International Journal of Advances in Applied Sciences (IJAAS)
Vol. 13, No. 2, June 2024, pp. 217~224
ISSN: 2252-8814, DOI: 10.11591/ijaas.v13.i2.pp217-224

Modern and comprehensive soil studies in grape agrocenoses in Azerbaijan

Anara Ikhtiar Nasirova
Department of Soil Biology, Ministry of Science and Education of the Azerbaijan Republic, Institute of Soil Science and Agrochemistry, Baku, Azerbaijan

Article Info

Article history:

Received Oct 19, 2023
Revised Dec 9, 2023
Accepted Jan 17, 2024

Keywords:

Fertilization
Irrigation systems
Microflora
Soil protection
Soil-ecological monitoring

ABSTRACT

The article presents some results of a comparative analysis of the agrochemical, microbiological, and environmental properties of grape plants and soil types common in regions located on the slopes of the Lesser Caucasus. The objectives of this study were to assess the current state and quality of soils used for vineyards in some villages of the Ganja-Kazakh economic region, taking into account the long-term use of fertilizers and chemicals to protect plantations from various diseases for the resulting wine materials. Growing and exporting grapes is of great importance for the development of the economy of the Republic of Azerbaijan. Since it is a break-even plant, expanding the area under grapes to attract wetlands to agriculture has been an important issue for soil scientists in recent years. During the period of rapid development of viticulture in the republic, ensuring rapid harvesting and longevity of vineyards is one of the important scientific and practical tasks.

Corresponding Author:

Anara Ikhtiar Nasirova
Department of Soil Biology, Ministry of Science and Education of the Azerbaijan Republic,
Institute of Soil Science and Agrochemistry
Mammad Rahim str.5. Az1073, Baku, Azerbaijan
Email: anara.nasirova@inbox.ru

1. INTRODUCTION

Since soils are one of the most important components of the ecological environment, the problem of soil protection, organizing constant monitoring of their condition, in short, creating soil monitoring is also very important from an environmental point of view. Currently, in most countries of the world, the area of agricultural land is decreasing, soil fertility is decreasing, and its condition is deteriorating. Managing the processes of soil degradation and reproduction requires comprehensive soil-ecological monitoring, which is a system of observations of the ecological state of soils for rational use and protection of soils. The Ganja-Kazakh economic region is located in the western part of the Republic of Azerbaijan, on the northern slopes of the Lesser Caucasus [1]–[4]. The territory has a favorable economic and geographical position and is 12,482 thousand km^2, which is 14.4% of the country's territory. As a result of the research, it was established that as a result of natural and anthropogenic processes, significant damage was caused to the natural resource potential of the economic region, and as a result, damage was caused to the ecological environment of the region. The vegetation is dominated by shrubs (hawthorn, blackthorn, wild grapes, wormwood, hemlock, sedge), poplar, willow, and oak.

