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IMPACT OF ORGANOMINERAL FERTILIZERS-AMELIORANTS BASED ON NATURAL ALUMINOSILICATES AND BIOLOGICALLY ACTIVE SUBSTANCES ON A CORN GROWTH. PART 1

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Abstract. This paper studies the impact of expanded vermiculite, humic substances and organomineral ameliorant fertilizers obtained by immobilizing humic substances on expanded vermiculite on the growth of corn plants. Immobilization of humic substances on natural aluminosilicates, such as expanded vermiculite allows achieving a synergistic effect combining the ameliorative properties of expanded vermiculite, which improves soil structure and water-holding capacity with the fertilizing properties of humic substances, stimulating plant growth and increasing their resistance to stress. In addition, the use of this organomineral ameliorant-fertilizer of prolonged action helps maintain soil fertility for a long time due to the gradual release of nutrients and improvement of the agrochemical characteristics of the soil. Indicators of total biomass, root and aboveground part mass, number and mass of green leaves, as well as morphometric parameters such as plant height and stem thickness were considered in laboratory experiments. The obtained results demonstrate a significant improvement in plant growth when using the developed ameliorant fertilizers under conditions of moisture deficiency and highly depleted soils. According to the results of the experiment, the total biomass with roots increased by 57.3% when using expanded vermiculite and by 80.7% when adding humic substances. The use of the ameliorant fertilizer "GumiVer" (soil:GumiVer/9:1) increased the biomass by 127.6% compared to the control, which confirms the synergistic effect between the components of the ameliorant fertilizer. The increase in the mass of the aboveground part and the mass of roots when using the ameliorant fertilizer "GumiVer" was 135.8 and 107.3%, respectively.

Key words: ameliorant, biofertilizer, expanded vermiculite, humic substances, biologically active substances.

INTRODUCTION

Decrease in soil fertility in Kazakhstan is a serious problem that has a negative impact on crop yields and food security of the country. In Kazakhstan, due to its geographical location and arid climate, issues of preservation and restoration of soil fertility require special attention. According to the author [1], up to 30% of humus has been lost in the non-irrigated zone of Northern Kazakhstan compared to the natural state, and up to 50% in irrigated soils of southern Kazakhstan, due to secondary salinization processes and soil pollution.

The excessive use of chemical fertilizers and pesticides is one of the reasons for the deterioration of soil properties. The use of synthetic fertilizers reduces the level of organic matter in the soil and leads to a decrease in its fertility. In addition, excessive use of fertilizers causes the accumulation of salts in the soil, which makes it less suitable for agriculture. This is especially problematic in regions with insufficient rainfall, where salts can accumulate in the surface layers of the soil.

In this regard, the development of organomineral ameliorant fertilizers based on natural minerals and biologically active compounds seems to be a very promising direction for improving soil properties and increasing the productivity of agricultural crops [2]. Among natural minerals, alumi-

nosilicate minerals can be distinguished. Such minerals include expanded perlite and vermiculite. The advantage of natural minerals is their low cost and functional ability to act as ameliorants [3-5].

Expanded vermiculite is a natural aluminosilicate that increases in volume during heat treatment due to the expansion of its layered structure. This material has unique physical and chemical properties, which makes it valuable in various industries, including agriculture. Expanded vermiculite has high porosity, which helps retain moisture and air in the soil. The ability of expanded vermiculite to adsorb water and nutrients, retain and gradually release them to plant roots reduces the loss of water and nutrients and ensures their long-term supply.

The expanded vermiculite is neutral to acids and alkalis, making it safe for use in agriculture without the risk of changing the acid-base balance of the soil. The expanded vermiculite does not decompose under the influence of microorganisms, does not emit toxic substances, and does not contain heavy metals, which makes it safe for use in environmentally friendly farming. The vermiculite contains magnesium, potassium, calcium and other microelements, which are additional nutrients for plants. The expanded vermiculite is used to improve the soil structure, increasing its looseness and water-holding capacity. This is especially useful for heavy or sandy soils, improving drainage and preventing nutrient leaching [6-8]. In general, the expanded vermiculite is a valuable material for improving the physical properties of soil, increasing crop yields and sustainability of agricultural crops.

Humic substances (HS) produced from various raw materials of organic nature, which easily included in the natural cycles of substances that activate the growth and development of living organisms. The presence of various functional groups in the HS, including aromatic structures determines their active participation in sorption processes, in reducing the mobility and bioavailability of toxic elements. Due to these properties, HS are recommended for practical use in many areas, including the restoration of the ecological state of soils exposed to chemical pollution, in particular heavy metals.

