Microelement Content of Quinoa Varieties Cultivated Under the Soil and Climatic Conditions of The Khorezm Region

Kholliev Askar Ergashovich
Doctor of Biological Sciences, Professor, Bukhara State University, Bukhara, Uzbekistan

D.I. Bazarboyev
PhD student, Khorezm Mamun Academy, Khiva, Uzbekistan

Received: 18 Feb 2026 | Received Revised Version: 03 Mar 2026 | Accepted: 28 Mar 2026 | Published: 21 Apr 2026

Volume 08 Issue 04 2026 | Crossref DOI: 10.37547/tajabe/Volume08Issue04-04

Abstract

In the present study, the microelement composition of the seeds of five distinct quinoa varieties, cultivated within the specific soil and climatic conditions of the Khorezm region, was rigorously analysed. Utilising the X-ray fluorescence method, the concentrations of essential microelements, including iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), silicon (Si), nickel (Ni), and iodine (J), were determined. The results of the analysis revealed statistically significant variations in the microelement content across the different quinoa varieties examined. Notably, the New-42 variety demonstrated superior concentrations of iron, copper, manganese, and silicon. Furthermore, the New-170 variety was found to possess a distinct advantage regarding its zinc content, while the New-36 variety exhibited the highest levels of iodine. These findings highlight the potential for selecting specific quinoa genotypes to address particular nutritional requirements and soil adaptation strategies.

Keywords: Quinoa, seed composition, X-ray fluorescence analysis, microelement content, spectral intensity, nutritional profiling.

Cite This Article: Kholliev Askar Ergashovich, & D.I. Bazarboyev. (2026). Microelement Content of Quinoa Varieties Cultivated Under the Soil and Climatic Conditions of The Khorezm Region. The American Journal of Agriculture and Biomedical Engineering, 8(04), 21–25. https://doi.org/10.37547/tajabe/Volume08Issue04-04

1. Introduction

Ensuring a diverse intake of nutritional substances within the human diet, by consuming a broad spectrum of nutrients from various food sources, serves as a critical factor in disease prevention and the general enhancement of human health [11].

The deficiency of microelements is a widespread phenomenon in numerous countries, primarily driven by factors such as soil alkalinity, elevated pH levels, low organic matter content, salinity stress, persistent drought, high bicarbonate concentrations in irrigation water, and the disproportionate application of fertilisers. Such deficiencies lead to an inadequate uptake of essential microelements by plants, resulting in significant yield losses across various crops and fodder. Ultimately, this nutritional deficit adversely affects the health of both livestock and humans [6].

Quinoa (Chenopodium quinoa Willd.) is recognised as a pseudocereal crop renowned for its exceptional nutritional quality and its potential to enhance global food security, particularly in marginal environments. Further research is essential to gain a more comprehensive understanding of the variations in quinoa's nutritional composition, to identify specific varieties that meet daily dietary requirements, and to explore how the interaction between genotype, environment, and management (G×E×M) influences nutritional quality [3].

Investigations into quinoa seeds using energy-dispersive X-ray microanalysis (EDX) have identified the presence of key microelements, specifically iron (15.0 mg/100 g) and zinc (4.0 mg/100 g) [5]. Similarly, Bratovcic, Amra, and Edita Saric conducted studies on the microelement content within the seeds of white quinoa and amaranth plants. Their research findings indicated that white quinoa seeds contain iron at 29.66 mg/kg, copper at 3.75 mg/kg, zinc at 19.74 mg/kg, and cadmium at 0.026 mg/kg. In comparison, amaranth seeds were found to contain iron at 47.34 mg/kg, copper at 3.69 mg/kg, zinc at 37.36 mg/kg, and cadmium at 0.1 mg/kg [1].

In research conducted by Mohsin Raghdan and colleagues, XRF spectroscopy was employed to analyse quinoa seeds, identifying a wide array of essential elements—including Ca, Si, Fe, Al, P, S, K, Mg, Ti, Cl, Zn, Sr, Ba, Zr, C, Cu, Mn, Pb, Cr, As, Ni, V, Br, Rb, Y, N, Se, and Ga—in both whole grains and ethanol extracts. The study revealed that the concentrations of elements such as Na, Ca, K, Si, Mg, P, Cl, S, and Al in whole seeds differed significantly from those found in ethanol extracts. Furthermore, the ethanol extracts contained other elements, such as Fe, Mn, Zn, Se, Mo, Rb, Ni, Co, and Cu, which exhibited their highest average concentrations compared to the whole plant material [8].

