The OSCAR PUBLISHING Services
American Journal of Applied Science and Technology

VOLUME Vol.06 Issue 09 2026
PAGE NO. 59-67
DOI 10.37547/ajast/Volume06Issue09-09

Biogeochemical Characteristics of Irrigated Sierozem Soils and Raspberry (Rubus Idaeus L.) In Fergana District, Uzbekistan

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Received: 27 July 2026; **Accepted:** 25 August 2026; **Published:** 23 September 2026

Abstract: This study aims to comprehensively investigate the biogeochemical characteristics of chemical elements within the system of irrigated typical sierozem soils and raspberry plants (Rubus idaeus L.) in the Fergana region. It also examines the relationship between the mineral nutritional status of the soil and the biochemical composition of raspberry fruits and develops agronomic recommendations for obtaining high-quality yields.

Keywords: Raspberry; Rubus idaeus L.; typical sierozem soils; biogeochemical characteristics; mineral nutrition; fruit biochemical composition.

Introduction:

Irrigated agriculture in arid and semi-arid regions depends heavily on the condition of the soil. Long-term irrigation can change soil texture, organic matter content, carbonate distribution, salinity, nutrient availability, and the migration of trace elements. These changes are particularly relevant in the Fergana Valley, where intensive farming has developed on irrigated sierozem soils under a dry continental climate. Recent studies conducted in northern and central parts of the valley have shown that irrigation and agricultural management alter the physicochemical and biogeochemical properties of these soils, including the distribution of macroelements, trace elements, soluble salts, and organic carbon [1,2]. Therefore, crop productivity in the region cannot be assessed solely through irrigation rates or fertiliser inputs. The soil–plant relationship must also be considered.

Raspberry (Rubus idaeus L.) is a perennial berry crop whose growth and fruit production are sensitive to the physical and chemical conditions of the root zone. Soil texture, drainage, organic matter, reaction, nutrient availability, and irrigation regime influence root development and the uptake of mineral elements. These factors can subsequently affect cane growth, yield, berry size, and fruit composition.

Studies on raspberry cultivation have shown that organic amendments and different fertilisation systems may alter mineral uptake and vegetative development, although their effects on yield, vitamin C, and antioxidant capacity can vary between growing seasons [3]. The form and balance of applied nutrients are also important because fertilisation can modify the soluble solids, acidity, taste, and storage characteristics of raspberry fruits [4]. Similarly, comparisons of organic, organo-mineral, and mineral fertilisers have confirmed that raspberry productivity and berry quality depend on both nutrient management and seasonal conditions [5].

Mineral nutrition is not the only factor controlling raspberry production. Soil organic matter improves soil structure, moisture retention, microbial activity, and nutrient cycling. Field observations have shown that higher soil organic matter can support raspberry yield independently of direct fertiliser effects, while biological factors such as insect pollination also contribute to berry formation and final productivity [6]. This means that an effective cultivation system should maintain soil fertility while taking into account the interaction between soil properties, plant nutrition, irrigation, and biological processes.

The value of raspberry production is determined not only by yield but also by fruit quality. Raspberry fruits contain vitamins, minerals, amino acids, sugars, organic acids, dietary fibre, anthocyanins, and ellagitannins. Their concentrations are not constant. Genotype, environmental conditions, nutrient availability, harvest season, and plant stress may all affect the biochemical composition of the fruit [7]. Phenolic compounds are especially important because they contribute to colour, antioxidant activity, and the nutritional value of raspberries. Anthocyanins and ellagitannins are considered the main contributors to their antioxidant properties, while vitamin C provides an additional contribution [8]. Consequently, changes in soil nutrient status may influence not only plant development but also the nutritional and biochemical characteristics of the harvested berries.

Most previous studies on raspberry nutrition and fruit composition have been conducted in temperate regions or on acidic and organically managed soils. Much less is known about raspberry cultivation on irrigated, carbonate-rich, slightly alkaline typical sierozem soils. In particular, the relationship between the elemental composition of these soils, the accumulation and redistribution of elements in raspberry roots, stems, leaves, and fruits, and the biochemical composition of the berries remains insufficiently studied under the agroecological conditions of the Fergana region. This information is required to develop locally adapted nutrient and soil-management practices rather than directly transferring recommendations developed for other soil and climatic conditions.

