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Dynamics of the Biogeochemical Properties of Biomicroelements in Irrigated Soils and in *Punica Granatum* L. (Pomegranate) Plants

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Abstract

This article analyzes the content of biomicroelements in the leaves, hornes, tree trunks and roots of pomegranate grown on irrigated soils of the Fergana Valley, their accumulation, and develops biological absorption coefficients. These studies will serve to more accurately plan agrotechnical measures on irrigated light calcisols and meadow sez soils, maintain soil fertility, and produce environmentally friendly agricultural products.

Keywords: irrigated soil, biomicroelement, biological absorption coefficient, migration, pomegranate.

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1 Introduction

Currently, irrigated lands worldwide possess specific agro-ecological conditions in which soil salinity, moisture, and the quantity and mobility of microelements directly influence the manner in which plants absorb them. Therefore, in order to preserve biological diversity, increase productivity, and improve product quality, it is essential to conduct an in-depth study of the biogeochemical properties of biomicroelements in soils across various agro-ecological zones.

Biomicroelements are chemical elements required in trace amounts for the normal growth and development of plants. They play a significant role in enzyme activity, respiration and photosynthesis processes, and the assimilation of nutrients.

2 Literature Review and Methodology

Elements such as Mn, Mo, Zn, and Cr participate in the biochemical and physiological processes of plants. Pomegranate has been cultivated since ancient times for nutritional, medicinal, and cultural purposes. Its fruits are considered beneficial in preventing cardiovascular diseases, diabetes, and cancer [1, 2]. In particular, its leaves, bark, and root parts—which are rich in microelements—are widely used as phytotherapeutic agents. These properties are closely associated with the concentrations of Zn, Mn, and Mo in the plant.

Research indicates that the chemical and physical properties of soil directly influence the uptake of microelements by plants [3, 4]. These results correspond with global research, as the absorption of microelements by plants depends on soil structure [5].

High salinity levels in soil restrict the uptake of microelements by plants. Elevated NaCl concentrations in soil reduce the degree of microelement absorption by plants, leading to insufficient assimilation of essential nutrients [6].

Studies conducted worldwide have demonstrated that fruit plants such as *Punica granatum* L. exhibit differences in microelement uptake. For example, research carried out in Iran and Türkiye has shown that pomegranate plants effectively absorb Zn, Mn, and Fe, whereas Mo and Cr are absorbed at considerably lower levels [7]. These findings confirm the diverse responses of plants to microelements and their dependence on ecosytree trunk conditions.

Previous studies have indicated variations in the uptake of these elements across different cultivars and regions. However, the distribution and biological absorption of these elements specifically in *Punica granatum* L. grown in irrigated light calcisols and irrigated meadow saz soils have not yet been sufficiently investigated.

This study aims to determine the concentrations of Mn, Mo, Zn, and Cr in the leaves, hornes, tree trunks, and roots of *Punica granatum* L. cultivated in the Kuva and Yozyovon districts of the Fergana Valley, Uzbekistan, and to examine their biological absorption coefficients. The results will contribute to understanding agro-ecological balance, fertilization sytree trunks, and the quality indicators of pomegranate products.

The research was conducted in two distinct agro-ecological areas of the Fergana Valley—irrigated light calcisols in the Kuva district and irrigated meadow saz soils in the Yozyovon district. Both regions have long-standing horticultural traditions in pomegranate cultivation, yet their agro-climatic characteristics differ significantly. These conditions directly influence the availability of biomicroelements in the soil and their uptake by plants.

In the field studies, soil samples were taken from genetic horizons, while plant samples were collected from the leaf, horn, tree trunk, and root parts. Samples from each organ were taken in six replications and analyzed in the laboratory.

The field research was conducted using V.V. Dokuchaev's morphogenetic method, and soil samples were collected from the plow layer down to the parent material in soil profiles. To determine the total concentrations of biomicroelements in the soil samples and in the organs of the grape plant, the neutron activation method was employed at the Institute of Nuclear Physics of the Academy of Sciences of the Republic of Uzbekistan. The values obtained for each element were recorded in mg/kg. The analytical results were processed through mathematical–statistical methods using Microsoft Excel and relevant software tools.

3 Results and Discussion

Scientific studies on biomicroelements indicate that their accumulation in plant tissues depends on their availability in the soil, pH level, organic matter content, and climatic conditions.

In the present research, the concentrations of biomicroelements in soil layers and in the organs of the pomegranate plant were determined and are presented in Table 1 [11].

Table 1. Content of biomicroelements in the soil and in the organs of *Punica granatum* L. (pomegranate), mg/kg

Organs		Biomicroelements			
		Mn	Mo	Zn	Cr
Pomegranate cultivated in irrigated light calcisols	leaf	54.8	<0.01	29.4	0.50
	horn	20.2	0.077	19.7	0.27
	tree trunk	41.7	0.15	12.8	0.50
	root	8.1	0.38	5.7	0.77
Soil (section 1)		432	0.69	70.04	61.66
Pomegranate cultivated in irrigated meadow saz soils	leaf	35.4	1.1	15.0	0.80
	horn	108	0.20	10.4	0.32
	tree trunk	3.3	0.32	10.0	0.073
	root	9.2	0.80	6.3	0.80
Soil (section 14)		478.3	0.93	73.6	29.3

This table presents the concentrations of biomicroelements in various organs of *Punica granatum* L. (pomegranate), including the leaf, horn, tree trunk, and root. In pomegranate grown on irrigated light calcisols, the concentration of Mn is highest in the leaves, reaching up to 54.8 mg/kg, followed by Zn at 29.4 mg/kg. Cr and Mo occur at the lowest levels, fluctuating around 0.50–0.01 mg/kg.

