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ARTICLE

The Role of Amino Acids in Soil

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Abstract

The study investigates the composition, distribution, and functional role of amino acids in the soils of northern Fergana, focusing on virgin and irrigated sierozems. Using a combination of genetic–geographical, geochemical, and morphogenetic research methods, the study analyzes the humus condition, nutrient composition, and energy potential of soil organic matter. Results show that despite their relatively small proportion in total soil nitrogen, amino acids play a critical role in plant nutrition and soil fertility by acting as bioactive compounds that regulate physiological processes such as chlorophyll synthesis, osmotic regulation, and stress tolerance. The research reveals that irrigation significantly affects the qualitative and quantitative composition of soil amino acids, leading to decreased humus content and transformation of nitrogen-containing compounds. In both virgin and irrigated sierozems, 14–20 amino acids were identified, with variations across soil horizons. The findings emphasize the energetic and biochemical importance of amino acids in maintaining soil fertility and highlight the need for further research on soil dehumification and fertility restoration.

Keywords: amino acids; soil fertility; humus; sierozem soils; irrigation; nitrogen compounds; soil biochemistry; Fergana Valley; soil organic matter; dehumification; soil energy potential.

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1 Introduction

Scientific research is being conducted worldwide in such priority areas of soil science as the study of the soil–ecological condition of irrigated and virgin soils, their humus content, and the processes of dehumification. Under these conditions, the development of highly efficient and competitive technologies is gaining increasing importance. Particular attention is devoted to examining the indicators that determine the level of potential soil fertility, namely the content and composition of humus reserves, the optimal degree of absorbed cations, the quantity and composition of nutrients, as well as the energetic characteristics of soil-bound and free amino acids and their temporal and spatial variability, along with the development of relevant recommendations.

2 Research Methods

Field research was conducted on the basis of V.V. Dokuchaev's genetic–geographical, profile–geochemical, stationary field, and morphogenetic methods. Humus content was determined according to I.V. Tyurin; total nitrogen, phosphorus, and potassium were analyzed following the methods of Maltseva and Gritsenko; soil free amino acids were determined according to D.G. Zvyagintsev. Mathematical and statistical analysis of the obtained data was performed using the dispersion method with the computer program developed by Sh. Karimov and G. Yuldashev, applying the recommendations on mathematical statistics in soil science by Samsonov et al.

Soil is a biocosmic body formed simultaneously by living organisms and processes of inorganic nature [1]. It is a polydisperse, multicomponent system unique in its chemical and physical properties. It serves as an almost ideal habitat for the development of the vast majority of organisms and represents the richest natural substrate in terms of microbial gene pool [2].

Extensive scientific research has been conducted both abroad [3–5] and in our Republic [6–8], as well as by others [9, 10], on the study of agrochemical, agrophysical, and biogeochemical properties and soil fertility. However, investigations on the current agrochemical, agrophysical, and especially biogeochemical and energetic state, as well as on improving the fertility of virgin and irrigated sierozems in northern Fergana, have not yet been fully completed.

The soil cover supports plant life and serves as a conveyor for the decomposition of plant residues. According to the vivid expression of V.I. Vernadsky, living matter itself creates soil. Changes in the quantity and quality of living matter occur under the influence of anthropogenic factors, which consequently alter the humus content and other soil components.

Under the influence of three years of irrigation, the humus content in the soil significantly decreased throughout the profile of alluvial meadow soils. Through irrigation and soil cultivation, the nature of soil and humus transformation acquires a different, that is, an individualized direction [11].

Table 1

Amino Acids	Functions in Plants
Arginine	Overcoming salt stress; development of the root system
Aspartic Acid	Stimulation of seed germination; building material for other amino acids
Glutamic Acid	Chlorophyll synthesis; seed germination; building material for other amino acids
Alanine	Chlorophyll synthesis; drought tolerance; regulation of leaf stomatal activity for optimizing water exchange
Glycine	Chlorophyll synthesis; regulation of stomatal activity and pollination process; chelation of microelements
Histidine	Chelating agent improving nutrient uptake; regulation of leaf stomatal activity
Threonine	Regulation of leaf stomatal activity during hot weather
Proline	Osmotic protectant; tolerance to heat, arid conditions, and salt stress; stomatal regulation; chlorophyll synthesis
Tyrosine	Salt stress tolerance; heat tolerance; seed germination; pollen process
Valine	Heat and scorching weather tolerance; seed germination; pollination
Methionine	Stimulation of ripening; regulation of leaf stomatal activity
Isoleucine	Osmotic protectant; heat and salt stress tolerance; pollen germination; pollination
Leucine	Osmotic protectant; heat and salt stress tolerance; pollen germination
Phenylalanine	Humic acid synthesis; pollination; lignin synthesis for strengthening cell walls
Lysine	Drought tolerance; stomatal regulation; chlorophyll synthesis; pollen germination
Tryptophan	Precursor for auxin-type phytohormone synthesis
Serine	Osmotic protectant; tolerance to heat, arid climate, and salt stress
Taurine	Drought and salt stress tolerance

3 Results

Despite their relatively low proportion within the pool of organic nitrogen, amino acids—with their high biogeochemical activity—play a significant role in the nutrition of agricultural plants. The functions of amino acids are multifaceted as well as highly specific, and they participate in numerous soil and plant processes, which can be observed in the data presented in [Table 1]. Amino acids may serve as an additional source of organic nitrogen, particularly under natural conditions. Root exudates of plants also represent an important source of free amino acids in the soil.