According to the State Statistics Committee of the Republic of Azerbaijan for the year 2023 the 178.317 ha cultivation (CULT) area was destroyed in the country due to water shortage, drought, and natural disasters (heavy rain, floods). More than $160 \cdot 10^3$ ha of land have been destroyed due to water shortage and drought. According to the information provided by the Azerbaijan Agrarian Services Agency, the natural disasters that occurred until September 28 of the current year affected a total area of $11.2 \cdot 10^3$ ha. This is why the latest soil research and the latest data are very important. Solving problems associated with land degradation is associated with improving technologies for protecting and increasing the biological productivity of agricultural land, developing land management, land use, and land protection, and creating effective organizational and legal mechanisms for managing agricultural land. An effective solution to these problems is based on the development of a system of state land monitoring and the formation of state information resources, as a result of obtaining timely and relevant information on the condition of soils. Currently, a system of soil-ecological monitoring has been formed in our republic, the scientific foundations of which were laid and developed in the works of G.Sh. Mammadov and other scientists. The Ganja-Kazakh economic region is considered one of the regions of Azerbaijan that has been heavily exposed to anthropogenic impact for a long time [5]–[9]. Since the soil and climatic conditions of this area are very suitable for agricultural use, intensive farming is carried out here, grapes, grains, vegetables, and other crops are grown. Among the pressing problems of modern winemaking is the production of environmentally friendly wine products with high nutritional, dietary, therapeutic, and prophylactic properties. Growing organic grapes is associated with many factors and requires an integrated approach, taking into account its specifics and development prospects. Solving this problem will help improve the stability of production, quality, and safety of the resulting grape products. The root system of the grapevine covers a large volume of soil and penetrates to a considerable depth. The roots go deep into the soil by 60-100 cm, and the bulk of the roots of all sizes, including the most active part, are developed below the arable layer (20-60 cm). Horizontal excavations have shown that the vines in Ganja have a large radius of extension, averaging 3 to 6 meters. With this nature of the development of the root system and grapevine, soil CULT must be carried out no deeper than 18 cm to avoid damage to the roots by agricultural methods. Vineyards are a perennial ampelocenosis, CULT in the same place for 20 years or more. In this regard, grape plantations are one of the most pesticide-intensive agrobiocenoses. Pesticides, repeatedly used in each season in order to protect the crop from pests or pathogens, remain in the ecosystem objects-soil, plants, and water bodies. A fruit vine is a shoot that has completed a full cycle of summer development [10]–[15]. The vines overwinter, carrying next year's harvest in their buds. In April, shoots with a harvest will emerge from the vines. And until they ripen, they are still vines. The shoots ripened-they became vines-and the vine became a branch.

Morphological characteristics. The morphological characteristics of the soil profile in the selected area in the Ganja region differ significantly from the structure of the soil profile described in previous years. The terrain consists of foothill plains. The soil-forming rocks are a mixture of alluvial-proluvial sediments with colluvial carbonate clay. AY'ai.z 0-24 cm; Dark grayish (4-5 days after watering), silty-sandy, sandy, aggregated, plant residues, many traces of insects and worm enzymes, soft, moist, slightly boiling under the influence of 10% HCl. AY" ai.z 24-45 cm; The granulometric composition is slightly thickened, it has a sticky-clay-like structure, and traces of insects and worm enzymes are relatively small. Bca 45-69 cm; The color is gray-brown when wet, light grayish when dry, dusty, and highly granular, the structure is quickly disrupted, and weak silty, fringed plant roots are observed. B/Ccap 69-85 cm; It differs from the previous layer in its light color, sandy-grain granulometric composition, poor structure formation, and increased boiling due to the influence of 10% HCl. Sandy-coarse deluvial-proluvial deposits with small pebbles and weak carbonate content. Ccap 85-106 cm; Sandy-granular deluvial-proluvial deposits with small pebbles and weak carbonate content. A comparative analysis of the studies shows that, in comparison with irrigated gray-brown soils, which have been used for a long time under grape plantations in the Ganja-Kazakh massif, in irrigated variants of gray-brown soils under various agricultural crops in the region, the agro-irrigated accumulative layer is relatively high, and the amount of humus is a significant minority. However, the movement of humus to a depth of 65-75 cm (1,3-1,8%) due to long-term irrigation and regular intensive agrotechnical measures is confirmed by the results of the analysis along with the morphological picture.

2. RESEARCH METHOD

The choice of route for agrochemical mapping was largely determined by the configuration of the field. Soil samples were studied in laboratory conditions, followed by their physicochemical analysis and processing by methods of variation statistics. The experiment was carried out on a site with 55 rows of 10-year-old vines in each section, with an area of 1.6-1.8 hectares. For analysis, plant samples were taken from leaves, stems, and leaves of bushes. 80 soil samples were collected from all genetic horizons.

