Гидрометеорология и экология

Scientific article

CHEMICAL-TECHNOLOGICAL CHARACTERISATION OF VERMICOMPOST AND ITS EFFECT ON THE AGROCHEMICAL PROPERTIES OF SOIL AND YIELD OF GREENHOUSE CROPS

Nurlan Akhmetov[1] PhD, Davlat Yuldashbek[1*], Yokubzhan Satanov[1], Zhuldyz Dyussenova[2] Candidate of technical sciences, Bekzhan Kossalbayev[1,3] PhD, Nuraly S. Akimbekov[1,4] PhD, Professor

[1]Khoja Ahmed Yasawi International Kazakh-Turkish University, Turkestan, Kazakhstan; nurlan.akhmetov@ayu.edu.kz (NA); davlat.yuldashbek@ayu.edu.kz (DY); yokubzhan.satanov@ayu.edu.kz (YS)
[2] RSE "Kazhydromet" , Climate Research Department of the Research Centre, Astana, Kazakhstan; dyussenova_zh@meteo.kz (ZhD)
[3]Satbayev Kazakh National Research Technical University, Almaty, Kazakhstan; kossalbayev.bekzhan@gmail.com (BK)
[4]Al-Farabi Kazakh National University, Almaty, Kazakhstan; akimbeknur@gmail.com (NSA)
*Author correspondent: Davlat Yuldashbek, davlat.yuldashbek@ayu.edu.kz

KEY WORDS

vermicompost,
Eisenia fetida,
cucumber (Cucumis sativus),
tomato (Solanum lycopersicum),
yield,
organic fertilizer,
Turkestan region,
soil properties

ABSTRACT

This study examines the influence of varying vermicompost application rates (0 %, 10 %, and 20 % of the substrate volume) on the growth, development, and yield of cucumber *(Cucumis sativus)* and tomato *(Solanum lycopersicum)* cultivated under greenhouse conditions in the Turkestan region of the Republic of Kazakhstan. The research is conducted within the framework of chemical and technological transformation of organic matter in soil substrates. The results indicate that the incorporation of vermicompost leads to notable changes in the physicochemical characteristics of the substrate, including an increase in organic matter content, stabilization of substrate pH, and improved availability of key macronutrients such as nitrogen, phosphorus, and potassium. These modifications contribute to more active mineralization processes and enhanced biochemical transformation of nutrients, which in turn stimulate root system development, promote vegetative growth, and increase crop yield. The highest overall productivity was recorded at a vermicompost application rate of 20 %, demonstrating its maximum agronomic effectiveness. At the same time, the 10 % application rate also showed a consistently positive effect, suggesting that it represents a balanced and economically viable option for greenhouse cultivation. Overall, the findings support the use of vermicompost as an efficient organic component in the chemical technology of soil substrate improvement for greenhouse vegetable production.

About article:
Received: 15.04.2026
Revised: 27.04.2026
Accepted: 23.06.2026
Published: 01.07.2026

1. INTRODUCTION

As the world transitions to more sustainable agricultural production systems, there is an increasing demand for organic and biotechnological methods to enhance soil fertility. The biological decomposition of organic waste by earthworms, known as vermicomposting, is a highly promising method for the production of eco-friendly biofertilizers that improve the physicochemical and microbiological properties of soils and increase crop yield [1, 2, 3]. Modern evaluations and applied studies have confirmed that vermicompost stabilizes nutrients, increases the content of humic substances, and enhances soil microbial activity, all of which have a positive impact on seed germination, plant growth, and product quality [4, 5, 6].

The southern region of Kazakhstan, which encompasses the Turkestan region, is distinguished by a continental climate that is marked by hot summers and a comparatively low level of natural humidity. The organic matter content of the soils in this region is frequently deficient, and their water-holding capacity is restricted. These circumstances underscore the importance of organic soil amendments: vermicompost treatment can improve the availability

IRSTI 68.33.29 https://doi.org/10.54668/2789-6323-2026-122-2-214-230 URL 631.86

For citation :
Akhmetov N., Yuldashbek D., Satanov Y., Dyussenova Zh., Kossalbayev B., Akimbekov N., Chemical-technological characterization of vermicompost and its effect on the agrochemical properties of soil and yield of greenhouse crops// Hydrometeorology and Ecology , 122 (2), 2026, 214-230.

of macronutrients, water retention, and soil structure in such soils, rendering this technique particularly relevant for local greenhouse vegetable production [7, 8].

Eisenia fetida is the critical biological agent in the majority of industrial and laboratory vermicomposting systems. This species is capable of producing a stable, biologically active vermicompost and has a high rate of organic matter processing [9, 10].

The primary objectives of research on the application of vermicompost in protected cultivation are twofold: (1) the enhancement of seedling quality and the maximisation of crop yields, and (2) the determination of the optimal vermicompost concentration in the substrate. Numerous experimental studies have demonstrated that the development of plants, the growth of root systems, and the efficiency of photosynthetic processes are all improved by the moderate addition of vermicompost (typically 5…30 % by volume) [11, 12, 13]. Furthermore, there have been reports of enhanced fruit quality, including soluble solids and vitamin C content, as well as increased yields [14]. However, high amounts (e.g., close to 100 %) do not always provide benefits and can result in nutrient imbalance or excessive salt accumulation [15, 16].

The Turkestan region's unique circumstances (soil texture, low organic matter content, high temperatures, and significant evapotranspiration) make it critical to experimentally identify the appropriate vermicompost treatment rate for cucumber and tomato growing. Beyond agronomic yield indicators, it is critical to analyse changes in soil agrochemical parameters (pH, organic matter, accessible N, P, and K), water-physical properties, and microbial activity after applying various vermicompost doses [17].

In this work, red Californian earthworms *(Eisenia fetida)* were employed to create vermicompost from local organic waste. The primary goal was to assess the effects of various vermicompost concentrations in the substrate (0 %, 10 %, and 20 %) on cucumber *(Cucumis sativus, hybrid cultivar Cedrik F1)* and tomato *(Solanum lycopersicum, hybrid cultivar Gamze F1)* growth and productivity under greenhouse conditions in the Turkestan region, as well as changes in key soil parameters. The findings will enable recommendations for ideal application rates based on local soil and climate circumstances.

2. MATERIALS AND METHODS

Study the object. The study focused on soil from the Turkestan region of the Republic of Kazakhstan that was used to grow cucumber (Cucumis sativus) and tomato (Solanum lycopersicum) under greenhouse conditions. This region's arable soils have a hot continental climate, low natural moisture availability, low organic matter content, and a compacted structure, limiting their natural fertility and water-holding capacity. These qualities require organic fertilisers to enhance soil agronomic properties.

Vermicompost, a byproduct of organic waste processing with red Californian earthworms (Eisenia fetida), was employed as the organic ingredient. Vermicompost is known for its potential to improve soil structure, increase the availability of key nutrients, and activate soil microbes, which is especially relevant in areas with low humus reserves [18, 19, 20].

Vermicompost preparation. Vermicompost was created by bioconverting organic waste using red Californian earthworms (Eisenia fetida). The substrate consisted of a mixture of cattle and goat dung, which was homogenised and hydrated to 70…80 %. The manure mixture was combined with sawdust at a 3:1 ratio.

Before filling the containers, substrate viability was evaluated to verify earthworm survival: 10…12 individuals were placed in 250…300 g of the prepared material and left for 24 hours. In the lack of earthworm mortality, the substrate was deemed suitable for continued usage.

The substrate was packed in boxes in layers about 15 cm thick. Following that, a thin layer of new organic feed was applied every 5…7 days to encourage earthworm migration to the top layers. Regular spraying every 2…3 days kept the moisture content between 60 and 80 %. The temperature was controlled with an electronic thermometer and kept between 15 and 25 degrees Celsius. The pH was stabilised at 6.5…7.7.

After earthworms finished processing the substrate, the resulting vermicompost was separated with a drum separator and used as fertiliser in greenhouse trials.

Applying Vermicompost to Soil. Greenhouse tests employed a 30 cm thick arable soil layer with plant residues and coarse mechanical inclusions. Before applying fertiliser, the soil was evenly loosened and levelled.

The previously collected vermicompost served as an organic fertiliser. It was applied according to the size of the experimental plots. The application rates were established at two levels: 10 % and 20 % of the dry soil mass in the 30 cm layer, equivalent to 500 and 1000 g/m2, respectively. Soil without vermicompost application was used as the control treatment (Table 1).

