International Journal of Advances in Applied Sciences (IJAAS)
Vol. 14, No. 1, March 2025, pp. 77~85
ISSN: 2252-8814, DOI: 10.11591/ijaas.v14.i1.pp77-85

Main eco-properties of hazelnut (*Corylus avellana* L.) on the Sheki-Zagatala economic region

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Article Info

Article history:

Received Jul 16, 2023
Revised Oct 20, 2024
Accepted Oct 23, 2024

Keywords:

Diagnostic edificators
Fertility
Leaf nutrient
Microbial biomass
Microbiological composition
Quality of nuts
Representative soils

ABSTRACT

The aim of the study is to determine leaf nutrients, the number of ecological-trophic groups of microorganisms and the structure of microbial communities, microbial biomass ratios, and soil parameters in the upper soil horizons in the territory of the Sheki-Zagatala economic region from five representative hazelnut gardens located in the hazelnut producing villages of Katex, Darvazbina, Boyuktala (Balakan region), and Car, Galal (Zagatala region). Has been reported that soils with slightly acidic reactions are ideal for hazelnut cultivation. Hazelnut trees in Azerbaijan have sustainable and nutritious characteristics. They grow naturally without using any chemical fertilizers and pesticides. The soil fertility of the orchards is a key factor affecting the yield and quality of nuts. The number of microorganisms at 0-15 cm in spring was $10.059 \cdot 10^3$, $7.786 \cdot 10^3$ bacterias, $3.009 \cdot 10^3$ ray fungi, and $73 \cdot 10^3$ other microscopic fungi. In moderately eroded areas, the total number of microorganisms in spring was $8.927 \cdot 10^3$, bacterias $5.895 \cdot 10^3$, ray fungi $1.874 \cdot 10^3$, and other microscopic fungi 68 10^3. In non-eroded fertile soils, the number of microorganisms at a depth of 0-15 cm in autumn was $8.020 \cdot 10^3$ bacteria, $5.246 \cdot 10^3$ bacteria, $1.789 \cdot 10^3$ radiant fungi, and $5.8 \cdot 10^3$ microscopic fungi. The nitrogen (N), phosphorus (P), and potassium (K) contents of tree leaves in each variant ranged from 0.49-1.07, 0.16-0.36, and 0.58-1.49%, respectively, with average values of 0.73, 0.21, and 1.03%.

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1. INTRODUCTION

Hazelnut is a type of temperate climate fruit, so it is very sensitive to high temperatures and frosts. Natural hazelnut forests occupy mountainous and foothill areas with adjacent lowlands. *Corylus avellana* L. prefers deep, fertile, loamy, moist, and carbonate soils, although it tolerates rocky soils, provided they are sufficiently humus-rich and moisture-rich. There is very little specific quantitative information on the response of hazelnut trees to the properties of rocky soils and it relates to regions with a humid climate. Organic matter

is very important for tree nutrition, root health, and drainage. The amount of organic matter required for the soil in hazelnut cultivation is 4-6% [1], [2]. A wide variety of hazelnut species grow in Azerbaijan, and its production occupies an important place in the country's economy. It is obvious that such plantings do not satisfy the growing demand for hazelnut raw materials. This issue can be resolved by planting industrial hazelnut orchards on rocky soils, mainly, but based on scientifically sound recommendations. The nutritional quality and yield of hazelnut kernels are affected by many factors, including varieties, location conditions, and cultivation methods, with soil fertility being the main limiting factor for hazelnut kernel production. Currently, a significant share of hazelnut production occurs in the northern regions of Azerbaijan, and much attention is paid to issues of soil fertility and fertilization of these gardens [3]–[6]. In the hilly Balakan region fertilizers have been shown to increase soil organic matter content by 50.30-61.1% improve the soil's capacity to supply nitrogen (N), phosphorus (P), and potassium (K), and reduce nitrogen leaching and volatilization. Hazelnut as a cultivated hazel is the result of a certain hybridization of the common hazel, which grows well on forest soils. The main thing is that the soil contains calcium and magnesium, which these plants need. If the pH is less than 5.5, it is worth thinking about melioration, that is, liming, and if it is more than 8, it is probably not worth growing hazelnuts, since the availability of microelements in the soil for it is sharply reduced, especially boron and zinc, and there are also likely to be signs of salinization, which this plant does not tolerate. Note that if you need to lime acidic soils, it is better to use magnesium-containing ameliorants (dolomite), since hazelnuts are sensitive to magnesium deficiency. In its exactingness to the reaction of the soil solution and the obligatory content of calcium and magnesium in the soil, hazelnuts to some extent resemble plums [7]–[9].

