J Open
http://dx.doi.org/10.70728/jopen.be.0325.005

ARTICLE

Quantitative and Qualitative Composition of Amino Acids in the Serozem Soils of North Fergana, Republic of Uzbekistan

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Abstract

The given data on the content of soil amino acids in soils and soil-forming rocks of serozems (calcisols) and chernozems shows that the relative accumulation or their increased formation varies depending on the type and subtype, the horizon of the soils and the soil-forming rocks.

Keywords: Dark calcisols, chernozem, bedrock, loess, neogene, oasis, soil fertility, irrigation, free amino acids, humus, landscape, group composition of humus.

1 Introduction

The principal significance of soil organic matter includes amino acids, which play an important role in the process of soil formation.

Citation
Mavlonjon M. Khaydarov (2025). Quantitative and Qualitative Composition of Amino Acids in the Serozem Soils of North Fergana, Republic of Uzbekistan. J Open, 01(03), 20–24.

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Submitted: June, 2025
Accepted: August, 2025
Published: September, 2025

Vol. 01, **No.** 03, 2025.
10.70728/jopen.be.0325.005

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They play a crucial role in soil fertility, serving as a source of nitrogen nutrition and as biologically active substances, and they occupy a significant place among the wide variety of compounds that form the group of nonspecific soil constituents. In soils, amino acids occur both in free form (as metabolic products of microorganisms and as decomposition products of plant and animal organisms) [1–7], and in bound form—as components of microbial and plant proteins and in humic acids [8–10].

It has been established that approximately 20–50% of total nitrogen in soil is present in the form of amino acids released after alkaline or acidic hydrolysis [11] of protein residues of plant, animal, and microbial origin, which is indicated by the high proteolytic activity of soil [12]. Despite their relatively low proportion within the organic nitrogen pool, free amino acids—with their high biochemical activity—are of great importance for plant nutrition.

The relationship between the content of amino acids and soil microorganisms has been studied. On the one hand, amino acids promote the activation of microbiological processes, and on the other, microorganisms have been shown to synthesize free amino acids that may be released and accumulated in the soil [13–16]. According to researchers, the greater the number of microorganisms in the soil, the higher the amino acid content [14, 17].

The increased interest in the qualitative and quantitative composition of amino acids is explained by the fact that, as biologically active substances, they play an essential role in the nitrogen cycle in soil [25]. In nitrogen transformation processes, free amino acids, being intermediate products, may be directly assimilated by soil biota, undergo mineralization, or bind with humic substances, thereby enriching the soil with organic nitrogen. They may also form organic

ligands with metals in the soil [18–24].

2 Materials and Methods

The aim of the present study was to determine the amino acid pool of typical serozem and to characterize it as a constituent component of soil organic matter. The object of the investigation of the quantitative and qualitative composition of free amino acids was the serozem soil of North Fergana, Republic of Uzbekistan. For the analysis of free amino acids, soil samples of typical serozem or chernozem were collected. The determination of amino acid content and their identification were carried out in fresh soil samples using high-performance liquid chromatography according to the method of Steven A. and Cohen Daviel, on an Agilent Technologies 1200 chromatograph equipped with a 75 × 4.6 mm Discovery HS C18 column. Solvent A: 0.14 M CH_3COONa + 0.05% TEA, pH = 6.4; Solvent B: CH_3CN. Flow rate: 1.2 mL/min; detection at 269 nm. Gradient %B/min: 1–6% / 0–2.5 min; 6–30% / 2.51–40 min; 30–60% / 40.1–45 min; 60–60% / 45.1–50 min; 60–0% / 50.1–55 min.

3 Results

In the study of the qualitative composition of free amino acids in the serozem soils of North Fergana, between 14 and 20 free amino acids were detected and identified. Among the commonly occurring amino acids, alanine, aspartic acid, cysteine, histidine, arginine, and glutamine were not found in soil sample "P2." In soils "P3," alanine, cysteine, and histidine were absent; in "P4," alanine, aspartic acid, cysteine, and histidine were absent; in "P5," cysteine and histidine were not detected; and in "P6," alanine, aspartic acid, glutamic acid, cysteine, and histidine were not identified (Fig. **??**).