Accordingly, this study aimed to evaluate the morphological, physical, chemical, agrochemical, and biogeochemical properties of irrigated typical sierozem soils in Fergana District and to examine their relationship with the mineral and biochemical composition of raspberry plants. Particular attention was given to the migration and accumulation of macro- and microelements in different plant organs, the nutritional composition of raspberry fruits, and the influence of soil and agroecological conditions on crop productivity. The results are intended to support practical recommendations for maintaining soil fertility and producing high-quality raspberries under the irrigated conditions of the northern Fergana Valley.

METHODS

The study was conducted on irrigated agricultural land in Fergana District, located in the northern part of the Fergana Valley, Uzbekistan. Field observations and sampling were carried out at the “Qator Terak Ko‘rki” and “Akbarali Karimjon Fayzi” farms. The main research objects were irrigated typical sierozem soils and raspberry plants (Rubus idaeus L.) grown under local field conditions.

The soils of the study area were generally medium loamy and had been exposed to long-term irrigation and agricultural use. Soil profiles were examined to determine their morphological, physical, chemical, agrochemical, and biogeochemical characteristics. Raspberry roots, stems, leaves, and fruits were

studied to assess the uptake, distribution, and accumulation of mineral elements within the soil–plant system.

Soil samples were collected from the main genetic horizons of the studied profiles, including the plough and subsoil layers. The samples were used to determine particle-size composition, physical clay content, humus, total nitrogen, the carbon-to-nitrogen ratio, and the distribution of chemical elements along the soil profile.

Plant samples were collected from raspberry plantations located within the same study sites. The sampled plants were separated into roots, stems, leaves, and fruits. This separation made it possible to compare element concentrations among individual plant organs and evaluate the movement of mineral elements from the soil and roots towards the above-ground parts of the plant.

Fruit samples were analysed separately to determine their nutritional and biochemical composition. The assessment included amino acids, vitamins, and other biologically active components relevant to raspberry fruit quality.

The physical and agrochemical assessment of the soils included particle-size distribution, physical clay content, humus, total nitrogen, and the C:N ratio. Particular attention was paid to changes in these properties across the soil profile because they reflect the effects of irrigation, cultivation, and element migration.

The elemental analysis covered major elements, including Na, Mg, Al, P, K, Ca, and Fe. Dispersed elements such as Rb, Cs, Br, and Sc, as well as the rare-earth elements Ce, Nd, and Sm, were also considered. Their concentrations and vertical distribution were evaluated in the soil profiles and compared with their occurrence in raspberry organs.

The accumulation or depletion of individual elements in the soil was assessed using geochemical concentration and distribution coefficients. Biological absorption was evaluated by comparing the concentration of each element in the plant organ with its concentration in the corresponding soil. Comparisons among roots, stems, leaves, and fruits were used to identify the main sites of element accumulation and their redistribution within the plant.

The amino acid and vitamin composition of raspberry fruits was evaluated to characterise their nutritional value. Individual amino acids and vitamins were expressed as proportions of their corresponding total contents.

Table 1. Main components and indicators included in the study

Study component	Samples examined	Main indicators
Soil morphology	Genetic soil horizons	Horizon structure, profile differentiation, signs of irrigation-induced change
Soil physical properties	Plough, subsoil, and lower horizons	Particle-size composition and physical clay content
Soil agrochemical properties	Soil samples from individual horizons	Humus, total nitrogen, and C:N ratio
Soil geochemistry	Soil profile samples	Macro-, micro-, dispersed, and rare-earth elements
Raspberry mineral composition	Roots, stems, leaves, and fruits	Element concentrations, distribution, and biological absorption
Fruit biochemical composition	Mature raspberry fruits	Amino acids, vitamins, and other bioactive components
Statistical analysis	Soil and plant datasets	Correlation coefficient (rr) and coefficient of determination (r^2)

The relationships between element concentrations in the soil and different raspberry organs were assessed using correlation analysis. Pearson's correlation coefficient (r) was used to determine the direction and strength of the relationships. The coefficient of determination (r2) was calculated to estimate the proportion of variation shared by the compared variables.