Hazelnut as a descendant of a mycotrophic plant of forest cenoses grows better in conditions of mycorrhizal symbiosis, that is, in cooperation with certain fungi. The hyphae of the latter significantly increase the area of contact of the root system with the soil, improve the absorption of nutrients from the soil, especially phosphorus, and stimulate the development of plants due to the formation of specific substances, in particular growth hormones. For mycorrhization of plantings, it is necessary to mycorrhizae, practically infect, the correct term to inoculate the root system of nut plants with fungi. For this, it is not necessary to take soil or water extract from the soil under the forest hazel [9], [10]. This affects the nutrient content of leaves and the accumulation of photosynthetic products. Hazelnuts should be picked only when they are fully ripe and when they have accumulated the greatest amount of nutrients (fat and protein). Unripe fruits, picked during the so-called "milk period", do not keep well and produce an incomplete "frail" kernel. As the fruits ripen, they acquire a darker color and a distinctive nut aroma. The cup dries out, and the nut gradually comes free from the wrapper. The kernel of a mature, full-fledged nut usually fills the entire fruit. Picking nuts is not particularly difficult and is done by picking the fruits directly from the plant if it is low-growing, or by shaking the fruits off a tall plant [6], [8].

Soil assessment: *Planctomycetes, Bacteroidetes, Nitrospirae*, and *Gemmatimonadaletes* are relatively rare. Although the texture classes of the soils vary, it was determined that the total samples were 40% clayey, followed by 25% clayey loam and 15% loamy. The pH of the soil samples was from 5.5-6.9 and it was determined that it ranged from moderately acidic to slightly alkaline. It was determined that 10% of the soil samples were moderately acidic, 22.5% neutral and 62.5% slightly acidic. It has been determined that all the soils subject to the research are salt-free. Irrigated agriculture should specialize in valuable crops such as *Corylus avellana* L. [7]. The relief of the southern slopes of the Greater Caucasus Mountains, the richest regions of the Republic of Azerbaijan, is divided into high-mountain, mid-mountain, and foothill parts [11]. Soil assessment: bonitet 87 points. The thickness and hardness of the grass cover is 7-10 cm. The layer where the root system extends is 10-30 cm. Granulometric composition is <0.001 mm 10-24%; <0.01 mm 40-50%. Structure of layer a granular-globular. Humus layer thickness is 12-20 cm. The layer and form of distribution of gypsum crystals is 90-100 cm [12]. A high concentration of salts is toxic not only for the hazelnut but also for all vegetation - it completely dehydrates their tissues. On saline and alkaline soils, the walnut is small and oppressed. The main ecological factors for cultivated varieties of walnut are moderate, calcareous loam, all types of chernozems, and gray forest soils [13], [14]. The frost-free period is 235-265 days. The area is mainly used as pasture. Ephemeris, ephemerides, wormwood, and perennial xerophytic herbs are common. *Nubian acacia, Corylus maxima, Malus, Tamarix, Calligonum elantum, Calligonum arbarences, Juniper, Astragalus microcephalus, Astragalus picnophyllus, Pistacia mutica, Olive, Fig, Common acacia, Common wormwood, Asparagus, Echinacea paradoxa, Echinacea angustifolia, Geum rivale* L., *Geum urbanum* L., *Ginseng, Ephedra, Populus alba, Prinus divaricata, Ficus carica, Cerasus avium, Paliurus* L., *Fagus* L., *Ulmus* L., *Mespilus L., Crataegus* L., *Cornus mas, Punica granatum, Vassilium vitis, Juglans regia, Castanea M., Rhus* L., *Pinus* L., *Pterocarya K.* are widespread [15]–[17]. The southern part of the territory is used for woodlands and shrubs, and the northern part is used for irrigated agricultural crops (Figure 1). The decomposition of polysaccharides by microorganisms in soils was assessed by the intensity of carbon dioxide emission, by the dynamics of the number and biomass of bacteria, and also by the length of the mycelium of fungi and actinomycetes. The emission of carbon dioxide from soil samples was studied on a gas chromatograph with an

electron capture detector. CO_2 in the samples was assessed one day after incubation at various temperatures and water content [14], [18], [19].