The combined sample is made up of many point samples (individual samples) taken evenly from the entire area of an elementary section of the field. These agrochemical analysis data apply to the entire area of the control plot of the field from which mixed samples are taken, so this elementary plot can be assessed by the level of provision with macro and microelements, uniformity of fertilizer application, soil and microclimatic parameters, taking into account the intended purpose of agricultural land [16]–[18]. Before fertilization, to study the agricultural field, soil samples were taken from a depth of 0-130 cm in the field area, mixed at horizons and 1 kg, and the soil samples were dried in the laboratory. Laboratory analyses of soil and plant samples were carried out in accordance with accepted methods. The amount of humus, pH of the water extract, calcium oxides by complexometric titration, the total nitrogen content during wet ashing-by the Kjeldahl method, and potassium and phosphorus oxides-using a plasma photometer were determined. Humus Tyurin I.V. method, water-soluble ammonia Konev D.P. Nitrate nitrogen was determined by the Grandval-Lyaju method, total nitrogen in plant and soil samples, Ginzburg K.E., total phosphorus Seglova G.M., free phosphorus Machigin B.P., non-protein nitrogen EV74 ionometer [19], [20]. During flowering (2021 and 2022) and harvest (2021, 2022, and 2023), ten soil cores per experimental unit were collected using sterile cores (6 cm dm×10 cm depth) attached to an auger with a sliding hammer in the form grids samples of grape bunches were taken during commercial harvest using individual sterilized blazers for each experimental unit. Ten clusters were randomly selected from each experimental unit. Subsamples from each experimental unit were pooled in sterile containers in the field, transported on ice, and stored at 20 °C until further analysis. A soil sample from each experimental unit was thawed at room temperature, completely homogenized, and then 0.25 g of soil was carefully removed, avoiding any non-soil particles [21], [22]. The analysis is recommended to be carried out a year before planting a new vineyard, this allows time to make changes and apply fertilizers before planting. Once planted, it becomes increasingly difficult to change the soil pH and levels of many elements because it is extremely difficult to work fertilizer into the soil without damaging the vine roots. Soil testing is also recommended every 3-5 years for older plantings to complement leaf assessment. Soil analysis is carried out a year before planting, then during significant procedures in working with the soil to assess their effectiveness and impact on its chemical composition, and in mature plantings-once every few years together with leaf analysis [23], [24].

3. RESULTS AND DISCUSSION

Atmospheric deposition and irrigation water are strong factors in nutrient distribution. Of great importance is the influence of nutrients on soil fertility, their importance in the nutrition of agricultural plants, the accumulation of nutrients in the soil, and the calculation of the amount of losses. Surface and underground leaching seriously affect the quality of the soil solution [25], [26]. Using the method of isotope indexing of nitrogen makes it possible to assess its environmental properties, determine the direction of transformation processes, and calculate nitrogen in the soil-plant system (Figure 1). If we take into account precipitation, it has a decisive influence on the rate of development of grapes. Usually, when there is a lot of precipitation, part of the heat is used to evaporate the precipitation. The relationship between bud opening, the length of the flowering period, and thermal conditions allows us to predict the flowering period of the grapevine. The general climate of the territory is semi-dry, warm, and flat. The wine industry is a promising direction for the development of the Azerbaijani economy, which is due to favorable soil and climatic conditions and a sufficient supply of labor resources. Today the stable and efficient operation of wineries is hampered by many problems, including a low supply of raw materials to processing plants, violation of priority relationships between producers of raw materials and wineries, high competition, insecurity of domestic producers, insufficient support from the state, and low quality of products (Figures 2 and 3).

Differences in the erosion of landscapes in the Ganja region are shown in Figure 3(a) broadleaf forest landscapes. Figure 3(b) shows bushy landscapes; Figure 3(c) shows sparse forest landscapes; and Figure 3(d) shows arid zone landscapes. There are weakly eroded, moderately eroded, severely eroded, very eroded, and non-eroded areas/ha.

