

EFFICIENCY OF CUCUMBER NUTRITION WITH MINERAL AND MICROELEMENTS UNDER DRIP IRRIGATION CONDITIONS**Jahongir Madaminovich Kuziev**

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Abstract: This study investigates the effectiveness of mineral and micronutrient fertilization of cucumber under drip irrigation conditions. The experiment compared different ratios and application schedules of NPK fertilizers, including their combined application with micronutrients as well as partially reduced fertilizer rates. The obtained results indicate that the split application of mineral fertilizers through drip irrigation systems, together with integrated use of micronutrients, significantly enhances cucumber growth, yield, and economic efficiency. The highest performance was observed in the treatment where the scientifically optimized NPK rate was applied in combination with micronutrients. This approach improved nutrient uptake efficiency by plants. At the same time, it was demonstrated that even under partially reduced fertilizer application rates, high agronomic efficiency can be maintained due to the contribution of micronutrients. The results suggest that this fertilization strategy provides a resource-efficient and highly productive system for cucumber cultivation under drip irrigation.

Keywords: mcucumber, drip irrigation, mineral fertilizers, NPK, micronutrients, fertigation, yield, nutrient elements, economic efficiency, resource-efficient technology.

Кириниш: Introduction: In recent years, population growth, the need to ensure food security, and climate change have made the sustainable production of agricultural crops one of the most pressing global challenges. Among vegetable crops, cucumber (*Cucumis sativus* L.) holds particular importance due to its high nutritional value, richness in vitamins and minerals, and year-round consumption. Cucumber is considered one of the leading vegetable crops worldwide in terms of production volume, and demand for its products continues to increase annually [1, 4].

In recent years, the growing population has significantly increased the demand for vegetable products. In this context, the introduction of intensive agricultural technologies aimed at achieving high yields, efficient use of water and nutrient resources, and improving product quality has become essential. In regions facing water scarcity in particular, drip irrigation technology is widely adopted as a highly efficient agronomic practice [2].

In global agricultural practice, drip irrigation technology enables the simultaneous application of mineral fertilizers with irrigation water, a method known as fertigation. This approach reduces nutrient losses in the soil and increases their uptake efficiency by plants. Research shows that cucumber has a high demand for nitrogen, phosphorus, and potassium for optimal yield formation, and a balanced supply of these elements has a direct impact on yield and product quality [1, 3, 5].

Cucumber crops are highly demanding in terms of nutrient supply and, under high-yield conditions, absorb on average 1.2-1.4 kg of nitrogen, 0.28-0.35 kg of phosphorus, and 2.0-2.2 kg of potassium per ton of produced yield. Therefore, in fertigation systems, it is of critical importance to supply nutrients in accordance with the plant's phenological stages. Scientific

literature reports that the application of nitrogen and potassium through fertigation under drip irrigation conditions provides the highest efficiency [4, 6].

In addition to mineral nutrition, the effective use of micronutrients is also considered one of the key factors for increasing cucumber productivity. Micronutrients such as copper, zinc, manganese, magnesium, molybdenum, boron, and iron activate photosynthetic processes, enhance enzymatic reactions, and improve the formation of generative organs. In particular, it has been found that the balanced application of magnesium together with water and nitrogen significantly increases yield, product quality, and water use efficiency [5].

Recent studies indicate that split application of fertilizers under drip irrigation not only increases cucumber yield but also improves the efficiency of water and fertilizer use. Experiments conducted in Sudan showed that the highest yield and improved soil fertility were achieved when daily drip irrigation was combined with fertigation applied three times per week [5, 6].

Research conducted in modern high-tech greenhouse systems has demonstrated that the electrical conductivity of the nutrient solution and the balance of micronutrients have a significant impact on cucumber yield, product quality, and economic efficiency. Optimized fertigation regimes not only increase yield but also contribute to environmental sustainability by reducing water and mineral fertilizer consumption [2, 6].