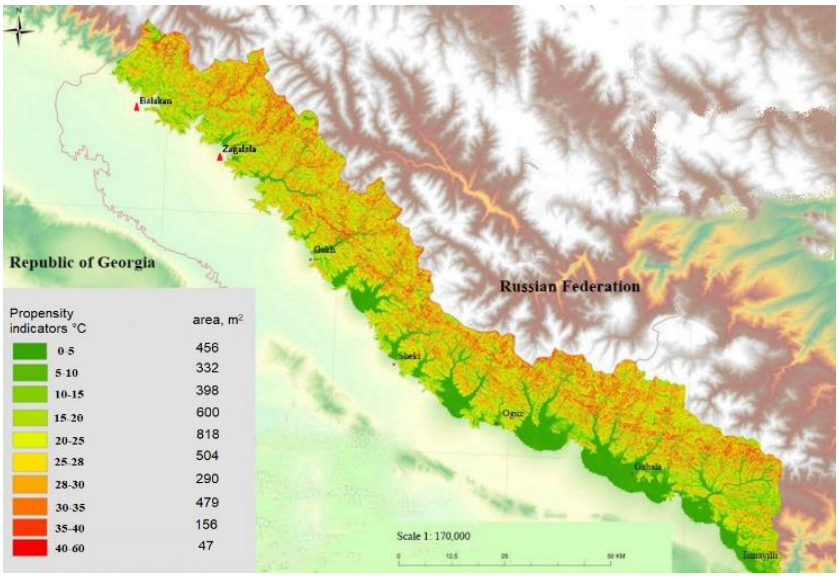

Figure 1. Research territory in the Great Caucasus area

2. RESEARCH METHOD

These representative hazelnut gardens have not been affected by chemical fertilizers and pesticide spraying. To minimize sampling errors, trees of similar growth were selected from five orchards to collect soil and leaf samples using a multi-point sampling strategy. Soil profiles with a depth of 50 cm were collected at a distance of 35 cm from the line. Figure 2 shows soil samples, soils' first and second horizons were collected and mixed by the quartering method. Five replicates (total of 35) from each garden were transported to the laboratory after removing plant debris, sand, and stones, dried, crushed to pass through 0.85 and 0.15 mm sieves, and stored in sealed bags for soil nutrient determination (Figures 2(a)-(e)). In the process of sampling the leaves of trees, mature and stable leaf samples were collected from the middle part of the outer trunk in the directions of east, south, west, and north, and then mixed. Approximately 550 g (20 samples) of leaves were collected from each tree. The leaves were washed with distilled water, placed in an oven to destroy chlorophyll at 105 °C for 22 minutes, and then dried to constant weight at 50 °C. Leaves were crushed to pass through a 0.15 mm sieve and stored in sealed bags for leaf nutrient analysis. The studies were carried out on virgin soils of natural cenoses. The object of study is the territory of the southern slope of the Greater Caucasus Kastanozems and Irragri Kastanozems. At the sampling points for microbiology analysis, the weeds are cleaned by digging and a 50 cm deep V-shaped pit is opened. Leaf samples should be taken 10-15 days before the hazelnut harvest, usually in the second half of July. If there are different hazelnut varieties in the garden, separate samples should be taken for each variety and should not be mixed with each other. If the garden differs in terms of soil characteristics, samples have to be taken separately from each different place. Leaves that have been eaten, torn, or damaged by any insect should not be taken. Big gardens (20 ha) have to be divided into two, for sampling should be done [8], [20]–[23].

