiveness of all other nutrients noticeably decreases - the absorption of nitrogen, potassium introduced with fertilizers, as well as macro- and microelements by plant roots and their movement to aboveground soil organs is inhibited [3].

However, the process of biological transformation of phosphorus in the soils of Uzbekistan has not been practically studied, there were no specific ways and methods of directed regulation of the processes associated with the transformation of phosphorus and its use by plants, in connection with which great damage was done to agriculture every year.

In connection with the foregoing, we were faced with the task of developing biologically balanced farming systems based on the maximum use of the biological potential of soils and obtaining environmentally friendly products on this basis.

One of the promising ways to solve the problem of soil phosphatization is the microbiological transformation of sparingly soluble phosphorus-containing compounds. It is known that some soil microorganisms are capable of secreting various organic acids and enzymes as a result of their vital activity and, being in symbiotic interactions with plant root systems and other microorganisms, they can increase the content of soluble phosphorus in the soil, which is easily assimilated by plants.

3 Results and discussion

In the laboratory of soil microbiology and biotechnology of the Institute of Microbiology of the Academy of Sciences of the Republic of Uzbekistan, we have created new environmentally friendly bacterial fertilizers and biopreparations to improve soil fertility, crop yields and quality of agricultural products [4-6].

Bacterial fertilizers of complex action based on new local strains of phosphorus mobilizing bacteria:

1) FOSSTIM-1 - for pre-sowing treatment of industrial crops (cotton, sugar beet) (patents no. IAP 02787, no. IAP 02788).

2) FOSSTIM-3 - for pre-sowing treatment of seeds and seedlings of vegetable crops both in open ground and in greenhouses, melons, legumes, potato tubers, seedlings and trees of horticultural crops and vineyards (patent No. IAP 4712).

Biopreparations of complex action based on new local strains of salt-resistant phosphorus and potassium-mobilizing rhizobacteria with polyfunctional properties.

3) RIZOKOM-1 - for pre-sowing treatment of cotton seeds when cultivating it on saline and native soils (patents No. IAP 05712, No. IAP 05713, No. IAP 05714, No. IAP 05715).

4) RIZOKOM-2 - for pre-sowing treatment of wheat seeds when cultivating it on saline and native soils.

5) SERHOSIL - for foliar feeding of all types of agricultural crops based on green microalgae (patent No. IAP 04933) (Figure 1).

Figure 1. List of patents derived for biopreparations.

At the same time, it should be noted that biofertilizers are not toxic to animals, bees, fish, earthworms, do not contain or emit toxic substances, and do not require special precautions when working with it. They belong to the 4th hazard category - that is, to non-hazardous products.

The mechanism of action of bacterial fertilizers of the FOSSTIM series and biological preparations of the RIZOKOM series in crop production is due to an increase in the symbiosis of plants and soil microbial communities, through an increase in the number of beneficial microorganisms, in particular, a group of free-living nitrogen fixers, phosphorus mobilizing, cellulose-decomposing, nitrifying and other types of microorganisms that are functionally necessary for soils and plants. This mechanism practically steadily increases the level of phosphorus, nitrogen and potassium available to plants in the soil, crop yields, product quality indicators, and also reduces the level of nitrate content in products and the degree of plant disease by several times.

Effective phosphorus mobilizing bacteria introduced into the soil convert soil hard-to-reach phosphates into forms that are assimilated by plants and increase the absorption rate of applied mineral fertilizers, nourish plants with their dead biomass and create optimal living conditions for the rest of the soil microflora and fauna.

Useful microflora of bacterial fertilizers heals plants and strengthens their immunity. This allows plants to tolerate adverse conditions much better, including drought, frost, salt and dust storms, and sudden changes in air temperature.

The mechanism of action of the biological product SERHOSIL is explained by an increase in the photosynthetic surface of the leaves, an improvement in the processes of photosynthesis due to the additional nutrition of plants with extracellular physiologically active substances of green microalgae (amino acids, lipids, extracellular polysaccharides, vitamins, available forms of macro-microelements).

A new science-based bioagrotechnology for environmentally oriented farming, based on the integrated use of bacterial fertilizers and biological products, has been developed and tested in practice.

In many years of field experiments, comprehensive studies have been carried out and the effective influence of the new bioagrotechnology on the state of the soil microbial community, the content of organic matter, mobile forms of nitrogen, phosphorus and potassium, the intensity and direction of biological processes in soils, the yield and quality of agricultural products have been proven.