Humic products are most widely used in agriculture as plant growth stimulants, and mainly in the form of easily soluble salts of humic acids with alkali metals. They are physiologically active forms of humic acids and act at the cellular level - they change the permeability of cell membranes; increase enzyme activity and the rate of physiological and biochemical processes; stimulate respiration, protein and carbohydrate synthesis in plants. The use of these preparations leads to an increase in crop yields, especially in unfavorable climatic conditions. Being non-specific activators of the immune system, humic products increase plant resistance to various diseases. Experiments with various crops of higher plants have shown that the use of industrial humates (salts of humic acids) of sodium, potassium and ammonium, regardless of the source of raw materials for their production. They in optimal doses significantly stimulates seed germination, improves respiration and nutrition of plants, increases the length and biomass of plant sprouts, enhances enzymatic activity and reduces the entry of heavy metals and radionuclides into plants. The positive effect of humic substances on plant growth is usually associated not only with the direct interaction of humic substances molecules with roots (“hormone-like activity”) and activation of physiological processes in the plant, but also through the manifestation of various indirect effects. For instance, humic products are capable of buffering pH that increasing water retention and mobilizing

the availability of nutrients [9-13]. Therefore, the creation of new organomineral fertilizers-ameliorants possessing fertilizing, meliorating and structure-forming effects can be used in agriculture to increase the fertility of degraded and low-productivity soils by improving their nutritional, physical-mechanical and water-saving properties, as well as the ability to convert toxicants - heavy metals into an immobile form that creating conditions for obtaining environmentally friendly plant products.

The main purpose of this study is to develop an organomineral fertilizer-ameliorant based on expanded vermiculite and humic substances and their effect on corn growth. For this purpose, pot experiments were conducted both using the developed preparations and with individual components of the preparation to test the hypothesis about the possible synergy of their properties.

MATERIALS AND METHODS

Natural sorbents and biologically active additives were used as a prepared of organomineral ameliorant fertilizer. For the production of organomineral ameliorant fertilizer, industrially produced samples of expanded vermiculite from the Kulantau deposit (Avenue LLC) and potassium humate (Black Biotechnology LLC) were used.

Main characteristics of expanded vermiculite grade M-150: bulk density of expanded vermiculite up to 140 kg/m^3, mass fraction of moisture from 0.15–0.8%. Water capacity is 345.0%. Granulometric composition of expanded vermiculite is from 0.1 to 7.0 mm. The main fraction is from 1.0 to 2.0 mm in size with a mass fraction of 53%. With a size from 2.0 to 5.0 mm, the mass fraction is 35.2% of the total mass. The chemical composition of the HS is in table 1.

Table 1. Chemical composition of the Humic substance solution (according to the manufacturer)

№	Sample	Determined indicators	The actual obtained results
1	Potassium humate solution	Total fulvic acid content	16.11 g/dm^3
2		The share of fulvic acids in the total content of humic substances	61%
3		Total dissolved humic acids	10.49 g/dm^3
4		The share of humic acids in the total content of humic substances	39%
5		Total nitrogen (N)	45.00 mg/dm^3
6		Total phosphorus (P)	54.60 mg/dm^3
7		Potassium (K)	29.1 g/dm^3

Pre-weighed samples of expanded vermiculite were dried to a constant mass in order to produce the ameliorant fertilizer. Then, with constant stirring, a 2% solution of humic substances is added to the expanded vermiculite until they are completely evenly distributed in the total mass. The volume of the humic substance solution corresponds to 80% of the maximum moisture capacity of the expanded vermiculite. The obtained preparation was incubated for 24 hours to fully equalize the humic substance content on the natural carrier. Then the samples were dried to an airdry state under ambient conditions. The thusmade ameliorant-fertilizer based on expanded vermiculite immobilized with humic substances is conventionally called "GumiVer".

Soil. In the experiments used soil selected in the foothill-steppe zone of the Almaty region near the village of Koldi, Karasai district on an old-irrigated, old-arable, depleted and degraded site with coordinates: 43°19'31.8"N 76 °42'44.9"E (figure 1).

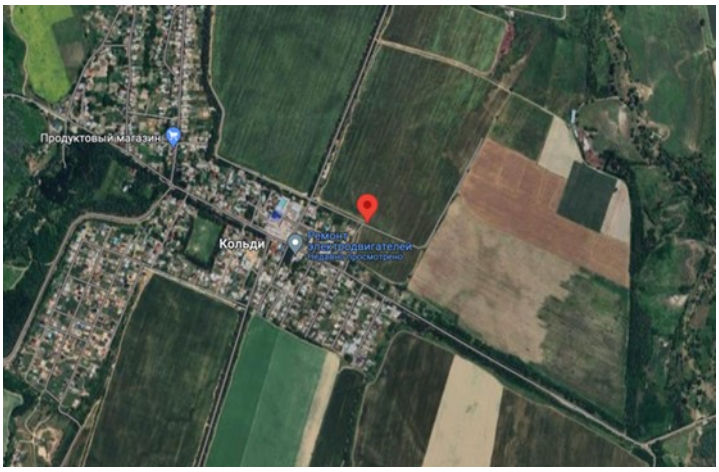

Figure 1 - Soil sampling site: Koldi village, Karasai district, Almaty region, Kazakhstan (43°19'31.8"N 76°42'44.9"E)

These soils are mostly all plowed and are actively used in agriculture for growing grains, soybeans and various grasses. According to the granulometric composition, the selected soil is sandy-silty-silty, physical clay in the soil is 39.3% (medium loam).