The content of free amino acids in serozem "P1" averages a total mass (TTM) of 44.33 mg/kg (ranging from 12.5 to 111.56 mg/kg across different soil layers). The relative distribution of free amino acids in serozem "P1" is as follows: monoaminocarboxylic acids (glycine, alanine, serine, cysteine, threonine, methionine, valine, leucine, isoleucine) – 25.13–71.37% (TTM – 14.381 mg/kg; 8.54–28.04 mg/kg in different soil layers); monoamino-dicarboxylic acids (aspartic acid, asparagine, glutamic acid, glutamine) – 24.9–52.25% (TTM – 19.62 mg/kg; 3.1–58.29 mg/kg in different soil layers); diamino-monocarboxylic acids (lysine, arginine) – 1.27–6.88% (TTM – 1.86 mg/kg; 0.19–4.62 mg/kg in different soil layers); aromatic amino acids (phenylalanine, tyrosine, tryptophan, histidine) – 3.72–25.61% (TTM – 7.535 mg/kg; 0.46–18.22 mg/kg in different soil layers); imino acids (proline) – 2.15–3.58% (TTM – 0.94 mg/kg; 1.37–2.39 mg/kg in different soil layers) of the total amino acid content.

	Monoaminocarboxylic acids									Monoamino-dicarboxylic acids			Diamino-monocarboxylic acids		Aromatic acids				Imino acids	Σ
	Glycine	Alanine	Serine	Cysteine	Threonine	Methionine	Valine	Leucine	Isoleucine	Aspartic acid	Asparagine	Glutamic acid	Glutamine	Lysine	Arginine	Phenylalanine	Tyrosine	Tryptophan	Histidine	Proline	
P1																					
1	1,61	0,79	0,29	0,53	15,5	1,46	0,2	4,03	3,64	1,24	1,65	0,94	54,5	1,24	3,37	2,27	1,41	6,88	7,66	2,39	111,6
2	1,019	0,838	0	0	5,46	0	0,382	2,693	1,628	0,7	1,09	0,81	9,93	0,79	1,85	0,89	4,18	3,12	1,63	1,37	38,38
3	1,114	0	0,18	0	6,38	0	0,196	0,129	0,543	0	1,08	0,44	2,99	0,19	0	0	1,64	0	0	0	14,882
4	0,851	0	0,11	0	7,18	0	0,364	0,226	0,181	0	0,83	0,29	1,98	0	0	0	0,46	0	0	0	12,472
P2																					
1	2,51	0	0	0	0	0	0	0,26	0,28	0	2,36	0	0	0,43	0	2,64	0	1,61	0	3,35	13,44
2	0,62	0	0,14	0	6,21	0,32	0,07	1,05	0,25	0	0,72	0,38	0	0,23	0	0,87	0,38	0,74	0	0	11,98
3	0,83	0	0,44	0	4,74	0	0,07	0,3	0,45	0	0,87	0	0	0,33	0	0,61	0,71	0	0	0	9,35
4	0,65	0	0,25	0	1,62	0	0,06	0	0	0	0,55	0,19	0	1,06	0	1,21	0,51	0	0	0	6,1
5	0,45	0	0,07	0	1,08	0	0	0	0	0	0,41	0	0	0,67	0	0,39	0,26	0	0	0	3,33
P3																					
1	1,56	0	0,38	0	14,4	3,64	0,74	0,36	0,99	1,87	1,53	0,85	5,86	0,31	0,79	3,07	0,88	1,43	0	5,49	44,15
2	0,79	0	0,22	0	8,08	1,41	0,24	0	0	0	0,82	0,35	0	0,11	0,38	1,08	0,24	0,54	0	0	14,26
3	1,01	0	0,13	0	6,31	0	0,18	0	0	0	0,94	0	0	0,09	0	0,96	0,22	0,29	0	0	10,13
P4																					
1	1,81	0	0,27	0	18,1	0,92	0,76	0,19	0,3	0	1,83	0,55	20,9	0,56	1,17	2,09	0,59	0,88	0	5,23	56,15
2	1,07	0	0,16	0	8,51	0,44	0,39	0,13	0,31	0	1,11	0,27	5,69	0,42	0	1,21	0,26	0,61	0	0	20,58
3	1,05	0	0,12	0	7,26	0,17	0,25	0	0	0	1,03	0,18	3,84	0,31	0	0,63	0,24	0	0	0	15,08
P5																					
1	1,77	0,67	0,52	0	17,2	1,71	0,65	0,16	0,28	0,95	1,7	2,04	23,2	0,97	1,37	3,28	0,53	4,14	0	2,91	64,05
2	1,11	0	0,42	0	9,74	0	0,36	0	0,23	0,38	1,14	1,06	6,56	0,68	0,67	1,42	0,45	1,47	0	0	25,69
3	0,97	0,11	0,38	0	2,35	0	0,29	0	0	0	0,91	0,66	3,14	0,71	0,33	0,15	0,38	0	0	0,28	10,66
4	0,79	0	0,3	0	1,34	0	0,12	0	0	0	0,72	0,36	1,55	0,33	0	0,16	0	0,17	0	0	5,84
P6																					
1	1,33	0	0,59	0	17,6	0,42	0,93	0,32	0,27	0	1,41	0	19,2	0,83	1,78	1,15	0,66	1,21	0	1,07	48,77
2	0,85	0	0,26	0	10,2	0	0	0	0,12	0	0,91	0	10,86	0,55	0,12	0,49	0,75	0,66	0	0	25,77
3	0,79	0	0,24	0	6,64	0,67	0,08	0,26	0,35	0	0,77	0	3,06	0,48	0,39	0,21	0,42	0,67	0	0	15,03
4	0,72	0	0,19	0	5,72	0	0,07	0	0,31	0	0,75	0	3,09	0,37	0,111	0,17	0,65	0	0	0	12,151