American researchers analysed the mineral composition of a total of 346 quinoa varieties from the Washington State University collection. The quinoa samples were initially processed in a muffle furnace until they reached a dry ash state and were subsequently converted into powder before being redissolved in nitric acid. Eighteen elements, including Ag, Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Ni, P, Pb, Sr, and Zn, were analysed using microwave plasma atomic emission spectroscopy (MP-AES). According to the results, the concentrations of these elements varied widely across the studied varieties:

Al (6.5–152 ppm), B (6.0–15.5 ppm), Ba (1.4–20.2 ppm), Ca (368–1259 ppm), Cu (2.5–5.9 ppm), Fe (39.7–163 ppm), K (6189–13,002 ppm), Mg (1708–3062 ppm), Mn (11.7–23.9 ppm), P (2367–6787 ppm), Sr (3.3–17.5 ppm), Zn (22.7–82.1 ppm).

The study concluded that, on average, a 200 g portion of quinoa meets the Recommended Dietary Allowance (RDA) for B, Mg, Mn, and P, while a 400 g portion aligns with the RDA for Cu, Fe, K, and Zn [2].

Manal Mhada and other scientists utilised a multi-element Agilent 5110 ICP-OES system to analyse quinoa samples, identifying elements such as K, P, S, Mg, Ca, Na, Fe, Zn, Mn, B, Cu, Ni, Co, and Mo. In the seeds of the Puno and Titicaca quinoa varieties, iron was found at levels of 85.05 and 57.62 mg/kg, respectively. Zinc concentrations were recorded at 32.33 and 29.37 mg/kg, manganese at 34.43 and 29.71 mg/kg, copper at 5.9 and 5.41 mg/kg, and nickel was detected at 1.40 and 1.11 mg/kg [7].

The concentrations of mineral elements such as Fe, Cu, Mn, Na, K, Ca, Mg, and P in quinoa and amaranth seeds were also examined using an AA240FS atomic absorption spectrophotometer. The results indicated that amaranth seeds contained Fe at 29.35 mg/100 g, Cu at 1.25 mg/100 g, and Mn at 4.07 mg/100 g. In quinoa seeds, the levels recorded were 10.28 mg/100 g for Fe, 1.55 mg/100 g for Cu, and 3.41 mg/100 g for Mn [9].

Kristina Toderich and colleagues established that microelement levels in quinoa seeds vary significantly depending on soil salinity conditions involving NaCl, Na2SO4, and combined NaCl + Na2SO4. The research demonstrated that concentrations of Fe (110 µg/g), Zn (48 µg/g), and Mn (30 µg/g) were notably higher under combined salinity (NaCl + Na2SO4) compared to other conditions, suggesting these elements play a crucial role in the plant's stress adaptation mechanisms. Conversely, Cu levels were found to decrease to 38 µg/g. Compared to the control group, the concentrations of Na (13–31%), Cl (90–133%), Fe (3–77%), and Zn (8–33%) increased. Simultaneously, reductions were observed in K (12–23%), Cu (4–44%), and Sb (84–87%). Under conditions of severe salinity, a decrease in Br (81%) and Co (52%) was noted, while the levels of Ca (92%), Cr (33%), and Sc (44%) increased [10].

In studies focusing on salt-tolerant quinoa varieties such as Ames 13,727, Ames 13,742, Ames 13,761, Ames 22,157, and NSL 106,398 cultivated in the marginal basins of the Aral Sea, significant variations were found in the mineral content (Na, Cl, Cu, Br, Ca, Rb, Fe, Zn, etc.) across the varieties. These variations reflect both the influence of local environmental growth conditions and inherent genotypic differences. The observations indicated that the highest levels of Mg, Mn, Na, K, Br, Ca, Sr, Co, and Fe were recorded in the Ames 13,727 variety. In contrast, the Ames 13,761 variety exhibited the highest Cu content, while NSL 106,398 contained the highest level of Ba. Specifically, the presence of microelements such as manganese (15–20 µg/g), copper (63–68 µg/g), iron (64–150 µg/g), and zinc (29–39 µg/g) has been empirically confirmed through these investigations [4].

2. Methods

The primary research objects for this study comprised five distinct quinoa varieties cultivated under the specific environmental conditions of the Khorezm region: Check-2; New-14; New-36; New-42; New-170.