The humus content of the soil was 0.59% (very low) and mobile nitrogen was 36.4 mg/kg (low); mobile phosphorus was 36 mg/kg (high) and mobile potassium was 236 mg/kg (average). The total nitrogen content was 0.056%, the total phosphorus content was 0.06%, and the total potassium content was 3.0%. The sum of absorbed bases was 13.74 mg-eq. /100 g, calcium and magnesium cations predominate in the sum of absorbed bases; CO_2 was 5.6% (strongly carbonate).

The selected soil was thoroughly mixed before the experiment and sifted through a sieve with 2 mm mesh sizes. Before filling the vessels, the soil was thoroughly mixed with the studied ameliorant fertilizers according to the experiment variants. The working moments of the experiment are shown in figure 2.

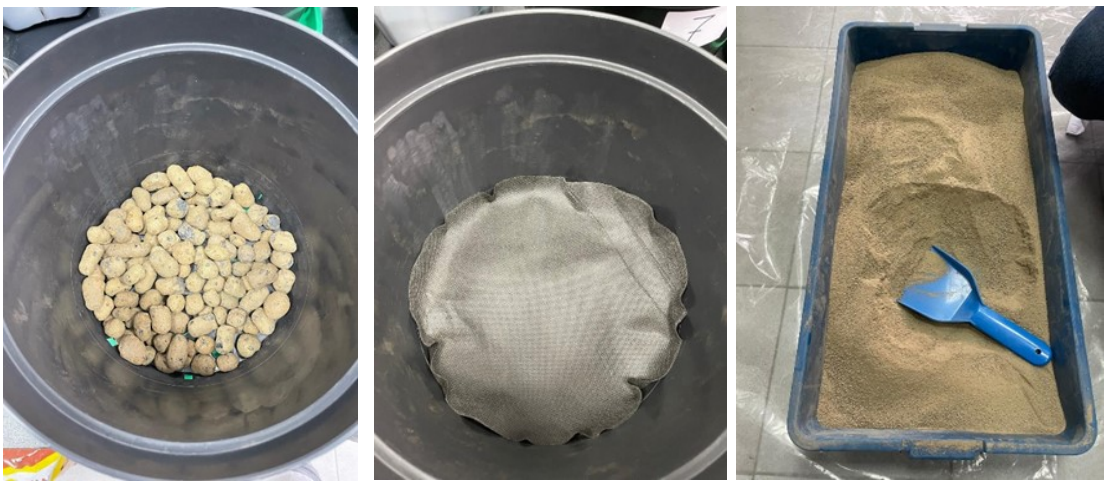

Figure 2 - Working moments of the experiment

Plastic container pots were used for the experiment. At the bottom of the container, a filter was created from expanded clay and fabric circles. The lowest moisture capacity (MC) of the soil was 25% according to RD 52.33.219 - 2002 in laboratory conditions.

The experiment was conducted on early-ripening corn plants of the FAO 160 variety provided by «KUSTO GROUP». The corn seeds were sown to a depth of about 3 cm in each container-pot. All containers were watered manually; the required amount of water was calculated to maintain HB at 40% by weighing each container. In order to eliminate the influence of indoor lighting, the position of each container was spatially changed once a week. All experimental variants were carried out in 4 repetitions.

Preparation of substrates and experimental design

The following substrate compositions were prepared for the experiment:

1. Soil 5 l;
2. Expanded vermiculite 5 l;
3. GumiVer 5 l;
4. Soil 5 l + HS 0.2 l;
5. Soil 4.5 l + Expanded vermiculite 0.5 l;
6. Soil 4.0 l + GumiVer 1.0 l (4:1);
7. Soil 4.5 l + GumiVer 0.5 l (9:1);
8. Soil 4.75 l + GumiVer 0.25 l (19:1).

The total volume of all substrates was 5 l.

The design of the experiment is based on the hypothesis that synergy will be achieved when using the developed ameliorant fertilizer "GumiVer" as opposed to using each of its components separately. Therefore, the first series of experiments were set up as follows:

Soil 5 l– control;

Soil 5l+HS 0.2 l, this amount of humic substances corresponds to its content in the composition of “GumiVer”;

Soil 4.5 l+0.5 l Expanded vermiculite, where the amount of expanded vermiculite corresponds to its content in the composition of "GumiVer";

Soil 4.5 l + 0.5 l GumiVer;

In the second series, various contents of GumiVer in the composition of the substrate were compared to determine the most optimal dose for its application to the soil.

Soil 5 l – Control;

Soil 4.0 l + GumiVer 1.0 l (4:1);

Soil 4.5 l + GumiVer 0.5 l (9:1);

Soil 4.75 l + GumiVer 0.25 l (19:1);

In addition, pure expanded vermiculite and GumiVer were used for comparison.

Research methods..

For the agrochemical characterization of the soil used in the experiment, analytical work was carried out in the analytical laboratory of the U.U. Uspanov Kazakh Research Institute of Soil Science and Architecture using methods generally accepted in soil science and agrochemistry [14-15]: total humus – according to Tyurin, total nitrogen – according to Kjeldahl, easily hydrolyzed nitrogen – according to Tyurin-Kononova, mobile phosphorus and potassium – according to Machigin; pH – potentiometrically, CO_2 – with a calcimeter, absorbed bases Ca^+, Mg^+ – trilonometrically, K^+, Na^+ – on a flame photometer.