In the hornes, Mn content is 20.2 mg/kg and Zn is 19.7 mg/kg, which are considerably lower compared to the leaves. Mo and Cr also appear in lower amounts—0.077 mg/kg and 0.27 mg/kg, respectively—indicating that these biomicroelements are absorbed less in hornes than in leaves.

In the tree trunk, Mn concentration is relatively high at 41.7 mg/kg, while Zn amounts to 12.8 mg/kg, which is lower than in the leaves and hornes. However, Mo increases to 0.15 mg/kg, indicating higher accumulation compared to leaves and hornes. The concentration of Cr shows almost no noticeable change. In the roots, Mn and Zn levels are the lowest compared to other organs, indicating minimal accumulation in root tissues. Conversely, Mo and Cr reach their highest concentrations in the roots relative to other plant organs.

In the leaves of pomegranate grown on irrigated meadow saz soils, the concentrations of Mn and Zn are considerably lower than those in the leaves of pomegranate grown on irrigated light calcisols. However, the Mo concentration is significantly higher, reaching 1.1 mg/kg. Cr concentration is also moderately high at 0.80 mg/kg, indicating that the distribution of microelements in the leaves differs markedly.

In the hornes, Mn concentration reaches its highest level—up to 108 mg/kg—demonstrating substantial Mn accumulation in these organs. The concentrations of Mo, Zn, and Cr show moderate differentiation.

In the tree trunk, Mn concentration is 3.3 mg/kg, while Mo and Zn are present at moderate levels. In contrast, Cr concentration is very low at 0.073 mg/kg. In the roots, Mn (9.2 mg/kg), Zn (6.3 mg/kg), Mo (0.80 mg/kg), and Cr (0.80 mg/kg) concentrations are all moderate, indicating that the roots have an average efficiency in microelement uptake.

Punica granatum L. exhibits significant differences in biomicroelement concentrations depending on soil conditions in different regions. The properties of irrigated meadow saz soils enhance the plant's efficiency in absorbing microelements, with Mo and Cr showing the highest values.

The leaves of pomegranate are the most physiologically active organs in terms of element uptake, and the high concentration of Zn (29.4 mg/kg) indicates that it accumulates most intensively in the leaves. The leaves also exhibit high efficiency in absorbing Mo and Cr, reflecting their high biochemical activity. In contrast, the horn and tree trunk organs contain lower amounts of microelements, as these organs primarily play roles in storing and transporting nutrients.

The results of the study demonstrate that the concentrations of biomicroelements in *Punica granatum* L. (pomegranate) vary significantly depending on soil type and plant organ. In pomegranate grown on irrigated light calcisols, the levels of manganese (Mn) in the leaves, hornes, tree trunk, and roots are relatively high. Compared to the soil concentration of 432 mg/kg, Mn reaches up to 54.8 mg/kg in the leaves, indicating strong accumulation. This reflects the high efficiency of leaves in absorbing manganese. However, in pomegranate grown on irrigated meadow saz soils, the Mn concentration in the leaves is somewhat lower (35.4 mg/kg), which may be associated with the characteristics of the local soil. Soil pH and mineral composition influence the plant's absorption capacity [8].

The findings regarding Mo and Cr in pomegranate organs are also noteworthy. In pomegranate leaves from irrigated meadow saz soils, the Mo coefficient is very high (1.183), demonstrating effective uptake by the leaves. Similarly, Cr concentration is also elevated (0.80 mg/kg), confirming that the plant can efficiently assimilate Cr. These results demonstrate the variations in microelement distribution across different soils and highlight the interactions between plants and their soil environments [9].

Furthermore, notable differences are observed between the leaves and hornes of pomegranate grown on irrigated light calcisols, as the Zn concentration is higher in the leaves (29.4 mg/kg) but lower in the hornes (19.7 mg/kg). This may indicate that the leaves perform antioxidant functions, since Zn plays an important role in activating numerous enzymes [10].

To determine the extent to which the plant and its various organs absorb these biomicroelements, biological absorption coefficients (BAC) were calculated (Table 2). According to this criterion, if Ax > 1, the plant is considered a bioaccumulator; if Ax < 1, the element is absorbed to a lesser degree (retained) by the plant [8].