The use of new biofertilizers in the cultivation of agricultural crops increases the field germination of seeds, stimulates root formation, growth and development of plants, improves nitrogen, phosphorus and potassium nutrition of plants, increases their resistance to phytopathogens and, as a result, helps to increase productivity and product quality, allows get earlier products, increases its safety.

The use of microbiological preparations in the cultivation of agricultural crops and a decrease in the doses of mineral fertilizers leads to an increase in economic efficiency and profitability of production.

The advantages of the new bioagro technology include such factors as a reduction in the consumption of mineral and organic fertilizers by 25-50%; almost 2 times reduction in irrigation water consumption; improving the balance of the soil microbial community in favor of beneficial microflora; increasing soil fertility; normalization of alkaline pH of saline soils; improving the balance of nutrients in the soil and plant nutrition; reduction in the incidence of cotton root rot, gommosis, alternariosis and wilt; reduction in the incidence of winter wheat with root rot, rust, smut, wilting; lowering the degree of phosphatization, soil salinity, reducing soil pollution with mycotoxins and organochlorine pesticides; increasing winter hardiness and drought resistance of plants; increase in the yield of raw cotton - by 8-10 q/ha, vegetable crops (cucumbers - by 3.6-4 t/ha, tomatoes by 12 t/ha), potatoes - by 5.2-5.9 t/ha and quality of agricultural products, increasing the profitability of agricultural production: raw cotton by 52%, wheat by 45%, vegetables and potatoes by 45-90%.

New bioagrotechnologies were developed within the framework of six state applied and one international projects and passed scientific and production state tests at the head institutes of the Ministry of Agriculture of the Republic of Uzbekistan - the Uzbek Research Institute of Cotton Growing, the Uzbek Research Institute of Cotton Breeding and Seed Growing, the Uzbek Research Institute of Vegetables, Melons and Potatoes, the Gallyaaral branch of the Research Institute grain and leguminous crops on irrigated lands, on saline soils of the Syrdarya and Bukhara scientific and experimental stations of the Research Institute of Selection, Seed Production and Agricultural Technology of Cotton Growing, as well as in several farms.

Biological preparation of complex action RIZOKOM-1 in 2014-2015 was introduced on cotton on saline soils in the farm "Suvchi Mirob Dalasi" of the Mirzaabad district of the Syrdarya region. As a result of its use, the fertility of saline soils, the yield of cotton and the quality of the fiber have increased. The increase in the yield of raw cotton amounted to 6-7 q/ha, profitability increased by 20-25%. On saline soils in the Syrdarya branch of the Research Institute of Grain and Leguminous Crops, when using RIZOKOM-2 and SERHOSIL on wheat, an increase in yield of 8-9 q/ha was obtained, the quality of grain improved [6, 7].

Bacterial fertilizers of the FOSSTIM series and biopreparationsof the RIZOKOM series in 2018 were included in the List of drugs approved by the Decree of the President of the Republic of Uzbekistan dated July 14, 2018, No. PP-3855 “On additional measures to increase the efficiency of commercialization of the results of scientific and scientific and technical activities”.

Biopreparations RIZOKOM-1 and SERHOSIL were included in the List of drugs approved by the order of the government of the republic dated October 14, 2018. No. 850-f "Comprehensive program for the development and implementation of the concept of personalized agriculture in the Republic of Uzbekistan for the period 2019-2021".

Biopreparations RIZOKOM-1 and SERHOSIL in 2019-2021 were introduced on cotton in the country on a total area of 20,000 hectares. As a result, the fertility of saline soils, the yield of cotton and the quality of the fiber have increased. The increase in the yield of raw cotton on average in the republic amounted to 7-8 q/ha.

Biopreparations RIZOKOM-2 and SERHOSIL in 2019-2021 were introduced on wheat in the country on a total area of 10,000 hectares. As a result, the fertility of saline soils has improved, the cost of mineral fertilizers has decreased by 50% and the cost of irrigation water has decreased by 20-25%.