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(a) (b) (c) (d) (e)

Figure 2. Soil samples of (a) Car village, (b) Galal village, (c) Darvazbina village, (d) Katex village, and (e) Boyuktala village, figures b and c have been sieved with 0.85 mm aperture sieve in candlenut orchard

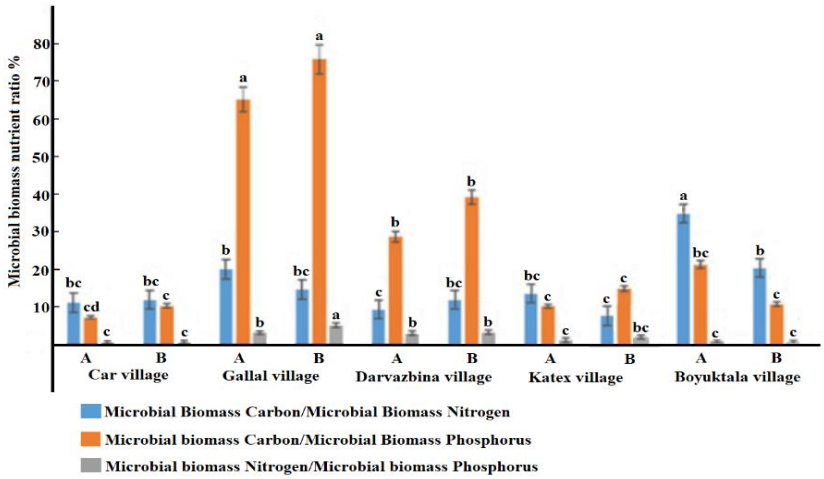
3. RESULTS AND DISCUSSION

Examples are from hazelnut gardens located in the hazelnut-producing villages like Katex, Darvazbina, Boyuktala (Balakan region), and Car, Galal (Zagatala region) in 2022-2023. It has been reported that soils with slightly acidic reactions are ideal for hazelnut cultivation. 25 soil samples were taken from hazelnut orchards in Balakan region. Achieving quality products and high yields in agriculture is possible by the amount of plant nutrients in the soil and at the same time, the presence of these elements in the soil in balanced proportions.

In microbiological studies, microbiological processes in soils are characterized by extreme dynamism [24]. The overwhelming majority of microorganisms live in the forest litter and humus horizon, and in the podzolic horizon, the number of microorganisms is sharply reduced. As we move from the southern climate to the colder northern climate, the number of soil microorganisms decreases. Microbiological studies were carried out in the spring and autumn of the 2022-2023 year. During the summer, the number of ammonifiers decreases, since most of the organic matter has decomposed, and the proportion of nitrifiers and oligonitrophils increases, and nitrification of ammonium nitrogen occurs. The remains of organic matter are subject to further decomposition, and the percentage of mineralization decreases by the spring of the following year, while the number of ammonifiers also decreases.

The intensity of nitrification is significantly lower than the intensity of ammonification [25]. As a number of researchers indicate, in soils under hazelnuts, the prevalence of ammonification processes is due to the peculiarities of the hydrothermal regime of the soils, the reaction of the soil solution, the composition of organic matter, and the presence of specific products of litter decomposition (wax resins and lignins). The microbiological composition was determined under laboratory conditions by classical methods of soil microbiology (in an agar medium with meat peptone). The activity of microorganisms has a great influence on the erosion process in the soil. To determine the structure of soil microbial complexes during the decomposition of cellulose, we used the initiating microbial shaking method by hydration and the introduction of the corresponding polysaccharides [19]. The contents of biomass in different soil horizons of five hazelnut gardens are shown in Figures 3 and 4.

The nutrient content of leaves is an important indicator for nutrient diagnosis of fruit trees. From the results shown in Figure 5, the soils obtained from different parent materials had significant effects on the plant nutrient contents of hazelnut leaves. Leaf analysis is more useful in determining mineral deficiency and toxicity in hazelnut cultivation. The mineral content in the plant depends on history, soil structure, climate, irrigation, and root activity. The inadequacy of the soil or the inability of the roots to absorb minerals directly affects the development of the plant (Figure 5).