Table 2. Biological absorption coefficients of biomicroelements [11]

Organs		Biomicroelements			
		Mn	Mo	Zn	Cr
Pomegranate cultivated in irrigated light calcisols	leaf	0.127	0.015	0.420	0.0081
	horn	0.047	0.112	0.281	0.0044
	tree trunk	0.097	0.217	0.183	0.0081
	root	0.019	0.551	0.081	0.0125
Pomegranate cultivated in irrigated meadow saz soils	leaf	0.074	1.183	0.204	0.0273
	horn	0.226	0.215	0.141	0.0109
	tree trunk	0.007	0.344	0.136	0.0025
	root	0.019	0.860	0.086	0.0273

According to the data presented in this table, the biological absorption coefficients of biomicroelements differ among plant organs, and these variations indicate the degree of element uptake by the plant. In almost all cases, the BSC values of biomicroelements show Ax > 1; therefore, based on their total concentrations, the microelements are retained by the plant organs to varying degrees rather than being actively accumulated.

In the leaves of pomegranate grown on irrigated light calcisols, the BSC of Zn is higher than in other organs, reaching 0.420. This is followed by Mn, indicating that these microelements are retained more effectively in the leaves. Mo and Cr, however, have very low BSC values, meaning that their retention by the leaves is weak or very weak.

In the hornes, the BSC values of Mo and Zn are higher compared to other organs, whereas Mn and Cr show low values, indicating limited uptake of Mn and Cr by the hornes. In the tree trunk, Mo (0.217) and Zn (0.183) exhibit moderate BSC values, while Mn (0.097) and Cr (0.0081) are relatively low. In the roots, only Mo shows a comparatively higher BSC (0.551), indicating moderate retention of Mo in root tissues. However, the BSC values of Zn, Cr, and Mn remain low.

In the leaves of pomegranate grown on irrigated meadow saz soils, the BSC of Mo is greater than 1 (1.183), indicating active accumulation of Mo in the leaves. The BSC values of Cr, Mn, and Zn are low to moderate. In the hornes, the BSC values of Mn, Mo, and Zn are relatively high, showing that these elements are moderately retained by the hornes, while Cr is retained weakly.

In the tree trunk and roots, these biomicroelements are retained to varying degrees depending on the organ.

The results show that the high BSC of Mo in the leaves of pomegranates grown on irrigated meadow saz soils indicates effective uptake of this element under these soil conditions. The concentrations of Cr, Mn, and Zn in other organs also differ slightly compared to pomegranates grown on irrigated light calcisols (Figures 1 and 2). Therefore, when developing agro-technical recommendations for each region, the degree of microelement uptake must be taken into account.

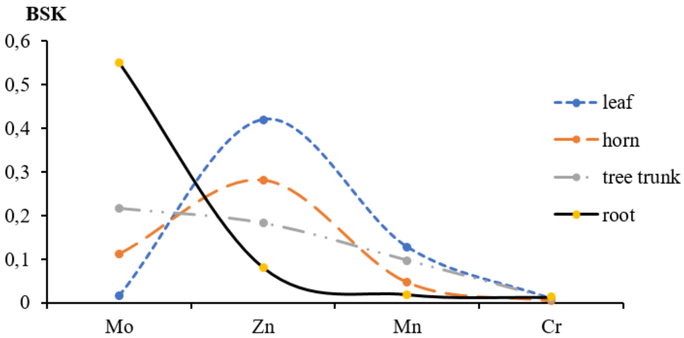

Figure 1. Diagram of the biological absorption coefficients (BAC) of biomicroelements in irrigated light calcisols and pomegranate organs

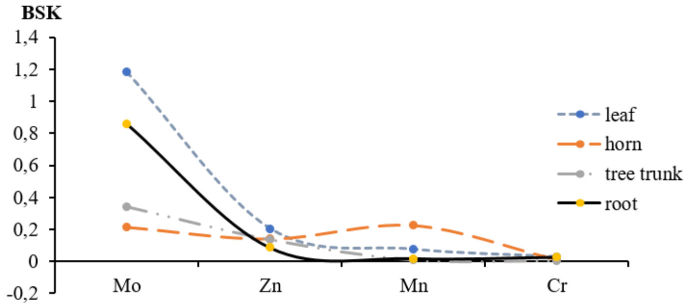

Figure 2. Diagram of the biological absorption coefficients (BAC) of biomicroelements in irrigated meadow saz soils and pomegranate organs

The biological absorption coefficients reflect the plant's capacity to assimilate microelements and confirm significant differences depending on the region. The high BSC values of Mo in the leaves of pomegranate grown on irrigated meadow saz soils indicate that the plant effectively absorbs this element under such conditions. In contrast, pomegranate grown on irrigated light calcisols shows relatively higher BSC values for Zn in its leaves, hornes, and roots.

4 Conclusion

These studies contribute to a deeper understanding of the ability of Punica granatum L. to absorb biomicroelements and provide insights that support further investigation into the plant's microelement uptake processes. The findings highlight the need to develop agro-technical approaches aimed at improving soil–plant interactions and optimizing the distribution of microelements. They also open new directions for enhancing nutrient absorption efficiency and improving crop quality.

Based on global experience, it is essential to determine the optimal concentrations of biomicroelements required for Punica granatum L. and to develop agro-technical measures that enhance the plant's ability to efficiently assimilate nutrients. Future research should focus on further examining the interactions of biomicroelements between soil and plant, as well as on optimizing agro-technical and environmental conditions through new scientific investigations.

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