The increase in the wheat harvest on average in the republic amounted to 9-10 centners per hectare, the quality of grain improved. Meanwhile, it should be noted that soil phosphating (an increase in phosphorus content) occurs due to the low solubility of soil phosphorus compounds due to the fixation (by 80%) of the applied phosphorus fertilizers with soil calcium in tricalcium phosphate $Ca_3(RO_4)_2$ and a low coefficient (20%) assimilation of phosphorus by plants from applied phosphate fertilizers. As a result, phosphorus and calcium become unavailable for plant nutrition. Soil phosphating also leads to salinization [8].

In addition, soils are also salinized with black salt as a result of the use of potash fertilizers, which leads to the fixation of potassium in the soil with soil silicon in the form of potassium aluminosilicates ($KAlSi_3O_8$), which are insoluble in water and, therefore, potassium and silicon also become unavailable for plant nutrition. According to the degree of saturation with salts, weakly saline soils are distinguished, on which the yield of agricultural crops falls by 25%, on medium saline soils - by 50%, on saline soils - by 75% and on highly saline soils - by 100%.

Soil pollution also occurs when mineral fertilizers are used in excessive amounts. Recently, another an unfavorable aspect of the immoderate consumption of mineral fertilizers and, first of all, nitrogen fertilizers. It turned out that a large amount of nitrates reduces the oxygen content in the soil, and this contributes to an increased emission of greenhouse gases into the atmosphere - nitrous oxide (N_2O) and methane (CH_4). Nitrates also have a negative effect on the human body. Thus, when nitrates enter the human body at a concentration of more than 50 mg/l, their direct general toxic effect is noted [9]. Soil pollution also occurs when a large number of chemical pesticides (fungicides, insecticides, herbicides, etc.) are used in agriculture for seed treatment, control of diseases, pests and weeds of agricultural crops.

Pesticides are able to penetrate into plants from contaminated soil through the root system, accumulate in biomass and subsequently infect the food chain. When spraying pesticides, intoxication and death of birds and beneficial insects is observed. The long-term use of pesticides is also associated with the development of resistant (sustainable) pests and the emergence of new pests whose natural enemies have been destroyed. The surface layers of soils are easily contaminated with pesticides. Large concentrations in the soil of various chemical compounds - toxicants adversely affect the vital activity of soil organisms - microorganisms, flora and fauna.

Currently, heavy metal pollution is a major environmental problem because metal ions remain in nature due to their non-degradable nature. One of the global manifestations of soil degradation, and of the entire environment in general, is desertification. Desertification is a process of irreversible change in soil and vegetation and a decrease in biological productivity, which in extreme cases can lead to the complete destruction of the biospheric potential and the transformation of an area into a desert. On the territory subject to desertification, the physical properties of soils deteriorate, vegetation dies, groundwater becomes saline, biological productivity drops sharply, and, consequently, the ability of ecosystems to recover is undermined.

According to available data, every minute in Central Asia, 9 sq.m. of fertile land turns into a desert. The fight against salinization, degradation and desertification of soils today is one of the foundations of food security. The areas of saline soils in 13 regions of the republic presented in Fig. 1 indicate the need for an urgent solution to improve the fertility of saline soils and the productivity of agricultural crops.

For this reason, it is considered an urgent problem to increase fertility and obtain a high-quality crop on saline, degraded soils through the use of biotechnologies based on the use of new generation biological fertilizers that have an environmentally safe, highly effective effect on degraded soils with the ability to increase seed germination, accelerate the growth and development of plants, improve nourish roots and plants, reduce soil salinity and pollution, prevent desertification, and improve crop immunity and protect plants from diseases and pests.

We, a group of scientists and specialists in the field of microbiology, biotechnology and ecology, have developed an environmentally safe, resource-saving, cost-effective innovative bioagrotechnology for growing agricultural crops on saline, degraded, contaminated with heavy metals, soils close to desertification in Uzbekistan.

The new bioagrotechnology is based on the complex application of new generation bacterial fertilizers of the TERIA series (patent No. FAP 02090) and biological product SERHOSIL (Patent No. IAP 04933).

Figure 2. List of patents derived for new generation bacterial fertilizers of the TERIA series.

We have studied the following polyfunctional properties of microorganisms that are part of the bacterial fertilizer of complex action TERIA:

1. Salt tolerance. Strains from the composition of the TERIA bacterial fertilizer - *Bacillus subtilis* K-4, *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 have high salt-tolerant activity. The influence of increasing concentrations of sulfate (Na_2SO_4 and $MgSO_4$) and chloride (NaCl and $MgCl_2$) toxic salts on their growth activity. The strains showed good growth in the presence of increasing concentrations from 3% to 10% of the above toxic salts in the peptone nutrient medium.