From this perspective, the development of scientifically based norms and application schedules for mineral and micronutrient fertilization of cucumber under drip irrigation conditions, as well as the assessment of their effects on plant growth, yield, product quality, and the efficiency of water and nutrient use, is of significant scientific and practical importance. The objective of this study is to determine the effects of different rates and ratios of mineral and micronutrient application on cucumber growth, development, yield, and economic efficiency under drip irrigation conditions.

Experimental Object and Field Trial Design

The research object was cucumber (*Cucumis sativus* L.) cultivated under drip irrigation conditions, along with its nutrient management system. The main objective of the study was to evaluate the effects of mineral and micronutrient fertilization applied at different rates and stages on plant growth, development, yield, and fruit quality.

The field experiment was designed considering the dynamic nutrient requirements of cucumber during its vegetation period. A ten-treatment experimental scheme was developed to assess the effects of split application of nitrogen, phosphorus, and potassium at different phenological stages, as well as the efficiency of micronutrient application.

In the experiment, an unfertilized treatment was used as the control. The second treatment represented the conventional fertilization practice used in local farming systems. In the remaining treatments, mineral fertilizers were applied at different ratios based on scientific recommendations, and in several variants, modern liquid micronutrient formulations were also included.

Field Experiment Scheme

Control (no fertilizer application)

NPK (farmer's practice)

NPK (scientific recommendation): P and K – 100% applied before plowing; N – 30% at the 2-3 true leaf stage, N – 70% at the fruiting stage

NPK (scientific recommendation): split application of P and K

NPK (scientific recommendation) + liquid micronutrients

50% of recommended NPK + liquid micronutrients

75% of recommended NPK + liquid micronutrients

PK + liquid micronutrients

PK + liquid micronutrients (two-stage application)

PK + liquid micronutrients (three-stage application)

The experimental design was developed taking into account the high mobility and leaching susceptibility of nitrogen in soil, as well as the relatively low mobility of phosphorus and potassium. Accordingly, the major portion of phosphorus and potassium was applied as a basal dose before plowing, while nitrogen was applied in a split manner according to the physiological demand of the plant at the 2-3 true leaf stage and during the fruiting stage.

In treatments involving micronutrients, the interaction between macro- and micronutrients and their effects on cucumber yield and fruit quality were evaluated. Furthermore, the application of mineral fertilizers at 50%, 75%, and 100% of the recommended rates enabled the assessment of resource-efficient and economically optimal fertilization strategies.

The inclusion of nitrogen-free treatments provided an opportunity to evaluate nitrate accumulation in fruits, product quality, and the independent effects of phosphorus and potassium. This approach is of significant importance for developing environmentally safe and highly efficient nutrient management technologies.

Research Results:

The experiments on cucumber yield demonstrated significant differences in the effectiveness of various fertilization systems. In the control treatment (no fertilizer application), the average yield was 14.9 t ha⁻¹. This value was considered the baseline for comparison across all treatments. In the treatment representing conventional farmer practice of NPK fertilization, yield increased to 21.9 t ha⁻¹, which is 7.0 t ha⁻¹ or 47.0% higher than the control. This confirms the positive effect of mineral fertilizers on cucumber growth and yield formation.

In treatments 3 and 4, where scientifically optimized NPK fertilization systems were applied, yields were even higher, reaching 26.4 and 29.7 t ha⁻¹, respectively. These values represent an increase of 11.5–14.8 t ha⁻¹, or 77.2–99.3% compared to the control. In particular, the split application of nitrogen (30% at the 2–3 true leaf stage and 70% at the fruiting stage), together with the balanced application of phosphorus and potassium, significantly improved the formation of generative organs.

The highest agronomic efficiency was recorded in treatment 5, where NPK fertilizers were applied in combination with micronutrients. In this treatment, cucumber yield reached 34.9 t ha⁻¹, which is 20.0 t ha⁻¹ or 134.2% higher than the control. This result indicates a strong synergistic interaction between macro- (NPK) and micronutrients. Micronutrients enhanced enzymatic activity and improved nutrient use efficiency in plants.

In treatments with reduced fertilizer rates (50% and 75% of recommended NPK combined with micronutrients), relatively high yields were still maintained. Specifically, treatment 6 produced 27.1 t ha⁻¹ (+81.9%), while treatment 7 produced 26.2 t ha⁻¹ (+75.8%). These results demonstrate that partial reduction of mineral fertilizers can be compensated by micronutrient application without a significant decrease in yield.

