Received: 15.11.2024. Revised: 07.02.2025. Accepted: 12.03.2025

Bulletin of the Kyrgyz National Agrarian University

Vol. 23, No. 1. 2025

Journal homepage: https://knau-bulletin.com/en

UDC 631. 811.2.3.16

DOI: 10.63621/bknau./1.2025.20

Effectiveness of manure under protected cultivation conditions

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Abstract. In modern agriculture, optimising the use of fertilisers is a key factor in enhancing cucumber yields. Manure, as a traditional organic fertiliser, alongside modern agronomic inputs such as mineral fertilisers and nanohumic substances, plays an important role in supplying plants with essential nutrients. This study aimed to conduct a comparative analysis of the effectiveness of traditional organic fertiliser (manure) when applied alone and in combination with nanohumic substance and mineral fertilisers on cucumber crops under greenhouse conditions. Such a comparison made it possible to determine optimal fertilisation strategies to achieve maximum cucumber yields. The research was carried out in greenhouse conditions using the cucumber hybrid Absolut. Various combinations of fertilisers, including manure, mineral fertilisers, and nanohumic substances, were applied during the experiment, followed by an analysis of their effects on yield and fruit quality. A positive influence of the full range of fertilisers – both mineral and manure, whether applied individually or in combination with nanohumic substance – on the productivity of cucumber plants were established. A particularly significant increase in cucumber yield was observed following the application of manure, although the average fruit weight was lower compared to the use of mineral fertilisers. However, the number of fruits per square metre significantly exceeded that recorded

Suggested Citation: Akhmatbekov, M., Eshimkulova, G., Moldoaitieva, A., Altynbubu, A., & Turdubekov, E. (2025). Effectiveness of manure under protected cultivation conditions. *Bulletin of the Kyrgyz National Agrarian University*, 23(1), 20-28. doi: 10.63621/bknau./1.2025.20.

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with mineral fertilisers, resulting in a higher overall yield. Thus, the application of mineral fertilisers increased cucumber yield to 14.88 kg per square metre, which was double the control value. When manure was used, the yield rose to 16.38 kg per square metre, representing a 10.08% increase compared with mineral fertilisers and a 2.2-fold increase over the control. The results of this study may be used by greenhouse operations and farmers to optimise cucumber fertilisation systems, thereby improving both yield and product quality

Keywords: greenhouse cultivation; organic fertiliser; mineral fertiliser; nanohumic substance; cucumber productivity; yield structure; fruit weight

Introduction

In modern agriculture, particularly in the context of finite resources and increasing demand for vegetable produce, optimising fertiliser application is a pivotal factor in enhancing crop yields. Among the diverse range of fertilisers, considerable attention is given to both traditional organic fertilisers, such as manure, and modern agrotechnical agents, including mineral fertilisers and nanohumic substances. Manure, as a widely utilised organic amendment, is recognised for its beneficial properties, such as improving soil structure and supplying plants with essential nutrients. However, its efficacy can fluctuate depending on cultivation conditions and its combination with other fertilisers. Mineral fertilisers, conversely, provide plants with readily available macro- and micronutrients, thereby promoting rapid growth and development (Kravchenko & Bykova, 2023). Nevertheless, as highlighted by L. Skivka & S. Hudz (2021), their excessive application can lead to detrimental environmental consequences and negatively impact production quality.

One promising avenue for improving ecological farming technology lies in the application of a group of natural, high-molecular-weight substances of the humate type, which exhibit high physiological activity. As noted by A. Maffia *et al.* (2025), nanohumic substances, as relatively novel agrotechnical agents, possess the potential to enhance fertiliser use efficiency and improve plant growth by stimulating physiological processes. Nanohumic substances are colloidal particles produced through physical or chemical treatment of humic substances (Verma *et al.*, 2022). Technologies based on physical methods of nanoparticle production are considered the safest (Ayenew *et al.*, 2025). Primarily, nanohumic substances increase the activity of biochemical processes in plants, particularly stimulating root system development. This simultaneously enhances the permeability of cell walls, facilitating the expansion of cell membrane size for the uptake of ions necessary for root growth and development, and activates the enzyme systems responsible for this process. It is also believed that humic substances act not only on plants but also exert a significant positive effect on the soil, improving its structure, denaturing particles, dissolving calcium and magnesium carbonate minerals (which are abundant in these soils), phosphate, and other sparingly soluble salts. This increases agrophysical properties (such as porosity, water-air, and thermal regimes), participates in adsorption processes, and stimulates the activity of beneficial soil microorganisms.