2. Phosphate mobilizing activity. Strains soil bacteria have phosphate-mobilizing activity, as evidenced by the results of a study of the dissolution of $Ca_3(PO_4)_2$.

Strains *bacillus subtilis* K-4, *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 showed the dissolution zones of $Ca_3(RO_4)_2$ on the Pikovskaya medium - 30(±1.5) mm, 31(±1.2) mm and 12(±1.6) mm, respectively.

The mobilization of P_2O_5 from $Ca_3(PO_4)_2$ by *Bacillus subtilis* K-4, *Bacillus thuringiensis* K-7, and *Priestia megaterium* K-8 strains was studied when the strains were cultivated on a peptone medium with a single source of phosphorus $Ca_3(PO_4)_2$: mobilization of P_2O_5 from $Ca_3(PO_4)_2$ in strains of *Bacillus subtilis* K-4, *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 was 115±0.12 mg P_2O_5/100 ml, 128±0.15 mg P_2O_5/100 ml and 128±0.1 mg P_2O_5/100 ml respectively.

3. Potassium mobilizing activity. Strains soil bacteria *bacillus subtilis* K-4, *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 dissolve potassium aluminosilicates $KAlSiO_4$, as evidenced by the dissolution zones of $KAlSiO_4$ strains on solid nutrient media Zak and A-27.

The strains showed the following dissolution zones on the 2 media above, respectively: *Bacillus subtilis* K-4 - 50 ± 1.6 mm and 20 ± 1.4 mm; *Bacillus thuringiensis* K-7 - 20 ± 1.5 mm and 20 ± 1.9 mm; *Priestia megaterium* K-8 - 30 ± 1.4 mm and 20 ± 1.3 mm. Thus, it has been proven that *Bacillus strains subtilis* K-4, *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 have a high potassium mobilizing activity. The release of mobile and water-soluble potassium from potassium aluminosilicate ($KAlSiO_4$) was tested. Mobilization of mobile potassium from $KAlSiO_4$ was 1265 mg/kg in the strain *bacillus subtilis* K-4, in *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 - 1229 mg/kg. Release of water-soluble potassium from $KAlSiO_4$ was 0.048 g/l *bacillus subtilis* K-4, in *Bacillus thuringiensis* K-7, this figure was 0.047 g/l and 0.049 g/l in the strain *Priestia megaterium* K-8.

4. Antifungal activity. The antifungal activity of strains of *Bacillus subtilis* K-4, *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 was tested by the well method. It was found that the studied strains to some extent have antifungal activity against phytopathogenic fungi *Fusarium moniliforme, Alternaria alternata, Alternaria solani, Fusarium solani, Fusarium oxysporium, Aspergilius niger* and *Cladosporium oxysporum* (Table 1).

Table 1. Growth inhibition of phytopathogenic fungi by salt tolerant soil bacteria.

Phytopathogens agricultural crops	**Zone of inhibition growth**	**Soil bacteria strains**		
		***Bacillus subtilis* K-4**	***Bacillus thuringiensis* K-7**	***Priestia megaterium* K-8**
Fusarium moniliforme	D, mm	50±0.58	75±0.58	50±0.58
Alternaria alternata	D, mm	67±1.53	52±1.53	60±1.43
Alternaria solani	D, mm	11.3±0.1	13.4±0.1	-
Fusarium solani	D, mm	-	-	51±0.58
Fusarium oxysporum	D, mm	11.6±0.1	10.2±0.1	-
Aspergilius niger	D, mm	11.2±0.1	8.3±0.1	15.6±0.2
Cladosporium oxysporum	D, mm	13.2±0.2	14.1±0.2	-

5. Ability to decompose gypsum. Strains soil bacteria *bacillus subtilis* K-4, *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 dissolve gypsum - CaSO4 . _ The study of the effect of bacteria on the content of gypsum, pH of the medium and the survival of bacterial cells was carried out in the dynamics of deep cultivation in flasks on a liquid peptone nutrient medium (200 ml) + gypsum (6 g). Deep cultivation was carried out on a rocking chair at 220 rpm at a temperature of 28 ^{0}C for 20 days. The use of a consortium of 3 strains of soil bacteria reduced the content of gypsum in the nutrient medium by 2 times, in the control medium - without bacteria - by 0.5 times. The use of a consortium of bacteria will contribute to the dissolution of gypsum, which can positively affect the development of crops on gypsum soils.