Note: a; b; c for the same item indicates significant differences at p <0.05

Figure 3. The microbial biomass ratios in different soil layers

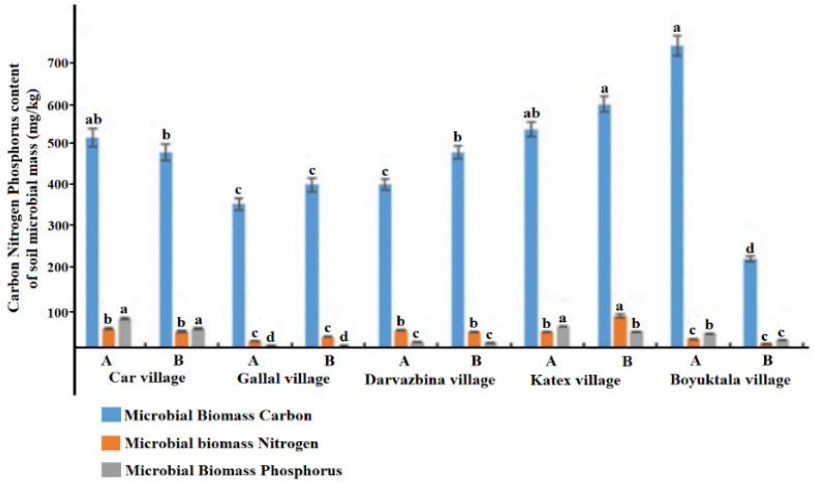
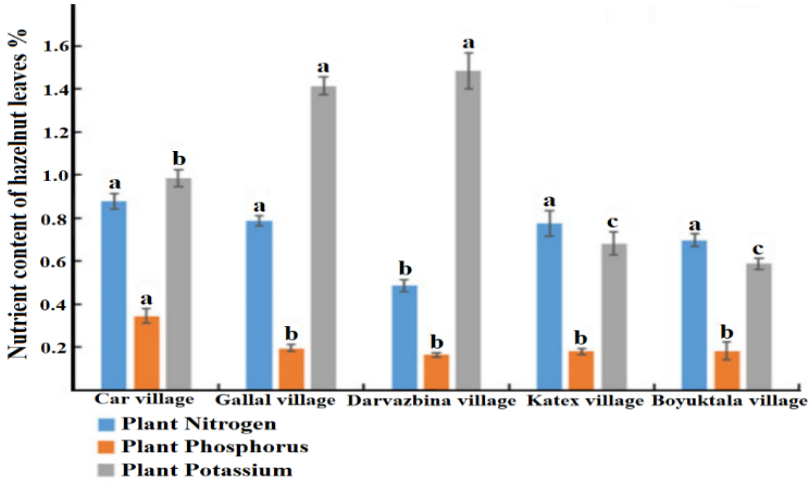


Figure 4. Soil layers of representative hazelnut garden (effect of microbial activity)



