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Growth, Development and Biological Characteristics of Medicinal Marshmallow (*Althaea officinalis* L.) and Quality Indicators of Raw Materials

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Abstract. *The results of the conducted studies showed that the biochemical and physiological processes occurring in the medicinal marshmallow (Althaea officinalis L.) plant are directly related to the availability of mineral elements. The obtained data indicate that each macronutrient performs a specific function in the vital activity of the plant, while their combined action forms an integrated system regulating plant growth and development. This article presents information on the relationship between mineral elements and biochemical processes in medicinal marshmallow, as well as the quality indicators of medicinal plant raw materials.*

Keywords: *medicinal marshmallow, biologically active substances, plant raw materials, Mucaltin, herbal preparations, pharmacognosy*

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Dərman gülxətmisinin (Althaea officinalis L.) böyüməsi, inkişafı və bioloji xüsusiyyətləri, həmçinin xammalın keyfiyyət göstəriciləri

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Xülasə. *Aparılmış tədqiqatların nəticələri göstərdi ki, dərman gülxətmi (Althaea officinalis) bitkisində baş verən biokimyəvi və fizioloji proseslər mineral elementlərlə birbaşa bağlıdır. Əldə edilmiş məlumatlardan məlum olduğu kimi, hər bir makroelement bitkinin həyatında özünəməxsus funksiyanı yerinə yetirir və onlar birlikdə bitkinin inkişafını idarə edən vahid sistem təşkil edir. Bu məqalədə dərman gülxətmi bitkisinin mineral elementlər və biokimyəvi proseslər arasındakı qarşılıqlı əlaqəsi, həmçinin xammalın keyfiyyət göstəriciləri haqqında məlumatlar təqdim olunur.*

Açar sözlər: *dərman gülxətmi, bioloji fəal maddələr, xammal, mukaltin, bitki preparatları, farmakoqnoziya*

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1. Introduction

Nitrogen is a major “building material” for plants, being a component of proteins, amino acids, and enzymes, and it accelerates biochemical reactions occurring in cells. Therefore, under conditions of sufficient nitrogen supply, plant growth is accelerated, leaves become larger and dark green, and photosynthetic processes proceed actively. The participation of nitrogen in chlorophyll further increases its importance (Meyghan & Moradi, 2018).

Phosphorus plays an important role in energy metabolism in plants. As a component of ATP, it ensures the accumulation and transfer of energy. Therefore, when phosphorus is supplied adequately, the root system develops well, the plant enters the generative stage earlier, and flowering and seed formation proceed effectively (Meyghan & Moradi, 2018).

Potassium regulates the synthesis, transport, and accumulation of carbohydrates. Its role is particularly important in the formation of mucilage and polysaccharides, which are important for medicinal marshmallow. In addition, potassium maintains water balance in cells and increases the plant’s resistance to various stress factors. Research on marshmallow cultivation also examines mineral nutrition under irrigation (Pryvedeniuk et al., 2021).

2. Materials and methods

The results were analyzed using mathematical and statistical methods, and the differences between treatments were found to be statistically significant ($p < .05$). This indicates that the effect of mineral nutrition on the quality of medicinal raw materials is scientifically substantiated and follows a regular pattern.

3. Results

The results of our studies showed that the highest efficiency is achieved when these elements are maintained in balance. In particular, in the N90P60K60 treatment, the main biochemical processes in the plant were observed to be activated to the highest level. This was manifested in enhanced photosynthesis, increased enzyme activity, and accelerated synthesis of carbohydrates and secondary metabolites.

At the same time, it was found that when mineral elements were applied in excessive amounts, the expected effect was not fully achieved. For example, a decrease in some indicators was observed in the N120P80K80 treatment. This can be explained by disruption of the balance among elements, reduced nutrient uptake, and decreased efficiency of metabolic processes.

Comparative analysis of the results obtained in the experimental fields showed that the effect of mineral elements on plants follows general regularities; however, its degree may vary depending to some extent on soil and climatic conditions, moisture regime, and agrotechnical practices. This further increases the reliability of the obtained results and the possibility of their wide practical application (Ahmedov et al., 2018).

The data in Table 1 show that the level of biochemical activity in medicinal marshmallow (*Althaea officinalis* L.) is directly dependent on mineral nutrition conditions.

Table 1
Efficiency of mineral nutrition treatments in medicinal marshmallow (Althaea officinalis L.)