Figure 1. Content of free amino acids in the serozem soils of North Fergana, Republic of Uzbekistan (mg/kg)

In serozem "P2," the content of free amino acids averages a total mass (TTM) of 8.84 mg/kg (ranging from 3.35 to 13.45 mg/kg across different soil layers). The relative distribution of free amino acids in serozem "P2" is as follows: monoaminocarboxylic acids (glycine, serine, threonine, methionine, valine, leucine, isoleucine) – 22.69–73.08% (TTM – 4.544 mg/kg; 1.61–8.68 mg/kg in different soil layers); monoamino-dicarboxylic acids (asparagine, glutamic acid) – 9.21–17.61% (TTM – 1.096 mg/kg; 0.41–2.36 mg/kg in different soil layers); diamino-monocarboxylic acids (lysine) – 1.94–20.14% (TTM – 0.544 mg/kg; 0.67–1.06 mg/kg in different soil layers); aromatic amino acids (phenylalanine, tyrosine, tryptophan) – 13.99–31.55% (TTM – 1.986 mg/kg; 0.66–4.24 mg/kg in different soil layers); imino acids (proline) – 24.95% (TTM – 3.35 mg/kg, found only in the P2-1 layer) of the total amino acid content.

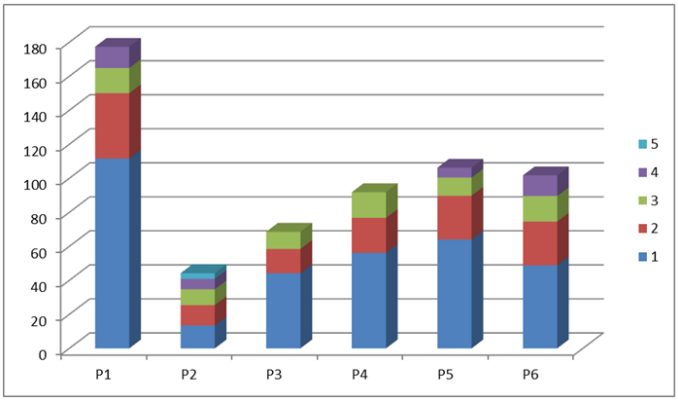
In serozem "P3," the content of free amino acids averages a total mass (TTM) of 22.85 mg/kg (ranging from 10.13 to 44.13 mg/kg across different soil layers). The relative distribution of free amino acids in serozem "P3" is as follows: monoaminocarboxylic acids (glycine, serine, threonine, methionine, valine, leucine, isoleucine) – 49.98–75.29% (TTM – 13.48

