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THE POTENTIAL OF LOCAL GRAPEVINE VARIETIES DEPENDING ON *TERROIR* IN THE REPUBLIC OF MOLDOVA

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The present thesis has been developed within the Department of Horticulture and Forestry, the Faculty of Agricultural, Forestry and Environmental Sciences, the Technical University of Moldova (*known until 2022, as the Department of Viticulture and Winemaking, the State Agrarian University of Moldova*).

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CONCEPTUAL FRAMEWORK OF THE RESEARCH

The relevance of the topic and the importance of the problem under consideration

In the context of climate change and of the growing demand for wines with a local identity, promoting indigenous Moldovan grape varieties such as Feteasca Neagra and Rara Neagra, as well as other local varieties, has become a strategic priority. Adapted to local soil and climatic conditions, these varieties have a valuable oenological potential and contribute to strengthening the image of Moldovan wines on the international market.

The rigorous definition of the *terroir* and its correlation with the potential of local varieties take on the role of crucial factors for a sustainable viticulture development. In this context, wine regions possessing Protected Geographical Indications provide the necessary foundation aimed at highlighting the local expressiveness and at valuating the regional specificities, which confers the topic of the research a high relevance and a scientific significance.

It is worth mentioning that the Republic of Moldova's diverse soils and climate, structured into four wine-producing regions with protected geographical indications-Codru, Valul lui Traian, Stefan Voda, and Divin - provides a solid foundation for producing wines with a distinct personality and unique quality. The specific characteristics of each region contribute to the diversity of sensory profiles in the resulting wines. Preserving these characteristics over time, despite the climatic variability and the modernization of winemaking practices, confirms the *terroir*'s role being a stable and a defining authenticity factor of the wine products. [1]

It should be stated that the grape variety decisively influences the quality of the wine, and the optimal expression of its potential depends both on the compatibility with the *terroir* and on the application of appropriate technologies [2;3;4]. Similarly, established wine-growing countries build their portfolios around their own varieties as an element of identity and a tool for international promotion, which highlights the central role of local varieties in consolidating national wine identity on the global market. [5].

The purpose of the research consists in the comparative assessment of the influence of *terroir* factors (specific to the Codru, Stefan Voda and Valul lui Traian wine-growing regions) on the agrobiological, technological and economic potential of cultivating the autochthonous Feteasca Neagra and Rara Neagra varieties, in order to optimize production quality and to valorize their oenological potential in the Republic of Moldova.

The research objectives include:

✓ The analysis of the agroecological conditions of the wine-growing areas from three wine-growing regions of the Republic of Moldova and the evaluation of the phenological particularities of the autochthonous wine varieties Feteasca Neagra and Rara Neagra;

✓ The determination of the physiological characteristics of grapevine growth and development by evaluating the photosynthetic, biomorphological and functional indices of the leaf canopy;

✓ The comparative evaluation of the fertility, productivity and grape quality indices, highlighting the correlations between the agroecological factors and the biological, productive and qualitative indices;

✓ The analysis of the uvological particularities and the evaluation of the oenological potential of the grapes;

✓ The determination of the economic efficiency of cultivating the studied varieties.

The research hypothesis. It is assumed that the interaction of the pedoclimatic, biological and technological factors specific to the *terroir* directly influences grapevine productivity and the quality of the grapes and of the resulting wines. Validating this hypothesis would allow identifying and

delimiting the preferential cultivation regions for each variety, contributing to optimizing the placement of vineyard plantations, to an efficient valorization of the potential of wine-growing terroirs and to obtaining wines of superior typicity and competitiveness.

The scientific research methodology. The observations, findings and analyses associated with the doctoral thesis have been carried out through various field observations, measurements and determinations, followed by laboratory chemical analyses, according to classical and modern methods accepted in this field. The research has been conducted during 2017-2021 within the project of the National Office of Vine and Wine "Demonstration Plot - Quality Grapes", implemented in collaboration with the State Agrarian University of Moldova (SAUM), the Technical University of Moldova and several wine-sector entities managing the experimental plantations: Purcari Winery, Mircesti Winery, Leova Vocational School, Nisporeni Vocational School, Chateau Vartely Winery and Castel Mimi.

