Influence of anthropogenic and natural factors on the enzymatic activity of soils pistachio and walnut forests of Kyrgyzstan

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ABSTRACT

The article presents the results of a study of the influence of anthropogenic and natural factors on the enzymatic activity of soils pistachio and walnut forests. The situation of production and immobilization of the enzymatic pool of microbiological activity of soils under various conditions of economic use of typical siorezem soils of the Fergana Range and the valley of the same name is a genetic diagnostic indicator of fertility and is used in planning agrotechnological measures to increase soil fertility. Among the soils studied, the enzymatic activity of mountain-forest black-brown soils is very high. This is related to the soil organic matter content because forest litter plays a key role as a precursor for the synthesis and stabilization of enzymes. The enzyme activity indicators presented in the article can be used as diagnostic indicators of soil fertility in this territory.

Key words: walnut-fruit forest, pistachio forest, sierozem soils, mountain-forest black-brown soils, humus, enzymes

INTRODUCTION

In Kyrgyzstan, walnut-fruit forest and pistachio fields are mainly found in the Jalal-Abad region. The pistachio tree is one of the oldest fruit-bearing plants in human history. It reaches up to 10 meters in height and can live up to 400 years. Pistachios contain a large number of useful substances, which has a beneficial effect on human health (Bolotov *et al.,* 2005). Due to its exceptional drought resistance and unpretentiousness to unfavorable soil conditions, pistachio is of great importance for forest reclamation – the development of currently treeless, eroded to varying degrees, low-productivity rained lands (Hemery, 1998).

Our walnut-fruit forests have enormous ecological and landscape (water protection, water regulation, soil protection), commercial (fruits, berries, medicinal plants, valuable timber, etc.), economic (sales of environmentally friendly nuts, fruits, berries, honey, medicinal herbs) and recreational (ecotourism, sanatoriums, resorts) significance. Walnut-fruit forests are distinguished by the uniqueness of the components of the biosphere, where on tens of thousands of hectares grow the most valuable species of trees and shrubs, medicinal and honey plants, forage herbaceous plants and the soils are represented by highly fertile black-brown soils. In addition, the mountain forest black-brown soils of the walnut-fruit forests serve as a fertility standard for the soils of Central Asia in terms of fertility indicators (Karabaev *et al*., 2022, Gryza *et al.*, 2008).

Anthropogenic and natural factors of soil formation have a significant impact on microbiological activity, and especially on the work of soil enzymes. Indeed, enzymes are actively involved in the biological processes of transformation of soil organic matter, on which the direction and intensity of synthesis, the release of nutrients, the breakdown of humus, as well as the hydrolysis of organic compounds and the redox regime depend. Nutrients, as a result of enzymatic processes, are transferred from difficult-to-digest compounds into easily accessible forms for microorganisms and plants, i.e. the higher the activity of the enzyme pool, the better the supply of living organisms.

To identify various types of anthropogenic load on the soils of the agroecosystem of the vertical zonality of the mountains, different types of economic impact were studied. The object of our study is to investigate the influence of anthropogenic and natural factors on the enzymatic activity of soils in pistachio and walnut forests.

MATERIALS AND METHODS

The study was conducted in the pistachio forestry of the Suzak district (elevation -853 m., latitude -40°54´58.41"N, longitude - 72°56´15.16"E) and the Kara-Alma walnut-fruit forest (elevation – 1801m., latitude -41°12´54.66"N, longitude - 73°23´00.05"E) of the Jalal-Abad region of Kyrgyzstan. The research work was carried out in 2019-2023 at the Jalal-Abad State University named after B. Osmonov.

To study the fertility of pistachio and walnut-fruit forests, soil samples were taken from genetic horizons. At the same time, soil sections were described based on the morphological characteristics of the genetic horizons of the soil profile. Laboratory analyzes were done according to generally accepted methods adopted in the Kyrgyz Republic, in the Republican laboratory of soil-agrochemical station of Kyrgyzstan (Arinushkina, 1963). The enzymatic activity of soils was determined in the laboratory of the University of Texas, USA, by Tabatabai method (1994).