In the context of modern agriculture in the Kyrgyz Republic, where cucumbers are a significant vegetable crop, optimising fertilisation regimes to enhance their productivity is of particular importance. Consequently, investigating the influence of novel agrotechnical agents, such as nanohumic substances, on cucumber yields represents a pertinent research objective (Selivanova, 2013). As one of the most popular greenhouse crops, cucumbers necessitate optimal nutrient provision to achieve high yields and quality produce. Therefore, examining the impact of various types of fertilisers, including manure, mineral fertilisers, and nanohumic substances, on cucumber productivity is a relevant task. Contemporary studies, such as the research by D. Khomiakov *et al.* (2020), indicate that the combined application of organic and mineral fertilisers can exert a synergistic effect, contributing to increased cucumber yield and quality. For instance, research demonstrates that using manure in conjunction with mineral fertilisers can ameliorate soil structure and furnish plants with essential nutrients, leading to enhanced yields (Kireev *et al.*, 2010). Concurrently, as A. Emelyanova & A. Novikova (2022) observe, the deployment of nanoparticles can help improve fertiliser use efficiency and stimulate plant growth by promoting physiological processes.

In greenhouse cucumber production, alongside adherence to cultivation techniques, optimal soil water-air balance, and pest and disease control, significant importance is placed on establishing optimal nutrient levels. This is because insufficient light during the colder months necessitates enhanced nutrient provision to the cucumber root system. Simultaneously, creating conditions that facilitate accelerated metabolic processes within the plant, through the application of physiological or biological growth and development stimulants, is equally crucial (Derevyanchenko *et al.*, 2023). In Kyrgyzstan, preparations derived from processing brown coal from the KaraKeche deposits in the Naryn Region have become widely used on field crops for this purpose. While the application technology for many field crops has been reasonably well-established, this process has not yet significantly extended to vegetable crops, particularly those grown under protected cultivation.

Despite a considerable body of research dedicated to investigating the influence of fertilisers on cucumber productivity, a need persists for further studies to determine optimal fertilisation strategies, especially within the context of greenhouse cultivation. Specifically, it is necessary to examine the impact of combining manure with nanohumic substances on cucumber productivity and to ascertain the optimal ratios of organic and mineral fertilisers for achieving maximum yield and produce quality. Accordingly, this study aimed to investigate the effect of various types of fertilisers, including manure, mineral fertilisers, and nanohumic substances, on cucumber productivity under greenhouse conditions.

Materials and Methods

The experiments were conducted during 2023-2024 in the collection nursery greenhouse at the Kyrgyz National Agrarian University, which features state-of-the-art technological and structural designs in this field. The project was provided by Korean specialists. The total area of the greenhouse is 240 m^2, with a usable area of 192.5 m^2. The facility comprises three sections; the first block houses the control equipment – a temperature control panel for the greenhouse, that operates around the clock. Temperature regulation is achieved by opening and closing supplementary vents located on the sides and roof of the greenhouse, which operate in both manual and automatic modes. Direct temperature monitoring is carried out using thermometers positioned above and below the soil. These thermometers are connected to the control panel, which, based on the signals received, automatically activates devices for supplying either cooled or heated air to the plant growth and development zones (manual mode is also available if required). During the colder period, heat is also supplied through the soil via heating pipes situated at a depth of 30 cm. The temperature was maintained at no lower than 15°C-18°C in the soil and 26°C-28°C in the air during the cold season. The heating system for the winter period was supplied by a solid-fuel stove, to which the soil and air heating systems for the greenhouse were connected.