Despite the fact that grapes are a drought-resistant crop, in order to get a good harvest and berries of high table quality, the vineyards must be watered. With artificial irrigation, it becomes possible to supply the plants with water at the time when they need it, so the efficiency of the method is very high. The increase in yield when irrigated can reach 1.5-2 times. The grape plant, due to the powerful development of the root system, its great sucking force, and the ability to slightly rearrange the anatomical and physiological structure in relation to growing conditions, has a relatively high drought resistance. At the same time, characterized by a relatively high need for water for all organs, it is a mesophyte and reacts very actively to soil moisture. Water supply sufficient for normal growth and fruiting of grapes is especially important in the conditions of Central Asia. High temperatures and extremely low air humidity in the summer, when the bush has a large leaf surface, cause a large consumption of water for evaporation, movement of nutrients in the plant, and cooling. Sufficient supply increases the yield and improves its quality. Irrigation of vineyards in Uzbekistan and Tajikistan is used in 90% of the area, and Azerbaijan-in 70%. Watering is organized with the aim of increasing growth vigor, size and appearance of bunches and berries, sugar content and taste; increasing productivity; and applying organic and mineral fertilizers along with irrigation water. Methods of watering a vineyard: watering in furrows, sprinkling, watering the vineyard in molehills, drip irrigation. Of all the methods, we found drip irrigation to be the most effective and economical. It allows you to regulate the rate of watering, thereby eliminating waterlogging of the soil and also allows you to apply fertilizers with irrigation water. When operating drip irrigation systems, special attention is paid to monitoring the good condition of the irrigation network and structures on it, as well as compliance with the irrigation regime. The use of such systems makes it possible to obtain a grape yield 20-25% higher than with furrow irrigation while reducing the irrigation rate by 2-2.5 times. In main and inter-farm canals, in on-farm irrigation systems, 40-50% of water is lost to evaporation and seepage into the soil. The use of such systems makes it possible to obtain a grape yield 20-25% higher than with furrow irrigation while reducing the irrigation rate by 2-2.5 times. In main and inter-farm canals, in on-farm irrigation systems, 40-50% of water is lost to evaporation and seepage into the soil. The use of such systems makes it possible to obtain a grape yield 20-25% higher than with furrow irrigation while reducing the irrigation rate by 2-2.5 times. In main and inter-farm canals, in on-farm irrigation systems, 40-50% of water is lost to evaporation and seepage into the soil. Shrubs are planted along the ditches to reduce the evaporation of water from the open surface. These activities are expensive, but they quickly pay off. In general, grapevine shoot growth depends on the availability of water and nutrients. If water is not limited, it can lead to excessive shoot growth, which can result in a dense, shaded canopy with reduced fertility and resulting yield (Figure 4).

Ganja is an ecologically highly stressed area. Mountain-forest and mountain-meadow landscapes, active landslide phenomena in certain places, and accumulation of waste after mining in valleys and on mountain slopes. Different sections of the region's territory included in the same mountain-forest landscape belt differ from each other, primarily in their local forms, which have different relief features (Figure 3).

The distribution of CULT varieties, taking into account the area they occupy, is given in Table 1. The largest areas are occupied by varieties: “Rkatsiteli”–205.86 hectares, “Chardonnay”–170.33 hectares, “Green Sauvignon”–159.85 hectares and “Aligote”–153.09 hectares. For other varieties, they range from 62.0 ha to 109.79 ha. According to the profile of the soil section, the humus content sharply decreases with depth by 0.7–1.0%, which is due to the peculiarities of the root system of vineyards, which penetrate to a considerable depth with an abundance of near-surface roots that actively take soil nutrients from the upper horizons. Depending on the regime of the Kura River, the level of slightly mineralized (1.7-12 g/l) groundwater varies between 1.5-2.3 m. During spring and autumn floods, the groundwater level temporarily approaches the soil surface (0.9-1.4 m). Soil-forming rocks are represented by alluvial deposits, consisting of weakly carbonated ($CaCO_3$ 1.8-4.6), layered-grained, sandy, and river stones (<0.01 1.5-9.7).