RESULTS AND DISCUSSION

As can be seen from Table 1, natural plant communities and agrocenoses of irrigated agriculture are a powerful factor in the life of microorganisms, incl. enzymatic activity. The biological characteristics of plants in pastures, pistachio woodlands and in irrigated agriculture leave a certain imprint on the activity of glucosidase enzymes. Plants create and form microbial cenoses and enzymes, influencing the microbial population of the root system and crop residues.

Natural plant biocenoses activate the soil enzyme pool, with the highest β-glucosidase activity observed in the 0-2 cm soil layer of pistachio woodlands (809.5 mg p-nitrophenol kg^{-1} soil h^{-1}), and then sharply decreases in the lower soil horizons (Table 1). This means that in the soils of pistachio woodlands, enzymatic activity is concentrated in the thin upper (0-2 cm) layer of soil, i.e. the bulk of Streptomeces microorganisms are located here and a rhizosphere is formed in close proximity to the daytime soil surface, favorable for the development of enzymatic activity. With such indicators, the probability of replenishing soil humus reserves with products of cellulose decomposition is high, where in the process of mineralization there is a synthesis of specific organic compounds - humus, specific mineral compounds - clay minerals, as well as the release of simple inorganic compounds (Sakbaeva *et al.*, 2013). As a result of such processes, the upper horizon of sierozem soils of pistachio open forests acquires erosion resistance, and here, as a result of enzymatic processes, nutrients are transferred from difficult-to-digest compounds into easily accessible forms for microorganisms and plants. These processes form the basis of soil fertility and lead to the redistribution of chemical elements in the landscape we study.

On pasture lands of sierosem soils, β - glucosidase in the A_0 horizon is 428.7 mg p-nitrophenol kg^{-1} soil $hour^{-1}$, (almost two times lower than in pistachio open forest), and in the A_1 layer β - glucosaminidase is 43.3 mg p-nitrophenol kg^{-1} soil $hour^{-1}$. In contrast to the soils of pistachio woodlands in layer A1 (2-13 cm), there is no sharp decrease in β - glucosidase (209.3 mg p-nitrophenol kg $^{-1}$ soil hour $^{-1}$) and β - glucosaminidase (34.5 mg p-nitrophenol kg $^{-1}$ soil hour $^{-1}$). As can be seen in natural phytocenoses of pastures, enzymatic activity is observed in the 0-13 cm layer of soil, where the largest mass of the plant root system is concentrated. The release of extracellular enzymes in roots during the metabolic process, manifesting a rhizosphere effect on soil microflora, activates their vital activity with root exudates (Sakbaeva *et al.*, 2021).

Here, for comparison, we can give the activity content of glucosidase enzymes in the mountain-forest black-brown soils of the walnut-fruit forests of the Kara-Alma basin of the Kok-Art river. As can be seen from Table 1, high enzymatic activity of the soil is noted for β-glucosidase and ranges from 11.1 to 1235.9 mg p-nitrophenol kg^{-1} soil h^{-1} in mountain-forest black-brown soil. Of the glucosidase enzymes, β-glucosidase is dominant over β-glucosaminidase. In general, soil enzymatic activity decreases with increasing depth. The decrease in enzyme activity with depth can be explained by a decrease in the biological activity of soils down the profile. A decrease in enzyme activity and microbial biomass with soil depth was noted in studies by Acosta-Martinez *et al.* (2007), Kizilkaya and DengIz, (2010). The enzymatic activity of soil depends on many natural conditions of soil formation, such as physical, chemical properties, geomorphological conditions of distribution of the studied soils, as well as the influence of anthropogenic factors (Mirkin and Naumova, 2015). Anthropogenic factors have different effects on the enzymatic activity of soil.

On irrigated arable lands of sierosem soils, there are serious changes in the enzymatic activity of soils. Here, in the arable horizon of the arable land, where the roots are concentrated and the soil is subject to anthropogenic influence (mechanical treatment, fertilizer, watering, etc.), the greatest enzymatic activity is observed. However, the intensity of enzymatic processes in arable soils of agroecosystems is significantly lower than in soils of natural landscapes. On the arable horizon of irrigated typical sierozem soil, where cotton is grown) contains 69.8 mg p-nitrophenol kg^{-1} soil h^{-1} β-glucosidase and 11.9 mg p-nitrophenol kg^{-1} soil h^{-1} β-glucosaminidase. Here, due to the low content of soil organic matter (spread of the root system of the agrocenosis, accumulation of humus and plant residues), immobilizers of humic substances enzymes, weak supply of enzymes with organic matter of plant origin and small secretions of plants and microflora, low glucosidase activity is observed on irrigated arable lands of sierozem soils.