№	Treatment	Biochemical activity	Note
1	Control	Low	Natural conditions
2	N40P40K40	Lower	Partial activation
3	N60P40K40	Medium	Partial activation
4	N60P60K60	Above medium	Activation
5	N90P60K60	Highest	All processes balanced
6	N90P80K80	Decrease	Beginning of imbalance
7	N120P80K80	Decrease	Imbalance

In the control treatment, biochemical activity was low, reflecting the growth of the plant under natural agro-background conditions. Under these conditions, the synthesis of biologically active substances was observed to proceed in a limited manner.

Partial activation of biochemical processes was recorded in the N40P40K40 and N60P40K40 treatments with mineral fertilizers. This can be explained by an increase in metabolic processes as a result of improved plant supply with nutrients (Berdiyev et al., 2016).

In the N60P60K60 treatment, an intensification of biochemical processes was recorded.

The highest biochemical activity was observed in the N90P60K60 treatment, where all physiological and biochemical processes in the plant proceeded in a balanced manner. The optimal ratio of mineral elements increased enzymatic activity and maximally stimulated the synthesis of carbohydrates and secondary metabolites.

However, a certain decrease in biochemical activity was observed in the N90P80K80 and N120P80K80 treatments, where mineral fertilizers were applied in excessive amounts. This can be explained by disruption of physiological and metabolic balance in the plant due to excessive nutrition and suppression of certain enzymatic processes.

Thus, the analysis results show that the correct selection of optimal rates and ratios in mineral nutrition is crucial for ensuring maximum biochemical activity in medicinal marshmallow. In particular, the N90P60K60 treatment was assessed as the most effective.

Quality indicators of medicinal marshmallow (*Althaea officinalis* L.) raw materials. The results of the conducted studies demonstrated that mineral nutrition has a significant effect on the main quality indicators of medicinal marshmallow (*Althaea officinalis*) raw materials. The experimental data were

consistent with one another, and a stable improvement in quality indicators was observed under conditions where mineral fertilizers were applied.

The results obtained for dry matter and extractive substances clearly confirm this trend. The increase in dry matter content under the influence of mineral nutrition indicates greater accumulation of organic substances in plant tissues. An increase in extractive substances is an important indicator determining the pharmacological value of medicinal plant raw materials, and a higher level indicates improved product quality.

The specific numerical results also confirm this regularity. In the first year of the study, 2023, the dry matter content in the control treatment was 22%, while extractive substances accounted for 18%; in the treatments with mineral fertilizers, these indicators increased gradually. In the N40P40K40 treatment, dry matter was 24% and extractive substances were 19.5%; in N60P40K40, dry matter was 25% and extractive substances 21%; in N60P60K60, dry matter was 26.5% and extractive substances 22.5%; and in N90P80K80, dry matter reached 27.5% and extractive substances 22.5%. The highest results were recorded in the N90P60K60 treatment, at 28% and 24%, respectively. This indicates that a balanced ratio of mineral elements most effectively promotes the accumulation of dry matter and biologically active compounds in plant tissues (Ahmedov et al., 2018).

At the same time, a certain decrease in the expected effect was observed when mineral fertilizers were applied in excessive amounts. In particular, in the N120P80K80 treatment, dry matter was 27% and extractive substances were 23%, but these indicators were lower than in the optimal treatment. This can be explained by disruption of metabolic balance in the plant as a result of excessive mineral nutrition and limitation of the synthesis of some biologically active compounds (Table 2).

In 2024, dry matter in the control treatment was 22.5% and extractive substances were 18%, while these indicators increased gradually in the treatments with mineral fertilizers. In N40P40K40, dry matter was 24% and extractive substances 19%; in N60P40K40, dry matter 25% and extractive substances 21%; in N60P60K60, dry matter 26% and extractive substances 23%; in N90P80K80, dry matter 27.5% and extractive substances 22%; and in N120P80K80, dry matter 26.5% and extractive substances 23%. These indicators were lower than those of the optimal treatment. The highest results were recorded in N90P60K60, reaching 28% and 24%, respectively.

In the third year of the study, 2025, dry matter in the control treatment was 22.5% and extractive substances were 18.5%, while these indicators increased gradually in the treatments with mineral fertilizers. In N40P40K40, dry matter was 24% and extractive substances 19%; in N60P40K40, dry matter 26% and extractive substances 21%; in N60P60K60, dry matter 26.5% and extractive substances 22%; in N90P80K80, dry matter 27.5% and extractive substances 22.5%; and in N120P80K80, dry matter 26% and extractive substances 23%. The highest results were recorded in N90P60K60, where dry matter reached 28.5% and extractive substances 24%.