The second and third sections housed the experimental crops – cucumbers and tomatoes – which constituted the subjects of this study. Each plot measured 3.64 m^2 (5.2 m in length and 0.7 m in width). The F1 hybrid of the cucumber variety Absolute was used for the research. Planting was carried out in ordinary grey soil, with the application of fertilisers at rates of 25 g nitrogen, 35 g phosphorus, 70 g potassium, and 15 kg of manure per m^2, respectively. The mineral fertilisers used were ammonium nitrate (34.5% nitrogen), ammophos (10.0% nitrogen and 49.0% phosphorus), and potassium chloride (60.0% potassium oxide), along with fresh manure having standard nitrogen, phosphorus, and potassium content and a moisture level of 78.0% (Borisov, 1978). Prior to commencing the experiment, all necessary preparatory work for cultivating vegetables in protected conditions was conducted following established protocols, including soil and seedling preparation, disinfection, etc. Seedlings were planted using a string guide in a two-row scheme, with a distance of 50 cm between rows and 40 cm between plants within a row, resulting in a bed width of 90 cm. Harvesting was performed in the morning, three times per week, with fruits being weighed on electronic scales and their quantity simultaneously counted for each experimental treatment.

In Kyrgyzstan, the use of various humate derivatives is prevalent, with sodium humates (such as Kyrgyz-Gumat, Nanogumus, Bioplant Flora, etc.) being the most frequently employed in practice. Among these is an innovative preparation, "Nanogumate", produced by OJSC Union Group, Kyrgyz Republic. This product is based on the comminution of humic substances into molecular fragments as small as 45 nm. This specific preparation was provided to the researchers by the Cabinet of Ministers of the Kyrgyz Republic and the Ministry of Water Resources, Agriculture, and Processing Industry for testing on cucumber crops under protected cultivation conditions. This particular product is obtained by crushing natural humic substances to a molecular nanostructure of less than 5 nm. Consequently, the resulting humic nanoparticles are exclusively of natural origin, having been formed from natural raw material – leonardite, found within brown coal. The research adhered to the principles of the Convention on Biological Diversity 1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973).

Results and Discussion

As evidenced by the experimental results, cucumber yield varied between 6.67 and 20.28 kg per 1 m^2 of cultivated area, depending on the treatment (Table 1).

Table 1. Cucumber yield, kg per 1 m^2 of cultivated area, experiment 1

No.	Treatment	Yield by replication				Increase			
						kg		%	
		I	II	III	Average	Over control	Over mineral fertiliser	Over control	Over mineral fertiliser
1	No fertiliser (control)	7.60	8.91	6.67	7.71	–	–	100	–
2	Mineral fertilisers	18.30	14.00	12.34	14.88	7.16	–	192.35	100
3	Manure	20.28	16.70	12.15	16.38	8.66	1.5	212.18	110.08

Source: compiled by the authors

It was established that improving the nutritional conditions for cucumbers plays a significant role in enhancing crop productivity. Specifically, the application of a full complement of mineral fertilisers contributed to an average cucumber yield increase across three replicates to 14.88 kg per 1 m^2 of area. This represents an increase of 7.16 kg/m^2 over the control, or 192.75%. An even more notable increase in yield was observed with the application of manure, where 16.38 kg of cucumbers were harvested per square metre. This is 8.66 kg or 2.12 times higher than the unfertilised control plots. This yield also surpasses the mineral fertiliser treatment by 10.28%. Consequently, manure serves as a beneficial nutritional source for cucumber growth and development when cultivated in field soil (native soil) as a spring-summer protected crop.

An analysis of the elements contributing to cucumber yield structure provides interesting insights. These analyses reveal which structural components primarily contribute to the additional yield observed with the application of mineral and organic fertilisers. As shown in Table 2, a significant component of the yield structure is the weight of individual fruits. The data indicates that, without fertilisation, the native soil can produce fruits weighing between 82.87 and 93.76 g. Fertiliser application demonstrably contributed to a noticeable increase in the weight of each cucumber fruit.