6. Properties of accumulation of heavy metals in the soil. In the last decade, under the influence of high anthropogenic loads, agrolandscapes have been polluted with various ecotoxicants (mercury, lead, cadmium, fluorine, aluminum, arsenic), which are considered toxic heavy metals. Exceeding the norms of toxic substances leads to a violation of soil

quality, an increase in pests and plant diseases, and a decrease in the quality of agricultural products. This negatively affects the health of people and animals. Thus, the use of nitrogen fertilizers increases the acidity of soils, increases the mobility of heavy metals (aluminum, cadmium, copper, lead) and leads to the accumulation in the soil of toxic elements for plants and microorganisms, in particular fluorine. Potash fertilizers, and especially potassium chloride (with excessive application), chlorine and lead are deposited in the soil, soil acidity increases, and the activity of soil microorganisms decreases.

Strains soil bacteria *bacillus subtilis* K-4, *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 are able to reduce the adverse effects of heavy metals entering the soil along with mineral fertilizers and pesticides, increase the fertility of saline, polluted degraded soils, reduce the consumption of heavy metals by plant organs, and increase productivity and product quality.

When using a consortium of 3 strains of bacteria, the amount of toxic heavy metals in the soil decreased compared to the control, without the use of bacteria against the background of mineral fertilizers (NPK): the amount of Zn in the soil decreased by 69.8 mg/kg, Cd - by 0.149 mg/kg, Pb - by 72.5 mg/kg, Mo - by 0.38 mg/kg, Cu - by 58.2 mg/kg, Co - by 7.8 mg/kg, Ni - by 29.9 mg/kg, As - by 2.1 mg/kg and Cr - by 18.7 mg/kg (Table 2).

Table 2. Influence of a consortium of strains of *Bacillus subtilis* K-4, *Bacillus thuringiensis* K-7 and *Priestia megaterium* K-8 on the accumulation of mobile forms of heavy metals in soils under winter wheat crops, adjacent fields of the Almalyk Mining and Metallurgical Combine of the Republic of Uzbekistan (mg/kg, maturation phase, June, n=3, average for 2021-2022).

Experience options	Zn	Cd	Pb	Mo	Cu	Co	Ni	As	Cr
Control, NPK	150,0	0,320	97,8	1,42	90,4	13,8	44,2	20,2	49,8
Experience, NPK, treatment of wheat seeds with bacterial fertilizer TERIA	80,2	0,171	25,3	1,04	32,2	6,0	14,3	18,1	31,1
MPC	55,0	0,5	32,0	2,1	30,0	5,0	14,0	20,0	30,0

Based on the complex application of bacterial fertilizer TERIA and biological product SERHOSIL we have developed a new environmentally friendly and cost-effective, resource-saving bioagro technology for growing agricultural crops on medium and highly saline soils of Uzbekistan (Table 3).

Table 3. Influence of complex application of bacterial fertilizer TERIA and biopreparation SERHOSIL on crop yields on saline degraded soils (field trials, average for 2021-2022).

Agricultural essential culture	Yield, q/ha		Yield increase	
	Control, NPK traditional sowing	Experience, NPK TERIA + SERHOSIL	q/ha, t/ha	%
Cotton	25.0±0.7	34.0±1.5*	9.0±0.05	36.0
Sugar beet, t/ha	34.5 ±1.2	75.0 ±2.6*	40.5 ±0.4	17.4
Winter wheat	3 8, 4 ±1.3	51.2±2.5*	12.8 ±1.3	13.3
Soya	22.1 ±0.6	34.1 ±1.2*	12.0 ±1.2	54.3
Potato, t/ha	41.5±0.5	46.7±1.3*	5.2±0.03	12.5
Tomatoes, t/ha	23.6±0.8	30.1 ±1.5*	6.5 ±0.4	27.5
Cucumbers, t/ha	19.0 ±1.2	22.5 ±0.6*	3.1 ±0.02	18.4

The created new bioagro technology can be effectively used in the production of environmentally friendly organic agricultural products that meet international Organic and Global standards. G.A.P (Figures 3-8 and Table 4).