Vermicompost was applied by equally dispersing a pre-weighed amount over the soil surface of each experimental plot, then thoroughly mixing with the upper 10…12 cm soil layer to ensure consistent organic matter distribution. Following treatment and mixing, the soil was hydrated to its field capacity, which increased microbial activity and enhanced soil structure.

Table 1

Vermicompost application rates and content in experimental treatments

Experimental treatment	Vermicompost mass, g/m^2	Content, %
Control (without vermicompost)	–	–
Soil + vermicompost	500	10
Soil + vermicompost	1 000	20

Methods for determining the chemical composition of vermicompost and soil. The chemical composition of vermicompost and soil was analysed using standardised methods governed by national and international norms.

Vermicompost's chemical composition was determined by analysing key elements and agrochemical factors using standardised procedures. The organic matter content was assessed using the gravimetric method based on sample ignition and subsequent mass loss estimation, as specified in GOST 23740-2016. The carbon and humus contents were determined using I.V. Tyurin's oxidation-titrimetric method. Total nitrogen was determined using Tyurin's microchromium method, which involves oxidising organic materials with a chromic combination. Following acid digestion of the samples, the phosphorus (P_2O_5) content was evaluated using a gravimetric method in accordance with GOST 27784-88, while potassium (K_2O) was determined using an ionometric method in accordance with GOST 26261-84. The pH of the aqueous extract was determined potentiometrically according to GOST 26423-85.

The agrochemical characteristics of the examined soil were determined using standardised analytical procedures. The mobile forms of phosphorus (P2O5) and potassium (K_2O) were determined using the Machigin method modified by CINAO, whereas carbon and humus levels were measured using the Tyurin method, as per GOST 26205-91. The chlorides were analysed using a titrimetric method in accordance with ST RK 1286-2004, and the bicarbonates (HCO3-) were calculated titrimetrically in accordance with GOST 31957-2012. The total dissolved solids of the aqueous extract were determined gravimetrically in compliance with GOST 26423-85, whereas sulphates (SO_4^{2-}) were quantified using a comparable gravimetric method according to ST RK ISO 11048-2007. The exchangeable calcium and magnesium were determined using CINAO titrimetric methods in line with GOST 26487-85, and the ammonium nitrogen (NH^{4+}) was determined using GOST 27753.8-88. The total forms of copper, zinc, and lead were analysed using the inversion voltammetric method described in MU 31-11/2005. The pH of the aqueous extract was determined potentiometrically according to GOST 26423-85.

Greenhouse Experiment with Cucumber and Tomato Seedlings. The experiment was conducted in 2025 in a greenhouse located at the Research Institute "Ecology" of Khoja Ahmed Yasawi International Kazakh-Turkish University. The crops under study were cucumber (Cucumis sativus, hybrid cultivar Cedrik F1) and tomato (Solanum lycopersicum, hybrid cultivar Gamze F1).

In late January 2025, seeds were sown in 8 cm diameter plastic cups filled with greenhouse substrate. For each experimental treatment, 10 plants of each crop were planted. Seedlings were grown under the following conditions: 20…25 °C during the day, 15…20 °C at night, 50…60% relative humidity, and 12…14 hours of natural and supplementary lighting per day. Irrigation was performed as the upper layer of the substrate dried. The seedling's growth phase lasted 30 days (Figure 1).

Figure 1. Seedlings: (a) cucumber (*Cucumis sativus*, hybrid cultivar *Cedrik F1*); (b) tomato (*Solanum lycopersicum*, hybrid cultivar *Gamze F1*)

At the end of February, the seedlings were transplanted onto prepared beds where the soil had been pre-treated and fertilised with vermicompost at various concentrations based on the experimental design (Table 1).

3. RESULTS AND DISCUSSION

Characteristics of the Chemical Composition of Soils in the Turkestan Region. The soils of the Turkestan region in southern Kazakhstan are developed under harsh continental climatic conditions that include scorching and arid summers, low air humidity, and little atmospheric precipitation. These natural and climatic factors determine the dominance of light chestnut and sierozem soils, which are distinguished by low organic matter content, poor humification, and high carbonate levels (Table 2). These soil types usually have an alkaline or slightly alkaline reaction, a high buffering capacity, moderate macronutrient availability, and a diverse distribution of nutrients throughout the soil profile.

Table 2

Chemical composition of the studied soil in the Turkestan region

Parameter	Content, %
Carbon (C)	1,56 %
Humus	3,1 %
Phosphorus (P_2O_5), available	185,6 mg/kg
Potassium (K_2O), available	3,85 mg/kg
pH (aqueous extract)	8,6
Total dissolved solids in aqueous extract	0,089 %
Ammonium nitrogen (NH_4^+)	0,009 mg/kg
Bicarbonates in aqueous extract	0,024 %
Chlorides in aqueous extract	0,0009 %
Sulfates in aqueous extract	< 0,048 %
Zinc (total)	77,0 mg/kg
Lead (total)	22 mg/kg
Copper (total)	24 mg/kg
Calcium in aqueous extract	0,02 %
Magnesium in aqueous extract	0,068 %

The examination of the soil chemical composition revealed a set of signs indicating that the soil is slightly alkaline, fairly humus-rich, and contains a diverse range of macro- and micronutrients. The carbon concentration was 1.56 %, indicating soils with a low to medium level of cultivation, while the humus percentage (3.1 %) shows moderate humification, which is typical of light chestnut and sierozem soils in southern regions. The available forms of nutrients exhibited pronounced differences: the phosphorus content (185.6 mg/kg) can be classified as high, but the level of available potassium was extremely low (3.85 mg/kg), indicating a K_2O

deficiency and a potential need for additional potassium fertilisation to ensure optimal mineral nutrition of plants.

The soil solution had a slightly alkaline reaction (pH 8.6), which is typical of carbonate soils in arid locations and may limit the availability of some micronutrients like iron, zinc, and manganese. The total dissolved solids (0.089 %) and bicarbonate concentration (0.024 %) support the aqueous extract's little mineralisation. The presence of chloride (0.0009 %) and sulphate (<0.048 %) indicates a lack of salinity and a balanced ionic composition.

The study of mobile macrocations revealed modest levels of calcium (0.02 %) and magnesium (0.068 %) in the aqueous extract, indicating adequate availability of these elements. The content of ammonium nitrogen (0.009 mg/kg) was exceedingly low, as is typical of mineralised and low-organic soils in the absence of new organic matter. The overall quantities of zinc (77 mg/kg), copper (24 mg/kg), and lead (22 mg/kg) did not exceed allowed levels, indicating that the soil is environmentally safe for these elements. Zinc was the most abundant element, with concentrations similar to natural background values in southern soils.

Overall, the findings show that the examined soil has a moderate humus content and a high phosphorus level, but there is a significant lack of accessible potassium and ammonium nitrogen, which may limit crop growth and production. These qualities highlight the importance of using organic fertilisers, such as vermicompost, to increase soil structure, nutritional status, and biological activity.

Chemical and Nutrient Content of Vermicompost. Chemical examination of vermicompost revealed that the examined sample contains a high concentration of organic matter, humified chemicals, and necessary macronutrients, proving its high agrochemical value and efficiency as an organic fertiliser for vegetable crops (Table 3).

Table 3
Nutrient content of vermicompost

Name of the parameter determined	Content and unit of measurement	Content in mg/100 g of vermicompost
Organic matter	34,2 %	34 200
Carbon (C)	11,74 %	11 740
Humus	23,19 %	23 190
Nitrogen	1,58 %	1 580
Phosphorus (P_2O_5)	1,19 %	1 190
Potassium (K_2O)	1,95 %	1 950
pH	7,7	-

Organic matter, carbon and humus. The vermicompost had an organic matter content of 34.2 %, showing that plant wastes were extensively decomposed by soil micro- and macrofauna, notably red Californian earthworms *(Eisenia fetida)*. This value greatly exceeds the minimal level required for standard organic fertilisers, resulting in increased soil structure, water retention, and aeration.

The carbon content was 11.74 %, indicating a significant carbon saturation in the organic portion. Carbon is the principal energy source for soil bacteria, promoting the creation of stable organomineral compounds and enhancing mineralisation and humification processes.