Table 2. Individual fruit weight, g, experiment 1

No.	Treatment	Individual fruit weight by replicates				Increase			
						g		%	
		I	II	III	Average	Over control	Over mineral fertiliser	Over control	Over mineral fertiliser
1	No fertiliser (control)	93.76	90.11	82.87	88.91	–	–	100	–
2	Mineral fertilisers	108.83	109.54	97.21	105.19	16.28	–	118.31	100
3	Manure	103.94	103.16	92.14	99.75	10.84	−5.44	112.19	94.83

Source: compiled by the authors

However, the impact of the fertilisers on this parameter was not uniform. The greatest increase in individual fruit weight was observed with the application of mineral fertiliser, where the additional weight reached 16.28 g, an increase of 118.31% over the control. In contrast, while manure increased the weight of individual cucumbers by 10.84 g, or 112.19%, compared to the control, this was 5.44 g less than the increase seen with mineral fertilisers, representing 94.83% of the increase obtained with the mineral treatment.

Another significant component influencing cucumber yield is the number of fruits harvested per unit area of the experiment. As shown in Table 3, the fertiliser treatments substantially increased the number of fruits per plant. While an average of 316 fruits were formed per unit area over the entire growing season in the control, the mineral fertiliser treatment yielded 593 standard fruits from the same area. This represents an increase of 197 fruits, or 162.34%, compared to the unfertilised treatment.

Table 3. Number of fruits per unit area, pcs, experiment 1

No.	Treatment	Number of fruits by replicates				Increase			
						pcs		%	
		I	II	III	Average	Over control	Over mineral fertiliser	Over control	Over mineral fertiliser
1	No fertiliser (control)	295	360	293	316	–	–	100	–
2	Mineral fertilisers	612	465	462	513	197	–	162.34	100
3	Manure	710	589	480	593	277	80	187.66	115.60

Source: compiled by the authors

At the same time, manure, having resulted in an average of 596 fruits across all three replicates, surpassed mineral fertilisers in this yield component. The increase in this case was 80 fruits, or 15.50%. Relative to the control, the additional yield in terms of fruit number was even more substantial, reaching 280 fruits, or 88.61%. This indicates that manure, while slightly inferior to mineral fertilisers in terms of individual fruit weight, significantly compensated for this by increasing the number of fruits, thereby contributing to a higher overall cucumber yield.

The figures for the total number of fruits per unit area from the experimental plots appear even more distinct (Table 4). Fertilised plots yielded between 54.12

and 76.10 more fruits compared to the control area. The difference in fruit yield between the mineral fertiliser and manure treatments is quite substantial, reaching nearly 22 fruits per square metre, which underscores the advantage of applying manure to cucumbers in greenhouse operations.

Table 4. Number of fruits per square metre, pcs, experiment 1

No.	Treatment	Number of fruits by replicates				Increase			
						pcs		%	
		I	II	III	Average	Over control	Over mineral fertiliser	Over control	Over mineral fertiliser
1	No fertiliser (control)	81.04	98.90	80.89	86.81	–	–	100	–
2	Mineral fertilisers	168.13	127.75	126.92	140.93	54.12	–	162.34	100
3	Manure	195.06	161.81	131.87	162.91	76.10	21.98	187.66	115.60

Source: compiled by the authors

The results of the second experiment, where all three main treatment variants were combined with a nanohumic substance, indicated that this physiological stimulant exerted a discernible positive influence on cucumber yield formation (Table 5). For instance, while mineral fertilisers without nanohumic substance increased the yield mass per square metre by 1 kg, representing 114.7% relative to the control, treatment with nanohumic substance resulted in an additional yield of 1.40 kg, or 121.2% more than the nanohumic substance treatment without fertilisers.