The novelty and the scientific originality of the work. The scientific novelty and originality of the thesis consist in the complex and multidisciplinary approach to the relationship between the autochthonous grapevine varieties and the viticultural terroir of the Republic of Moldova, by integrating agrobiological, physiological, ecological and oenological indices into a unified evaluation system. For the first time, under the pedoclimatic conditions of the wine-growing regions of the Republic of Moldova, an in-depth comparative analysis of the behavior of autochthonous varieties in relation to *terroir* particularities has been carried out, highlighting the differences in productivity, adaptability and qualitative expression of grapes and wines. The study employs statistical regression and correlation models to identify the determining factors of sugar content, titratable acidity and oenological potential, providing a scientific basis for optimizing the placement of vineyard plantations.

The solved scientific problem. A study has been held as to the complex influence of the *terroir* factors (soil, climate, topography) on the agrobiological behavior and the oenological quality of local grape varieties from the Republic of Moldova. Such a study allowed to provide a scientific basis for a rational ecological zoning and an optimal placement of the varieties in accordance with the potential of the region aimed at producing authentic, environmentally sustainable and high-quality wines.

The object of research in the doctoral thesis was constituted by the autochthonous wine varieties (Feteasca Neagra and Rara Neagra) cultivated in: the Codru wine-growing region - the areas of Mircesti (Ungheni district), Speia (Anenii Noi district) and Nisporeni (Nisporeni district); the Stefan Voda wine-growing region - the Purcari area (Stefan Voda district); the Valul lui Traian wine-growing region - the areas of Alexandru Ioan Cuza (Cahul district), Bugeac (Comrat district) and Leova (Leova district).

The theoretical significance of the thesis. The scientific results obtained and reflected in the doctoral thesis contribute to consolidating the theoretical foundations regarding the interaction between the *terroir* (pedological, climatic and topographical factors) and the biological behavior of native grape varieties. The understanding of the way local ecological factors influences the phenological development, the adaptive capacity and the qualitative expression of grape varieties has been deepened, consolidating the concept of typicality and regional wine identity. The research results complement the specialized literature on ecological zoning and the selection of planting material according to the *terroir*, with a relevance within the temperate wine-growing contexts under the pressure of climate change.

The applicative value of the work. The applicative value of the research consists in the scientific substantiation of the placement and valorisation of the autochthonous Feteasca Neagra and Rara Neagra varieties according to the terroir particularities of the main wine-growing regions of the

Republic of Moldova. The results obtained allow identifying the sectors with superior potential for producing quality grapes and wines, optimizing viticultural technologies and orienting production in a differentiated way according to its oenological destination and economic efficiency.

The research has demonstrated that the Speia, Nisporeni, Mircesti and Purcari sectors are favorable for valorizing the Feteasca Neagra variety, while the Alexandru Ioan Cuza, Mircesti and Purcari sectors are favorable for the Rara Neagra variety, where high levels of productivity, profitability and oenological parameters have been recorded. The statistical-mathematical models developed can be used for forecasting the harvest, evaluating grape quality and substantiating technological decisions in viticulture and winemaking.

Implementation of scientific results. The scientific results obtained are implemented in the vineyard plantations of the wine-sector entities - Purcari Winery; Mircesti Winery, Leova Vocational School, Nisporeni Vocational School, Chateau Vartely Winery, Castel Mimi.

The results approval. The reflected results have been approved at the meetings of the Department of Viticulture and Winemaking and of the Council of the Faculty of Horticulture, State Agrarian University of Moldova, through the presentation of annual reports during the doctoral studies. At the same time, the materials have been presented, discussed and approved at various national and international scientific events, such as: International Symposium on Viticulture and Winemaking between Tradition and Innovation (Romania, Bucharest, 2025); The 46th World Congress of Vine and Wine (Chisinau, 2025); The 44th World Congress of Vine and Wine (Spain, Cadiz/Jerez, 2023); International Scientific Symposium "Modern trends of agricultural higher education" (Chisinau, 2023); The 22nd International Conference Life Sciences for Sustainable Development (Romania, Cluj-Napoca, 2023); The International Conference Agriculture for Life, Life for Agriculture (Romania, Bucharest, 2022, 2023); The International Scientific Symposium "Life Sciences Today for Tomorrow" (Romania, Iasi, 2022); International Agriculture Congress (Turkey, Ankara, 2022); the Conference "Regulating the use of natural resources: achievements and perspectives", dedicated to the 70th anniversary of the founding of the Faculty of Cadastre and Law (Chisinau, SAUM, 2022); the International Scientific Symposium "The agri-food sector - achievements and perspectives" (Chisinau, SAUM, 2021; 2022); the International Scientific Symposium "Modern horticulture - achievements and perspectives", Horticulture, Viticulture and Winemaking, Forestry and Public Gardens, Plant Protection (Chisinau, SAUM, 2018); the scientific conferences of students, master's and doctoral students of SAUM, 2017-2022, as well as at the meetings of the Technical-Scientific Council of the National Office of Vine and Wine within the Trial Plots - Quality Grapes project during 2017-2021.