Correlations were examined for the root–leaf, root–stem, root–fruit, and leaf–fruit relationships. Positive coefficients were interpreted as evidence of coordinated element uptake and redistribution from the root system to the above-ground organs and fruits.

RESULTS

The irrigated typical sierozem soils had a medium-loamy particle-size composition. Physical clay content generally ranged from 36.60% to 40.11%. A higher value of 43.11% was recorded in some middle horizons, indicating a gradual increase in fine particles within this part of the profile.

Humus content was 1.30% in the plough layer and decreased to 1.10% in the subsoil. Total nitrogen also declined with depth, whereas the C:N ratio increased. This pattern suggests that the lower horizons contained organic compounds that were relatively poor in nitrogen.

Table 2. Selected physical and agrochemical properties of the irrigated typical sierozem soils

Indicator	Recorded value	Main observation
Physical clay	36.60–40.11%	Medium-loamy particle-size composition
Maximum physical clay in middle horizons	43.11%	Accumulation of fine particles within the soil profile
Humus in the plough layer	1.30%	Highest value within the examined profile
Humus in the subsoil	1.10%	Gradual decline with depth
Total nitrogen	Decreased with depth	Lower nitrogen availability in deeper horizons
C:N ratio	Increased with depth	Relative accumulation of nitrogen-poor organic compounds

Rubidium, caesium, bromine, and scandium occurred at different concentrations in the soil profile. Rubidium content ranged from 54.3 to 59.4 mg kg^{-1}. Its concentration coefficient was below one, indicating no pronounced enrichment relative to the selected reference value.

Caesium was distributed comparatively evenly throughout the profile, with concentrations ranging from 6.3 to 7.2 mg kg^{-1}. Its concentration coefficient ranged from 1.26 to 1.44, whereas the distribution coefficient remained below one.

Bromine occurred at approximately 5 mg kg^{-1}. Its low concentration and weak accumulation confirmed its dispersed behaviour in the studied soils. Scandium content ranged from 9.4 to 12.6 mg kg^{-1}. Its concentration coefficient was higher than that of rubidium, although its distribution coefficient remained below one.

Table 3. Concentrations and geochemical coefficients of selected dispersed elements

Element	Soil concentration, mg kg^{-1}	Concentration coefficient	Distribution coefficient	General behaviour
Rb	54.3–59.4	0.54–0.59	1.68–1.70	Relatively abundant but not strongly concentrated

Cs	6.3–7.2	1.26–1.44	0.69–0.79	Nearly uniform distribution
Br	Approximately 5.0	Not reported	Not reported	Low concentration and weak accumulation
Sc	9.4–12.6	1.34–1.80	0.56–0.74	Moderate enrichment but limited profile accumulation

Among the analysed dispersed elements, rubidium had the highest absolute concentration. Scandium showed the highest concentration coefficient, while the distribution coefficients of scandium and caesium were below one. Overall, these elements did not show strong accumulation in the examined soil horizons.

The concentrations of mineral elements differed among the roots, stems, leaves, and fruits. The highest uptake values were recorded for sodium and potassium in the root system. This indicates that the roots acted as the first site of element accumulation before their subsequent transfer to the above-ground organs.

A strong positive relationship was found between element concentrations in the roots and leaves (r=0.80; r2=0.64). Positive correlations were also recorded for the root–fruit (r=0.75; r2=0.56) and root–stem relationships (r=0.74; r2=0.54).

Table 4. Correlations between element concentrations in raspberry organs

Compared organs	r	r^2	Interpretation
Root–leaf	0.80	0.64	Strong positive relationship
Root–fruit	0.75	0.56	Strong positive relationship
Root–stem	0.74	0.54	Strong positive relationship

The root–leaf relationship was the strongest among the reported correlations. Leaves therefore appeared to be an important intermediate site for the accumulation and redistribution of elements. The slightly lower root–stem and root–fruit coefficients suggest that the transfer of elements to fruits involved further physiological regulation within the above-ground organs.