Note: a; b; c element indicates significant differences at p <0.05

Figure 5. Leaf nutrients in hazelnut garden

This approach makes it possible to identify and calculate the number of particular phylogenetic groups of microorganisms in samples of different natures. It is widely applied in modern studies of microbial communities in freshwater ecosystems, peat, rhizosphere, and other natural and anthropogenic media [26]. Hazelnut bushes are 2.5 m high and are grown in greenhouses. The porosity is quite high, the soil particles are suitable for the passage and accumulation of rainwater and air molecules, it is very fertile, and indispensable for agriculture with the use of modern technologies and the development of the agricultural industry. Since these are dark brown soils, they dry well under laboratory conditions. The studied soils consist of sand by 11.92%, silt, and silt by 24.34%, and clay fraction of 63.74%, according to the class of mechanical composition they are called clayey. *Proteobacteria, Actinobacteria, Acidobacteria, Firmicutes, Chloroflexi* are dominant under *huzelnuts. Verrucomicrobia, Planctomycetes, Bacteroidetes, Nitrospirae, Gemmatimonadaletes*, and others are relatively rare (Figure 6). Characterization of the structure of micromycetes registered in the course of research in terms of frequency of occurrence made it possible to identify dominant, frequent, random, or rare species both in general and in individual biotopes. Soil moisture had the most significant effect on the intensity of utilization by microorganisms compared to the use of fiber. *Aspergillus niger* incidence of fungus is 60.0% in soils under hazelnut, 56.4% in irrigated soils, and 50.6% in natural cenoces soils. The silty fraction of gray-brown soils is characterized by a lower content of SiO_2 compared to the soil as a whole, with an increased amount of sesquioxides. The clay fraction in the soil horizons contains less SiO_2, but more Fe_2O_3 and Al_2O_3 in the most clayey horizons, indicating the accumulation here, although insignificant, of sesquioxides. The study of gray-brown soils involved in agricultural production showed that along with gray-brown dark, ordinary light, slightly alkaline, and calcareous soils, developed, cultivated, cultivated and planted soils stand out. Agriculture on the studied soils has great prospects for irrigation, which should be combined with the construction of engineering hydraulic structures and effective reclamation devices since these soils are almost always at risk of secondary salinization. The size of river runoff and water reserves in the southern slopes of the Greater Caucasus does not prevent an increase in irrigated areas in some areas: in a number of places, it is expedient to use groundwater, including artesian pressure. Hazelnuts begin to bear at approximately two years old and at six years yields should approach 2-2.5 kg/tree. Mature trees grown without irrigation or fertilizers can produce 15-20 kg/tree. With intensive management, yields can be up to 40 kg/tree. Soil assessment: bonitet 87 points.

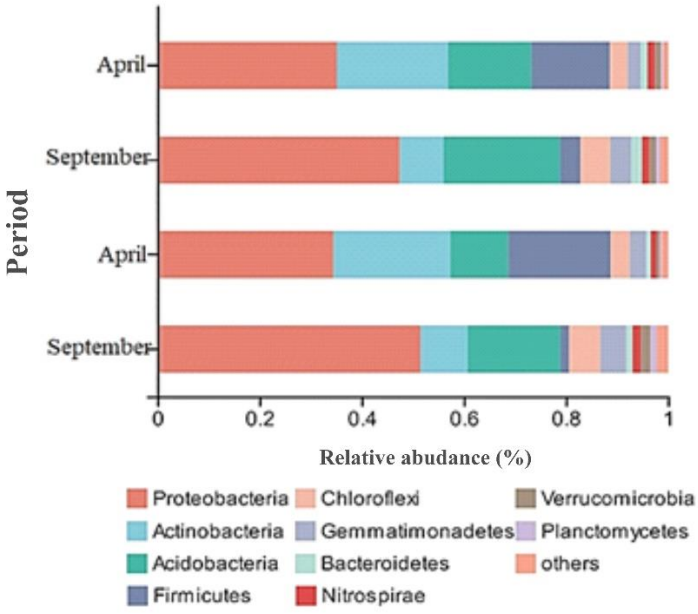


Figure 6. Relative abundance of bacterial biota in soils under the crop

4. CONCLUSION

Elements are found in low amounts in the soil and are added to the structure by the plant's roots. This is a one-way movement and occurs with the help of water. If the elements added to the plant's structure with water are not sufficient, the plant root tries to take in nutrients with the help of diffusion. If there are enough

nutrients in the soil, the plant meets its needs. If there is an excessive amount of nutrients in the soil, the plant is exposed to this and toxic substance accumulation can be seen in the plant in the long term. Toxic substance accumulation means that an element is found in excessive amounts in the plant's circulation and poisons the plant accordingly. The most important point to prevent excessive accumulation is to analyze water, soil, and leaves and constantly control these two sources. Comprehensive research allows for obtaining accurate information about the ecological state of the soil and using it in agriculture. The highest number of microorganisms was identified on the 8^{th}-15^{th} days of the experiment. CO_2 emission from soils treated with the studied polysaccharides increased significantly in all experiments and at all studied soil moisture rates compared to the control options. Soil moisture had the most significant effect on the intensity of utilization by microorganisms compared to the use of fiber. Car village had the highest N and P contents of leaves with 0.87 and 0.36%, while Darvazbina village had the lowest N and P contents with 0.49% and 0.16%. The K content of leaves was the highest in Galal and Darvazbina villages, 1.42 and 1.48% respectively, while Darvazbina village had the lowest K content, only 0.59%. The nutrient content of leaves showed that the soils formed from alluvial parent rocks were favorable for N and P accumulation in leaves, while the mountain meadow soil was favorable for K accumulation but the N and P content was relatively low.