The humus percentage was 23.19 %, indicating that the vermicompost was very mature. Humic compounds enhance the physical and chemical properties of soil by enhancing cation exchange capacity, buffering capacity, water-holding capacity, and nutrient retention. The high humus level makes vermicompost particularly helpful for soils with low organic matter content, which are common in Kazakhstan's southern areas.

Major nutrients (nitrogen, phosphorus, and potassium). The macronutrient makeup of the vermicompost is well balanced, containing:

Nitrogen (1.58 %), predominantly in organic and ammonium forms, is gradually released and available to plants.

Phosphorus (P_2O_5 - 1.19 %) is required for root growth, energy metabolism, and the creation of flower and fruit structures.

Potassium (K_2O - 1.95 %) is the greatest of the macronutrients, making this vermicompost especially beneficial for crops with high potassium requirements, such as cucumber and tomato. Potassium enhances plant water relations, drought resistance, carbohydrate storage, and fruit quality.

This nutrient balance promotes long-term and uniform plant feeding, lowering the possibility of deficiencies or uneven nutrient supplies.

Medium acidity (pH). The pH of the vermicompost was 7.7, indicating a somewhat alkaline response. This degree of acidity is ideal for most vegetable crops and does not impede growth even at relatively high application rates (up to 20 %). Vermicompost's pH helps to stabilise soil reactions, increase the activity of beneficial soil bacteria, and improve phosphate and potassium availability.

The combination of these statistics permits the examined vermicompost sample to be classified as a high-quality organic substance, possessing:

• High organic matter and humus content.
• Optimised carbon-to-nitrogen ratio.
• Maintain balanced amounts of N, P_2O_5, and K_2O.
• The reaction is somewhat alkaline and favourable.
• Stable biological activity.

This combination of chemical qualities accounts for the observed stimulatory effect on cucumber *(Cucumis sativus)* and tomato *(Solanum lycopersicum)* cultivation in the experimental treatments. Vermicompost promotes faster plant growth, improved root system development, and increased crop physiological activity.

Impact of Vermicompost on Cucumber Growth. Growth dynamics data for cucumbers revealed that the treatment of vermicompost had a significant stimulatory effect on plant development throughout the observation period. The plant height steadily rose in the control treatment, although it remained lower throughout the experiment than in the experimental treatments. The application of vermicompost at a 10 % rate stimulated growth: plants accumulated more aboveground biomass, resulting in consistently larger height than the control (Figure 2).

The most significant benefit was seen at a 20 % treatment rate, which resulted in maximum cucumber growth throughout the vegetative period. The plants in this treatment outperformed the control by an average of 20…35 %, depending on the observation time. These findings can be attributed to improved soil physicochemical qualities, enhanced availability of nutrient forms, and activation of soil microbes, all of which are vermicompost-specific.

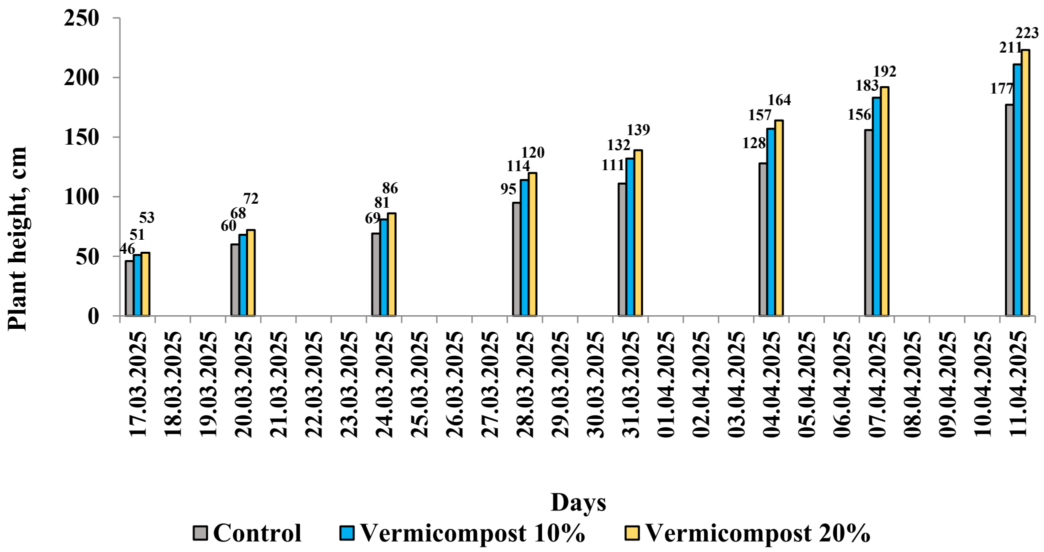

Figure 2. Cucumber growth over time with vermicompost application

The Impact of Vermicompost on Tomato Growth and Development. A similar tendency was observed with tomato cultivation. Plants under the control treatment had the lowest height values, but vermicompost application resulted in a considerable increase in growth. Differences between the experimental and control treatments emerged early in the development process.

The 10 % vermicompost application rate resulted in a moderate increase in plant height, while the 20 % rate produced the greatest stimulatory impact, with plants exceeding the control by an average of 15…30 % (Figure 3).

Tomato plants were very sensitive to changes in the nutritional and microbiological quality of the substrate, emphasising the necessity of organic soil enrichment for this crop. Vermicompost contained not only vital nutrients but also phytohormones, humic acids, and biologically active chemicals that aided in rapid growth.

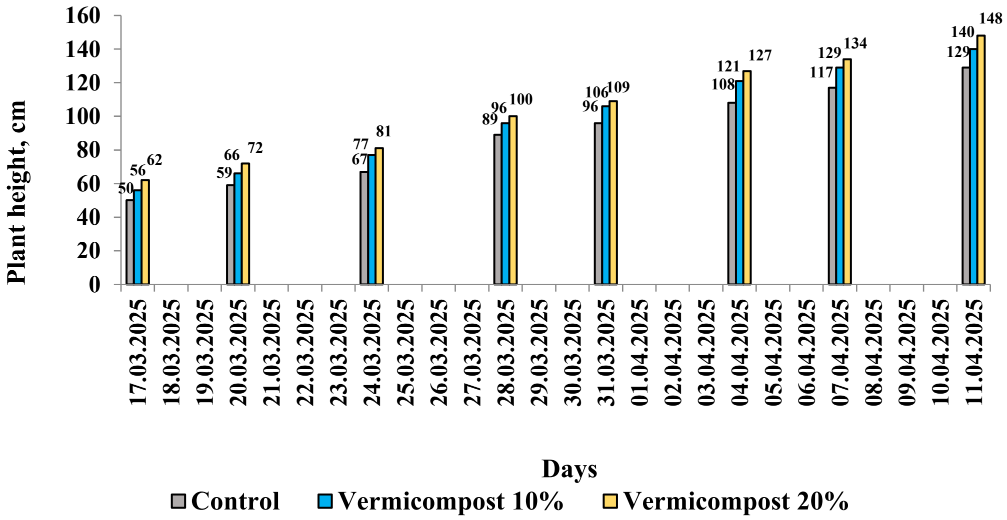

Figure 3. Tomato growth over time with vermicompost application

Comparison of Effects. In summarising the results for both crops, a general trend emerges: increasing the vermicompost dose by up to 20 % has the greatest stimulatory effect. The control treatment showed minimal growth dynamics.

The 10 % dose resulted in evident but minor gains in development.

The 20 % dose produced the largest plant heights throughout the experiment.

The comparable response patterns of tomato and cucumber show vermicompost's effectiveness as an organic fertiliser. The stimulatory impact is connected with improved soil structure, better water-holding capacity, lower bulk density, increased aeration, and substrate enrichment with accessible forms of N, P, and K, as well as biologically produced growth biostimulants.

The Effect of Various Vermicompost Doses on Cucumber Yield under Greenhouse Conditions. During the experiment, the dynamics of cucumber yield production were assessed using two vermicompost doses (10 % and 20 % of the substrate volume) in contrast to the control treatment. Fruit was harvested on a regular basis throughout the fruiting season (April-May 2025), and the product mass (g) was analysed for each treatment.

At the early stages of fruiting (the first harvest dates, April 4 and 7), the mass of harvested fruits was considerably greater in the vermicompost treatments than in the control. On April 4, the yield of the 20 % vermicompost treatment (743.81 g) was higher than that of the 10 % treatment (219.57 g), while the control had yet to produce any yield. On April 7, a similar pattern was seen, with the 10 % and 20 % vermicompost treatments generating 1,465.61 and 1,435.34 grams, respectively.