Dispersed elements occurred at low concentrations in the soil solution and plant tissues. Their biological absorption coefficients were generally low, particularly in the roots and leaves. A relatively greater proportion was detected in the fruits, although the absolute concentrations remained limited.

The total content of the identified amino acids in the raspberry fruits was 41.50 mg per 100 g. Aspartic acid was the most abundant amino acid and accounted for 15.793% of the total. It was followed by proline, glutamic acid, and cystine. Alanine, glycine, and leucine each accounted for up to 2%.

The analysed fruits also contained asparagine, serine, histidine, arginine, threonine, lysine, tyrosine, valine, methionine, isoleucine, and other amino acids in smaller proportions.

Vitamin C and vitamin B6 represented the largest reported shares of the identified vitamins. Smaller proportions were recorded for vitamins B9, B3, and B2.

Table 5. Main amino acids and vitamins identified in raspberry fruits

Biochemical component	Reported value
Total identified amino acids	41.50 mg 100 g^{-1}
Aspartic acid	15.793%
Proline	4.698%
Glutamic acid	4.353%
Cystine	3.458%
Alanine, glycine, and leucine	Up to 2% each
Vitamin C	34.33%
Vitamin B6	33.22%
Vitamin B9	6.74%
Vitamin B3	6.55%
Vitamin B2	2.04%

The biochemical results show that the raspberries grown on the studied irrigated sierozem soils contained a diverse amino acid and vitamin profile. Aspartic acid dominated the amino acid fraction, while vitamins C and B6 formed the largest shares of the identified vitamins.

DISCUSSION

The medium-loamy texture of the studied soils is generally suitable for irrigated horticulture because it provides a balance between water retention and aeration. However, the increase in physical clay to 43.11% in the middle horizons may reduce water movement if the soil becomes compacted. Similar changes in the particle-size distribution and physicochemical properties of irrigated Calcisols have been reported in northern and central parts of the Fergana Valley. Long-term irrigation can redistribute fine particles, carbonates, soluble salts, and nutrients within the profile. Thus, the properties of the root zone may differ from those of the surface layer even within the same field.

Humus content was comparatively low, reaching 1.30% in the plough layer and 1.10% in the subsoil. This result is important for raspberry cultivation because a perennial root system depends on stable soil structure, moisture retention, and continuous nutrient cycling. Research on raspberry plantations has shown that organic amendments can improve plant biomass and mineral uptake, although their effects on fruit yield and biochemical quality may vary between years. Soil organic matter can also support raspberry productivity independently of the direct effect of mineral fertilisers. The present results therefore indicate that maintaining organic matter should be considered alongside fertiliser application.

The decline in total nitrogen and the increase in the C:N ratio with depth reflect the vertical differentiation of organic matter. For raspberry plants, most active roots and applied nutrients are usually concentrated within the cultivated root zone. A gradual decline in nitrogen availability below this layer may restrict deeper root nutrition, particularly during periods when the surface soil becomes dry. Balanced fertilisation should therefore be based on actual soil and plant analyses rather than on a uniform fertiliser rate.

Rubidium had the highest absolute concentration among the dispersed elements examined. Nevertheless, its concentration coefficient remained below one. Rubidium and caesium have chemical properties similar to potassium, but they are not considered essential plant nutrients. Their uptake may partly follow potassium transport pathways, although plants usually show stronger biological selectivity for potassium [9,10].

The nearly uniform distribution of caesium and the low distribution coefficients of caesium and scandium indicate limited movement or accumulation within specific horizons. Bromine also occurred at a low concentration. These findings support the classification of Rb, Cs, Br, and Sc as dispersed elements under the studied conditions. Their presence is relevant to the biogeochemical characterisation of the soil, but the available concentrations do not indicate that they were major factors controlling raspberry growth.

The interpretation of these coefficients should remain linked to soil texture, carbonates, organic matter, irrigation water, and fertiliser history. Element mobility is not determined by total concentration alone. Soil reaction, sorption capacity, competing ions, and moisture regime control how much of an element becomes available to plant roots [9]. Consequently, a relatively high total concentration does not necessarily result in high biological absorption.