Publications on the thesis topic. Based on the materials obtained during the research for the doctoral thesis, 19 scientific papers have been published, including: four in journals from the Web of Science database (IF 0.3), two in journals from other international databases such as DOAJ and CABI, two in the proceedings of scientific events included in the SCOPUS database, one in a journal from the National Register of specialized journals, category B, and ten in volumes of scientific papers of national and international scientific conferences.

The thesis volume and structure. The doctoral thesis is written in Romanian on 130 pages, including: introduction - 6 pages, chapter 1 - 30 pages, chapter 2 - 20 pages, chapter 3 - 69 pages, general conclusions and recommendations - 5 pages, bibliography - 15 pages, which includes 214 sources in Romanian, Russian, English, French, etc. The thesis includes 20 tables, 27 figures and 12 annexes.

Keywords: Quality, Climatic factors, Feteasca Neagra, Phenology, Fertility, Productivity, Rara Neagra.

THESIS CONTENT

1. THEORETICAL APPROACHES TO THE INFLUENCE OF *TERROIR* ON THE BEHAVIOUR OF GRAPEVINE VARIETIES

The present chapter reveals a literature review highlighting the crucial role of the *terroir* within the growth, the development, and the fruiting of grapevines which influence the yield and the quality of grapes and wine. The main components of the *terroir*— the soil, the climate, the topography, and the technological influences - act interdependently to determine the biological behavior of grape varieties [6; 7].

Varieties respond differently to the soil and climate conditions, highlighting the importance of adapting the sortiment to local environmental conditions. Due to their natural adaptation and resistance to the abiotic and biotic stresses, local varieties offer advantages [8; 9]. Climate change requires reassessing the resource management and using resilient varieties, as well as modern technologies intended at optimizing the relationship between the variety and the plant – the *terroir* [10-13].

Soil properties and the microclimate influence the biochemical composition of grapes, the expression of genes for the *terroir*-specific phenolic compounds and volatile metabolites [6; 14-16]. Their proper use is essential for the growth and fruiting of grapevines, for producing typical wines, and for a sustainable viticulture development [17–22]. The physicochemical properties of the soil - pH, the texture, the cation exchange capacity and the organic matter - all this determines the mobility of nutrients and the quality of the wine [23; 24].

The climatic conditions influence the grape phenology and the quality, accelerating the grape ripening [25; 26]. The extreme temperatures, the drought and the late frosts can reduce the production, while the moderate water stress can improve the anthocyanin content [27-30]. Adapting the viticulture through the variety selection, through the green work management and the climate monitoring is essential [31; 32].

Pruning and management systems influence the grape yield and the quality by means of controlling bud fertility and the leaf-to-vine ratio [33–37]. Managing the leaf area and conducting leaf removing optimize the photosynthesis and the phenolic compound accumulation, whilst the LAI and the PAR indices allow adapting the viticultural practices [38-45].

The wines produced out of local varieties, such as Feteasca Neagra, reflect the *terroir* through their phenolic and aromatic composition. Viticultural practices, such as cluster thinning and optimal light providing, increase the anthocyanin and the polyphenol content, improving wine quality [46-49]. Adapting the varieties and the technologies ensures the authenticity, the traceability, and the international competitiveness [50-52].