Differences in the enzymatic activity of the studied soils of anthropogenic and natural ecosystems cover the entire soil profile. The high intensity of biological processes in natural soils is characteristic mainly of the upper root-saturated layer of the soil profile, and in natural biogeocenoses enzymatic activity is not distributed to significant depths than in arable soils. If on irrigated arable lands an additional impulse is given for the supply of phytomass (green manure, cultivation of alfalfa, leaving a lot of plant residues by-products), then better conditions are created for increasing the enzymatic activity of arable land. This means that the entire range of agricultural technology for agricultural crops should be aimed at increasing the supply of plant residues and creating optimal air, water, nutrient and thermal regimes for arable land.

Table 2 shows the activity of phosphatase enzymes in sierozems. Genetic characteristics, plant composition, level of agricultural culture and physicochemical properties are the determining components of phosphatase activity. Soils containing acid phosphatases have an acidic reaction; in soils with a slightly alkaline reaction, alkaline phosphatases predominate, which is confirmed by our research materials. In the soils of pistachio woodlands, alkaline phosphatase (1021.5 and 67.3 mg p-nitrophenol kg^{-1} soil h^{-1} in the upper layers of soil) is much higher than acid phosphatase (286.4 and 22.9), this indicates the provision of phosphorus regime Alkaline phosphatase enzymes play a major role in the nutrition of these soils. These indicators are very important for diagnosing the genetic characteristics of sierozem soils of pistachio open forests. Table 2 shows that sierozem soils of pastures contain much less alkaline phosphatase (594.3 and 285.5 mg p-nitrophenol kg^{-1} soil h^{-1}) than in soils of pistachio woodlands and they dominate over acid phosphatase (176.2 and 81.8). Enzymes that provide the most important metabolic processes in the soil are more significant, and among the hydrolytic enzymes, the most informative are: invertase and phosphatase (Khaziev, 1982).

As can be seen in Table 2, mountain sierozem soils contain from 1.3 to 176.2 mg nitrophenol kg^{-1} soil $hour^{-1}$ acid phosphatase, from 9.6 to 594.3 mg nitrophenol kg^{-1} soil $hour^{-1}$ alkaline phosphatase, from 5.3 to 303.6 mg nitrophenol kg^{-1} soil h^{-1} phosphodiesterase. The amount of enzymes sharply decreases in the subarable soil horizon, which directly correlates with the humus content of the arable land (Sakbaeva *et al*., 2012). In the upper horizons of mountain gray soils, an increased content of enzymes is observed. This is due to the abundance of organic matter and soil microorganisms on the surface horizons of mountain sierozems (Sakbaeva *et al.*, 2013). The pH of the serozem soils in the Kok-Art river basin fluctuates at 7.9-8.3, which contributes to an increase in the content of alkaline phosphatases. The highest amount of acid and alkaline phosphatases and phosphodiesterase accumulates in the upper soil horizon of pistachio woodland (1868.8 mg p-nitrophenol kg^{-1} soil $hour^{-1}$). Enzyme activity decreases sharply down the soil profile. This picture of the distribution of enzymes confirms that it is necessary to protect the surface horizons of these soils from erosion and to guard against excessive grazing pressure. The content of acid phosphatase in irrigated sierozem soil is 228.9 mg nitrophenol kg^{-1} soil $hour^{-1}$, alkaline phosphatase - 162.1, phosphodiesterase - 83.4. In cotton fields, the increased content of acid phosphatase is explained by the influence of applied nitrogen and phosphorus fertilizers, which have an acidic pH environment and an optimal temperature regime (+25-35C^{o}), against the background of good regular watering. These anthropogenic factors contribute to the active supply of mineral phosphorus to the roots and improve the phosphorus nutrition of cotton. Many works have noted that mountain forest black-brown soils are characterized by high natural fertility. The soils of walnut-fruit forests have large amounts of phosphorus in the form of organic compounds, which comes with the dying remains of plants, animals and microorganisms that accumulate in humus. As shown in Table 2, the enzymatic activity of acid phosphatase in mountain forest black-brown soil ranges from 18.0 to 712.7 mg nitrophenol kg-1 soil h-1, the amount of alkaline phosphatase ranges from 8.1 to 1809.8 mg nitrophenol kg -1 soil hour-1, while alkaline phosphatase dominates over acid phosphatase and phosphodiesterase (Sakbaeva *et al.*, 2012).