The relatively high accumulation of sodium and potassium in the roots reflects the role of the root system as the first physiological and geochemical barrier between soil and plant. Potassium is required for enzyme activation, osmotic regulation, stomatal function, assimilate transport, and fruit development. Sodium is not required in the same quantity and may compete with potassium under saline or alkaline conditions [10]. The balance between these two elements may therefore be more informative than their individual concentrations.

The strong root–leaf correlation ($r=0.80r = 0.80$) indicates coordinated element uptake and transport towards photosynthetically active tissues. Leaves require a continuous supply of nutrients because they regulate photosynthesis, transpiration, and many metabolic processes. The positive root–fruit and root–stem relationships also confirm that element concentrations in the root system were associated with their distribution in the above-ground organs.

These correlations should not, however, be interpreted as direct proof of a single transport pathway. Element movement is influenced by xylem transport, phloem redistribution, transpiration, growth stage, and the physiological demand of each organ. The slightly weaker root–fruit correlation suggests that the mineral composition of the berries was regulated not only by root uptake but also by redistribution through the stems and leaves.

The amino acid profile was dominated by aspartic acid, followed by proline, glutamic acid, and cystine. Amino acids contribute to fruit metabolism, taste formation, stress responses, and the synthesis of other biologically active compounds. Proline may also accumulate in response to environmental stress, although the present data do not allow the effect of a specific stress factor to be separated from normal varietal metabolism.

The reported vitamin composition was dominated by vitamins C and B6. Raspberry fruit composition is known to vary with genotype, growing environment, harvest season, and agricultural management. Fertilisation may modify fruit acidity, soluble solids, flavour, and storage behaviour, but increasing nutrient inputs does not always improve every quality indicator. This explains why soil fertility management should aim for nutritional balance rather than maximum fertiliser application.

Raspberries are also recognised as sources of anthocyanins, ellagitannins, and other phenolic compounds. These compounds contribute to fruit colour and antioxidant activity [8,11,12]. Their concentrations may change in response to cultivar, temperature, moisture availability, soil nutrition, and harvest maturity. Although the present study focused mainly on amino acids, vitamins, and mineral elements, the results provide a basis for future assessment of phenolic compounds and antioxidant activity in raspberries grown on sierozem soils.

Overall, the findings show a close connection between soil condition, element uptake, their redistribution within raspberry plants, and fruit composition. The results also underline the need for locally adapted management. Maintaining soil organic matter, monitoring the Na:K balance, avoiding excessive fertilisation, and regularly assessing soil and leaf nutrient status may help

sustain raspberry productivity under the irrigated conditions of the northern Fergana Valley.

CONCLUSION

The irrigated typical sierozem soils of the studied raspberry plantations had a medium-loamy texture, with physical clay contents ranging from 36.60% to 40.11%. Its increase to 43.11% in some middle horizons indicated the redistribution and accumulation of fine particles within the soil profile. Humus content decreased from 1.30% in the plough layer to 1.10% in the subsoil. The simultaneous decrease in total nitrogen and increase in the C:N ratio showed that the deeper horizons contained organic compounds relatively poor in nitrogen.

Among the dispersed elements, rubidium had the highest absolute concentration, ranging from 54.3 to 59.4 mg kg^{-1}. Caesium, bromine, and scandium occurred at lower concentrations and did not show pronounced accumulation within the examined soil profile. Sodium and potassium showed the highest uptake values in raspberry roots.

Element concentrations in the roots were strongly correlated with those in the leaves (r=0.80; r2=0.64). Positive correlations were also found for the root–fruit (r=0.75; r2=0.56) and root–stem relationships (r=0.74; r2=0.54). These results indicate coordinated element uptake and redistribution among raspberry organs, although their transport to the fruits was also influenced by physiological regulation within the stems and leaves.

The total content of identified amino acids in the raspberry fruits was 41.50 mg per 100 g. Aspartic acid formed the largest proportion, followed by proline, glutamic acid, and cystine. Vitamins C and B6 accounted for the largest shares of the identified vitamins. The findings confirm that raspberry fruit composition is associated with soil properties, mineral availability, and element redistribution within the plant.

