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Development of an Organo-Mineral Fertiliser Based on Glauconite and Vermicompost

Arman Makhanbetov[1], Davlat Yuldashbek[1*], Tulkinzhon Gaipov [1], Aidarbek Adylov[1]

[1]*Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkistan, Kazakhstan*

*Corresponding author: davlat.yuldashbek@ayu.edu.kz

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Abstract

This study presents the development of an organo-mineral fertiliser based on vermicompost and the natural aluminosilicate mineral glauconite, as well as the evaluation of its agrochemical properties. It was shown that vermicompost enhances soil biological activity and, through organic compounds and microbiological processes, accelerates the transformation of mineral components. Glauconite acts as a source of potassium and trace elements with prolonged release and, due to its high cation-exchange capacity, ensures their retention and gradual availability. Various component ratios (4:6-7:3) were investigated, and the optimal ratio was determined to be 6:4 (glauconite:vermicompost), providing a balanced proportion of organic and mineral constituents. The proposed production technology includes grinding the mineral raw material to a fraction of 0.1-1.0 mm, mixing the components, granulation with particle formation of 5-10 mm, and subsequent mild drying at 40-60 °C. This technological scheme ensures controlled and prolonged release of nutrients. It was established that the developed organo-mineral system improves soil moisture retention capacity, reduces nutrient losses due to leaching, and stabilises the plant's nutrient supply regime.

Cite

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INTRODUCTION

Currently, one of the most pressing issues in agriculture is soil degradation caused by a decline in soil fertility, a reduction in organic matter content, and the impact of adverse climatic factors such as drought and increasing temperatures (*Przemieniecki et al., 2021*). This problem is particularly acute in arid and semi-arid regions, where soil structure deterioration, moisture deficiency, and low efficiency in the use of nutrients significantly limit agricultural productivity (*Vuković et al., 2021*).

The restoration of soil fertility is largely associated with the use of organic fertilisers, among which vermicompost occupies a special place *(Pierre-Louis et al., 2021)*. Its application contributes to an increase in soil organic matter and humic substances, activation of microbiological processes, and improved nutrient availability *(Singh et al., 2020)*. In addition, vermicompost has a positive effect on plant growth and development, increasing yield and resistance to abiotic stress factors (*Singh, A. et al., 2020*).

However, despite the high efficiency of vermicompost in enhancing soil biological activity, its composition does not always provide complete plant nutrition, particularly due to insufficient levels of potassium and certain micronutrients (*Soltys et al., 2020*). This necessitates its combined use with mineral components, including natural aluminosilicates as sources of potassium.

Organic compounds and microbiological activity characteristic of vermicompost promote the accelerated breakdown of mineral components and the release of contained nutrients. In this context, glauconite is considered a valuable natural source of potassium and trace elements with prolonged action (*Rakesh et al., 2020*). However, their initial availability is limited due to strong fixation within the mineral crystal lattice (Dasi *et al., 2024*). The combined application of glauconite and vermicompost enhances the release processes of nutrients and increases their availability to plants.

Thus, the combined use of organic and mineral components ensures both rapid and long-term nutrient supply, contributing to the stabilisation of soil nutrient regimes (*Rudmin et al., 2019*).

In this regard, a promising scientific and practical direction is the development of systems based on the combination of organic and mineral components, allowing for the mutual compensation of their limitations and enhancement of their advantages. Natural aluminosilicate minerals, due to their high cation-exchange capacity, are able to adsorb nutrients and ensure their gradual release, as well as improve soil moisture retention and reduce nutrient losses through leaching. Vermicompost, in turn, activates biological processes and accelerates nutrient cycling in the soil. Their combined application provides a comprehensive improvement of agrochemical, physical, and biological soil properties.

For the conditions of Kazakhstan, especially the Turkestan region, the issue of improving soil fertility is of particular importance. The arid climate, limited precipitation, and low humus content negatively affect agricultural productivity. In addition, degradation of arable and pasture lands is observed. Research results indicate that the application of biological fertilisers enhances soil microbial activity and improves the productivity of degraded lands (*Palansooriya et al., 2023*).