There are areas in the form of clearings with good grass cover. Various types of carbonate alluvial meadow-forest and carbonate alluvial-meadow soils are common in the territory. Morphologically, the soil profile shows sharp layering and a buried humus layer. Research has shown that the lack of organic fertilizers in agriculture can be compensated for by organic waste. It has been established that the amount of nutrients needed by the plant in the arable soil layer of 0-25 and 25-50 cm changes under the influence of organic and mineral fertilizers applied in different doses depending on the phases of plant growth (Table 1).

In the morphogenetic profile of chestnut soils under long-term irrigation, a CULT high-humus layer (2.2-2.9%) with accumulative irrigation and an aggregated grain-soil structure of dark gray color (AU'a+AU"a=45-50 cm). It has been established that chestnut and light gray-brown soils under grapes have weak nutrients absorbed by the plant, and mountain-brown soils are poorly provided with active phosphorus but are well provided with exchangeable potassium. In vineyards where grapes are grown biogenically, more ash elements accumulate than from other CULT plants (Table 2).

Foliar application doses are applied every 10-15 days, and application doses are applied weekly with the drip irrigation method. In foliar fertilization, it is recommended to use spreader-adhesive products to facilitate the passage of nutrients to plant cells and increase the effectiveness of the fertilizer (Table 3). Additionally, the presence of $CaCO_3$ and organic materials has a positive effect on vine growth, but it all depends on the variety you choose. In general, grapes prefer a pH between 6.5 and 8.5. The root system of grapes is very developed; it is capable of penetrating the soil to a depth of 2–3 m or more. The lifespan of grapes depends on the quality of their care. If the plant is properly cared for, its yield can reach 500-800 kg per bush. If there is insufficient aeration, the roots are less able to absorb nutrients and water in the soil. Drained chernozem, containing more than 65% clay and 41% silt, also has poor agrophysical properties. On such soils, the length of grape roots is 5 times less; the yield is 2–3 times lower than normal, the sugar content of the berries drops by 2–4%, and the acidity increases by 1–2%. The timing and speed of the grape growing season are affected by soil temperature, which depends on the amount of solar energy absorbed. The rate of soil warming is related to its color. A dark color attracts more rays than a light color calcareous, sandy, and rocky. Consequently, the grapes develop faster on them and ripen earlier (Figure 5). Figure 5(a) explains PCoA1 (63.1% of variance) of fungal communities in soil and Figure 5(b) explains PCoA1 (17.1% of variance) grape from all harvest years (2021; 2022; 2023).

Grape microbiomes can be shaped by climate, region, location, and grape variety, and also appear to be related to the composition of the microbiome involved in wine fermentation, as well as the profiles and abundance of wine metabolites. These studies suggest the importance of a biological component to wine regional typicality through the vineyard microbiome, indicating the importance of specific vineyard properties for wine characteristics depending on microbiome composition.

Fungal community profiles showed a clear clustering of samples obtained from grapes and soil collected under the grapevines (Figure 5). Soil samples clustered clearly together and separately from grapes along the first PCoA axis, explaining 66% of the variance in the data. The three-year average under-grapevine vegetation cover level for native vegetation (NV) was over 71%, while cover levels for glyphosate (GLY), and CULT were less than 20% early in the season. PCoA plots with samples from each of the three study years showed that NV soil fungal communities differed from those treated. In 2021 and 2022, soil samples were taken at two different phenological stages of grapes-flowering and harvest-which showed separation according to PCoA ordination (Figure 5).