Throughout the investigation, the treatments with vermicompost consistently outperformed the control. On average, the 20 % vermicompost treatment produced the best yield values, although the 10 % dose similarly outperformed the control (Figure 4).

Peak yield values recorded in late April/early May need special attention. On April 28, the 20 % treatment yielded 5,176.52 g, and the 10 % treatment yielded 5,038.50 g, while the control yielded only 3,069.85 g. A similar peak was seen on May 2, when the 20 % vermicompost treatment produced 5,377.47 g, which was 2,148.75 g more than the control.

By the end of the growing season (second half of May), the discrepancies between treatments remained, but with a trend toward yield stabilisation. For example, on May 23, the yield in the 20 % treatment was 4,396.28 g, more than 3.3 times greater than the control (1,321.43 g). On the final harvest date (May 26), all treatments produced decreased yields; however, the 10% (1,986.2 g) and 20 % (1,508.11 g) vermicompost treatments exceeded the control (891.57 g).

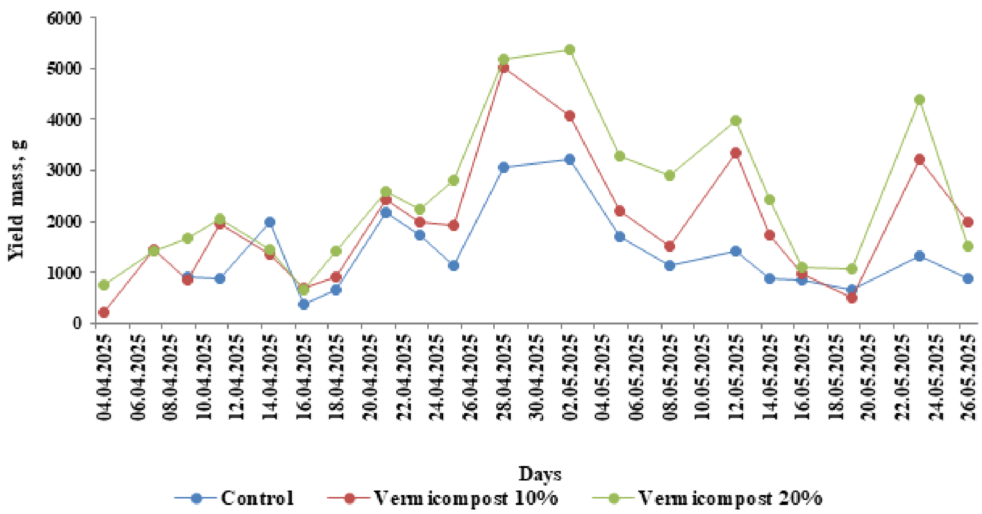

Figure 4. Dynamics of cucumber yield over time with the application of vermicompost

The results clearly show that vermicompost has a good influence on cucumber productivity under greenhouse circumstances. The greatest substantial effect was observed during vigorous fruiting (late April - early May), when the differences between treatments peaked (Figure 6).

Vermicompost promotes early fruiting. Even in the early phases of observation, vermicompost treatments produced fruit significantly earlier and in larger quantities than the control. This effect is connected with enhanced macro- and micronutrient availability, improved substrate structure, and the activation of microbiological activities.

The 20 % dose gives the maximum yield. Across all time intervals, the 20 % treatment consistently produced the highest fruit mass. Peak yields exceeded the control by more than 1.5…3.5 times, demonstrating the remarkable efficacy of this ideal degree of organic substrate enrichment.

The 10 % dose likewise produced a significant favourable effect. Although yields at 10 % were marginally lower than at 20 %, they continuously outperformed the control for the majority of harvest dates. This suggests that even mild vermicompost application considerably increases cucumber fruiting.

The control treatment produced the lowest and most unstable yields. The absence of organic substrate enrichment resulted in decreased fruiting intensity, particularly during periods of peak plant load.

Overall, the results show that using vermicompost is a highly beneficial agronomic approach for greenhouse cucumber growing. The 20 % dose proved to be the most productive, with the largest cumulative yield over the course of the observation period. The 10 % dose might also be viewed as an economically and agronomically advantageous alternative for protected cucumber cultivation.

Effect of Various Vermicompost Doses on Tomato Yield Under Greenhouse Conditions. The study also looked at the impact of two vermicompost doses (10 % and 20 % of substrate volume) on tomato yield versus a control treatment with no organic amendments. Fruit harvesting occurred on a regular basis from May 12 to June 16, 2025, and product mass was recorded for each treatment (Figure 5).

At the earliest fruiting stage (May 12), all treatments had modest yields. Nonetheless, even at the first harvest date, the vermicompost treatments excelled the control: the 20 % treatment yielded 778.77 g, which was six times more than the control (128.31 g), while the 10 % treatment surpassed the control nearly twofold (230.04 g).

On successive observation dates, yield increased in all treatments; however, the rate of fruit mass accumulation was significantly faster in the vermicompost treatments. On May 16, harvest masses were as follows: control - 1,051.40 g; 10 % - 1,571.16 g; 20 % - 2,055.68 g.

Thus, the benefit of the 20 % vermicompost treatment was sustained, with the highest values. On May 20, the 10 % treatment (2,481.05 g) marginally outperformed the 20 % treatment (2,182.50 g), showing a brief "equalisation" in fruiting intensity between the two doses. Nonetheless, over time, the 20 % therapy showed the best results.

The most noticeable changes occurred during peak fruiting periods. On May 23, the fruit mass reached: control – 2,722.56 g; 10 % – 3,826.97 g; and 20 % – 3,459.34 g.

By the end of May (May 26), the control yield was 2,921.03 g, while the 10 % and 20 % treatments produced 2,423.96 g and 2,473.78 g, respectively.

The most significant comparison occurred on May 30, when the 20 % treatment reached 4,665.61 g, more than 2.5 times greater than the control (1,851.71 g). The 10 % treatment likewise significantly outweighed the control (2,020.42 g).

In early June (June 2…10), the pattern of increasing differences across treatments persisted. On June 10, the fruit mass was: control - 3,912.76 g; 10 % - 6,157.65 g; and 20 % - 4,972.38 g.

During this time, the 10 % treatment produced the best yield, presumably due to the ideal balance of nutrient availability and substrate aeration.

By the end of the observation period (June 16), yields in all treatments had dropped, but the disparities between treatments remained: control - 2,610.00 g; 10 % - 3,105.61 g; 20 % - 2,226.84 g.

The observed non-linear dose–response relationship between vermicompost application rate and tomato yield can be explained by the combined influence of substrate physicochemical properties, plant physiological responses, and prevailing microclimatic conditions during the experimental period. While Figures 2-3 demonstrate a clear positive correlation between vermicompost dose and vegetative growth (plant height), yield formation is a more complex, multi-factorial process that depends not only on biomass accumulation but also on reproductive efficiency, nutrient balance, and environmental stress conditions.

One of the key factors underlying the superior performance of the 10 % vermicompost treatment on May 30 is the optimisation of substrate aeration and nutrient availability. At moderate application rates (10 %), vermicompost improves soil structure, increases porosity, and enhances oxygen diffusion to the root zone. This promotes balanced root respiration and efficient nutrient uptake. In contrast, higher application rates (20 %) despite increasing organic matter and nutrient supply may lead to partial compaction of the substrate, increased water retention, and reduced aeration. Under such conditions, excessive moisture combined with limited oxygen availability can suppress root activity and reduce the efficiency of generative processes such as flowering and fruit filling.

Additionally, nutrient balance plays a crucial role. Vermicompost is rich in available nitrogen, phosphorus, and potassium; however, excessive concentrations particularly at the 20% rate may disrupt the optimal nutrient ratio. High nitrogen availability can stimulate vegetative growth at the expense of reproductive development, leading to delayed or reduced fruit set. Therefore, the 10 % treatment likely provided a more balanced nutrient environment during the critical fruiting stage, resulting in higher yield on May 30.