The determination of microelement concentrations within the quinoa seeds was performed using a Rigaku ZSX Primus III NEXT (Rigaku Corporation, Japan) wavelength-dispersive X-ray fluorescence (WDXRF) spectrometer. To ensure high analytical precision and enhance the detection sensitivity for lighter elements, all analyses were conducted under a vacuum regime. The resulting data and all concentration values were recorded and expressed in milligrams per kilogram (mg/kg) based on the dry matter content. Furthermore, the total ash content of the quinoa seeds was determined for each variety, yielding values of 3.2%, 2.95%, 3.33%, 3.45%, and 2.9%, respectively.

3. Results and Discussion

In this section of the study, the concentrations of specific microelements, namely iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), silicon (Si), nickel (Ni), and iodine (I), were investigated within the seeds of various quinoa varieties. The quantitative distribution of these microelements in the seeds is comprehensively illustrated in Figure 1.

The analysis of the research results regarding the iron (Fe) content in the seeds of the studied quinoa varieties revealed concentrations ranging between 387.20 mg/kg and 510.60 mg/kg. The minimum value was recorded in the Check-2 variety, while the maximum accumulation of iron was identified in the New-42 variety. Furthermore, varieties that maintained intermediate levels of Fe included New-170 (408.90 mg/kg), New-36 (456.21 mg/kg), and New-14 (466.10 mg/kg).

When conducting a comparative analysis of the zinc (Zn) microelement content in the quinoa seeds, the values were observed to range from 91.91 mg/kg to 113.68 mg/kg. The highest concentration was detected in the New-170 variety (113.68 mg/kg), whereas the lowest zinc levels were found in the New-36 variety (91.91 mg/kg). It is important to note that, according to the analytical results, the zinc element was not detected in the Check-2 and New-42 varieties.

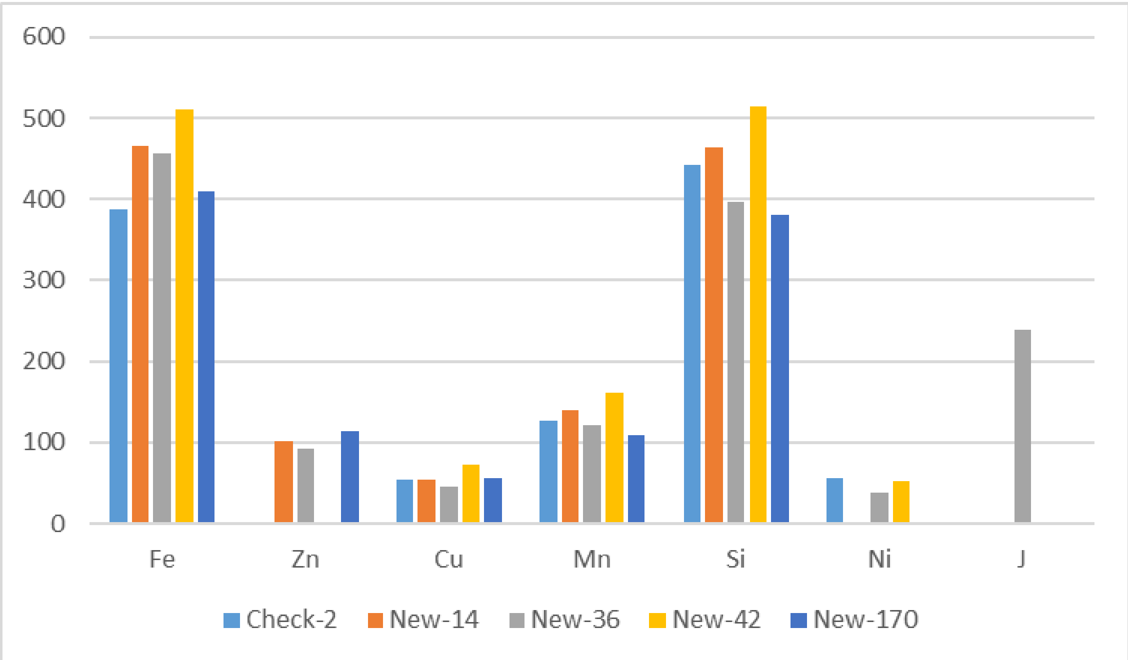

Figure 1. Microelement content of quinoa varieties, mg/kg.

A comparative study of the copper (Cu) microelement content within the seeds of the different varieties revealed values ranging between 45.29 mg/kg and 72.45 mg/kg. The maximum concentration was identified in the New-42 variety (72.45 mg/kg), whereas the minimum concentration was observed in the New-36 variety (45.29 mg/kg). Intermediate values were recorded in the New-170 (55.39 mg/kg), New-14 (54.28 mg/kg), and Check-2 (54.72 mg/kg) varieties.

