Impact of microalgae-based biopreparation on soil fertility

Mukhayo Tagaeva[1*], *Bakhtiyar* Takhirov[1], and *Zarnigor* Toxirova[1]

[1]Bukhara State University, Bukhara, Uzbekistan

Abstract: This study highlights the analysis of changes in the total humus content, nitrogen, phosphorus, potassium, and easily assimilable nutrients in soil samples to evaluate the impact of a biopreparation based on algological objects on soil fertility. Additionally, the experiments indicated that the use of microbiological biopreparations, such as "Algobiostim" and "Serhosil", through foliar spraying can effectively stimulate the growth of plants. The liquid form of the "Algobiostim" biopreparation was particularly noted for its ease of application, growth-stimulating properties, and effectiveness in combating microbiological diseases. Subsequent studies at the "IGX Ziraboti" farm in the Bukhara region confirmed the biological effectiveness of the "Algobiostim" biopreparation when applied at 4.0 l/ha. The results indicated that the biological effectiveness of the experimental plot was 50.20% lower than the experimental plot treated with "Algobiostim" and Serhosil biopreparations, which achieved 86.42% and 93.24% effectiveness, respectively. When applied at 4.5 l/ha, the biological effectiveness of the "Algobiostim" biopreparation was 92.18%, while the Serhosil-treated plot achieved 94.31%, 2.13% higher than the experimental plot. The experimental plots treated with "Algobiostim" yielded an additional 2.38 q/ha at 4.0 l/ha and 3.16 q/ha at 4.5 l/ha, while the Serhosil-treated plot yielded an additional 4.83 q/ha.

1 Introduction

It is well-documented in scientific literature that one of the most critical properties of soil is its fertility, which is determined by several factors, including humification, dehumification, nitrogen fixation, ammonification, nitrification, denitrification processes, as well as the soil's carbon, phosphorus, and sulfur exchange or storage capacities[1]. The humus-retaining capability of the soil is a particularly important attribute of soil fertility. This property depends on numerous interconnected and highly significant processes. For instance, the humus content in soil is influenced by the microbiological processes occurring within it, as well as the biological activity and population of beneficial microorganisms present [2-5].

The rate of microbiological processes in soil and their active role in humus formation are largely determined by the types of microbes involved and their adaptability to environmental conditions. The object of this study, the meadow-alluvial soils commonly found in the Bukhara region, exhibits unique characteristics in this context[2].

* Corresponding author: m.b.tagaeva@buxdu.uz

When assessing soil fertility, it is essential to consider multiple soil properties, including microbiological factors. These factors are crucial for predicting soil fertility and evaluating its future potential [2, 6-13]].

2 Results and Analysis

Since one of the primary objectives of our research was to evaluate the role of microbiological biopreparations in enhancing soil fertility, laboratory experiments were conducted to assess the impact of biopreparations derived from algological objects on the fertility of soil with a defined composition. The focus of the study was to monitor changes in the total humus content, nitrogen, phosphorus, potassium, and readily assimilable nutrient elements in soil samples.

For this purpose, soil samples were collected from cotton-growing fields in the Bukhara district, Bukhara region, at a depth of 0–30 cm. The collected samples were analyzed to determine the soil's main plant-accessible nutrient elements and humus content (see Table 1).

The total humus content was determined using the conventional I.V. Tyurin method, while the total nitrogen, phosphorus, and potassium contents were analyzed using the traditional Malseva and Gritsenko methods. The mobile phosphorus content was assessed using the I. Machigina method, and potassium content was measured photometrically[2].

During the study, a 100 m² plot was divided into 10 sections. From each section, three samples were collected from depths of up to 30 cm. The 30 cm depth was chosen because soil microflora typically thrive within this layer. The results indicated that the average humus content in the first variant soil samples was 0.842%, with an average nitrogen content of 0.129%, phosphorus content of 0.284%, and potassium content of 1.641%.

The quantities of readily assimilable mobile elements were recorded as follows: nitrogen compounds, 14.23 mg/kg; phosphorus elements, 16.75 mg/kg;

and potassium elements, 193.02 mg/kg. These findings highlight the significant role of biopreparations in improving soil fertility through the enrichment of essential nutrients.