ACKNOWLEDGMENTS

The authors express gratitude for the research project to the ISSA of the MSEA and BSU. The authors are also grateful to the Azerbaijan Forest Service in the Balakan and Zagatala regions for assistance during fieldwork.

REFERENCES

[1] E. A. Paul, *Soil microbiology, ecology and biochemistry*, 4th ed. Colorado: Elsevier, 2015. doi: 10.1016/C2011-0-05497-2.
[2] J. W. Doran and M. R. Zeiss, "Soil health and sustainability: managing the biotic component of soil quality," *Appl. Soil Ecol.*, vol. 15, no. 1, pp. 3–11, Aug. 2000, doi: 10.1016/S0929-1393(00)00067-6.
[3] M. P. Babayev, V. H. Hasanov, and S. M. Huseynova, *Morphogenetic characteristics, nomenclature, and taxonomy of the soils of azerbaijan*. Baku, 2011.
[4] P. S. Ahmed, "Complexes and bioenergy of invertebrates in oil-polluted gray-brown soils of absheron," *Int. J. Adv. Appl. Sci.*, vol. 13, no. 1, p. 141, Mar. 2024, doi: 10.11591/ijaas.v13.i1.pp141-147.
[5] A. N. Ikhtiar, "Modern and comprehensive soil studies in grape agrocenoses in azerbaijan," *Int. J. Adv. Appl. Sci.*, vol. 13, no. 2, p. 217, Jun. 2024, doi: 10.11591/ijaas.v13.i2.pp217-224.
[6] U. Gadiyeva, G. Mammadova, T. Babayeva, A. Mikayilov, and A. Mammadov, "The main characteristics of the application of perennial herbs and mineral fertilizers in increasing the fertility of eroded gray brown soils in the mountainous shirvan," *J. Surv. Fish. Sci.*, vol. 10, no. 2S, pp. 1175–1180, 2023, [Online]. Available: https://sifisheriessciences.com/journal/index.php/journal/article/view/818/798
[7] S. M. Talibi and T. A. Hasanova, "Environmentally significant indicators of mountain meadow soils in azerbaijan," *Bull. Nizhnevartovsk State Univ.*, vol. 57, no. 1, pp. 102–107, Jan. 2022, doi: 10.36906/2311-4444/22-1/11.
[8] G. Mammadova, A. Gahramanova, L. Bunyatova, T. Babayeva, and L. Huseynova, "Determination of main properties and fertility capacity of soils under hazelnut cultivation in azerbaijan," *Proc. Bulg. Acad. Sci.*, vol. 77, no. 4, Apr. 2024, doi: 10.7546/CRABS.2024.04.18.
[9] H. T. Allahverdi, "Complexes (ecogroups) of the invertebrates, phytomass and dynamics of microbiological population and their importance at grey-brown soils diagnostics in azerbaijan," *Univers. J. Agric. Res.*, vol. 3, no. 4, pp. 130–134, Jul. 2015, doi: 10.13189/ujar.2015.030403.
[10] H. T. Allahverdi, M. G. Israphil, B. L. Novruz, and G. A. Yarish, "Importance of biodiagnostics and irrigation gray-brown soils," *Univers. J. Agric. Res.*, vol. 9, no. 3, pp. 63–69, Jun. 2021, doi: 10.13189/ujar.2021.090301.
[11] T. Hasanova, G. Mammadova, and G. Asgarova, "Phytomass of gray-brown soils forming in arid ecosystem of azerbaijan," *Bull. Sci. Pract.*, vol. 7, no. 9, pp. 110–115, Sep. 2021, doi: 10.33619/2414-2948/70/11.
[12] T. Hasanova and G. Mammadova, "The impact of changes in soil moisture indicators on biological activity in recent years on the southern slope of the greater caucasus," *Nat. Sci.*, vol. 5, no. 3, pp. 7–12, Mar. 2023, doi: 10.36719/2707-1146/30/7-12.
[13] V. G. Gasanov, "Environmental genetic features and diagnosis of alluvial marsh marled soils in the dry-steppe subtropical zone of the kura floodplain," *Russ. Agric. Sci.*, vol. 43, no. 3, pp. 249–254, May 2017, doi: 10.3103/S1068367417030077.
[14] A. Yadav, V. K. Suri, A. Kumar, A. K. Choudhary, and A. L. Meena, "Enhancing plant water relations, quality, and productivity of pea (pisum sativum l.) through arbuscular mycorrhizal fungi, inorganic phosphorus, and irrigation regimes in an himalayan acid alfisol," *Commun. Soil Sci. Plant Anal.*, vol. 46, no. 1, pp. 80–93, Jan. 2015, doi: 10.1080/00103624.2014.956888.
[15] IUSS Working Group WRB, "World reference base for soil resources 2014, update 2015 international soil classification system for naming soils and creating legends for soil maps," Rome: Italy, 2014. [Online]. Available: https://www.fao.org/3/i3794en/I3794en.pdf
[16] A. M. Oqtay, R. M. Nazim, and N. A. Dursun, "Ecological assessment of pastures semi-deserts and dry steppes of azerbaijan," *Int. J. Adv. Appl. Sci.*, vol. 13, no. 2, p. 439, Jun. 2024, doi: 10.11591/ijaas.v13.i2.pp439-446.
[17] A. Ismayilov and F. Mikailsoy, "Mathematical models of fertility for the soils of azerbaijan," *Eurasian J. Soil Sci.*, vol. 4, no. 2, p. 118, Apr. 2015, doi: 10.18393/ejss.89702.
[18] N. A. I., M. R. N., A. M. M., and H. T. A., "Bioecological edificators of gray-brown soils in ganja-gazakh massif (azerbaijan)," *Environ. Ecol. Res.*, vol. 10, no. 3, pp. 392–397, Jun. 2022, doi: 10.13189/eer.2022.100307.
[19] L. V.T., P. S.A., and Z. A.I., "Soil and biological aspects of a biologization of modern agriculture," *Russ. J. Agric. Socio-Economic Sci.*, vol. 49, no. 1, pp. 67–72, 2016, [Online]. Available: https://ideas.repec.org/a/scn/031261/16401807.html
[20] D. L. Rowell, *Soil science*. Routledge, 2014. doi: 10.4324/9781315844855.