2. RESEARCH OBJECTS, METHODS AND CONDITIONS

2.1. Research objects

The research for the doctoral thesis "The Potential of *Terroir*-Based Autochthonous Vine Varieties Within the Conditions of the Republic of Moldova," has been conducted in the framework of the NVWO, project High-Quality Grapes within the period from 2017 to 2021. The role of project partners has been taken on by the NVWO, the SAUM, the TUM, and by the organizations (the Purcari Winery, the Mircesti Winery, the Leova Vocational School, the Nisporeni Vocational School, the Chateau Vartelly Winery, and the Castel Mimi) managing the vineyards included in the research project.

To achieve the goals and the objectives of the doctoral thesis, the research has quintessentialized to a comparative study of local wine varieties (Feteasca Neagra and Rara Neagra) cultivated in three wine-growing regions: the Codru wine-growing region (Centre), with the areas of Speia, Nisporeni and Mircesti; the Stefan Voda wine-growing region (South-East), with the area of Purcari; and the Valul lui Traian wine-growing region (South, Cahul), with the areas of Alexandru Ioan Cuza, Bugeac and Leova.

Based on the above, the experimental design is as follows:

Table 2.1. The structure of the experience scheme according to the studied factors

Nr.	The B factor - Wine-growing locality / wine-growing area	The A factor – the variety	
		Feteasca Neagra	Rara Neagra
1	*The Codru wine-growing region*		
	Speia	X	
	Nisporeni	X	
	Mircesti	X	X
2	*The Stefan Voda wine-growing region*		
	Purcari	X	X
3	*The Valul lui Traian wine-growing region*		
	Alexandru Ioan Cuza	X	X
	Bugeac	X	X
	Leova	X	

2.2. Research Methods

To achieve the purpose and the objectives of the doctoral thesis, a list of observations, records and analyses was compiled, which is as follows:

a) phenological observations;
b) observations, recordings and soil analyses;
c) observations and meteorological records;
d) biometric records;
e) uvological records;
f) biochemical analyses;
g) physiological analyses;

For the purpose of holding the mathematical and statistical data processing, the following variation statistics methods have been used: The Analysis-of-Variance Method; The Differences Method; The Method of Correlation and Regression Analysis, etc., using the standard MS Office Excel analytical package and the mathematical models of Dospekhov/Доспехов Б.А. (1985), Lakin/Лакин Г. Ф. (1990).

Table 2.2. The classification of variants by the significance level as a result of variance analysis

Nr.	The difference value	Rating	The significance level
1	$(V-M)<DL_{0.95}$	-	A non-significant difference
2	$DL_{0.95}<(V-M); (V-M)<DL_{0.99}$	x	A significant positive difference
3	$DL_{0.99}<(V-M); (V-M)<DL_{0.999}$	xx	A distinctly significant positive difference
4	$DL_{0.999}<(V-M)$	xxx	A very significant positive difference
5	$-DL_{0.99}<(V-M); (V-M)<-DL_{0.95}$	o	A significant negative difference
6	$-DL_{0.999}<(V-M); (V-M)<-DL_{0.99}$	oo	A distinctly significant negative difference
7	$(V-M)<-DL_{0.999}$	ooo	A very significant negative difference

Note: V - compared variant, M – the comparison unit

The correlation and regression analysis has been based on the multifactorial linear regression equation model, determined in accordance with the identified correlation (2.1):

$$\mathbf{Y=B+A_1X_1+ A_2X_2+ A_3X_3+ A_4X_4+ A_5X_5+ A_6X_6+ A_7X_7+ A_8X_8+ A_9X_9+ A_{10}X_{10}} \quad (2.1)$$

where:

$\mathbf{X_1}$ – the vine load at pruning, the number of buds per vine;

$\mathbf{X_2}$ - the number of shoots developed per vine;

$\mathbf{X_3}$ - the number of fertile shoots developed;

X_4 - the number of developed inflorescences, pcs.;
X_5 - the average annual temperature, ^oC;
X_6 - the sum of effective temperatures, ^oC;
X_7 - the amount of precipitation, mm;
X_8 - the leaf surface, cm^2;
X_9 - the chlorophyll content index (CCI);
X_{10} - the photosynthetically active radiation (PAR).

2.3.Organization and placement of the experiments

The experimental allotment has been located in the vineyards of several companies from different wine-growing regions on the outskirts of the nearby settlements.