Table-1. Initial Composition of Soil Samples Collected from the "Sayfillo Bobo Ziraboti" Farm in the Bukhara District, Bukhara Region

Experimental Variants	Soil samples and replicates	Humus Content by Variants, %	Average content of humus, %	Total, %						Mobile Elements, mg/kg					
				$N{\times}NH_4$ Content by Variants	Average $N{\times}NH_4$ Content	P_2O_5 Content by Variants	Average P_2O_5 Content	K_2O Content by Variants	Average K_2O Content	$N{\times}NH_4$ Content by Variants	Average $N{\times}NH_4$ Content	P_2O_5 Content by Variants	Average P_2O_5 Content	K_2O Content by Variants	Average K_2O Content
1	№1: 0-30	0,841	0,842	0,138	0,129	0,283	0,284	1,661	1,641	14,23	14,09	16,82	16,75	203,14	193,02
	№1: 0-30	0,854		0,127		0,292		1,627		13,72		16,73		187,29	
	№1: 0-30	0,832		0,123		0,276		1,634		14,31		16,69		188,62	
2	№2: 0-30	0,931	0,867	0,141	0,137	0,268	0,274	1,801	1,759	13,48	13,56	15,13	15,48	201,31	202,94
	№2: 0-30	0,828		0,137		0,274		1,792		13,62		15,24		204,17	
	№2: 0-30	0,842		0,133		0,281		1,684		13,57		16,08		203,33	
3	№3: 0-30	0,913	0,864	0,121	0,125	0,301	0,288	1,645	1,656	14,08	14,06	16,27	16,26	198,55	197,72
	№3: 0-30	0,856		0,125		0,287		1,651		14,27		16,34		198,18	
	№3: 0-30	0,824		0,129		0,276		1,672		13,82		16,18		196,44	
4	№4: 0-30	0,853	0,842	0,128	0,127	0,291	0,288	1,823	1,791	14,23	14,41	16,23	16,21	203,15	204,11
	№4: 0-30	0,841		0,127		0,284		1,782		14,48		16,54		206,06	
	№4: 0-30	0,832		0,125		0,289		1,768		14,52		15,87		203,11	

5	№5: 0-30	0,857	0,838	0,131	0,130	0,303	0,297	1,882	1,802	13,81	13,83	15,92	15,84	198,62	197,20
	№5: 0-30	0,824		0,130		0,293		1,756		13,76		15,78		194,76	
	№5: 0-30	0,833		0,130		0,296		1,768		13,91		15,81		198,23	
6	№6: 0-30	0,871	0,844	0,127	0,126	0,301	0,300	1,648	1,661	14,23	14,48	16,13	16,24	198,38	198,46
	№6: 0-30	0,836		0,124		0,306		1,671		14,68		16,42		197,64	
	№6: 0-30	0,825		0,127		0,292		1,664		14,52		16,18		199,35	
7	№7: 0-30	0,844	0,828	0,129	0,125	0,274	0,281	1,648	1,656	13,74	13,64	16,28	16,27	204,28	204,10
	№7: 0-30	0,823		0,123		0,286		1,653		13,51		16,36		203,84	
	№7: 0-30	0,818		0,123		0,284		1,667		13,68		16,17		204,18	
8	№8: 0-30	0,901	0,860	0,124	0,125	0,283	0,284	1,658	1,653	14,08	14,08	16,28	16,21	201,33	201,12
	№8: 0-30	0,842		0,124		0,279		1,643		14,27		16,09		200,87	
	№8: 0-30	0,836		0,127		0,291		1,657		13,88		16,25		201,16	
9	№9: 0-30	0,818	0,822	0,126	0,125	0,281	0,286	1,823	1,787	14,72	14,35	15,92	15,97	199,23	199,00
	№9: 0-30	0,824		0,123		0,283		1,783		14,48		15,87		196,74	
	№9: 0-30	0,824		0,127		0,294		1,754		13,86		16,13		201,04	
10	№10: 0-30	0,825	0,828	0,131	0,129	0,294	0,293	1,684	1,700	13,27	13,35	16,14	16,32	201,43	201,27
	№10: 0-30	0,835		0,128		0,296		1,713		13,41		16,43		200,92	
	№10: 0-30	0,823		0,128		0,289		1,704		13,38		16,38		201,46	
O'rtacha miqdor ko'rsatkichi, %		0,844		1,279		0,288		1,711		13,98		16,16		199,89	