During the main growth and development phases of maize plants, biometric studies and selections of plant samples were conducted to study their growth and development dynamics depending on various types and doses of nitrogen fertilizers. The leaf surface area and photosynthetic productivity were determined using the formula of A.A. Nichiporovich, L.E. Stroganov, and others [16].

The obtained experimental material was processed statistically according to B.A. Dospekhov [17] and V.N. Peregudov [18].

The experimental data were subjected to statistical analysis using the analytical package Excel. The analysis of the

regression dependence, taking into account the effect and interaction of the substrate components on the growth indicators of corn was carried out using a nonlinear regression model. Regression equations were constructed by sequential evaluation and exclusion of insignificant regression terms ($P<0.05$). The consistency of theoretical and actual data was estimated using the determination coefficient (R^2). The effects and interactions of the factors under study were presented in the form of a regression equation:

$$У=a_0+a_1x_1^{0,5}+a_2x_1+a_3x_2^{0,5}+a_4x_2+a_5x_3^{0,5}+a_6x_3+a_7(x_1x_2)^{0,5}+a_8(x_1x_3)^{0,5}+a_9(x_2x_3)^{0,5} \quad (1)$$

where:

У – resulting (dependent) factor;

a_0 – a free term reflecting the value of the resulting factor without using the factors being studied; a_1, a_2, a_3, … a_n – regression coefficients reflecting the action and interaction of factors;

x_1 x_2 и x_3 – the studied substrate components were the proportion of soil and vermicompost, and the dose of humic salt, respectively.

RESULTS AND DISCUSSION

The creation of new organomineral ameliorant fertilizers with fertilizing, meliorating and structure-forming effects can be used in agriculture to increase the fertility of degraded, low-productivity soils byimproving their nutritional, physical-mechanical and water-saving properties [19].

Therefore, the development of new types of ameliorant fertilizers based on Kazakh raw materials and the study of their properties seems very promising. The experimental data were subjected to regression analysis to identify the dependence of the studied biometric indicators on the composition of the substrate.

The results of the experiment showed that the greatest increase in the total biomass and other parameters of corn growth is observed when using the ameliorant fertilizer "GumiVer" (table 2). The study of the impact of the ameliorant fertilizer "GumiVer" and its components - expanded vermiculite and humic substances on the growth of corn was conducted within the framework of two series of experiments. In the first series, the impact of individual components and their combination in the composition of "GumiVer" was assessed; and in the second series, different dosages of the ameliorant fertilizer in the soil.

During the first series of experiments, a comparison was made between the control soil sample and substrates containing humic substances, expanded vermiculite and GumiVer. The amounts of humic substances and expanded vermiculite in the substrate exactly matched their amounts in the composition of the ameliorant fertilizer GumiVer, and the ratio Soil:GumiVer was 9:1 in volume terms.

Comparison of the main morphometric parameters for the first series of experiments allows us to arrange the studied substrates in the following order: Control (soil) < Expanded vermiculite < HS < GumiVer.

As can be seen from table 3, the total biomass with roots increased by 57.3% when using expanded vermiculite and by 80.7% when adding HS. The use of GumiVer increased the biomass by 127.6% compared to the control, which indicates its effectiveness. The increase in the mass of the above-ground part and the mass of roots when using GumiVer was 135.8 and 107.3%, respectively.

Table 2 - The impact of the ameliorant fertilizer GumiVer in the substrate on the corn growth

Corn parameters Substrate composition	Total biomass with roots, g	Weight of above-ground part, g	Root mass, g	Total number of green leaves, pcs.	Weight of green leaves, g	Plant height, cm	Stem thickness at the first node, mm	Plant leaf area, mm^2
1. Soil 5 l (Control)	1.92	1.37	0.55	3.95	0.69	14.19	1.96	49.92
2. Expanded vermiculite 5 l	2.38	1.02	1.36	3.25	0.42	13.89	1.55	28.59
3. GumiVer 5 l	3.76	1.56	2.22	3.44	0.62	16.25	1.85	39.92
4. Soil 5 l + HS 0.19 l	3.47	2.41	1.03	5.3	1.09	19.65	2.21	72.2
5. Soil 4.5 l + Expanded vermiculite 0.5 l	3.02	2.25	0.75	4.38	1.02	20.33	2.45	63.1
6. Soil 4.0 l + GumiVer 1.0 l (4:1)	4.01	2.63	1.4	5.65	1.18	24.93	2.28	74.55
7. Soil 4.5 l + GumiVer 0.5 l (9:1)	4.37	3.23	1.14	6.06	1.46	24.81	2.43	97.1
8. Soil 4.75 l + GumiVer 0.25 l (19:1)	3.07	2.4	0.67	5.5	1.13	17.67	2.37	76.69
$LSD_{0,5}$	0.21	0.25	0.15	0.47	0.15	1.05	0.15	7.91
Accuracy of the experiment, %	2.15	4.27	4.39	3.41	5.26	1.9	2.34	4.29

Table 3 - Comparison of morphometric parameters of corn using different substrates