mg/kg; 7.63–22.05 mg/kg in different soil layers); monoamino-dicarboxylic acids (aspartic acid, asparagine, glutamine, glutamic acid) – 8.21–22.9% (TTM – 4.07 mg/kg; 0.935–10.11 mg/kg in different soil layers); diamino-monocarboxylic acids (lysine, arginine) – 0.91–3.45% (TTM – 0.56 mg/kg; 0.09–1.09 mg/kg in different soil layers); aromatic amino acids (phenylalanine, tyrosine, tryptophan) – 12.19–14.57% (TTM – 2.9 mg/kg; 1.48–5.38 mg/kg in different soil layers); imino acids (proline) – 12.44% (detected only in the upper layer) of the total amino acid content.

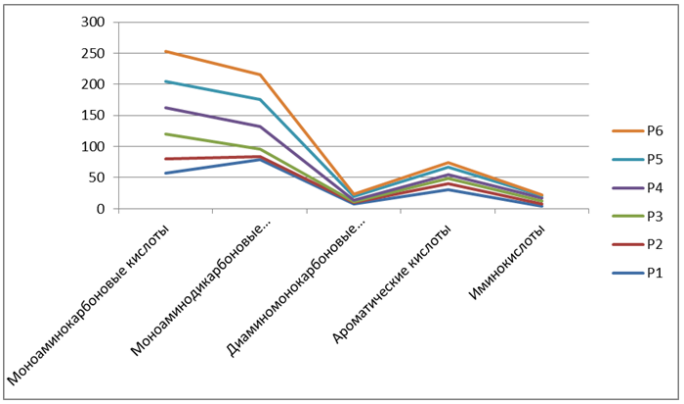
The content of free amino acids in serozem "P4" averages a total mass (TTM) of 30.06 mg/kg (ranging from 15.08 to 56.23 mg/kg across different soil layers). The relative distribution of free amino acids in serozem "P4" is as follows: monoaminocarboxylic acids (glycine, serine, threonine, methionine, valine, leucine, isoleucine) – 39.77–58.74% (TTM – 14.07 mg/kg; 8.86–22.36 mg/kg in different soil layers); monoamino-dicarboxylic acids (asparagine, glutamic acid, glutamine) – 33.49–41.47% (TTM – 11.8 mg/kg; 5.05–23.32 mg/kg in different soil layers); diamino-monocarboxylic acids (lysine, arginine) – 2.01–3.07% (TTM – 0.82 mg/kg; 0.302–1.73 mg/kg in different soil layers); aromatic amino acids (phenylalanine, tyrosine, tryptophan) – 5.75–10.12% (TTM – 2.17 mg/kg; 0.87–3.58 mg/kg in different soil layers); imino acids (proline) – 9.31% (found in the upper layer) of the total amino acid content.

In serozem "P5," the content of free amino acids averages a total mass (TTM) of 26.56 mg/kg (ranging from 5.83 to 64.24 mg/kg across different soil layers). The relative distribution of free amino acids in serozem "P5" is as follows: monoaminocarboxylic acids (glycine, alanine, serine, threonine, methionine, valine, leucine, isoleucine) – 35.55–46.11% (TTM – 10.4 mg/kg; 2.55–22.84 mg/kg in different soil layers); monoamino-dicarboxylic acids (aspartic acid, asparagine, glutamic acid, glutamine) – 35.53–45.04% (TTM – 11.09 mg/kg; 2.62–27.92 mg/kg in different soil layers); diamino-monocarboxylic acids (lysine, arginine) – 3.65–9.65% (TTM – 1.26 mg/kg; 0.33–2.34 mg/kg in different soil layers); aromatic amino acids (phenylalanine, tyrosine, tryptophan) – 4.99–13.07% (TTM – 3.04 mg/kg; 0.33–8.22 mg/kg in different soil layers); imino acids (proline) – 2.62–4.43% of the total amino acid content.