The average quantitative indicators of the 30 soil samples collected from the studied farm were as follows:

- Total humus content: 0.84%
- Average nitrogen content: 1.23%
- Average phosphorus content: 0.3%
- Average potassium content: 1.71%

The quantities of mobile nutrient elements were determined as follows:

- Average nitrogen compounds: 13.98 mg/kg
- Average phosphorus compounds: 16.16 mg/kg
- Average potassium compounds: 199.89 mg/kg

These results were accepted as the initial state of the soil.

Subsequently, 10 g of dry biopreparation was added to each soil sample (each weighing 6 kg), ensuring uniform distribution by thorough mixing. The biopreparation was a model "Algobiostim" biopreparation based on B. braunii-AnDI-115 and Ch. infusionum-AnDI-76 strains, grown in Chu-13 nutrient medium. Each gram of the dry biopreparation contained 30 billion viable cells per gram.

During the experiment, the soil samples were left outdoors for 30 days, with irrigation applied every 10 days based on the standard procedure (30 ml/kg). The goal of the 30-day observation period was to identify the changes in the humus content and the quantity of readily assimilable nutrients in the soil.

After 30 days of observation, the soil composition was analyzed using the same methods and procedures (see Figure 1.).

The results showed that, while no significant changes were observed in the chemical composition of the soil, the humus content increased slightly, though insignificantly. Specifically, the average quantitative indicators of the soil samples treated with the microalgae-based dry biopreparation were as follows: total humus increased from 0.84% to 0.88%, while no significant changes were noted in the nitrogen, phosphorus, and potassium contents.

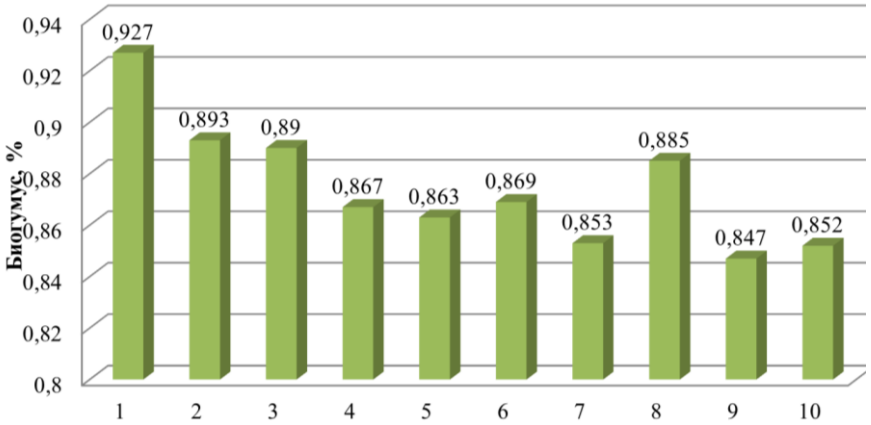

Fig. 1. Biohumus Retention in Soil Treated with Biopreparation,%
(Soil Samples Numbered 1-10)

Based on the obtained results, it was concluded that the dry biomass of the microalgae applied to the soil led to a partial change in the humus content. The following conclusions were drawn from the experimental findings:

1. **Irrelevance in Production Conditions:** The achieved quantitative indicator does not have significant importance in industrial conditions.
2. **Impact on Microbiological Processes:** The dry biopreparation applied to the soil may not have directly influenced the humus content but could have affected the microbiological processes in the soil.
3. **Role as Nutrient Source:** The dry biopreparation, based on microalgae, may have decomposed in the soil, serving as a nutrient source for microbiological processes. Microalgae are known for their rapid decomposition, which is due to the high amount of quickly decomposing organic matter present in their cells.