During the research process, the analysis of manganese (Mn) levels in the seeds indicated a concentration range of 108.46–162.15 mg/kg. Among the microelements present in the seed composition, manganese reached its peak concentration in the New-42 variety (162.15 mg/kg), while the lowest concentration was found in the New-170 variety (108.46 mg/kg).

Furthermore, the investigation into the silicon (Si) content demonstrated that concentrations fluctuated between 379.9 mg/kg and 514.05 mg/kg. The highest accumulation of silicon was observed in the New-42 variety (514.05 mg/kg), whilst the lowest index was recorded for the New-170 variety (379.9 mg/kg).

Regarding the nickel (Ni) content, the Check-2 variety was identified as containing the highest concentration (56.96 mg/kg), while the lowest levels of the Ni element were recorded in the New-36 variety (37.96 mg/kg). Notably, the nickel element was not detected in the New-14 and New-170 varieties.

Among the microelements analysed in the quinoa seeds, iodine (I) was identified exclusively in the New-36 variety (238.43 mg/kg). No detectable levels of iodine were found in the other varieties examined.

To precisely determine the microelement composition of the quinoa varieties, the results were expressed in units of spectral intensity (kcps), representing the number of pulses recorded by the instrument's detector per second. The research findings demonstrated that significant differences exist between the varieties in terms of spectral intensity (kcps) when determining microelement concentrations (Figure 2).

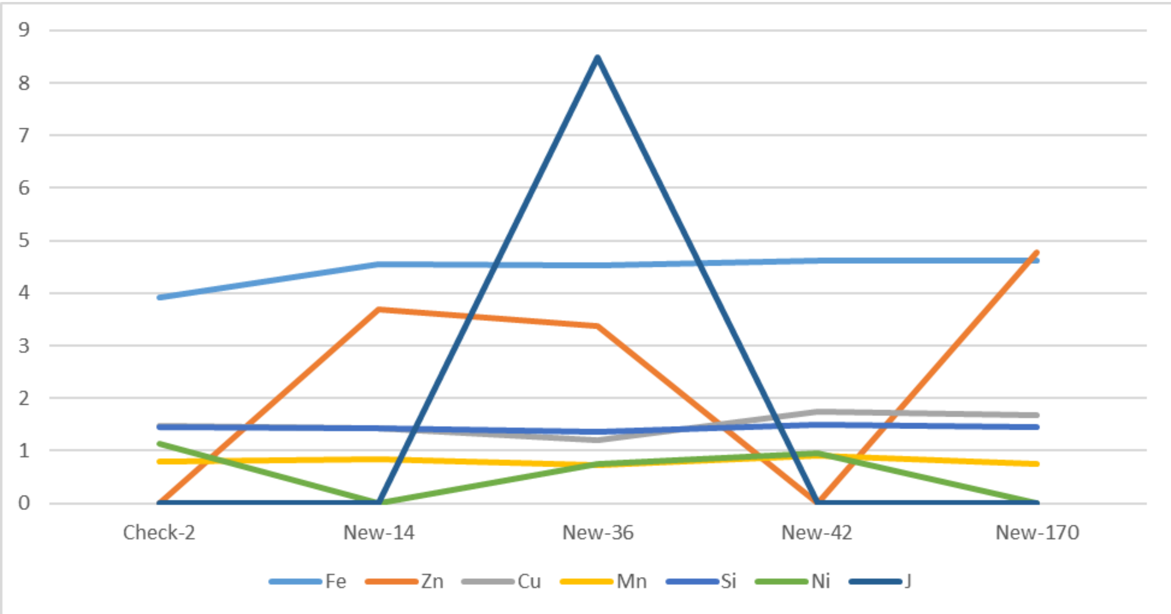

Figure 2. Spectral intensity (kcps) for the determination of microelement content in quinoa varieties.

According to the results of the conducted research, the spectral intensity for the iron (Fe) microelement was found to range between 3.91 and 4.62 kcps across the studied varieties. The highest intensity levels were recorded in the New-42 and New-170 varieties (both at 4.62 kcps), while the lowest index was observed in the Check-2 variety.

The zinc (Zn) element was detected only in specific varieties, with spectral intensities ranging from 3.38 to 4.78 kcps. Since the Zn element was not detected in the New-42 and Check-2 varieties, no spectral intensity was recorded for them. The highest value was observed in the New-170 variety, whereas the lowest was found in the New-36 variety.