The relative abundance of unclassified fungal genera in soil samples ranged from approximately 10% to over 25%. Based on average relative abundance across all soil samples, the top five fungal genera found in soil (excluding unclassified ones) were *Verticillium*, *Nectria*, *Mortierella*, *Gibberella*, and *Fusarium*. Differences in the relative abundance of fungal genera were found in *Gibberella*, *Neopestalotiopsis*, *Verticillium*, and an unclassified genus of the family *Amphisphaeriaceae*, where NV soils contained less *Gibberella* ($P<0.005$ in 2021) and more *Verticillium* $P<0.05$. Compared to the other two treatments less *Neopestalotiopsis* $P<0.05$ and unclassified *Amphisphaeriaceae* $P<0.05$ compared to GLY soils. CULT soils had less *Neopestalotiopsis* $P<0.05$ compared to GLY soils. *Neopestalotiopsis* and *Verticillium* are among the top five most important variables along with *Monographella*, *Paraphaeosphaeria*, and unclassified genera under *Nectriaceae* in the Random Forest model for predicting tillage. The silt content of irrigation water ranges from 6.897 to 0.645 g/l depending on the season and water source. The highest amount of NH_3+NO_3 was observed in June and July 3.53-4.90 kg/ha. The optimal soil moisture in the root layer varies between 75-80%, and according to the growing season, it is as follows: period of shoot growth 85-95%; flowering 80-90%; berry growth 70-90%; ripening 60-70%. The bulk of water (more than 99%) is spent by the grape plant to optimize the conditions necessary for the processes of transpiration and respiration, and only 0.25% is used for the direct formation of organic matter. A feature of the use of drip irrigation is watering along the rows of plants, as a result of which a zone of optimal moisture is created 1-1.5 m wide, depending on the type of soil, where the bulk of the roots are concentrated in a layer with a depth of 25-35 to 100 cm. The rest of the row spacing remains poorly moistened, except during natural precipitation.