Maintaining soil organic matter, applying balanced mineral nutrition, monitoring the Na:K ratio, and regularly assessing soil and leaf nutrient status are recommended for the sustainable cultivation of raspberries on irrigated sierozem soils in the northern Fergana Valley.

REFERENCES

1. Turdaliev, A., Yuldashev, G., Khaydarov, M., Abdukhakimova, K., Muratova, R., Azimov, Z., Sotiboldieva, G., Mirzaev, U., Isagaliev, M., Holdarov, H., Obidov, M., Novikova, E., Nizamutdinov, T., & Abakumov, E. (2024). Irrigation-initiated changes in physicochemical properties of the Calcisols of the northern part of Fergana Valley. Applied Sciences, 14(13), Article 5762. https://doi.org/10.3390/app14135762
2. Turdaliev, A., Askarov, K., Abakumov, E., Makhkamov, E., Rahmatullayev, G., Mamajonov, G., Akhmadjonov, A., & Axunov, A. (2023). Biogeochemical state of salinized irrigated soils of Central Fergana (Uzbekistan, Central Asia). Applied Sciences, 13(10), Article 6188. https://doi.org/10.3390/app13106188
3. Hargreaves, J. C., Adl, M. S., Warman, P. R., & Rupasinghe, H. P. V. (2008). The effects of organic amendments on mineral element uptake and fruit quality of raspberries. Plant and Soil, 308(1–2), 213–226. https://doi.org/10.1007/s11104-008-9621-5
4. Valentinuzzi, F., Pii, Y., Mimmo, T., Savini, G., Curzel, S., & Cesco, S. (2018). Fertilization strategies as a tool to modify the organoleptic properties of raspberry (Rubus idaeus L.) fruits. Scientia Horticulturae, 240, 205–212. https://doi.org/10.1016/j.scienta.2018.06.024
5. Stojanov, D., Milošević, T., Mašković, P., Milošević, N., Glišić, I., & Paunović, G. (2019). Influence of organic, organo-mineral and mineral fertilisers on cane traits, productivity and berry quality of red raspberry (Rubus idaeus L.). Scientia Horticulturae, 252, 370–378. https://doi.org/10.1016/j.scienta.2019.04.009
6. Chen, K., Fijen, T. P. M., Kleijn, D., & Scheper, J. (2021). Insect pollination and soil organic matter improve raspberry production independently of the effects of fertilizers. Agriculture, Ecosystems & Environment, 309, Article 107270. https://doi.org/10.1016/j.agee.2020.107270

7. Mazur, S. P., Nes, A., Wold, A. B., Remberg, S. F., & Aaby, K. (2014). Quality and chemical composition of ten red raspberry (Rubus idaeus L.) genotypes during three harvest seasons. Food Chemistry, 160, 233–240. https://doi.org/10.1016/j.foodchem.2014.02.174
8. Lopez-Corona, A. V., Valencia-Espinosa, I., González-Sánchez, F. A., Sánchez-López, A. L., Garcia-Amezquita, L. E., & Garcia-Varela, R. (2022). Antioxidant, anti-inflammatory and cytotoxic activity of phenolic compound family extracted from raspberries (Rubus idaeus): A general review. Antioxidants, 11(6), Article 1192. https://doi.org/10.3390/antiox11061192
9. Kabata-Pendias, A. (2011). Trace elements in soils and plants (4th ed.). CRC Press.
10. Marschner, P. (Ed.). (2012). Marschner's mineral nutrition of higher plants (3rd ed.). Academic Press.
11. Ponder, A., & Hallmann, E. (2019). Phenolics and carotenoid contents in the leaves of different organic and conventional raspberry (Rubus idaeus L.) cultivars and their in vitro activity. Antioxidants, 8(10), Article 458. https://doi.org/10.3390/antiox8100458.
12. Mullen, W., McGinn, J., Lean, M. E. J., MacLean, M. R., Gardner, P., Duthie, G. G., Yokota, T., & Crozier, A. (2002). Ellagitannins, flavonoids, and other phenolics in red raspberries and their contribution to antioxidant capacity and vasorelaxation properties. Journal of Agricultural and Food Chemistry, 50(18), 5191–5196. https://doi.org/10.1021/jf020140n.