Parameters	Substrate				Difference, %		
	Soil (control)	Soil+Expanded vermiculite	Soil+ HS	Soil+ GumiVer	Soil+ Expanded vermiculite	Soil+ HS	Soil+ GumiVer
Total biomass with roots, g	1.92	3.02	3.47	4.37	57.3	80.7	127.6
Weight of above-ground part, g	1.37	2.25	2.41	3.23	64.2	75.9	135.8
Root mass, g	0.55	0.75	1.03	1.14	36.4	87.3	107.3
Number of green leaves, pcs.	3.95	4.38	5.30	6.06	10.9	34.2	53.4
Weight of green leaves, g	0.69	1.02	1.09	1.46	47.8	58.0	111.6
Plant height, cm	14.19	20.33	19.65	24.81	43.3	38.5	74.8
Stem thickness, mm	1.96	2.45	2.21	2.43	25.0	12.8	24.0
Leaf area, mm^2	49,92	63,10	72,20	97,10	26,4	44,6	94,5

"GumiVer" shows the best results in all indicators in comparison with the use of its individual components (expanded vermiculite and HS). This confirms our hypothesis about the synergy that occurs as a result of immobilization of humic substances on expanded vermiculite. The substrate with "GumiVer" demonstrates a significant improvement in biomass, mass of the above-ground part, the number of leaves and their area, which makes it the most effective for improving the corn growth.

The use of expanded vermiculite or humic substances separately also gives improved results compared to the control, however they do not achieve the same effect as the ameliorant fertilizer "GumiVer" developed on their basis (figure 3).

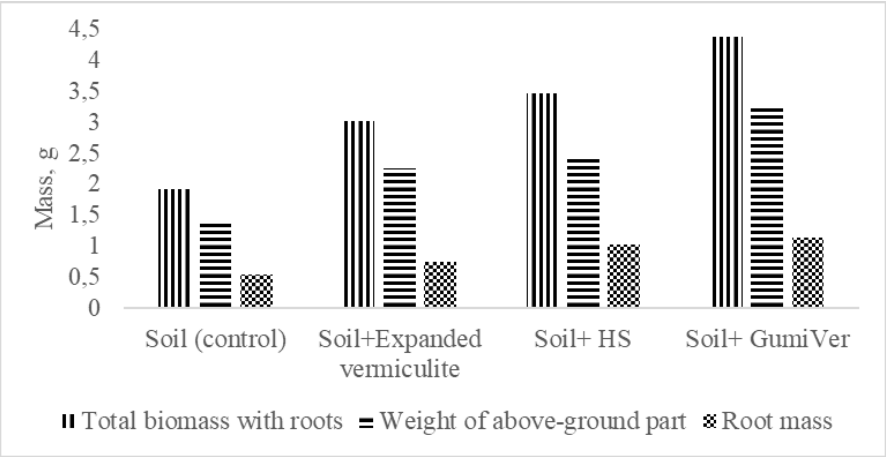

Figure 3 - Impact of different substrates on the corn growth

The dosage of 1 l (4:1) also shows good results; however, increasing the dosage does not lead to a significant increase in efficiency. It is possible that the increase in the content of "Gumiver" in the substrate stimulates the growth and activity of soil microorganisms, followed by competition of microphores for nutrients with plants. The dosage of 0.25 l (19:1) gives results better than the control, however was significantly inferior to higher doses (figure 4).

Table 4. Comparison of morphometric parameters of corn at different dosages of the ameliorant-fertilizer "GumiVer"

Parameters	Soil (control)	GumiVer			Difference, %		
		4:1	9:1	19:1	4:1	9:1	19:1
Total biomass with roots, g	1.92	4,01	4,37	3,07	108,9	127,6	59,9
Weight of above-ground part, g	1.37	2,63	3,23	2,40	92,0	135,8	75,2
Root mass, g	0,55	1,40	1,14	0,67	154,5	107,3	21,8
Number of green leaves, pcs.	3,95	5,65	6,06	5,50	43,0	53,4	39,2
Weight of green leaves, g	0,69	1,18	1,46	1,13	71,0	111,6	63,8
Plant height, cm	14,19	24,93	24,81	17,67	75,7	74,8	24,5
Stem thickness, mm	1,96	2,28	2,43	2,37	16,3	24,0	20,9
Leaf area, mm^2	49,92	74,55	97,10	76,69	49,3	94,5	53,6