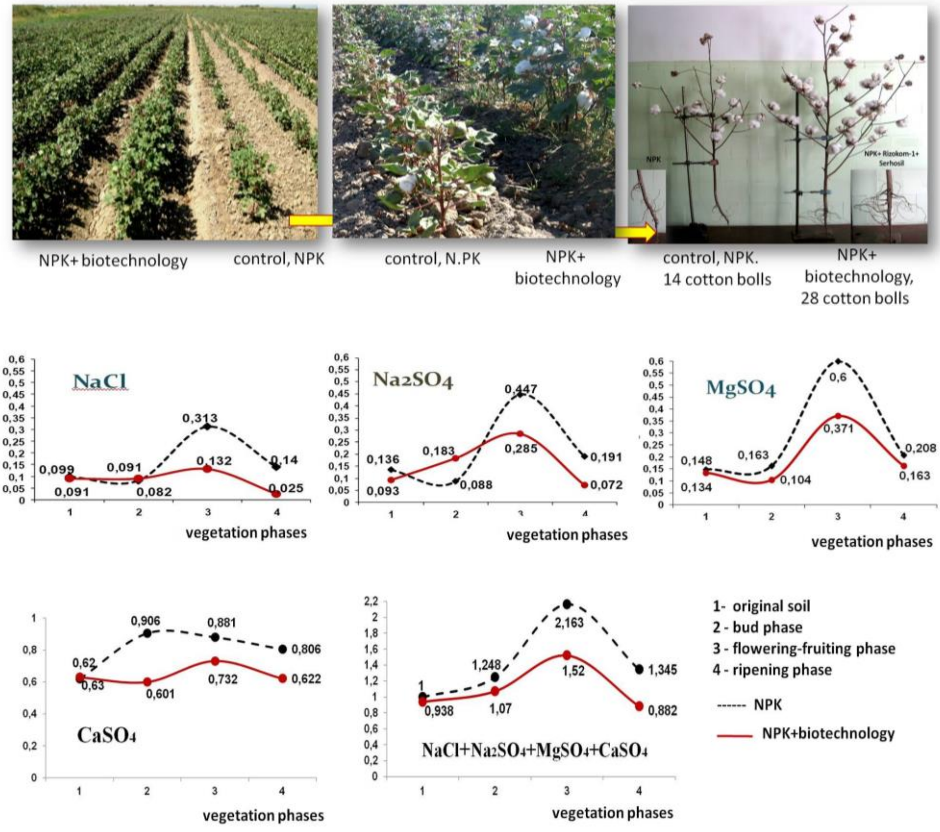

Figure 3. Influence of biotechnology on the development of cotton on highly saline soils of the Sirdarya Branch of the Institute of Cotton Growing (Uzbekistan).

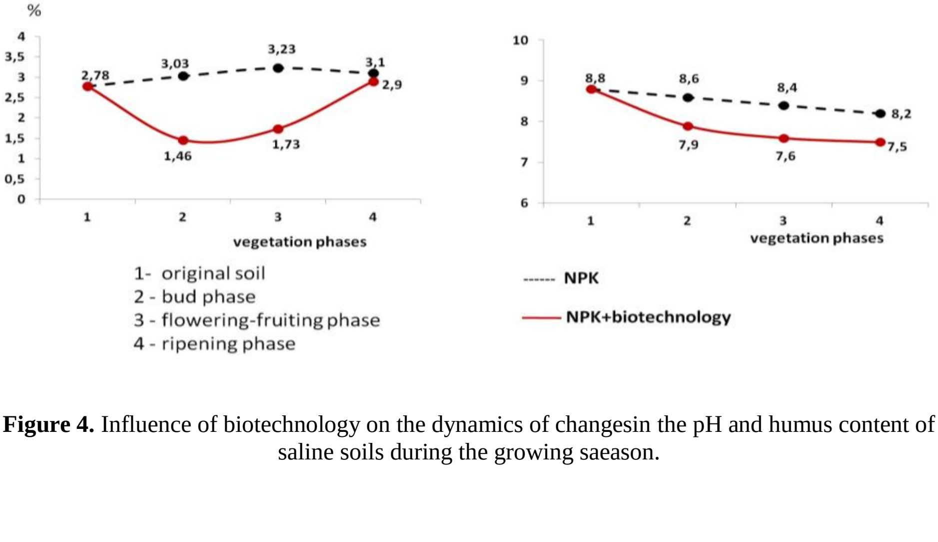

Figure 4. Influence of biotechnology on the dynamics of changesin the pH and humus content of saline soils during the growing saeason.