Considering the three years of the study as a whole, the control treatment had 22.2% dry matter and 18.2% extractive substances, while these indicators varied in the treatments with mineral fertilizers. In N40P40K40, dry matter was 24% and extractive substances 19.2%; in N60P40K40, dry matter 25.3% and extractive substances 21%; in N60P60K60, dry matter 26.3% and extractive substances 22.5%; in N90P80K80, dry matter 27.5% and extractive substances 22.2%; and in N120P80K80, dry matter 26.5% and extractive substances 23%. The highest results were recorded in N90P60K60, with dry matter reaching 28.2% and extractive substances 24%.

Overall, in the N90P60K60 treatment of medicinal marshmallow (*Althaea officinalis* L.), the contents of dry matter and extractive substances increased more markedly than in the other treatments during all three years.

This indicates that a balanced ratio of mineral elements brings the accumulation of dry matter and biologically active compounds in plant tissues to the most effective level.

The obtained results once again confirmed that the application of mineral nutrition at scientifically justified rates is crucial for increasing the quality indicators of medicinal raw materials.

Table 2

Quality indicators of raw materials under mineral nutrition of medicinal marshmallow (Althaea officinalis L.), 2023–2025

No	Treatment	2023 Dry matter (%)	2023 Extractive substances (%)	2024 Dry matter (%)	2024 Extractive substances (%)	2025 Dry matter (%)	2025 Extractive substances (%)	Mean Dry matter (%)	Mean Extractive substances (%)
1	Control	22	18	22.5	18	22	18.5	22.2	18.2
2	N40P40K40	24	19.5	24	19	24	19	24	19.2
3	N60P40K40	25	21	25	21	26	21	25.3	21
4	N60P60K60	26.5	22.5	26	23	26.5	22	26.3	22.5
5	N90P60K60	28	24	28	24	28.5	24	28.2	24
6	N90P80K80	27.5	22.5	27.5	22	27.5	22.5	27.5	22.2
7	N120P80K80	27	23	26.5	23	26	23	26.5	23

4. Discussion

Related work has examined the accumulation of polysaccharides under different cultivation practices (Pryvedeniuk et al., 2026), the structural and rheological properties of root polysaccharides (Karimi et al., 2021), and leaf mucilage composition (Tomoda et al., 1981). These studies provide background for interpreting raw-material characteristics; they do not independently validate the measurements reported here. Good agricultural practices and raw-material testing are addressed in World Health Organization guidelines (World Health Organization, 2003, 2011).

According to the observations, the contents of dry matter and extractive substances in the treatments with mineral fertilizers were consistently higher than in the control treatment. This can be explained by the accumulation of organic substances and activation of the synthesis of biologically active compounds in the plant under the influence of mineral elements.

At the same time, the occurrence of certain differences is considered natural. These differences are associated with the soil composition, moisture availability, climatic characteristics, and agrotechnical practices of the study areas. In particular, differences in soil humus content or irrigation regime may directly affect the accumulation of dry matter and extractive compounds in plants.

It was also noted that a general regularity was maintained in both study areas: the application of mineral elements at balanced and scientifically justified rates improves the quality indicators of the plant. This indicates the reliability of the obtained results and the possibility of implementing them in practice under different soil and climatic conditions.

Comparative analysis of the obtained results showed that in both study areas, mineral nutrition was a significant factor in increasing the quality indicators of medicinal marshmallow (*Althaea officinalis*) raw materials. When mineral elements were applied in sufficient and balanced amounts, the accumulation of organic substances in plant tissues increased, resulting in a stable increase in dry matter and extractive substances.

At the same time, some differences recorded between the study areas were associated with natural and agroecological factors, which further demonstrates the correspondence of the results to real conditions and increases their practical significance. In other words, the observation of the same general pattern under different conditions supports the reliability of the study results.

5. Conclusion

In conclusion, the highest quality indicators of medicinal marshmallow (*Althaea officinalis*) raw materials were recorded in the N90P60K60 treatment. In this treatment, the contents of dry matter and extractive substances reached their maximum levels, and it may be considered the most effective mineral nutrition rate for practical application.

Thus, the application of mineral elements in an optimal ratio is an important agrotechnical factor for improving the quality of medicinal raw materials, and its wider implementation is appropriate.

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