When comparing the obtained results with global scientific literature, it was found that cyanobacteria like Nostoc, Cylindrospermum, and Anabaena are typically more effective in significantly increasing soil humus content. For instance, Moldovan scientists prepared a biopreparation using a mixture of these three cyanobacteria, which, when applied to cucumbers in greenhouse conditions, significantly increased nitrogen levels in the soil and altered its acidity. This led to a 30.5-46.4% increase in plant growth and a 12.3-44.4% increase in flower count. However, these studies did not show a direct effect on soil humus content[2].

Additionally, research has indicated that the use of microalgae suspensions (Chlorella vulgaris) during rainy weather when applied to wheat increased the content of humic acids in the soil. Similar to our findings, these researchers concluded that the microalgae primarily provided nutrients to the soil's microbiological and biochemical processes, which likely led to the slight increase in humic acid content in the soil[2].

From the comparative analysis with global scientific sources, we are confident that our conclusions are correct. Therefore, the results presented in the dissertation are scientifically and theoretically valid. Based on these findings, we concluded that algological biopreparations prepared from microalgae are most effective when applied during the plant's growing phase via foliar spraying. We hypothesize that microalgae influence plant growth positively through phytohormones, thereby promoting plant development. Consequently, in further research, the application of liquid biopreparations in industrial processes will be tested.

3 Conclusion

During the research, the effect of a biopreparation prepared from the co-cultures of *B. braunii-AnDI-115* and *Ch. infusionum-AnDI-76* on cotton seed germination was studied under production conditions. The initial experimental trials for the introduction of the biopreparation into practice were conducted at the "Sayfillo Bobo Ziraboti" farm in the Bukhara district, Bukhara region. The biological effectiveness of the "Algobiostim" biopreparation, prepared from microalgae, was studied based on its application in the growth and development of the medium-sized cotton variety Bukhoro-10 in a production environment.

The production conditions for the experiment were as follows: the experimental object was the medium-sized Bukhoro-10 cotton variety, and the biopreparation was prepared from *B. braunii-AnDI-115* and *Ch. infusionum-AnDI-76* strains, cultivated in the CHu-13 nutrient medium. The biopreparation was applied at a rate of 4.0-4.5 l/ha (30 billion cells/ml).

The experiment was carried out in the first section of the "Sayfillo Bobo Ziraboti" farm on an area of 2.0 hectares. As a control, 0.5 hectares were left untreated. A sample plot was also allocated, which was treated with the Serhosil biopreparation (2.5 l/ha, "Agro Natural Life" LLC, Uzbekistan).

Cotton seedlings were treated three times by spraying a liquid on the leaves when the first 4-5 true leaves appeared, during the bud formation, and at the flowering stage. The experiment was monitored every 10 days by measuring the biometric parameters of the seedlings. The biopreparation was mixed with 300 liters of water at a rate of 4.0/4.5 liters per hectare.

According to the results, when the "Algobiostim" biopreparation was applied at a rate of 4.0 l/ha, it demonstrated a clear biological effectiveness compared to the control and sample plots. Biometrics of untreated cotton seedlings of the Bukhoro-10 variety in the control plot showed 56.31% lower biological effectiveness compared to the experimental plot, with a 32.84% reduction in chlorophyll content and root length.

In the experimental plot, biological effectiveness was 89.15%, and the sample plot, treated with Serhosil, achieved 94.46%, which was 5.31% higher than the experimental plot. When the biopreparation was applied at 4.5 l/ha, its biological effectiveness increased to 93.23%, while the sample plot showed a 94.87% effectiveness, 1.64% higher than the experimental plot.

The biological effectiveness of the experimental plot was 19.86% higher compared to the untreated control (73.37%). Furthermore, the results of the study showed that the use of "Algobiostim" at 4.0 l/ha under conventional agricultural technologies increased cotton yield by 3.11 q/ha, and at 4.5 l/ha, it increased the yield by 4.68 q/ha. In comparison, the Serhosil biopreparation-treated plot yielded an additional 4.96 q/ha.