In this regard, the development of organo-mineral biocomplexes based on a combination of organic and mineral components represents a promising direction. Such systems make it possible to improve soil moisture retention, reduce nutrient leaching, increase plant resistance to stress factors, and enhance soil biological activity.

The aim of this study is to develop an organo-mineral biocomplex based on a natural mineral component and vermicompost, as well as to evaluate its agrochemical properties.

MATERIALS AND METHODS

The main components of the organo-mineral biocomplex used in this study were vermicompost and a natural aluminosilicate mineral – glauconite. The external morphological characteristics of the organic and mineral components are shown in Figure 1.

Vermicompost (Figure 1a) is characterised by a dark-brown colour and a loose, granular structure, which indicates a high content of humic substances and organic compounds (Jakubus *et al., 2022*).

Glauconite (Figure 1b) is a greenish-grey powdery material. Its colouration is due to the presence of iron ions, while its aluminosilicate nature provides pronounced sorption and cation-exchange properties. The finely ground state increases its specific surface area, thereby enhancing the adsorption of nutrients and their prolonged release.

Fig. 1. *Organic and mineral components: (a) vermicompost; (b) glauconite*

The chemical composition of the studied samples was determined using inductively coupled plasma atomic emission spectrometry (ICP-AES). This method is based on the registration of element emission spectra in a high-temperature argon plasma and enables accurate qualitative and quantitative analysis of sample composition (*Karpukhina et al., 2021*).

The organo-mineral biocomplex was obtained by combining organic and mineral components in an optimal ratio. The technological process included the following stages: preparation of mineral raw material, mixing of components, granulation, and drying (*Das et al., 2022*).

At the first stage, the natural aluminosilicate mineral was ground to a particle size of 0.1-1.0 mm. This increased the specific surface area by 2-3 times, thereby enhancing sorption and cation-exchange properties.

At the second stage, glauconite was mixed with vermicompost in an optimal ratio of 6:4. Mixing was carried out in mechanical mixers for 15-20 minutes until a homogeneous mixture was obtained. The moisture content of the mixture was maintained at 30-40%.

At the third stage, the obtained mixture was subjected to granulation (Figure 2). The granule size ranged from 5-10 mm, ensuring uniform application to the soil and gradual release of nutrients (*Rudmin et al., 2022*).

Fig. 2. *Granulation stage of the organo-mineral biocomplex*

At the final stage, the granules were subjected to mild drying at a temperature of 40-60 °C for 40-60 minutes. The final moisture content was adjusted to 20-25%, which ensured storage stability while preserving biological activity.

RESULTS AND DISCUSSION

The chemical and agrochemical composition of the studied mineral is presented in Table 1. It was established that the mineral contains a wide range of macro- and microelements essential for plant growth and development, including potassium, iron, magnesium, silicon, and calcium. The aluminosilicate structure of the mineral provides a high cation-exchange capacity, contributing to the retention of moisture and nutrients in the soil.

Table 1. Composition of natural aluminosilicate mineral and its agrochemical effect

Component	Content	Main elements	Effect on soil and plants
Potassium (K_2O equivalent)	1.79 %	K	Increases plant resistance to drought, activates enzymatic processes
Iron (Fe)	8.72 %	Fe	Involved in chlorophyll synthesis, prevents chlorosis
Magnesium (Mg)	1.64 %	Mg	Component of chlorophyll, involved in photosynthesis
Silicon (Si)	3.13 %	Si	Strengthens plant cell walls, increases stress resistance
Calcium (Ca)	0.845 %	Ca	Promotes root system development
Sodium (Na)	0.12 %	Na	Involved in osmotic regulation (in small amounts)
Aluminosilicate matrix	~7.1 % (Al+Si)	Al, Si	Increases cation-exchange capacity and moisture retention
Trace elements (total)	~0.6-0.8 %	Zn, Cu, Co, Ni, Mn, B, Mo, Sr, V, Cr, etc.	Activate enzymatic systems and regulate metabolism

The composition of vermicompost and its agrochemical effect are presented in Table 2. It was found that vermicompost is characterized by a high content of organic matter (19.2%) and humus (13.48%), which improves soil structure and increases its moisture retention capacity. The presence of nitrogen (0.58%), phosphorus (0.89%), and potassium (1.95%) allows it to be considered an additional source of plant nutrients.