[21] W. Ding, Y. Cai, Z. Cai, K. Yagi, and X. Zheng, "Soil respiration under maize crops: effects of water, temperature, and nitrogen fertilization," *Soil Sci. Soc. Am. J.*, vol. 71, no. 3, pp. 944–951, May 2007, doi: 10.2136/sssaj2006.0160.
[22] G. V. Dobrovol'skii, "Soil classification principles: soil bodies and the environment," *Eurasian Soil Sci.*, vol. 38, no. 1, pp. S1–S5, 2005.
[23] S. H. Maharram, A. I. Ismayil, M. B. Pirverdi, and A. J. Musa, "Taxonomic attribution of the haplic gleysols of the azerbaijan republic in world reference base for soil resources," *Int. J. Adv. Appl. Sci.*, vol. 13, no. 1, p. 116, Mar. 2024, doi: 10.11591/ijaas.v13.i1.pp116-122.
[24] D. C. Coleman, M. A. Callaham, and D. A. C. Jr., *Fundamentals of soil ecology*, 3rd ed. Academic Press, 2017.
[25] M. M. Howard, T. H. Bell, and J. Kao-Kniffin, "Soil microbiome transfer method affects microbiome composition, including dominant microorganisms, in a novel environment," *FEMS Microbiol. Lett.*, vol. 364, no. 11, Jun. 2017, doi: 10.1093/femsle/fnx092.
[26] D. Strickler, *The complete guide to restoring your soil*. Storey Publishing, LLC, 2021.

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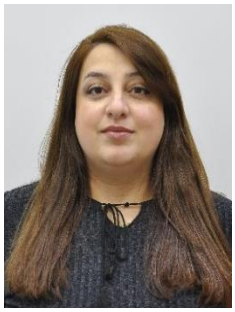

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