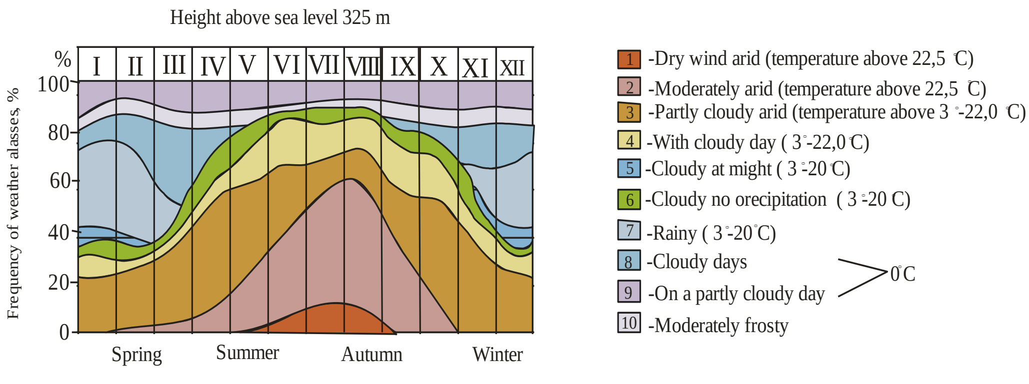

Figure 1. Changes in weather classes in Ganja in different seasons

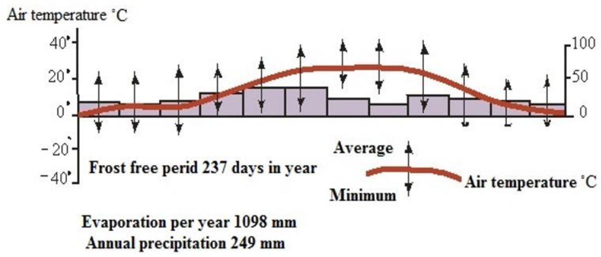

Figure 2. Changes in air temperature in the Ganja region in different months

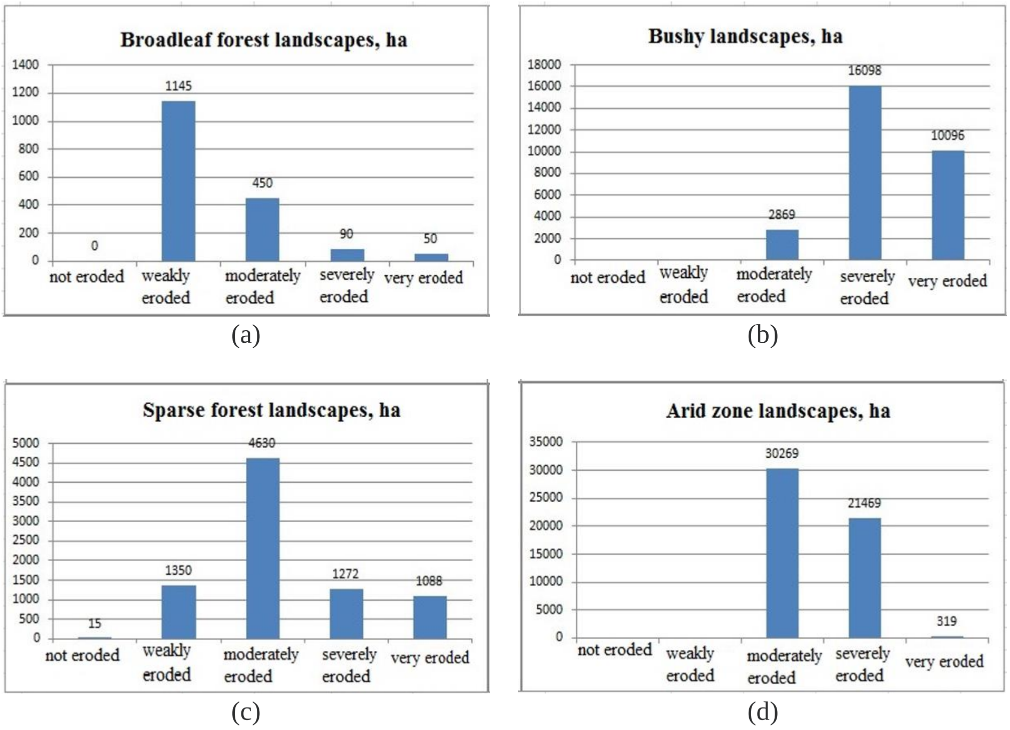

Figure 3. Differences in erosion of landscapes in Ganja (a) broadleaf forest landscapes; (b) bushy landscapes; (c) sparse forest landscapes; and (d) arid zone landscapes