Simultaneously, a substantial increase in cucumber productivity was ensured by manure, both in combination with nanohumic substance and without it. The increased cucumber yield in the former case amounted to 5.05 kg/m^2, equivalent to 176.5% over the baseline (presumably the control without fertiliser or nanohumic substance), and 4.40 kg/m^2, or 164.2%, in the latter case (manure without nanohumic substance compared to the control without fertiliser or nanohumic substance). Overall, the use of nanohumic substance proved most effective on native greenhouse soil when it was fortified with manure containing macro- and micronutrients, and favourably influenced the soil's agrophysical properties. The adequate supply of carbon dioxide, resulting from the decomposition of fresh manure, likely played a significant role in this process.

Table 5. Cucumber yield recording per 1 m^2 of cultivated area, experiment 2

No.	Treatment	Yield by replication				Increase	
						kg	%
		I	II	III	Average	Over control	Over control
1	No fertiliser, no nanohumic substance (control)	6.70	–	6.67	6.80	–	100
2	No fertiliser with nanohumic substance (control)	6.55	–	6.65	6.60	–	100
3	Mineral fertilisers without nanohumic substance	7.60	8.00	–	7.80	1.00	114.7
4	Mineral fertilisers with nanohumic substance	7.70	8.20	–	8.00	1.40	121.2
5	Manure without nanohumic substance	–	10.50	11.90	11.20	4.40	164.7
6	Manure with nanohumic substance	–	11.20	12.10	11.65	5.05	176.5

Source: compiled by the authors

Pre-planting application of mineral fertilisers at a dose of $N_{150}P_{150}K_{150}$ prior to cultivation ensured maximum yield in the experiment, with an increase of 1.61 kg/m^2 or 13.3% compared to the control treatment. A systematic increase in the dose of mineral fertilisers applied during pre-planting cultivation did not significantly influence the growth in crop productivity. The average yield of cucumber fruits under protected cultivation (2021-2022) in the control treatment (without fertiliser application) was 11.85 kg/m^2. The highest cucumber yield in the experiment was obtained with the application of $N_{200}P_{200}K_{200}$ mineral fertilisers in spring prior to pre-planting cultivation. The yield exceeded the control treatment by 1.73 kg/m^2 or 14.6%. The final data on cucumber yield based on the experimental results are presented in Figure 1.

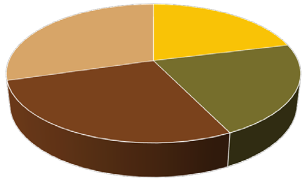

Figure 1. Cucumber yield with the use of mineral fertilisers
Source: compiled by the authors

As A. Kuramshin (2011) posits, the substrate is a significant factor that largely determines the yield of vegetable crops. Various types of substrates are used in protected cultivation, including perlite, peat, rock wool, expanded clay aggregate, and others. When selecting a substrate, facility managers consider its cost, delivery expenses, and disposal requirements. In practice, using a questionable substrate without knowledge of its physicochemical properties or intended use, and without guidance on working with it, leads to operational difficulties (Autko, 2007). This often results in reduced yield or plant death. According to A. Kuramshin (2011), cultivating cucumbers under protected conditions, facilitates the production of ecologically safe produce: the heavy metal content in the produce for individual elements is more than 10 times below the maximum permissible concentration, and nitrates are up to 2.5 times lower. When growing cucumber plants in the third light zone during the winter-spring period in a greenhouse, it is recommended to apply organo-mineral fertiliser at a base rate of 1,250 kg/ha ($N_{29}P_{29}K_{33}$) in conjunction with simple mineral fertilisers ($N_{90}P_{120}K_{150}$) to increase yield and improve fruit quality (Yakovleva, 2003). In the opinion of R. Bulavintsev (2017), the development of greenhouse enterprises in the Russian Federation will facilitate significant import substitution, enhance the quality and competitiveness of vegetable produce, and expand the assortment of crops grown under protected cultivation.