Microclimatic conditions further contributed to this non-linear response. During May, air temperature fluctuated between +25 °C and +40 °C, while relative humidity ranged from 11 % to 36 %, indicating generally hot and arid conditions typical of greenhouse environments in southern Kazakhstan. On May 30 specifically, the temperature was approximately +28 °C with relative humidity around 20 %. These conditions are close to optimal for tomato fruit set and development, as moderate temperatures (25…30 °C) combined with low to moderate humidity (20…30 %) favour pollination, reduce fungal disease pressure, and enhance assimilate transport to fruits.

Under these favourable environmental conditions, the advantages of the optimally balanced 10 % vermicompost treatment became more pronounced. The improved aeration and moderate nutrient supply likely allowed plants to fully utilise the favourable temperature–humidity regime, resulting in maximal fruit formation and accumulation of biomass in fruits rather than vegetative organs. Conversely, in the 20 % treatment, the potential limitations in aeration and possible nutrient imbalance may have restricted the plant's ability to capitalise on these optimal climatic conditions.

It is also important to consider plant physiological regulation under stress conditions. At higher temperatures (approaching 35…40 °C), which were periodically observed during May, plants experience increased transpiration and potential water stress, especially under low humidity (11…20 %). In substrates with higher organic content (20 % vermicompost), increased water retention may initially be beneficial; however, under fluctuating irrigation regimes, it can lead to uneven water availability and root zone hypoxia. In contrast, the 10 % treatment likely maintained a more stable water–air balance, enabling better physiological adaptation to temperature and humidity fluctuations.

Thus, the temperature–humidity dependence for achieving high tomato yield in this study can be summarised as follows: optimal productivity was observed under temperatures of +25…30 °C and relative humidity of 20…30 %, in combination with a moderately enriched substrate (10 % vermicompost), which which provided an optimal balance between aeration, water retention, and nutrient availability.

In conclusion, the superior performance of the 10 % vermicompost treatment on May 30 reflects a synergistic interaction between optimal substrate conditions and favourable microclimatic parameters. These findings confirm that the relationship between vermicompost dose and crop productivity is non-linear and strongly dependent on environmental conditions and substrate physical properties. Therefore, the optimal application rate of vermicompost should be determined not only based on its chemical composition but also considering greenhouse microclimate and crop developmental stage.

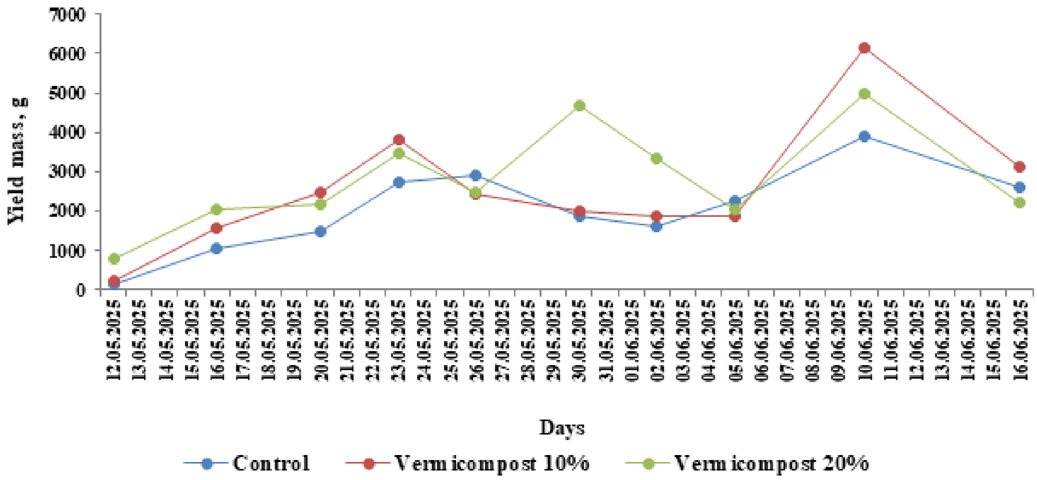

Figure 5. Dynamics of tomato yield over time with the application of vermicompost

The observed non-linear dose–response relationship between vermicompost application rate and tomato yield can be explained by the combined influence of substrate physicochemical properties, plant physiological responses, and prevailing microclimatic conditions during the experimental period. While Figures 2…3 demonstrate a clear positive correlation between vermicompost dose and vegetative growth (plant height), yield formation is a more complex, multifactorial process that depends not only on biomass accumulation but also on reproductive efficiency, nutrient balance, and environmental stress conditions.

One of the key factors underlying the superior performance of the 10 % vermicompost treatment on May 30 is the optimisation of substrate aeration and nutrient availability. At moderate application rates (10 %), vermicompost improves soil structure, increases porosity, and enhances oxygen diffusion to the root zone. This promotes balanced root respiration and efficient nutrient uptake. In contrast, higher application rates (20 %) despite increasing organic matter and nutrient supply may lead to partial compaction of the substrate, increased water retention, and reduced aeration. Under such conditions, excessive moisture combined with limited oxygen availability can suppress root activity and reduce the efficiency of generative processes such as flowering and fruit filling.

Additionally, nutrient balance plays a crucial role. Vermicompost is rich in available nitrogen, phosphorus, and potassium; however, excessive concentrations particularly at the 20 % rate may disrupt the optimal nutrient ratio. High nitrogen availability can stimulate vegetative growth at the expense of reproductive development, leading to delayed or reduced fruit set. Therefore, the 10 % treatment likely provided a more balanced nutrient environment during the critical fruiting stage, resulting in higher yield on May 30.

Microclimatic conditions further contributed to this non-linear response. During May, air temperature fluctuated between +25 °C and +40 °C, while relative humidity ranged from 11 % to 36 %, indicating generally hot and arid conditions typical of greenhouse environments in southern Kazakhstan. On May 30 specifically, the temperature was approximately +28 °C with relative humidity around 20 %. These conditions are close to optimal for tomato fruit set and development, as moderate temperatures (25…30 °C) combined with low to moderate humidity (20…30 %) favour pollination, reduce fungal disease pressure, and enhance assimilate transport to fruits.

Under favourable environmental conditions, the advantages of the optimally balanced 10% vermicompost treatment became more pronounced. The better aeration and moderate nutrient supply probably helped the plants make the most of the good temperature and humidity conditions, which led to the most fruit formation and the most biomass being stored in the fruits instead of the vegetative organs. Conversely, in the 20 % treatment, the potential limitations in aeration and the possible nutrient imbalance may have restricted the plant's ability to capitalise on these optimal climatic conditions.

It is also important to consider plant physiological regulation under stress conditions. At higher temperatures (approaching 35…40 °C), which were periodically observed during May, plants experience increased transpiration and potential water stress, especially under low humidity (11…20 %). In substrates with higher organic content (20 % vermicompost), increased water retention may initially be beneficial; however, under fluctuating irrigation regimes, it can lead to uneven water availability and root zone hypoxia. In contrast, the 10 % treatment likely maintained a more stable water–air balance, enabling better physiological adaptation to temperature and humidity fluctuations.

Figure 6. Appearance of cucumber *(Cucumis sativus)* and tomato *(Solanum lycopersicum)* yield with different vermicompost application rates

Vermicomposting, particularly at 10 % and 20 % rates, is a successful agricultural strategy for tomato growing in greenhouses. The treatments with organic fertiliser produced the highest yields, demonstrating vermicompost's excellent agribiological value as a substrate component for fruiting vegetable crops.

The results of this research unequivocally indicate that the soils of the Turkestan region are distinguished by specific physicochemical characteristics that are indicative of arid and semi-arid conditions in southern Kazakhstan. Light chestnut and sierozem soils, which are extensively distributed throughout this region, are produced in the presence of high evapotranspiration, limited precipitation, and carbonate accumulation. An alkaline soil reaction (pH 7.8…8.8), low nitrogen availability, moderate to low organic carbon content, and heterogeneous distribution of nutrients throughout the soil profile are the primary characteristics of soils in arid zones, as indicated by prior research [21...22]. The pH value of 8.6 determined in the present study fully corresponds to these characteristics and confirms the carbonate nature of the investigated soil.

The investigated soil exhibits only a moderate degree of biological activity and organic matter transformation in comparison to intensively cultivated soils described in recent studies (organic carbon levels of 1.0…2.5 % in irrigated arid agroecosystems). Nevertheless, the humus content (3.1 %) can be assessed as moderate for southern Kazakhstan. The literature underscores that soils in arid climates are particularly susceptible to organic matter declines as a result of accelerated mineralisation at high temperatures and the insufficient return of plant residues.