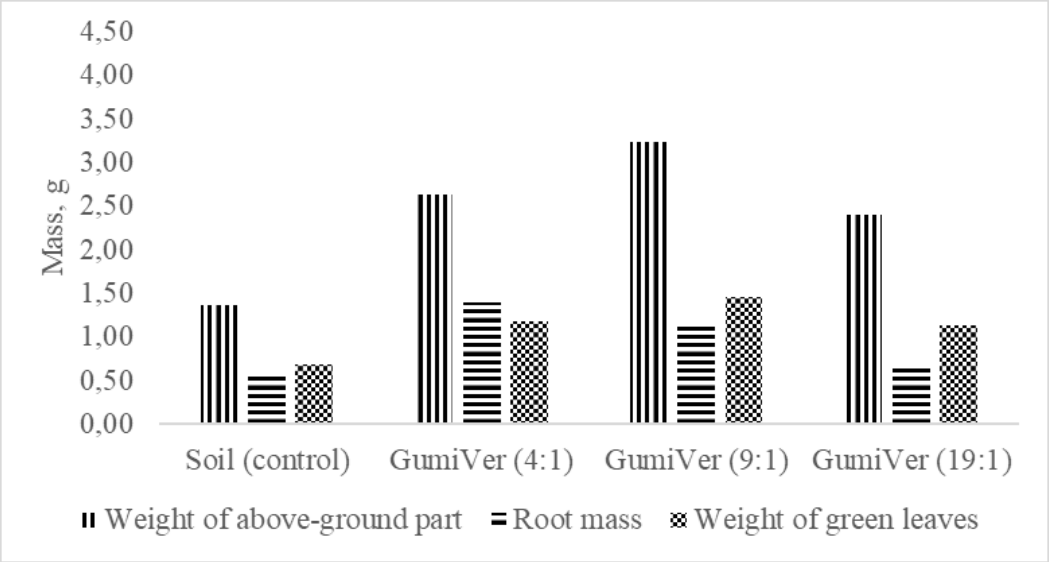

Figure 4 - Impact of different dosages of GumiVer on the corn growth

The use of pure expanded vermiculite showed a positive impact on root mass (+147%), however, at the same time reduced such important indicators as the mass of the aboveground part, the number of leaves and the leaf area. "GumiVer" (in pure form and mixed with soil) provides a more significant improvement in the corn growth compared to pure expanded vermiculite (figure 5).

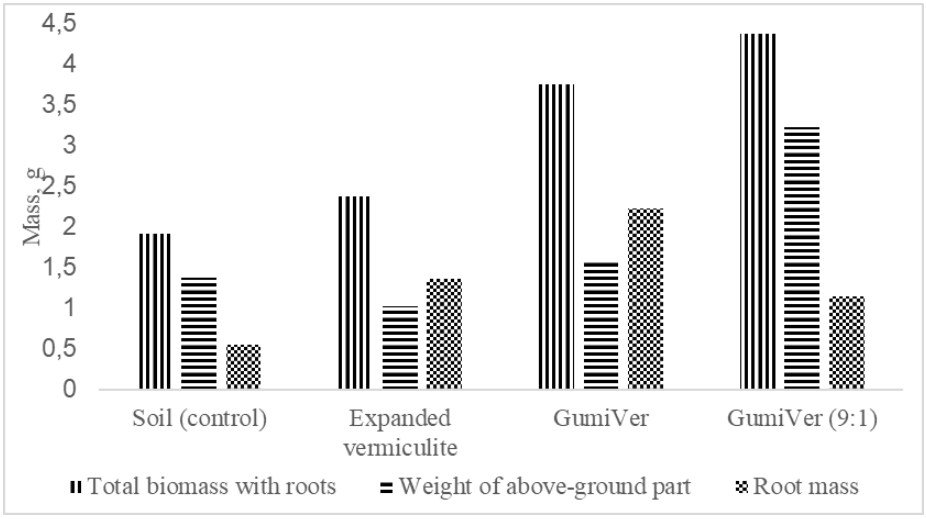

Figure 5- The impact of expanded vermiculite, the ameliorant fertilizer GumiVer and the mixture Gumiver:Soil (9:1) on the corn growth

In all likelihood, the ameliorant-fertilizer "Gumiver" in optimal combination with soil in the substrate stimulates metabolic processes in plants and increases their growth activity.

Mathematical analysis showed a complex nonlinear regression relationship between the studied substrate components and biometric indicators, which is confirmed by high values of the determination coefficients (R^2 = 0.917-0.982).

The regression relationship of biometric indicators of corn (U) with the studied variants of the combination ofsubstrate components with different proportio-ns of expanded vermiculite (x_1), soil (x_2) and treatment with humic salt (x_3) is reliably described by the following equations (2-9).

Total plant biomass:

$$У=748,16 - 745,78x_1^{0,5} - 746,24x_2^{0,5} - 94,81x_3 + 107,59x_3^{0,5} + 562,13(x_1x_2)^{0,5} - 11,40(x_1x_3)^{0,5} - 61,73(x_2x_3)^{0,5};\ R^2 = 0,982 \quad (2)$$

Aboveground mass of plants, g:

$$У=535,5 - 534,49x_1^{0,5} - 534,14x_2^{0,5} - 71,45x_3 + 79,94x_3^{0,5} + 562,13(x_1x_2)^{0,5} - 11,40(x_1x_3)^{0,5} - 45,65(x_2x_3)^{0,5};\ R^2 = 0,962 \quad (3)$$

Plant root mass, g:

$$У=197,09 - 195,73x_1^{0,5} - 196,53x_2^{0,5} - 21,39x_3 + 25,33x_3^{0,5} + 173,36(x_1x_2)^{0,5} - 3,09(x_1x_3)^{0,5} - 14,69(x_2x_3)^{0,5};\ R^2 = 0,968 \quad (4)$$