I. Pigorev & N. Dolgopolova (2018) observe that in greenhouse environments, where agrocenosis is particularly susceptible to attacks from parasitic mycobiota due to the favourable microclimate and limited range of cultivated plants, the disruption of any factor contributes to a loss of ecological stability. This, in turn, leads to plant diseases and reduced yields. To maintain stability and control the spread of harmful organisms, it is necessary to implement an integrated protection system encompassing prophylactic, agrotechnical, breeding and genetic, chemical, and biological methods. A. Sergeeva (2020) found that to increase cucumber yields under protected cultivation and enhance produce quality, it is essential to apply complex feeding regimes combining root and foliar fertiliser application. This approach can achieve a significant increase in both yield and the proportion of standard produce. M. Selivanova *et al*. (2013) emphasise that optimising the mineral nutrition of plants, using both root and foliar feeding and combining mineral and organic fertilisers, is crucial for increasing cucumber yields in protected cultivation and meeting consumer demand for vegetable produce. They highlight that despite the effectiveness of individual fertiliser types, their combined application yields the greatest economic benefit, substantially increasing both productivity and profitability of production.

Conclusions

The experimental results demonstrate the feasibility of achieving satisfactory yields in the region's native soil without the use of imported bulk substrate, provided there is adequate mineral or organic (manure) fertilisation for spring-summer cucumber cultivation. It was established that in field soil, the application of mineral fertilisers at a rate of 25 g nitrogen, 35 g phosphorus, and 70 g potassium per square metre resulted in a nearly twofold increase in cucumber yield compared to the control, reaching 14.88 kg per unit area. Incorporating manure at a rate of 15 kg per m^2 led to a further yield increase of 1.5 kg per square metre compared to the mineral fertiliser treatment. This represented more than double the yield of the control and a 10.08% increase over the yield achieved with mineral fertilisers alone.

In this instance, the crop's productivity was primarily determined by an 18.31% increase in individual fruit weight and a 62.34% increase in the number of harvested fruits. Conversely, in the manure treatment, the main factor contributing to the increased yield was the number of harvested cucumbers, which reached 187.66% of the control yield per m^2. This exceeded the yield from the mineral fertiliser treatment by 80 fruits per plot or 22 fruits per unit area. Although it should be emphasised that the weight of individual fruits here was 10.84 g heavier than the control, it was 5.44 g lighter than with the mineral fertiliser treatment. As for the effect of the physiological stimulant – nanohumate – its application generally had a beneficial influence on cucumber growth and development, which is evident from the increased yield observed in conjunction with fertilisers. Moreover, this effect was more pronounced when manure was used as the primary nutrient source for the cucumbers. Thus, manure can serve as a viable alternative to mineral fertilisers for introducing organic farming practices and cultivating cucumbers in greenhouse settings, particularly in the native field soils of the grey soil type prevalent in Kyrgyzstan. For a more comprehensive understanding of the impact of organic and mineral fertilisers on cucumber yield under greenhouse conditions, a promising avenue for further research involves investigating the dynamics of soil microbial composition and fruit quality under the long-term application of these fertilisers.

Acknowledgements
None.

Funding
None.

Conflict of Interest
None.