Consequently, the scientific justification for the administration of supplementary organic fertilisers in the regions that have been identified is clear [23...24].

During the soil analysis, the exceedingly low content of available potassium (3.85 mg/kg) and ammonium nitrogen (0.009 mg/kg) was identified as a critical limiting factor. A comparable potassium deficiency has been documented in the irrigated soils of Central Asia, where the depletion of exchangeable potassium reserves is a result of long-term monoculture and insufficient application of organic fertilisers. Potassium plays a fundamental role in osmotic regulation, carbohydrate transport, and the resistance of vegetable crops to stress factors. Its deficiency, particularly under greenhouse cultivation conditions, can significantly reduce productivity. Therefore, the pronounced increase in the yield of cucumber *(Cucumis sativus)* and tomato *(Solanum lycopersicum)* observed after vermicompost application in this study is consistent with results previously reported by other researchers [25, 26].

The chemical composition of the vermicompost used in the experiment confirms its high agronomic value. The elevated content of organic matter (34.2 %) and humus (23.19 %) indicates a high degree of stabilisation and maturity of the substrate. According to literature data, vermicompost produced using *Eisenia fetida* is characterised by enhanced humification, increased cation exchange capacity, and improved nutrient retention compared to conventional compost. The balanced N–P–K ratio identified in the present study corresponds to the ranges typical of high-quality vermicompost (1…2 % N, 0.5…1.5 % P_2O_5, 1…2 % K_2O) [27...28].

The slightly alkaline reaction of the vermicompost (pH 7.7) is particularly important when applied to alkaline soils similar to those studied. The literature indicates that vermicompost is capable of buffering soil reaction, reducing the negative effects of excessive alkalinity, and increasing the availability of micronutrients through chelation by humic substances [29]. This partially explains the improvement in the vegetative growth of cucumber *(Cucumis sativus)* and tomato *(Solanum lycopersicum)*.

The stimulating effect on the growth of cucumber *(Cucumis sativus)* and tomato *(Solanum lycopersicum)* is confirmed by the results of controlled greenhouse experiments. Norman Q. Arancon et al. [30] reported an increase in plant height and biomass of vegetable crops by 20…40 % when vermicompost was applied at rates of 10…30 % of the substrate volume. Similarly, María Lazcano et al. [31] demonstrated enhanced root system development and accelerated phenological stages in tomatoes grown in substrates amended with vermicompost. In the present study, the 20 % application rate provided the most stable increase in plant height (20…35 % higher than the control for cucumber and 15…30 % for tomato), which is consistent with international findings.

Yield dynamics under protected cultivation conditions also confirm the agronomic effectiveness of vermicompost. Numerous meta-analyses indicate that vermicompost application can increase vegetable crop yields by 15…60 %, depending on plant species, application rate, and substrate characteristics [32]. In the present study, yield increases during the peak fruiting period reached 1.5…3.5 times compared to the control in cucumber and up to 65 % or more in tomato, confirming the high responsiveness of these crops to organic enrichment of the substrate.

An important observation is the differentiated response of tomato to the application of 10% and 20% vermicompost during different fruiting stages. While the 20 % rate provided higher performance in the early and middle fruiting phases, the 10 % rate showed better results during the peak fruiting period in early June. Similar nonlinear “dose-response” relationships have been described in the literature, where excessive application of organic substrate may alter aeration or nutrient balance [33]. These findings indicate that the optimal concentration of vermicompost may vary depending on the crop’s developmental stage and environmental conditions.

The stimulating effect of vermicompost is not limited solely to its nutritional value. Contemporary studies emphasise the role of humic acids, phytohormones (auxins and cytokinins), and beneficial microbial communities present in vermicompost [34]. These biologically active compounds stimulate root system development, enhance nutrient uptake efficiency, and increase plant resistance to abiotic stresses-factors that are particularly significant under the alkaline and potassium-deficient soil conditions of the Turkestan region.

Overall, the results of the present study are fully consistent with contemporary international scientific findings and confirm that vermicompost is an effective tool for improving the fertility of arid and semi-arid soils. Under the specific soil and climatic conditions of southern Kazakhstan, the application of vermicompost at rates of 10…20 % significantly enhances growth dynamics and yield formation of cucumber and tomato under protected cultivation conditions.

From an agroecological perspective, the integration of vermicompost into greenhouse production systems contributes not only to increased yields but also to the sustainable management of soil resources. Its application promotes the restoration of organic matter reserves, stimulates biological activity, improves soil structure, and reduces reliance on mineral fertilisers. In the context of escalating soil degradation and nutrient imbalances in arid regions, organic fertilisers such as vermicompost represent a scientifically justified and environmentally safe strategy for the sustainable production of vegetable crops.

4. CONCLUSION

The application of vermicompost to substrates for cucumber and tomato cultivation under greenhouse conditions in the Turkestan region has a significant positive effect on plant growth and development. The use of this organic fertilizer promotes the accelerated formation of both aboveground biomass and root systems, improves physiological processes, enhances photosynthetic activity, and increases overall plant vitality.

The most pronounced stimulatory effect was observed at the 20 % application rate, which resulted in the highest plant height and cumulative yield throughout the observation period. The 10 % rate also had a positive effect, accelerating plant growth and improving productivity compared to the control, making it an economically and agronomically justified option for organic amendment.

Vermicompost application improves the physicochemical properties of the soil: it increases humus and carbon content, enhances the availability of key macronutrients (N, P, K), stabilizes substrate pH, and stimulates soil microbial activity. These changes create favorable conditions for early and intensive fruiting, reduce the time to the first harvest, and ensure more stable fruit development throughout the entire growing period.

Thus, the use of vermicompost in protected cultivation in the Turkestan region is a highly effective organic agricultural practice, contributing to increased yield and quality of cucumber and tomato, improved soil structure and fertility, and enhanced crop resilience to adverse soil and climatic conditions.

DATA AVAILABILITY

The data supporting the findings of this study are fully presented within this article. All experimental data generated and analysed during the current study are included in the text, tables, and figures of this publication. All materials necessary to support and verify the conclusions of the study are contained within this article.

AUTHORS' CONTRIBUTION

Conceptualization – NA, DY; resources - YS, ZhD, NSA; formal analysis – ZhD; methodology - NA, DY, BK; software - YS, NSA; supervision - NA, DY; visualization – YS, DY, BK; writing—original draft preparation – DY; writing—review and editing – all authors.

REFERENCES

1. Enebe, M. C., Erasmus, M. (2023). Vermicomposting technology – A perspective on vermicompost production technologies, limitations and prospects. *Journal of Environmental Management,* 345, 118585. https://doi.org/10.1016/j.jenvman.2023.118585
2. Ganapathy, N. R. V., Elango, A. C., Balaji, G., Sankaranarayanan, M., Sharma, M. (2025). A comprehensive review of earthworm-derived vermiproducts and their role in sustainable agriculture. *Discover Applied Sciences,* 7, 995. https://doi.org/10.1007/s42452-025-07614-w