Number of leaves, pcs:

$$У=3,28 + 0,66x_2^{0,5} - 5,57x_3 + 5,68x_3^{0,5} + 1,52(x_1x_2)^{0,5};\ R^2 = 0,923 \quad (5)$$

Leaf weight, g:

$$У = 221,27 - 220,85x_1^{0,5} - 220,58x_2^{0,5} - 30,21x_3 + 33,1x_3^{0,5} + 196,15(x_1x_2)^{0,5} - 2,69(x_1x_3)^{0,5} - 18,7(x_2x_3)^{0,5};\ R^2 = 0,950 \quad (6)$$

Plant height, mm:

$$У=3832,74 - 3818,85x_1^{0,5} - 3818,56x_2^{0,5} - 457,69x_3 + 515,46x_3^{0,5} + 3392,71(x_1x_2)^{0,5} - 55,4(x_1x_3)^{0,5} - 298,55(x_2x_3)^{0,5};\ R^2 = 0,973 \quad (7)$$

Stem thickness, mm:

$$У=1,959 - 0,409x_1^{0,5} + 3,419x_3^{0,5} + 2,413(x_1x_2)^{0,5} - 3,128(x_1x_3)^{0,5} - 2,808(x_2x_3)^{0,5};$$

$$R^2 = 0,917 \quad (8)$$

Leaf area, mm^2:

$$У=15115,6 - 15087x_1^{0,5} - 15065,7x_2^{0,5} + 2260,12x_3^{0,5} - 2095,27x_3 + 13384(x_1x_2)^{0,5} - 153,526(x_1x_3)^{0,5} - 1273,28(x_2x_3)^{0,5};\ R^2 = 0,972 \quad (9)$$

Thus, the introduction of expanded vermiculite and HS into the soil substrate has a significant impact on the corn growth. However, combinations of these substances in the composition of the ameliorant fertilizer "GumiVer" contribute to a greater increase in biomass, aboveground part and other growth indicators.

It should be noted that the studied range of shares and doses of substrate components in the experiment does not allow extrapolating the results beyond them due to the insufficiency of their combination. Therefore, it is not possible to apply the obtained equations for practical use in composing substrate components. The obtained experimental results are of scientific value and show the possibility of combining the studied components in composing substrates. For the widespread use of various combinations of these components, further research is needed to more thoroughly study the mechanisms of interaction of these components in field conditions on the productivity of agricultural crops and soil fertility.

CONCLUSION

The developed ameliorant-fertilizer "GumiVer" based on expanded vermiculite immobilized with HS has the greatest positive impact on plant growth compared to the separate use of its components. All key growth parameters: biomass, weight of the aboveground part, weight of roots, plant height and leaf area are significantly improved when using "GumiVer".

The first series showed that the use of individual components (expanded vermiculite and humic substances) has a positive impact on plant growth compared to the control; however, does not achieve the same impact as their combined use in the composition of "GumiVer". For instance, the total biomass with roots when using expanded vermiculite increased by 57%, and humic substances by 81%, while the combined use in the composition of "GumiVer" led to an increase of 127%. The mass of the aboveground part increased by 136% when using "GumiVer" compared to 64% for expanded vermiculite and 76% for humic substances.

These results confirm our hypothesis about the synergy between the components of GumiVer. The combination of expanded vermiculite and humic substances has a more pronounced positive impact on plant growth and development than their separate use.

In the second series, different dosages of GumiVer were compared to determine the optimal concentration:

- The dosage of 1 l (4:1) increased biomass by 109%, the weight of the aboveground part by 92% and the weight of the roots by 155%.
- The dosage of 0.5 l (9:1) showed the greatest increase in all parameters, increasing biomass by 127%, the weight of the aboveground part by 136%, the weight of the roots by 107% and the leaf area by 94%.
- The dosage of 0.25 l (19:1) also gave positive results, however was less effective compared to higher dosages.

Thus, the most optimal dosage for the use of "GumiVer" was the proportion of 9:1 (soil:GumiVer), at which the maximum growth of biomass, leaves and roots was observed. The use of pure expanded vermiculite increases the mass of roots (+147%), however reduces the mass of the aboveground part (-26%) and the area of leaves (-43%). This indicates a limited im-pact of expanded vermiculite as an ameliorant fertilizer, especially in terms of the development of the aboveground part of the plant.

Pure application of "GumiVer" (without soil) also leads to an increase in biomass (+96%) and the mass of the aboveground part (+14%); however, these results are inferior to the indicators of combined use with soil. Thus, the results of the experiment demonstrate that the ameliorant fertilizer "GumiVer" is highly effective that significantly improving the growth and development of corn. The most optimal option for its use is a proportion of 9:1, which makes "GumiVer" a promising tool for increasing crop yields and improving soil quality.