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Аннотация. Заманбап айыл чарбасында жер семирткичтерди колдонууну оптималдаштыруу бадыраңдын түшүмдүүлүгүн жогорулатуунун негизги фактору болуп саналат. Салттуу органикалык жер семирткич катары кык жана минералдык жер семирткичтер жана наногуматтар сыяктуу заманбап айыл чарба продукциялары өсүмдүктөрдү керектүү азыктар менен камсыз кылууда маанилүү роль ойнойт. Бул иштин максаты салттуу органикалык жер семирткичтин (кык) өзүнчө да, ошондой эле наногумат жана минералдык жер семирткичтер менен айкалыштырып колдонууда күнөскана шарттарында бадыраң өсүмдүктөрүнүн натыйжалуулугун салыштырып талдоо болгон. Бул салыштыруу бадыраңдын максималдуу түшүмдүүлүгүнө жетүү үчүн уруктандыруунун оптималдуу стратегияларын аныктоого мүмкүндүк берди. Изилдөө Абсолют бадыраң гибридинин жардамы менен күнөскана шарттарында жүргүзүлгөн. Эксперименттин жүрүшүндө жер семирткичтердин ар кандай комбинациялары, анын ичинде кык, минералдык жер семирткичтер жана наногуматтар колдонулуп, андан кийин алардын мөмө-жемиштердин түшүмдүүлүгүнө жана сапатына тийгизген таасирине талдоо жүргүзүлдү. Жер семирткичтердин бүткүл комплексинин – минералдык жана кыкты өзүнчө жана наногумат менен айкалыштыруу – бадыраңдын өндүрүмдүүлүгүнө оң таасири аныкталган. Бир жемиштин салмагы минералдык жер семирткичтерге салыштырмалуу азыраак болгону менен кык колдонуунун фонунда бадыраңдын түшүмдүүлүгүнүн өзгөчө олуттуу өсүшү байкалды. Бирок, мөмө-жемиштердин саны бир чарчы метрге минералдык жер семирткичтер менен болгон варианттан бир топ ашып кетти, анын эсебинен жогорку түшүм түзүлдү. Ошентип, минералдык жер семирткичтерди колдонуу бадыраңдын түшүмдүүлүгүн бир чарчы метрден 14,88 килограммга чейин жогорулатты, бул контролдук көрсөткүчтөн эки эсе көп. Кыкты колдонууда түшүмдүүлүк 1 чарчы метрден 16,38 килограммга чейин өскөн, бул минералдык жер семирткичтерди колдонууга караганда 10,08 %га жана контролдук көрсөткүчтөн 2,2 эсеге жогору. Бул иштин натыйжаларын күнөскана чарбалары жана фермерлер бадыраңды жер семирткичтүү системаларды оптималдаштыруу үчүн пайдалана алышат, бул продукциянын түшүмүн жана сапатын жогорулатат

Негизги сөздөр: күнөскана чарбасы; органикалык жер семирткич; минералдык жер семирткич; наногумат; бадыраңдын өндүрүмдүүлүгү; өсүмдүк структурасы; салмак

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Аннотация. В условиях современного сельского хозяйства оптимизация использования удобрений является ключевым фактором для повышения урожайности огурцов. Навоз, как традиционное органическое удобрение, и современные агротехнические средства, такие как минеральные удобрения и наногуматы, играют важную роль в обеспечении растений необходимыми питательными веществами. Целью данной работы был сравнительный анализ эффективности традиционного органического удобрения (навоза) при его использовании как отдельно, так и в сочетании с наногуматом и минеральными удобрениями на посевах огурцов в условиях тепличного хозяйствования. Такое сравнение позволило определить оптимальные стратегии удобрения для достижения максимальной урожайности огурцов. Исследование проводилось в тепличных условиях с использованием гибрида огурца Абсолют. В ходе эксперимента применялись различные комбинации удобрений, включая навоз, минеральные удобрения и наногуматы, с последующим анализом их влияния на урожайность и качество плодов. Установлено положительное влияние всего набора удобрений – как минеральных, так и навоза в отдельности и в сочетании их с наногуматом – на продуктивные показатели огурца. Особенно существенный рост урожая огурцов наблюдался на фоне применения навоза, хотя масса одного плода при этом была меньше по сравнению с минеральными удобрениями. Однако количество плодов на квадратный метр существенно превышало вариант с минеральными удобрениями, за счет чего формировался более высокий урожай. Так, применение минеральных удобрений увеличило урожай огурцов до 14,88 кг на квадратный метр, что в два раза превысило контрольный показатель. При использовании навоза урожайность возросла до 16,38 кг на квадратный метр, что на 10,08 % больше, чем при использовании минеральных удобрений, и в 2,2 раза выше контрольного показателя. Результаты данной работы могут быть использованы тепличными хозяйствами и фермерами для оптимизации систем удобрения огурцов, что позволит повысить урожайность и качество продукции

Ключевые слова: тепличное хозяйство; органическое удобрение; минеральное удобрение; наногумат; продуктивность огурца; структура урожая; масса