3. Ratnasari, A., Syafiuddin, A., Mehmood, M. A., Boopathy, R. (2023). A review of the vermicomposting process of organic and inorganic waste in soils: Additives effects, bioconversion process, and recommendations. *Bioresource Technology Reports,* 21, 101332. https://doi.org/10.1016/j.biteb.2023.101332
4. Manzoor, A., Naveed, M. S., Ali, R. M. A., Naseer, M. A., UL-Hussan, M., Saqib, M., Hussain, S., Farooq, M. (2024). Vermicompost: A potential organic fertilizer for sustainable vegetable cultivation. *Scientia Horticulturae,* 336, 113443. https://doi.org/10.1016/j.scienta.2024.113443
5. Das, D., Kalita, N., Langthasa, D., Faihriem, V., Borah, G., Chakravarty, P., Deka, H. (2022). Eisenia fetida for vermiconversion of waste biomass of medicinal herbs: Status of nutrients and stability parameters. *Bioresource Technology,* 347, 126391. https://doi.org/10.1016/j.biortech.2021.126391
6. Elissen, H., van der Weide, R., Gollenbeek, L. (2023). *Effects of vermicompost on plant and soil characteristics – A literature overview* (Report No. WPR-995). Wageningen Plant Research. https://doi.org/10.18174/587210
7. Safadoust, A., Azimi, S. B., Dehghan, M. B. (2025). Restoring soil functionality in drylands: Soil texture-specific impacts of vermicompost as an organic waste-based amendment. *Journal of Arid Environments*, 231, 105446. https://doi.org/10.1016/j.jaridenv.2025.105446
8. Mustafayeva, N. B., Mustafayev, B. A., Kobzhassarov, T., Omarov, M. M., Miciński, J., Orzechowski, B., Sobotka, W. (2022). Use of vermicompost for recovery of soil fertility and increase of field crop capacity under conditions of the dry-steppe zone. *Journal of Elementology,* 27(3), 679-693. https://doi.org/10.5601/jelem.2022.27.2.2287
9. Permatasari, D., Fitrihidajati, H. (2025). Effectiveness of earthworms (Eisenia fetida) and vermicompost combination in bioremediation of oil-contaminated soil. *LenteraBio: Berkala Ilmiah Biologi,* 14(2), 229-235. https://doi.org/10.26740/lenterabio.v14n2.p229-235
10. Zazouli, M. A., Hezarjaribi, H. Z., Charati, J. Y., Ahmadnezhad, A., Mahvi, A. H., Asgharnia, H. (2021). Investigating the effects of vermicomposting process using Eisenia fetida earthworms on the reduction of parasite populations. *Journal of Environmental Health Science & Engineering,* 19(2), 1623-1633. https://doi.org/10.1007/s40201-021-00718-6
11. Jankauskienė, J., Laužikė, K., Kavaliauskaitė, D. (2022). Effects of vermicompost on quality and physiological parameters of cucumber (Cucumis sativus L.) seedlings and plant productivity. *Horticulturae,* 8(11), 1009. https://doi.org/10.3390/horticulturae8111009
12. Büyükarslan, D., Demir, H. (2024). Effects of vermicompost as an alternative substrate on yield and quality of cauliflower and pepper seedlings. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca,* 52(2), 13587. https://doi.org/10.15835/nbha52213587
13. Haque, M., Khan, M., Akram, S. (2023). Evaluation of e-vermicompost for tomato production. *Bangladesh Journal of Nuclear Agriculture,* 37(1), 31-40. https://doi.org/10.3329/bjnag.v37i1.69921
14. Boyacı, S., Atilgan, A., Rolbiecki, R., Kocięcka, J. (2025). The effect of irrigation and vermicompost applications on the growth and yield of greenhouse pepper plants. *Water*, 17(22), 3219. https://doi.org/10.3390/w17223219
15. Raza, S. T., Zhu, B., Yao, Z., Wu, J., Chen, Z., Ali, Z., Tang, J. L. (2023). Impacts of vermicompost application on crop yield, ammonia volatilization and greenhouse gases emission on upland in Southwest China. *Science of The Total Environment,* 860, 160479. https://doi.org/10.1016/j.scitotenv.2022.160479
16. Terefe, Z., Feyisa, T., Molla, E., Ejigu, W. (2024). Effects of vermicompost and mineral fertilizers on soil properties, malt barley (Hordeum distichum L.) yield, and economic benefits. *Agrosystems Geosciences & Environment,* 7(3), e20550. https://doi.org/10.1002/agg2.20550
17. Hossain, M. L., Shapna, K. J., Li, J., Lai, D. Y. F., Khandker, S., Salam, M. A., Beierkuhnlein, C. (2025). Vermicompost integration in smallholder farming: Evaluating household practices and stakeholder involvement in diverse agricultural contexts of Bangladesh. *Sustainable Futures,* 10, 101281. https://doi.org/10.1016/j.sftr.2025.101281
18. Sharma, K., Garg, V. K. (2018). Comparative analysis of vermicompost quality produced from rice straw and paper waste employing earthworm Eisenia fetida (Sav.). *Bioresource Technology,* 250, 708-715. https://doi.org/10.1016/j.biortech.2017.11.101
19. Li, X., Su, Y., Ahmed, T., Ren, H., Javed, M. R., Yao, Y., An, Q., Yan, J., Li, B. (2021). Effects of different organic fertilizers on improving soil from newly reclaimed land to crop soil. *Agriculture*, 11(6), 560. https://doi.org/10.3390/agriculture11060560
20. Sainova, G. A., Kaliyeva, N. A., Yuldashbek, D. K., & Akbasova, A. D. (2023). The Influence of Vermicompost and Various Concentrations of Lead on the Enzymatic Activity of Sierozem Soils of Kazakhstan. *Scientifica (Cairo),* 2023, 8490234. https://doi.org/10.1155/2023/8490234
21. Doszhanova, A., Ospanbayev, Z., Sembayeva, A., Kassipkhan, A., Nazarova, A., Bekbauov, M., Kazkeyev, D. (2024). Unveiling the soil physicochemical dynamics of bare soils in Southeast Kazakhstan: A comprehensive study in the Akdala Massif. *Eurasian Journal of Soil Science,* 13(2), 125-132. https://doi.org/10.18393/ejss.1408067
22. Kakabayev, A. A., Sharipova, B. U., Baranovskaya, N. V., Rodrigo-Ilarri, J., Rodrigo-Clavero, M.-E., Lo Papa, G., Muratbekova, S., Nurmukhanbetova, N., Durmekbayeva, Sh., Toychibekova, G.B., Kurmanbayev, R., Zhumabayeva, A. (2024). Impact of environmental conditions on soil geochemistry in Southern Kazakhstan. *Sustainability,* 16(15), 6361. https://doi.org/10.3390/su16156361
23. Liu, Q., Yang, L., Ma, L., Zhai, Y., Wang, D. (2026). Effects of organic fertilizers on soil properties in arid zones and their mechanism of action. *Frontiers in Environmental Science,* 10, 1681958. https://doi.org/10.3389/fenvs.2026.1681958
24. Ma, D., Ju, W., Zhao, W., He, Z., Li, R., Sun, W., Yang, R., Zhang, Y. (2025). Salt effects on soil organic carbon in irrigated farmland in arid region. *Geoderma,* 405, 117628. https://doi.org/10.1016/j.geoderma.2025.117628
25. Guliyeva, Z., Maxsudov, Sh., Garibova, S., Ashurova, N., Aliyeva, A., Novruzova, S., Guliyev, S. (2025). Effects of vermicompost application rates and irrigation regimes on tomato yield, nutrient uptake and soil properties under greenhouse conditions. *Eurasian Journal of Soil Science,* 14(3), 270-279. https://doi.org/10.18393/ejss.1703816

26. Bhardwaj, S., Kapoor, B., Kapoor, D., Thakur, U., Dolma, Y., Raza, A. (2025). Manifold roles of potassium in mediating drought tolerance in plants and its underlying mechanisms. *Plant Science,* 351, 112337. https://doi.org/10.1016/j.plantsci.2024.112337
27. Kumari, S., Singh, R. K., Singh, A., Choubey, A. K., Srivastava, P. K. (2025). Optimization and evaluation of Eisenia fetida based vermicompost derived from fish processing waste, rice straw, and biogas slurry for sustainable agriculture. *Process Safety and Environmental Protection,* 198, 107225. https://doi.org/10.1016/j.psep.2025.107225
28. Niebles, C. C. C., Hernández, H., Muñoz Salas, K., Hasse, A., Gindri Ramos, C. (2025). Comparative evaluation of humic substance production from organic wastes in tropical vermicomposting using Eisenia foetida. *Bioresource Technology Reports,* 31, 102292. https://doi.org/10.1016/j.biteb.2025.102292
29. Wu, D., Chen, C., Liu, Y., Zhang, G., Yang, L. (2023). Vermicompost improves tomato yield and quality by promoting carbohydrate transport to fruit under salt stress. *Horticulturae,* 9(9), 1015. https://doi.org/10.3390/horticulturae9091015
30. Arancon, N. Q., Edwards, C. A., Lee, S., Byrne, R. (2006). Effects of humic acids from vermicomposts on plant growth. *European Journal of Soil Biology,* 42(1), 65-69. https://doi.org/10.1016/j.ejsobi.2006.06.004
31. Lazcano, M., Gómez-Brandón, M., Domínguez, J. (2008). Comparison of the effectiveness of composting and vermicomposting for the biological stabilization of cattle manure. *Chemosphere,* 72(7), 1013-1019. https://doi.org/10.1016/j.chemosphere.2008.04.016
32. Oyege, I. B., Adejumo, M., Usman, A. (2025). The Role of Vermicompost and Vermicompost Tea in Enhancing Crop Productivity and Plant Health. *Agriculture,* 15(13), 1433. https://doi.org/10.3390/agriculture15131433
33. Toor, M. D., Ay, A., Ullah, I., Demirkaya, S., Kızılkaya, R., Mihoub, A., Zia, A., Jamal, A., Ghfar, A. A., Di Serio, A., Ronga, D. (2024). Vermicompost Rate Effects on Soil Fertility and Morpho-Physio-Biochemical Traits of Lettuce. *Horticulturae,* 10(4), 418. https://doi.org/10.3390/horticulturae10040418
34. Rehman, S. u., De Castro, F., Aprile, A., Benedetti, M., Fanizzi, F. P. (2023). Vermicompost: Enhancing Plant Growth and Combating Abiotic and Biotic Stress. *Agronomy,* 13(4), 1134. https://doi.org/10.3390/agronomy13041134