Based on the findings established during the investigation, the spectral intensity of the copper (Cu) microelement was recorded within the range of 1.20–1.75 kcps. The maximum value was identified in the New-42 variety (1.75 kcps), and the minimum value was found in the New-36 variety (1.20 kcps). Regarding the microelements manganese (Mn), silicon (Si), and nickel (Ni), the spectral intensities were recorded in the following ranges:

− Mn: 0.73–0.91 kcps

− Si: 1.36–1.50 kcps

− Ni: 0.74–1.14 kcps

The research results further confirmed that the iodine (I) element was present exclusively in the New-36 variety, exhibiting a spectral intensity of 8.50 kcps.

4. Conclusions

Based on the results of the comprehensive research conducted, it was established that the microelement content in quinoa varieties exhibits statistically significant variations. The New-42 variety demonstrated the highest concentrations of iron, copper, manganese, and silicon, which potentially signifies superior physiological activity and a higher degree of resilience to abiotic stress factors in this specific genotype. The New-170 variety was distinguished by its dominance in zinc content, highlighting its critical functional role in supporting enzymatic processes.

Furthermore, the iodine microelement was uniquely detected in the New-36 variety, marking a significant distinction as it was entirely absent in the other studied varieties. It was also observed that nickel accumulated at elevated levels in certain specific genotypes. In summary, the findings confirm that the microelement composition is profoundly dependent on the genotype. These results serve as a vital criterion for the selection of quinoa varieties that are optimally adapted to the specific soil and climatic conditions of the Khorezm region, particularly for biofortification and agricultural development.

References

1. Bratovčić, A., & Sarić, E. (2019). Determination of essential nutrients and cadmium in white quinoa and amaranth seeds. Croatian Journal of Food Science and Technology, 11(1), 135–139.
2. Cladis, D. P., Gallant, K. H., & Murphy, K. (2024). Quantifying the quinoa ionome: Mineral content of 346 quinoa varieties. Current Developments in Nutrition, 8.
3. Craine, E. B., & Murphy, K. M. (2020). Seed composition and amino acid profiles for quinoa grown in Washington State. Frontiers in Nutrition, 7, 126.
4. Khaitov, B., Karimov, A. A., Toderich, K., Sultanova, Z., Mamadrahimov, A., Allanov, K., & Islamov, S. (2020). Adaptation, grain yield and nutritional characteristics of quinoa (Chenopodium quinoa) genotypes in marginal environments of the Aral Sea basin. Journal of Plant Nutrition, 44(9), 1365–1379.
5. Konishi, Y., Hirano, S., Tsuboi, H., & Wada, M. (2004). Distribution of minerals in quinoa (Chenopodium quinoa Willd.) seeds. Bioscience, Biotechnology, and Biochemistry, 68(1), 231–234.
6. Malakouti, M. J. (2008). The effect of micronutrients in ensuring efficient use of macronutrients. Turkish Journal of Agriculture and Forestry, 32(3), 215–220.
7. Mhada, M., Metougui, M. L., El Hazzam, K., El Kacimi, K., & Yasri, A. (2020). Variations of saponins, minerals and total phenolic compounds due to processing and cooking of quinoa (Chenopodium quinoa Willd.) seeds. Foods, 9(5), 660. https://doi.org/10.3390/foods9050660
8. Mohsin, R. H., Allami, R. H., & Mouhamad, R. S. (2019). X-ray fluorescence technique for studying mineral nutrients of quinoa seed cultivated in Iraq. Revista Bionatura, 4(4), 966–971.
9. Palombini, S. V., Claus, T., Maruyama, S. A., Gohara, A. K., Souza, A. H. P., Souza, N. E., & Matsushita, M. (2013). Evaluation of nutritional compounds in new amaranth and quinoa cultivars. Food Science and Technology, 33(2), 339–344.
10. Toderich, K. N., Mamadrahimov, A. A., Khaitov, B. B., Karimov, A. A., Soliev, A. A., Nanduri, K. R., & Shuyskaya, E. V. (2020). Differential impact of salinity stress on seed minerals, storage proteins, fatty acids, and squalene composition of new quinoa genotype grown in hyper-arid desert environments. Frontiers in Plant Science, 11, 607102. https://doi.org/10.3389/fpls.2020.607102
11. Xu, X., Sharma, P., Shu, S., et al. (2021). Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. Nature Food, 2, 724–732. https://doi.org/10.1038/s43016-021-00358-x