Arylsulfatases play an important role in the sulfur cycle, i.e. hydrolysis of sulfate esters in the soil and they play a positive role in improving the quality of agricultural products. The content of organic matter, total nitrogen and activity of the enzyme arylsulfatase in the sierozem soils of the Kok-Art river basin are given in Table 3.

The content of the arylsulfatase enzyme on the surface soil horizon of pistachio open forests is 115.4 mg p-nitrophenol kg -1 soil hour -1 and pastures - 81.3, which indicates that the activity of the arylsulfatase enzyme in sierozem soils is directly correlated with organic matter and the rhizosphere of natural plant communities. Their quantity on irrigated arable land (cotton) is much lower than the above indicators for similar soils (23.4 mg p-nitrophenol kg^{-1} soil $hour^{-1}$). Enzymes are fixed in the soil, maintaining their activity and becoming protected from the action of microorganism proteases. In this case, the inhibitory effect of humic acids on enzyme activity appears (Shcherbkova, 1983). As can be seen, in comparison with other types of soils studied, the sierozem soils of the Kok-Art river basin were formed under conditions dominated by an arid climate with a deficiency of precipitation and high temperatures, which affects the activity of the enzyme arylsulfatase. Among sierozem soils, the lowest activity of the arylsulfatase enzyme was observed in arable lands where cotton was grown for many years in a row. Aryl sulfatase activity in these areas ranges from 9.1 to 23.4 mg p-nitrophenol kg^{-1} soil h^{-1}. This is probably due to the low content of organic matter and the small supply of post-harvest plant mass on cotton plantations, when, according to existing technology, all above-ground mass is alienated for economic needs. As can be seen from Table 3, a low amount of organic matter (OM) and total nitrogen (N) is contained in irrigated sierozem soils, which is correlated with the content of the enzyme arylsulfatase. In mountain-forest black-brown soils of walnut-fruit forests, the content of organic substances was at a high level, i.e. 12-16% in A_0 and 9-12% in A_1 horizons. In accordance with this, the activity of arylsulfatase was also at a high level, which was contained within 498.9 mg p-nitrophenol kg^{-1} soil h^{-1} in the A_0 horizon and 439.2 mg p-nitrophenol kg^{-1} soil h^{-1} in A_1 horizons.

CONCLUSIONS

The enzymatic activity of sierozem soils of various uses is a complex of natural and anthropogenic components, combined into three groups: biological (quantitative and qualitative composition of phytomass, content and composition of microflora, enzymatic activity, intensity of CO_2 release and cellulose decomposition in the soil); agrochemical (humus, pH, indicators of the soil-absorbing complex, content and forms of plant nutrients); agrophysical (mechanical composition, structure and structure of the arable layer, thickness of the humus horizon, density, porosity, reserves of productive moisture, air, thermal properties and their regimes). And of these, biological activity and enzyme activity works to improve the nutritional regime of soils and is one of the diagnostic indicators of fertility.

The soils of pistachio forests and pastures of sierozem soils, compared to irrigated arable land, are characterized by increased enzymatic activity, which indicates the provision of nitrogen and phosphorus nutrition and to increase the enzymatic pool of arable land, an additional supply of organic substances is required.