In treatments 8–10, where only PK fertilizers combined with micronutrients were applied, yields were lower, ranging from 17.1 to 24.1 t ha⁻¹. Although yield increases compared to the control ranged from 14.8% to 61.7%, nitrogen deficiency emerged as the main limiting factor. This confirms the critical agronomic role of nitrogen in cucumber production.

Overall, the results show that scientifically optimized NPK fertilization, combined with micronutrients and split application strategies, significantly improves cucumber yield. At the same time, partial reduction of fertilizer rates can be effectively compensated by micronutrients while maintaining high agronomic efficiency.

Economic Efficiency of Fertilization Systems:

Economic analysis based on yield dynamics revealed substantial differences in profitability among treatments. The control treatment showed the lowest economic efficiency and was considered the baseline (100% relative profitability). In the farmer practice NPK treatment, profitability increased due to a 47.0% yield increase; however, higher fertilizer costs limited overall economic efficiency to a moderate level.

In treatments 3 and 4, where optimized NPK systems were applied, profitability increased significantly (177.2% and 199.3%, respectively), due to higher yields (77.2–99.3%) and relatively lower production costs per unit yield. The highest economic efficiency was recorded in treatment 5 (NPK + micronutrients), where profitability reached 234.2%, indicating the most economically optimal fertilization system.

Even in treatments with reduced NPK rates (50% and 75%) combined with micronutrients (treatments 6 and 7), high and stable profitability was maintained due to reduced fertilizer costs and sustained yields. This confirms that resource-efficient fertilization strategies can ensure both agronomic and economic benefits.

In contrast, PK + micronutrient treatments showed lower profitability due to nitrogen deficiency, which limited yield formation and reduced economic returns. Therefore, the highest economic efficiency in cucumber production is achieved through balanced NPK fertilization combined with micronutrients.

Table 1.**Economic Efficiency (Profitability Index) of Cucumber Production**

Treatment	Yield (t ha ⁻¹)	Increase vs Control (%)	Profitability Index (%)	Economic Evaluation
1. Control (no fertilizer)	14.9	0	100.0	Very low
2. Farmer NPK practice	21.9	+47.0	147.0	Moderate
3. Optimized NPK	26.4	+77.2	177.2	High
4. Optimized NPK	29.7	+99.3	199.3	Very high
5. NPK + micronutrients	34.9	+134.2	234.2	Highest
6. 50% NPK + micronutrients	27.1	+81.9	181.9	High
7. 75% NPK + micronutrients	26.2	+75.8	175.8	High
8. PK + micronutrients (100%)	17.1	+14.8	114.8	Low
9. PK + micronutrients (50%)	23.5	+57.7	157.7	Medium
10. PK + micronutrients (25%)	24.1	+61.7	161.7	Medium-high

Conclusion:

The study demonstrated that fertilization systems have a strong influence on cucumber yield and economic efficiency. The highest results were achieved in the treatment combining NPK fertilizers with micronutrients, confirming a strong synergistic interaction between macro- and

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micronutrients. Partial reduction of NPK rates (50–75%) combined with micronutrients also ensured high agronomic and economic efficiency, demonstrating the potential for resource-saving fertilization strategies. Treatments based only on PK resulted in lower yields due to nitrogen deficiency.

Recommendations:

It is recommended to apply nitrogen, phosphorus, and potassium fertilizers in a scientifically optimized split system and in combination with micronutrients under drip irrigation conditions. Such an integrated approach not only increases yield but also significantly improves economic efficiency and resource-use sustainability.

The findings of this study provide practical recommendations for cucumber cultivation on degraded soils in Karakalpakstan, supporting the development of optimized fertigation regimes and soil fertility restoration technologies. This research was conducted within the framework of the applied project AL-9124093877, titled “Development of modern agricultural technologies for crop production on degradation-prone soils,” and its results are expected to contribute to improving food security and agricultural efficiency in the region.

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