Table 4. Use of bioagrotechnology on highly saline soils of Karakalpakstan (Uzbekistan).

Region	**Farm**	**Year**	**Cotton variety**	**Cotton yield, q/ha**		**Increase in yield, q/ha**	**Increase in yield, %**
				control, NPK	**NPK+ Teria+Serhosil**		
Turtcul district	“Turtcul Agroclaster” LLC	2022	C-4727	12.0±0.6	30.0±1.5	18.0±1.0	25.0
Biruni district	"Fozilbek Komolovich"	2022	Sulton	20.0±2.7	40.0±1.7	20.0±2.1	100.0
Average				17.0±0.7	28.5±2.6	11.5±1.0	53.1

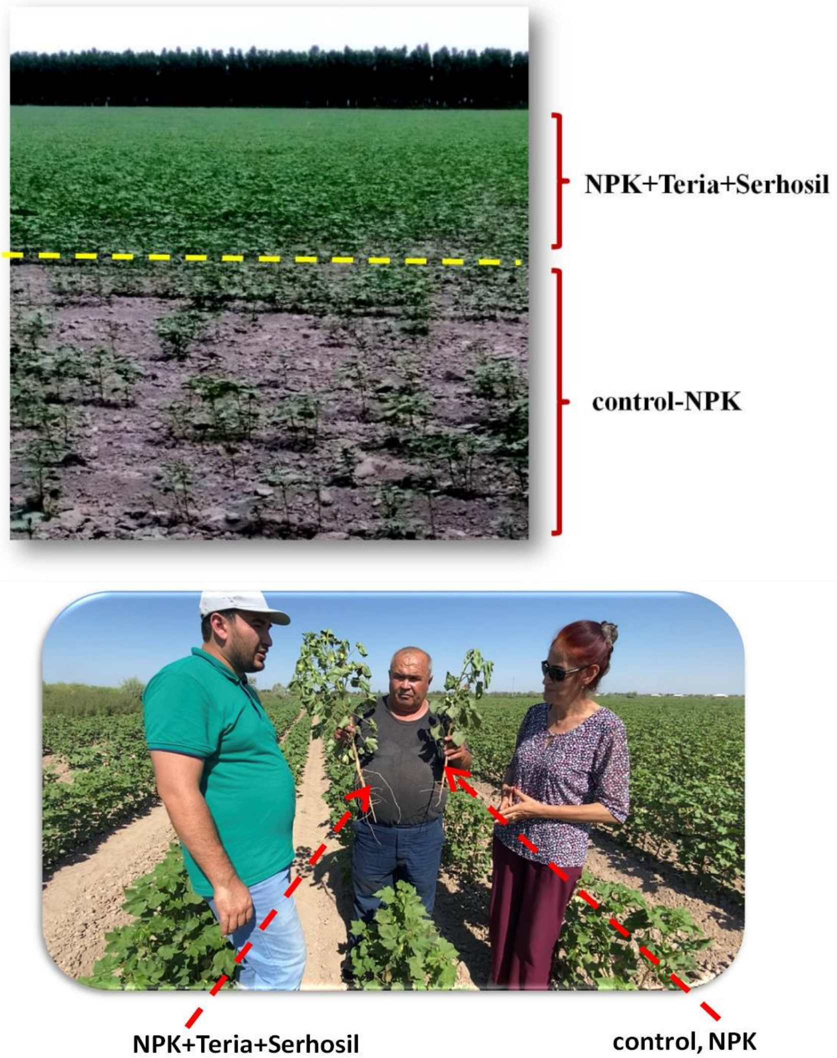

Figure 5. Use of bioagrotechnology on highly saline soils of Karakalpakstan (Uzbekistan).

Figure 6. Cotton crop of “Uztex Cluster” based cotton farms using bioagrotechnology in Khorezm (Uzbekistan).