In serozem "P6," the content of free amino acids averages a total mass (TTM) of 25.43 mg/kg (ranging from 12.15 to 48.78 mg/kg across different soil layers). The relative distribution of free amino acids in serozem "P6" is as follows: monoaminocarboxylic acids (glycine, serine, threonine, methionine, valine, leucine, isoleucine) – 43.92–60.04% (TTM – 12.23 mg/kg; 7.02–21.42 mg/kg in different soil layers); monoamino-dicarboxylic acids (asparagine, glutamine) – 25.45–45.62% (TTM – 10.01 mg/kg; 3.82–20.64 mg/kg in different soil layers); diamino-monocarboxylic acids (lysine, arginine) – 2.58–5.86% (TTM – 1.16 mg/kg; 0.47–2.62 mg/kg in different soil layers); aromatic amino acids (phenylalanine, tyrosine, tryptophan) – 6.18–8.64% (TTM – 1.76 mg/kg; 0.82–3.01 mg/kg in different soil layers); imino acids (proline) – 2.19% (present in the upper layer) of the total amino acid content.



Comparison of the categories of amino acids in the same layers across different samples.



4 Conclusion

The study of the quantitative and qualitative composition of free amino acids in the serozem (calcisol) soils of North Fergana demonstrated that their accumulation patterns are closely linked to soil type, genetic horizon, and soil-forming material. Across the investigated profiles, 14 to 20 free amino

acids were identified, with notable variations in their presence and concentration reflecting differences in organic matter transformation and microbiological activity.

Monoaminocarboxylic and monoamino-dicarboxylic acids constituted the dominant groups in most profiles, indicating active decomposition of organic residues and the prevalence of protein-derived humic substances. In contrast, diamino and aromatic amino acids occurred in lower proportions, which is characteristic of carbonate-rich soils with limited deep organic mineralization. The absence of alanine, cysteine, histidine, aspartic acid, and glutamic acid in several profiles suggests that their formation and retention are highly sensitive to moisture regime, carbonate accumulation, and biological activity.

Total free amino acid content varied widely among the profiles, ranging from very low levels in P2 (8.84 mg/kg), indicating weak biological processes, to substantially higher levels in P1 and P4 (30–44 mg/kg), reflecting enhanced organic matter turnover and relatively favorable pedoecological conditions. Vertical distribution patterns further confirm the decline of biologically active amino acids in deeper horizons, consistent with reduced humification intensity and lower microbial biomass.

Overall, the findings reveal that the composition of free amino acids is a sensitive biochemical indicator of soil formation processes, organic matter dynamics, and ecological status in serozem soils. These results contribute to a deeper understanding of nitrogen transformation pathways in arid and semi-arid soils and provide a scientific basis for improving soil fertility assessment, land management, and monitoring of irrigated agroecosystems in the North Fergana region.

Author Contributions:

The author carried out all aspects of the study.

Funding: The authors declare that no funds, grants, or other financial support were received during the preparation of this manuscript.

Institutional Review Board Statement: This research did not include any experiments involving human participants or animals, so Institutional Review Board (IRB) approval was not necessary.

Informed Consent Statement: This study did not involve human subjects; therefore, informed consent was not required.

Data Availability Statement: Data supporting the report's findings can be found here.

Acknowledgments: The authors express their sincere gratitude to Associate Professor (PhD) **Zokirjon J. Isomiddinov** of Kokand State University for his valuable review of the study's results and his contributions to its publication.

Conflicts of Interest: The authors declare no conflicts of interest related to this study.

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