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ТҮЙІН

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ТАБИҒИ АЛЮМОСИЛИКАТТАР МЕН БИОЛОГИЯЛЫҚ БЕЛСЕНДІ ЗАТТАРДЫҢ НЕГІЗІНДЕ ЖАСАЛҒАН ОРГАНОМИНЕРАЛДЫҚ МЕЛИОРАНТ-ТЫҢАЙТҚЫШТАРДЫҢ ЖҮГЕРІ ӨСІМДІГІНІҢ ӨСУІНЕ ӘСЕРІ. БӨЛІМ 1

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Бұл жұмыста гуминдік заттарды кеңейтілген вермикулитке иммобилизациялау арқылы алынған кеңейтілген вермикулит, гуминді заттар және органоминералды мелиорант-тыңайтқыштарының жүгері өсімдіктерінің өсуіне әсері зерттеледі. Табиғи алюмосиликаттарға, мысалы, кеңейтілген вермикулитке гуминді заттарды иммобилизациялау, кеңейтілген вермикулиттің мелиоративті қасиеттерін біріктіретін синергетикалық әсерге қол жеткізуге мүмкіндік береді, ол топырақ құрылымы мен суды ұстау қабілетін жақсартады, гуминді заттардың тыңайтқыш қасиеттерімен біріктіреді. өсімдіктердің өсуін ынталандырады және олардың стресске төзімділігін арттырады. Сонымен қатар, бұл органоминералды ұзақ әсер ететін мелиорант-тыңайтқышын қолдану қоректік заттардың біртіндеп бөлінуіне және топырақтың агрохимиялық сипаттамаларының жақсаруына байланысты топырақ құнарлығын ұзақ уақыт сақтауға көмектеседі. Зертханалық тәжірибелер жалпы биомасса көрсеткіштерін, тамырлар мен ауа бөліктерінің массасын, жасыл жапырақтардың саны мен массасын, сондай-ақ өсімдік биіктігі мен сабақтың қалыңдығы сияқты морфометриялық параметрлерді зерттейді. Алынған нәтижелер ылғал тапшылығы және қатты тозып кеткен топырақ жағдайында әзірленген мелиорант-тыңайтқыштарды қолдану кезінде өсімдіктердің өсуінің айтарлықтай жақсарғанын көрсетеді. Эксперимент нәтижесі бойынша тамыры бар жалпы биомасса кеңейтілген вермикулитті қолданғанда 57,3%-ға, гуминді заттарды қосқанда 80,7%-ға өскен. «ГумиВер» мелиорант-тыңайтқышын қолдану (топырақ: ГумиВер / 9:1) бақылаумен салыстырғанда биомассаны 127,6%-ға арттырды, бұл мелиорант-тыңайтқыштың компоненттері арасындағы синергетикалық әсерді растайды. «ГумиВер» мелиорант-тыңайтқышын қолдану кезінде өсімдіктің жер беті бөлігі массасының және тамыр массасының өсуі сәйкесінше 135,8 және 107,3% құрады.

Түйінді сөздер: мелиорант, биотыңайтқыш, топырақ, кеңейтілген вермикулит, гуминді заттар, биологиялық белсенді заттар.

РЕЗЮМЕ

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ИЗУЧЕНИЕ ВЛИЯНИЯ ОРГАНОМИНЕРАЛЬНЫХ УДОБРЕНИЙ-МЕЛИОРАНТОВ НА ОСНОВЕ ПРИРОДНЫХ АЛЮМОСИЛИКАТОВ И БИОЛОГИЧЕСКИ АКТИВНЫХ ВЕЩЕСТВ НА РОСТ РАСТЕНИЙ КУКУРУЗЫ.

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В данной работе исследуется влияние вспученного вермикулита, гуминовых веществ и органоминеральных мелиорант-удобрений, полученных путем иммобилизации гуминовых веществ на вспученный вермикулит, на рост растений кукурузы.

Иммобилизация гуминовых веществ на природные алюмосиликаты, как вспученный вермикулит, позволяет достичь синергетического эффекта, объединяющего мелиорирующие свойства вспученного вермикулита, который улучшает структуру почвы и водоудерживающую способность, с удобряющими свойствами гуминовых веществ, стимулирующих рост растений и повышающих их устойчивость к стрессам. Кроме того, применение данного органоминерального мелиорант-удобрения пролонгированного действия способствует поддержанию плодородия почвы на длительный срок за счет постепенного высвобождения питательных веществ и улучшения агрохимических характеристик почвы. В лабораторных экспериментах рассматриваются показатели общей биомассы, массы корней и надземной части, количества и массы зеленых листьев, а также морфометрические параметры, такие как высота растений и толщина стеблей. Полученные результаты демонстрируют значительное улучшение роста растений при использовании разработанных мелиорант-удобрений в условиях дефицита влаги и сильно истощённых почв. По результатам эксперимента общая биомасса с корнями увеличилась на 57,3% при использовании вспученного вермикулита и на 80,7% при добавлении гуминовых веществ. Применение мелиорант-удобрения «ГумиВер» (почва:ГумиВер / 9:1) увеличило биомассу на 127,6% по сравнению с контролем, что подтверждает синергетический эффект между компонентами мелиорант-удобрения. Увеличение массы надземной части и массы корней при использовании мелиорант-удобрения «ГумиВер» составило 135,8 и 107,3% соответственно.

Ключевые слова: мелиорант, биоудобрение, почва, вспученный вермикулит, гуминовые вещества, биологически активные вещества.

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