Among the studied soils, the enzymatic activity of mountain-forest black-brown soils of walnut forests is very high and it depends on the gross content of humus and organic phosphorus, which are the food substrate for the enzyme. The enzyme of mountain forest black-brown soils is involved in the decomposition of plant, animal and microbial residues, as well as the synthesis of humus. Forested areas tend to contain higher microbial biomass compared to pastures and croplands, which can be explained by the higher levels of enzymes found in forested areas.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1: Activity of glucosidase enzymes in sierozem and mountain-forest black-brown soils of Kok-Art river basin of Jalalabat region (mg p-nitrophenol kg $^{-1}$ soil hour $^{-1}$)

Location	Soil types	Horizon	Depth (cm)	β-glucosidase	β-glucosaminidase
Pastures	Foothill typical sierozem soils	A_0	0-2	428,7	43,3
		A_1	2-13	209,3	34,5
		AB	13-44	25,7	11,2
		B	44-86	7,4	6,2
		C	86-170	2,0	2,9
Pistachio forest	Typical sierozem soils	A_0	0-2	809,5	51,0
		A_1	2-14	38,3	8,8
		B_1	14-52	16,0	10,6
		$B_к$	52-105	7,6	7,5
		C	105-165	5,3	5,6
Arable land (cotton)	Irrigated sierozem soils	A	0-14	69,8	11,9
		A_1	14-30	22,8	5,8
		B	30-50	3,3	4,2
Walnut-fruit forest	Mountain forest black-brown soils	A_0	0-4	1235,9	298,5
		A_1	4-18	546,9	106,0
		A_2	18-57	74,6	7,3
		AB	57-91	17,8	10,9
		B	91-130	14,7	1,7
		C	130-185	11,1	14,4

Table 2: Activity of phosphatase enzymes in sierozem and mountain-forest black-brown soils of Kok-Art river basin of Jalalabat region (mg p-nitrophenol kg $^{-1}$ soil hour $^{-1}$)

Location	Soil types	Depth (cm)	Acid phosphatase	Alkaline phosphatase	Phosphodiesterase
Pasture	Foothill typical sierozem soils	0-2	176,2	594,3	303,6
		2-13	81,8	285,5	177,7
		13-44	21,0	72,7	53,4
		44-86	2,4	20,5	11,5
		86-170	1,3	9,6	5,3
Pistachio woodland,	Typical sierozem soils	0-2	286,4	1021,5	560,9
		2-14	22,9	67,3	17,6
		14-52	17,9	59,0	33,7
		52-105	12,0	36,0	26,0
		105-165	2,8	6,6	8,0
Arable land (cotton), Suzak	Irrigated sierozem soils	0-14	228,9	162,1	83,4
		14-30	42,7	84,5	53,9
		30-50	31,5	80,4	67,7
Walnut-fruit forests	Mountain forest black-brown soils	0-4	712,7	1809,8	714,2
		4-18	897,7	757,8	754,5
		18-57	272,5	283,9	225,9
		57-91	59,8	27,7	41,7
		91-130	27,7	18,7	11,9
		130-185	18,0	8,1	15,4

Table 3: Activity of the enzyme arylsulfatase in sierozem and mountain-forest black-brown soils of Kok-Art river basin of Jalalabat region(mg p-nitrophenol kg^{-1} soil hour^{-1})

Land use	Soil types	Horizon	Depth, (cm)	Organic substance, %	Total Nitrogen, %	Arilsul-phatase
Pasture	Foothill typical sierozem soils	A_0	0-2	2,13	0,15	81,3
		A_1	2-13	1,49	0,12	34,9
		AB	13-44	0,60	0,10	18,4
		B	44-86	0,23	0,04	3,5
		C	86-170	0,21	0,04	2,4
Pistachio woodland,	Typical sierozem soils	A_0	0-2	3,55	0,46	115,4
		A_1	2-14	0,96	0,08	5,3
		B_1	14-52	0,74	0,08	8,7
		$B_к$	52-105	0,42	0,05	8,1
		C	105-165	0,22	0,04	1,7
Arable land (cotton), Suzak	Irrigated sierozem soils	A	0-14	0,79	0,07	23,4
		A_1	14-30	0,64	0,06	14,0
		B	30-50	0,52	0,14	9,1
Walnut-fruit forests	Mountain forest black-brown soils	A_0	0-4	16,13	1,88	498,9
		A_1	4-18	12,5	0,84	439,2
		A_2	18-57	5,51	0,38	158,3
		AB	57-91	2,06	0,13	15,3
		B	91-130	1,37	0,14	4,8
		C	130-185	1,23	0.08	2,2