The results showed that vermicompost enhances soil microbial activity, including the development of phosphate-solubilizing and nitrogen-fixing microorganisms. In particular, bacterial strains Arthrobacter subterraneus and Phyllobacterium ifriqiyense, capable of phosphate solubilization and atmospheric nitrogen fixation, were identified, confirming its high biological value.

Table 2. Composition of vermicompost and its agrochemical effect

Component	Content, %	Main elements	Effect on soil and plants
Organic matter	19.2	Organic compounds	Increases soil biological activity
Humus	13.48	Humic and fulvic acids	Improves soil structure and aggregation
Nitrogen (N)	0.58	N	Promotes plant growth, involved in protein synthesis
Phosphorus (P_2O_5)	0.89	P	Stimulates root development
Potassium (K_2O)	1.95	K	Increases plant stress resistance

Despite the pronounced positive effect of vermicompost, the content of certain nutrients, particularly potassium, may be insufficient to fully meet the requirements of agricultural crops. In addition, the release of nutrients from organic materials is prolonged and depends on soil and climatic conditions. Therefore, its combined application with mineral components is considered appropriate.

The integrated use of organic and mineral components provides a synergistic effect. Natural aluminosilicates have the ability to adsorb and gradually release ions, as well as improve soil moisture retention. Vermicompost, in turn, activates microbiological processes, accelerates the transformation of organic and mineral substances, and promotes nutrient mobilisation. As a result, their combination ensures a comprehensive improvement of soil fertility.

Considering the above, the selection of an optimal component ratio is a key factor determining the efficiency of the organo-mineral system. Mixing vermicompost and glauconite in different proportions results in the formation of an organo-mineral composition (Figure 3).

***Fig. 3**. Organo-mineral composition based on vermicompost and glauconite*

In this study, different component ratios of 4:6, 5:5, 6:4, and 7:3 (glauconite: vermicompost) were investigated, as presented in Table 3.

Table 3. Component ratios of the organo-mineral composition

Glauconite: Vermicompost	Organic matter, %	Humus, %	N, %	P_2O_5, mg/kg	K, %
4:6	11.52	8.09	0.35	6082	1.69
5:5	9.60	6.74	0.29	5378	1.70
6:4	7.68	5.39	0.23	4674	1.72
7:3	5.76	4.04	0.17	3969	1.74

Analysis of the obtained data showed that the 6:4 ratio is optimal, providing a balanced combination of organic and mineral components. This option ensures an adequate level of mineral nutrients while maintaining sufficient organic matter content and biological activity.

The application of the developed composition improves soil structure; increases moisture retention capacity by 15-20%; reduces nutrient leaching; and ensures their gradual release. In addition, an increase in soil biological activity and stabilisation of plant nutrient supply were observed.

The organo-mineral composition is recommended for application during primary tillage or before sowing. The application rate ranges from 1 to 5 t/ha depending on soil agrochemical characteristics.

CONCLUSION

As a result of the conducted research, an organo-mineral biocomplex based on a natural mineral component and vermicompost was developed. The proposed composition is aimed at the comprehensive improvement of the agrochemical, physical, and biological properties of soil.

According to the obtained and expected results, the application of the organo-mineral biocomplex contributes to an increase in the yield and quality of agricultural crops, as well as to improved plant resistance to drought and other adverse stress factors.

The practical significance of the study lies in the development of an environmentally safe and cost-effective solution aimed at improving soil fertility under the arid climatic conditions of Kazakhstan, particularly in the Turkestan region. The use of local mineral raw materials reduces dependence on imported mineral fertilisers and enhances the resource efficiency of agricultural production.

In addition, the developed organo-mineral product can be effectively used for the restoration of degraded and low-humus soils, which allows it to be considered a promising tool within sustainable land use and soil resource management systems.

AUTHOR CONTRIBUTIONS

Writing-review & editing, methodology, supervision: A. M.; D. Y.; conceptualization, writing-review & editing, data curation: T. G.; A. A.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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