Additionally, the experiments indicated that the use of microbiological biopreparations, such as "Algobiostim" and "Serhosil", through foliar spraying can effectively stimulate the growth of plants. The liquid form of the "Algobiostim" biopreparation was particularly noted for its ease of application, growth-stimulating properties, and effectiveness in combating microbiological diseases.

Subsequent studies at the "IGX Ziraboti" farm in the Bukhara region confirmed the biological effectiveness of the "Algobiostim" biopreparation when applied at 4.0 l/ha. The results indicated that the biological effectiveness of the experimental plot was 50.20% lower than the experimental plot treated with "Algobiostim" and Serhosil biopreparations, which achieved 86.42% and 93.24% effectiveness, respectively.

When applied at 4.5 l/ha, the biological effectiveness of the "Algobiostim" biopreparation was 92.18%, while the Serhosil-treated plot achieved 94.31%, 2.13% higher than the experimental plot. The experimental plots treated with "Algobiostim" yielded an

additional 2.38 q/ha at 4.0 l/ha and 3.16 q/ha at 4.5 l/ha, while the Serhosil-treated plot yielded an additional 4.83 q/ha.

In conclusion, the application of microbiological biopreparations through foliar spraying has proven to be a highly effective method for stimulating plant growth and improving yield, with the "Algobiostim" biopreparation showing strong potential for further use in cotton production.

References

1. Mukhayo Tagaeva, Anorgul Gulova, and Nafisa Koshshaeva. BIO Web of Conferences **141**, 03016 (2024)
2. Alvarez, A. L., Weyers, S. L., Goemann, H. M., Peyton, B. M., Gardner, R. D. (2021). Algal Res. **54**, 102200. doi: 10.1016/j.algal.2021.102200
3. Anastopoulos, I., Omirou, M., Stephanou, C., Oulas, A., Vasiliades, M. A., Efstathiou, A. M., et al. (2019). J. Environl. Manage. **250**, 109389. doi: 10.1016/j.jenvman.2019.109389
4. Balasubramaniam, V., Gunasegavan, R. D. N., Mustar, S., Lee, J. C., Mohd, N., Mohd, F. (2021).Molecules **26**, 943. doi: 10.3390/molecules26040943
5. Bibi, S., Saadaoui, I., Bibi, A., Al-Ghouti, M., Dieyeh, M. H. A. (2024). Bioresource Technol. Rep. **25**, 45–57. doi: 10.1016/j.biteb.2024.101789
6. Chen, G., Wu, C., Wang, F., Lyu, H., Lu, Y., Yan, C., et al. (2022). Biotech **5,** 1–17. doi: 10.1007/s13205-022-03167-6
7. Dalal, R. C., Strong, W. M., Weston, E. J., Cooper, J. E., Lehane, K. J., King, A. J. (2018). Soil Res. **4,** 429–440. doi: 10.1071/SR17228
8. Lakatos, G., Balogh, D., Farkas, A., Ordod, V., Nagy, P. T., Biro, T., et al. (2017). Algal Res. **28**, 161–171. doi: 10.1016/j.algal.2017.10.024
9. Liu, Z. X., Liu, J. J., Yu, Z. H., Yao, Q., Li, Y. S., Liang, A. Z., et al. (2020). Soil. Till. Res. **197**, 104503. doi: 10.1016/j.still.2019.104503
10. FAO; UNICEF; WFP; WHO. The State of Food Security and Nutrition in the World 2017: Building Resilience for Peace and Food Security; FAO: Rome, Italy, 2017.
11. Babalola, O.O. Beneficial bacteria of agricultural importance. Biotechnol. Lett. 2010, **32**, 1559–1570.
12. Reed, M.; Glick, B.R. Applications of plant growth-promoting bacteria for plant and soil systems. In Applications of Microbial Engineering; Taylor and Francis: Enfield, CT, USA, 2013; pp. 181–229.
13. Glick, B.R. Introduction to plant growth-promoting bacteria. In Beneficial Plant-Bacterial Interactions; Springer: Berlin/Heidelberg, Germany, 2020; pp. 1–37.