ВЕРМИКОМПОСТТЫҢ ХИМИЯЛЫҚ-ТЕХНОЛОГИЯЛЫҚ СИПАТТАМАСЫ ЖӘНЕ ОНЫҢ ТОПЫРАҚТЫҢ АГРОХИМИЯЛЫҚ ҚАСИЕТТЕРІ МЕН ЖЫЛЫЖАЙ ДАҚЫЛДАРЫНЫҢ ӨНІМДІЛІГІНЕ ӘСЕРІ

Нурлан А. Ахметов[1] PhD, Давлат Х. Юлдашбек[1*], Ёкубжан С. Сатанов[1], Жулдыз А. Дюсенова[2] техника ғылымдарының кандидаты, Бекжан Д. Қосалбаев[1,3] PhD, Нуралы Ш. Акимбеков[1,4] PhD, Профессор

[1]Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, Түркістан, Қазақстан; nurlan.akhmetov@ayu.edu.kz (НАА); davlat.yuldashbek@ayu.edu.kz (ДХЮ); yokubzhan.satanov@ayu.edu.kz (ЁСС)
[2]«Қазгидромет» РМК, Ғылыми-зерттеу орталығының Климаттық зерттеулер басқармасы, Астана, Қазақстан; dyussenova_zh@meteo.kz (ЖАД)
[3]Қ. И. Сәтбаев атындағы Қазақ ұлттық техникалық зерттеу университеті, Алматы, Қазақстан; kossalbayev.bekzhan@gmail.com (БДҚ)
[4]Әл-Фараби атындағы Қазақ Ұлттық Университеті, Алматы, Қазастан; akimbeknur@gmail.com (НША)
*Автор корреспондент: Давлат Х. Юлдашбек, e-mail: davlat.yuldashbek@ayu.edu.kz

ТҮЙІН СӨЗДЕР

вермикомпост,
Eisenia fetida,
қияр (Cucumis sativus),
қызанақ (Solanum lycopersicum),
өнімділік,
органикалық тыңайтқыш,
Түркістан облысы,
топырақ қасиеттері

Мақала жайында:

Алынды: 15.04.2026
Қайта қаралды: 27.04.2026
Қабылданды: 23.06.2026
Жарияланды: 01.07.2026

АБСТРАКТ

Бұл зерттеу Қазақстан Республикасының Түркістан өңірінде жылыжай жағдайында өсірілген қиярдың *(Cucumis sativus)* және қызанақтың *(Solanum lycopersicum)* өсуіне, дамуына және өнімділігіне вермикомпостты әртүрлі мөлшерде (субстрат көлемінің 0 %, 10 % және 20 %) енгізудің әсерін қарастырады. Зерттеу топырақ субстратындағы органикалық заттардың химиялық-технологиялық трансформациясы аясында жүргізіледі. Нәтижелер вермикомпостты енгізу субстраттың физика-химиялық қасиеттерінде елеулі өзгерістер тудыратынын көрсетеді, соның ішінде органикалық заттардың артуы, субстрат pH-ының тұрақтануы, азот, фосфор және калий сияқты негізгі макроэлементтердің қолжетімділігінің жақсаруы байқалды. Бұл өзгерістер минералдану процестерінің белсенділенуіне және қоректік заттардың биохимиялық түрленуінің күшеюіне ықпал етеді, нәтижесінде тамыр жүйесінің дамуы, вегетативті өсу және өнімділік артады. Ең жоғары жалпы өнімділік вермикомпосттың 20 % мөлшерінде байқалды, бұл оның агрономиялық тиімділігінің ең жоғары екенін көрсетеді. Сонымен қатар 10 % мөлшері де тұрақты оң әсер беріп, оны жылыжайда өсіру үшін теңгерімді және экономикалық тұрғыдан тиімді нұсқа ретінде қарастыруға болатынын көрсетті. Жалпы алғанда, алынған нәтижелер вермикомпостты жылыжай көкөніс өндірісінде топырақ субстратын жақсартудың химиялық технологиясында тиімді органикалық компонент ретінде қолдануды қолдайды.

ХИМИКО-ТЕХНОЛОГИЧЕСКАЯ ХАРАКТЕРИСТИКА ВЕРМИКОМПОСТА И ЕГО ВЛИЯНИЕ НА АГРОХИМИЧЕСКИЕ СВОЙСТВА ПОЧВЫ И УРОЖАЙНОСТЬ ТЕПЛИЧНЫХ КУЛЬТУР

Нурлан А. Ахметов[1] PhD, Давлат Х. Юлдашбек[1*], Ёкубжан С. Сатанов[1], Жулдыз А. Дюсенова[2] кандидат технических наук, Бекжан Д. Косалбаев[1,3] PhD, Нуралы Ш. Акимбеков[1,4] PhD, Профессор

[1]Международный казахско-турецкий университет им. Ходжи Ахмеда Ясави, Туркестан, Казахстан; nurlan.akhmetov@ayu.edu.kz (НАА); davlat.yuldashbek@ayu.edu.kz (ДХЮ); yokubzhan.satanov@ayu.edu.kz (ЁСС)
[2]РГП «Казгидромет», Управления климатических исследований Научно-исследовательского центра, Астана, Казахстан; dyussenova_zh@meteo.kz (ЖАД)
[3]Казахский национальный исследовательский технический университет им. К. И. Сатпаева, Алматы, Казахстан; kossalbayev.bekzhan@gmail.com (БДК)
[4]Казахский Национальный Университет им. Аль-Фараби, Алматы, Казахстан; akimbeknur@gmail.com (НША)
*Автор корреспондент: Давлат Х. Юлдашбек, e-mail: davlat.yuldashbek@ayu.edu.kz

КЛЮЧЕВЫЕ СЛОВА

вермикомпост,
Eisenia fetida,
огурец (Cucumis sativus),
томат (Solanum lycopersicum),
урожайность,
органическое удобрение,
Туркестанская область,
свойства почвы

По статье:
Получено: 15.04.2026
Пересмотрено: 27.04.2026
Принято: 23.06.2026
Опубликовано: 01.07.2026

АБСТРАКТ

В данном исследовании рассматривается влияние различных доз внесения вермикомпоста (0 %, 10 % и 20 % от объема субстрата) на рост, развитие и урожайность огурца *(Cucumis sativus)* и томата *(Solanum lycopersicum)*, выращиваемых в тепличных условиях Туркестанского региона Республики Казахстан. Исследование проводится в рамках химико-технологической трансформации органического вещества в почвенных субстратах. Полученные результаты показывают, что внесение вермикомпоста приводит к существенным изменениям физико-химических свойств субстрата, включая увеличение содержания органического вещества, стабилизацию pH субстрата и улучшение доступности основных макроэлементов, таких как азот, фосфор и калий. Данные изменения способствуют активизации процессов минерализации и усилению биохимической трансформации питательных веществ, что, в свою очередь, стимулирует развитие корневой системы, усиливает вегетативный рост и повышает урожайность. Наивысшая общая продуктивность была зафиксирована при внесении вермикомпоста в дозе 20 %, что свидетельствует о его максимальной агрономической эффективности. В то же время дозировка 10 % также показала устойчиво положительный эффект, что позволяет рассматривать её как сбалансированный и экономически целесообразный вариант для тепличного выращивания. В целом полученные результаты подтверждают эффективность использования вермикомпоста как органического компонента в химической технологии улучшения почвенных субстратов для тепличного овощеводства.