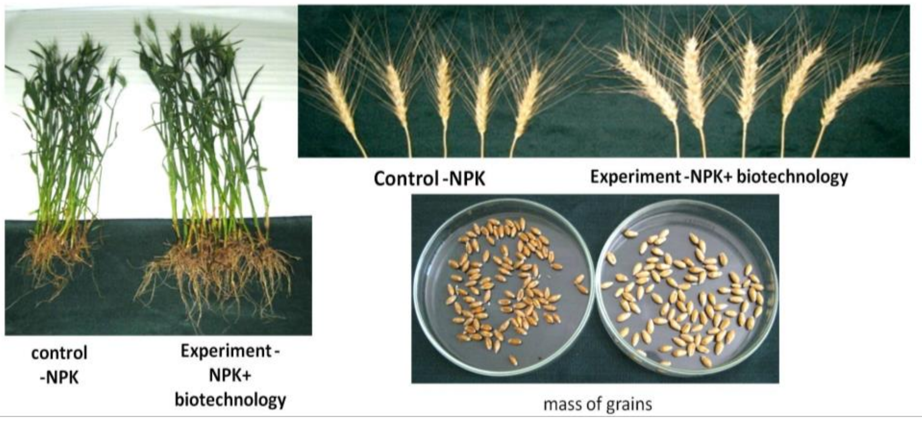

Figure 7. Influence of new biotechnology on the development of the root system of the aboveground mas of wheat (Uzbekistan).

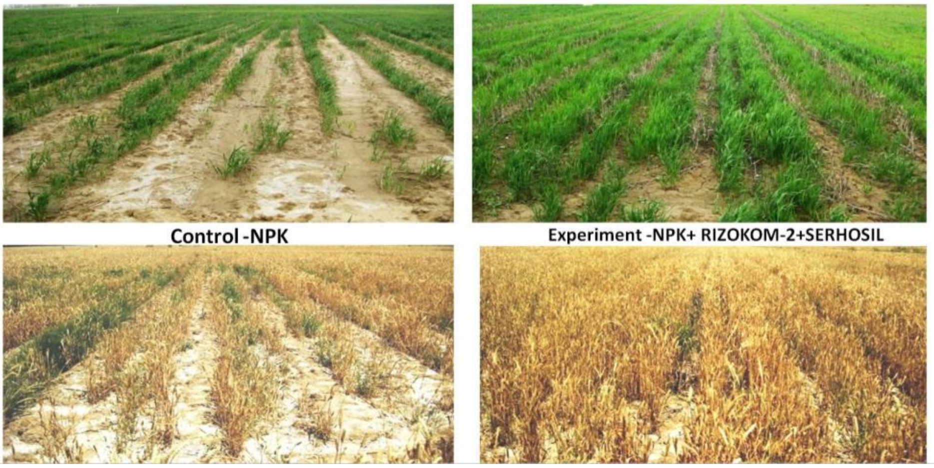

Figure 8. Efficiency of biotechnology on winter wheat on highly saline soils of Sirdarya (Uzbekistan).

4 Conclusions

Thus, based on the conducted scientific research and field tests and implementation on saline, degraded soils in the Syrdarya, Jizzakh, Bukhara, Namangan, Andijan, Fergana, Khorezm regions and Karakalpakstan, a new bioagrotechnology on cotton on an area of 7,500 hectares and on wheat on an area of 2,500 ha, the following tangible 4 beneficial effects were identified:

1) resource saving effect:
- increase in the coefficient of digestibility of applied fertilizers;
- restoration and increase of soil fertility;
- increasing the field germination of seeds of agricultural crops on saline soils;
- reduction of seeding rates by 10-30%;
- reduction of irrigation water consumption by 30-40%.

2) economic effect:
- increase in productivity of agricultural crops by 12-54% and product quality;
- reduction of damage to agricultural crops by diseases and pests;
- increase of immunity, drought resistance and winter hardiness of plants;
- reduction of terms of ripening of agricultural products by 15-20 days;
- increasing the profitability of agricultural production up to 35-40%;
- increasing the shelf life of finished products in warehouses.

3) environmental effect:
- reduction of chemical load on the soil and agricultural crops;
- reduction of doses of chemical fungicides for dressing seeds;
- decrease in the degree of phosphatization, salinity, soil pollution with heavy metals, health improvement of soil environment.

4) social effect:
- improving the quality of agricultural products (reducing the content of nitrates in products, increasing the content of vitamins and useful macro-microelements);
- improving the health of the population.

The developed new bioagro technology may well be used to manage the fertility of saline and degraded soils and the processes of plant nutrition. The soil becomes healthy, its productivity increases significantly.

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