Changes in the qualitative and quantitative composition of amino acids across the genetic horizons of virgin and irrigated dark sierozems are presented in Table 2. The data show that the distribution and quantity of amino acids in virgin dark sierozems are uneven. In the 0–7 cm layer, almost all 20 amino acids, including proline, are present in varying amounts. Within the group of monoaminocarboxylic amino acids in the 0–7 cm horizon, threonine accounts for the highest amount, with its content reaching 15.5 mg/kg. Valine is present in the lowest amount, at 0.2 mg/kg. Among the monoamine dicarboxylic acids, high concentrations are observed for glutamine.

Table 2. Content of Free Monoaminocarboxylic Acids in Dark Sierozems, mg/kg

Depth, cm	Glycine	Alanine	Serine	Cysteine	Threonine	Methionine	Valine	Leucine	Isoleucine	Total
Virgin soils, profile 1										
0–7	1.61	0.79	0.29	0.53	15.5	1.46	0.20	4.03	3.64	28.05
7–17	1.02	0,838	0	0	5.46	0	0,38	2,69	1,63	12,02
17–43	1.11	0	0,18	0	6.38	0	0,19	0,13	0,54	8,542
43–73	0.85	0	0.11	0	7.18	0	0.36	0.23	0.18	8.912
Irrigated soils, profile 2										
0–30	2.51	0	0	0	0	0	0	0.26	0.28	3.05
30–42	0.62	0	0.14	0	6.21	0.33	0.07	1.06	0.25	8.66
42–70	0.83	0	0.44	0	4.74	0	0.07	0.30	0.45	6.83
70–100	0.65	0	0.25	0	1.62	0	0.06	0	0	2.58
100–135	0.45	0	0.07	0	1.08	0	0	0	0	1.6

The content of aromatic amino acids is rather high and ranges from 1.41 to 7.66 mg/kg.

The imino group accounts for 2.39 mg/kg, and the total amount of all amino acids is 111.6 mg/kg. In the second (7–17 cm), third (17–43 cm), and fourth (43–73 cm) horizons, slight changes in the amino acid composition are observed [Table 3].

For example, there is a decrease in glycine, alanine, and others. There are data showing that beginning from the sub-turf horizon certain amino acids, such as cysteine, are not detected. In addition, there are data indicating an increase in the content of tyrosine and glutamine in the sub-turf horizon.

Table 3. Content of Free Monoaminodicarboxylic, Diaminocarboxylic, Aromatic, and Imino Acids in Dark Sierozems, mg/kg

Depth, cm	Monoaminodicarboxylic				Diaminocarboxylic		Aromatic				Imino
	Aspartic acid	Asparagine	Glutamic acid	Glutamine	Lysine	Arginine	Phenylalanine	Tyrosine	Tryptophan	Histidine	Proline
Virgin soils, profile 1											
0–7	1,24	1,65	0,94	54,5	1,24	3,37	2,27	1,41	6,88	7,66	2,39
7–17	0,7	1,09	0,81	9,93	0,79	1,85	0,89	4,18	3,12	1,63	1,37
17–43	0	1,08	0,44	2,99	0,19	0	0	1,64	0	0	0
43–73	0	0,83	0,29	1,98	0	0	0	0,46	0	0	0
Irrigated soils, profile 2											
0–30	0	2,36	0	0	0,43	0	2,64	0	1,61	0	3,35
30–42	0	0,72	0,38	0	0,23	0	0,87	0,38	0,74	0	0
42–70	0	0,87	0	0	0,33	0	0,61	0,71	0	0	0
70–100	0	0,55	0,19	0	1,06	0	1,21	0,51	0	0	0
100–135	0	0,41	0	0	0,67	0	0,39	0,26	0	0	0

Certain amino acids, such as histidine, tryptophan, phenylalanine, arginine, methionine, cysteine, and alanine, are absent in the underlying layers, i.e., in the carbonate-illuviated horizons and deeper. Partial accumulation of threonine and valine is observed at a concentration of 7.18 mg/kg. These changes are characterized by the composition and molecular masses of amino acids, as well as the contents of humus and humic acids, which contain amino acids in varying amounts.

In serozems, 14 to 20 amino acids have been identified. In virgin light serozems, cysteine and histidine are present, whereas in irrigated soils, alanine, aspartic acid, glutamine, cysteine, and histidine are detected. Dicarboxylic amino acids, such as lysine and histidine, which possess isoelectric points in alkaline environments, are present in nearly all studied soils.

4 Conclusions

The increase in the number of amino acids, in particular arginine, which under the influence of the enzyme arginase enhances urea synthesis in soils, can be regarded as a positive factor. In serozems, 14 to 20 amino acids have been identified. In virgin light serozems, cysteine and histidine are present, whereas in irrigated soils, alanine, aspartic acid, glutamine, cysteine, and histidine are detected, along with dicarboxylic amino acids such as lysine and histidine, which possess isoelectric points in slightly alkaline environments and are present in nearly all studied soils.

The content of potential energy of humus and free amino acids is of great importance in the assessment of irrigated soils, in the development of calculations of elemental composition, and in estimating their potential energy, which is expended in the soil formation process and in the cycling of mass and energy. An energetic approach to characterizing humus and free soil amino acids allows for both quantitative and qualitative determination of the potential energy value of humus and free soil amino acids, as well as for predicting processes of dehumification and the restoration of soil fertility.

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The author carried out all aspects of the study.

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