Figure 4. Protecting the soil under grapes in the cold season

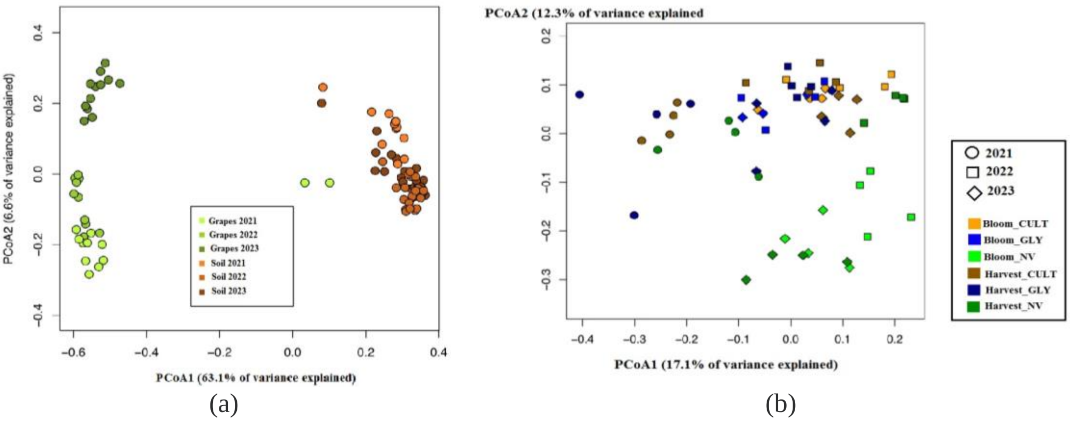

Figure 5. Principal coordinates analysis (a) PCoA1 (63.1% of variance explained) of fungal communities in soil and (b) PCoA1 (17.1% of variance explained) grape from all harvest years (2021; 2022; 2023)

Table 1. Important indicators of irrigated chestnut soils (Irrigated Kastanozems) under grapes and grain crops

Profile genetic horizons, depths	Humus (%)	Nitrogen (%)	$CaCO_3$ (%)	pH water extract	A sum of absorbed bases
No. 28 region Tovuz (soils under cereals)					
AYa'ca 0-24	2.59	0.231	8.4	8.0	27.40
AY"ca 24-48	2.34	0.180	9.3	8.1	25.36
Bca 48-75	1.70	0.126	10.2	8.1	26.01
B/Cca 75-95	0.72	-	12.3	8.2	21.52
Cca 95-120	0.44	-	12.6	8.3	22.58
No. 49 region Shamkir (soils under grapes)					
AYa'ca 0-25	2.88	0.192	4.7	8.1	22.79
AY"ca 25-48	1.98	0.184	5.9	8.3	21.34
Bca 48-79	1.21	0.163	6.7	8.4	20.20
B/Cca 79-94	0.89	-	9.1	8.3	18.69
Cca 94-115	0.53	-	3.2	8.4	16.37

Table 2. Basic water-physical properties of soils in natural cenoses of the village of Kadirli

Profile No. 54 Genetic horizons, depths	Granulometric grad		Silt coefficient (%)	Volumetric weight g/cm^3	Specific gravity g/cm^3	Porosity (%)
	<0.001	<0.01				
AU_g^h 0-20	16.8	39.6	33.8	1.14	2.30	65.9
A/B_p 20-45	19.9	59.8	30.3	1.18	2.67	55.9
B/C 45-90	19.4	67.9	26.9	1.29	2.70	51.1

Table 3. Special fertilization from drip irrigation

Fertilizer	Application time	Drip irrigation (0.1 ha 1 ton of water)
15.0.0	Starting from the period when the	1000 cc
MICRO	buds wake up and the shoots have 2-3	500-1000 cc
10.30.10	leaves	2-3 kg
20.20.20	Throughout the development period,	2-4 kg
CALCIUM	starting from the period when the	2-4 liter
BOR-8	grains are 3-4 cm	300-500 cc
10.5.40	From mole to pre-harvest	4-5 kg
MICRO		400-900 cc

4. CONCLUSION

Based on the results of morphological and microbiological analysis, it is known that growing grape plants on these soils enriches the soil with nutrients; comprehensive studies show that it increases its resistance to erosion. Very valuable literary material can be considered in planting methods and soil during the winter period of growing grapes, analysis results obtained over the past 3 years.

ACKNOWLEDGEMENTS

The author thanks the Institute of Soil Science and Agrochemistry of Azerbaijan and the Scientific Research Institute of Viticulture and Winemaking for financial support acknowledgments.

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BIOGRAPHIES OF AUTHORS

Anara Ikhtiar Nasirova is an experienced Ph.D. with a demonstrated history of working in the Department of Soil Biology. Strong education professional with a Bachelor's and Master's degree focused in ecology from the Institute of Soil Science and Agrochemistry. She is the author of two scientific books and a monograph. She is currently preparing to receive the title of Doctor of Science. Her research on grapes, sunflower plants, and the soil under these plants using innovative methods was of great importance and is used by young scientists. She can be contacted at email: anara.nasirova@inbox.ru.