The studied varieties were planted in accordance with the vineyard establishment and management project (table 2.3.)

Table 2.3. The characteristics of the experimental allotments

Nr.	Wine region	Enterprise	Location, District	Variety	Planting year	Planting scheme, m x m	Vine training method
1	Valul lui Traian	Vinăria Bostavan SRL	Alexandru Ioan Cuza, dist. Cahul	Feteasca Neagra	2015	2,50 x 1,25	Bilateral Cazenave cordon
				Rara Neagra	2015	2,50 x 1,25	Bilateral Cazenave cordon
		ÎM Chateau Vartely SRL	Bugeac, dist. Comrat	Feteasca Neagra	2008	2,75 x 1,4	Double Guyot
				Rara Neagra	2008	2,75 x 1,4	Arched Guyot
		Vocational School, Leova	Leova	Feteasca Neagra	2009	2,25 x 0,9	Single arched Guyot
2	Stefan Voda	Vinăria Purcari SRL	Purcari, dist. Stefan Voda	Feteasca Neagra	2010	2,75 x 1,3	Bilateral Royat cordon
				Rara Neagra	2010	2,75 x 1,4	Bilateral Cazenave cordon
3	Codru	Mimi Castle	Speia, dist. Anenii Noi	Feteasca Neagra	2015	2,20 x 1,0	Double Guyot
		Vocational School, Nisporeni	Varzaresti, dist. Nisporeni	Feteasca Neagra	2006	2,25 x 0,9	Single arched Guyot
		Wine cellar, Mircesti	Mircesti, dist. Ungheni	Feteasca Neagra	2014	2,20 x 1,3	Single Guyot

2.4. Conditions for conducting the research

2.4.1. Meteorological conditions

Aiming at achieving the goals and objectives for the doctoral thesis "The Potential of *Terroir*-Based Autochthonous Vine Varieties Within the Conditions of the Republic of Moldova", have been used meteorological data from local weather stations, such as *i-Metos*, as well as data from various platforms with archival meteorological data - www.rp5.ru, www.meteo.md, www.gismeteo.ru, https://weather.com/ etc.

During the 2017-2021 research period, the meteorological conditions have been determined based on the following indicators: the average monthly and annual temperature, the absolute minimum and maximum temperature, the sum of effective temperatures, the monthly and the annual precipitation.

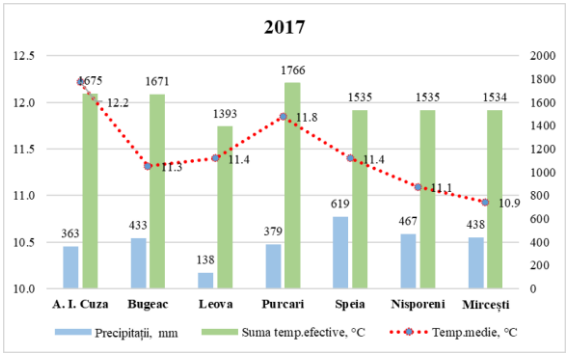


Fig. 2.1. Weather conditions for the year 2017

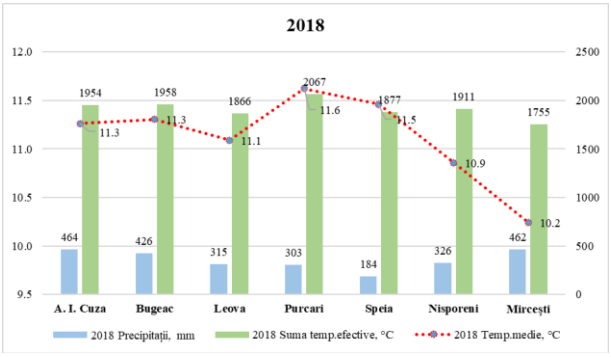


Fig. 2.2. Weather conditions for the year 2018

The reflected data (fig. 2.1- 2.5) present the dynamics of the average annual temperature (°C), the sum of the effective temperatures (°C) and the annual amount of precipitation (mm) within the seven experimental locations (the sectors of A. I. Cuza, Bugeac, Leova, Purcari, Speia, Nisporeni and Mircesti) during the 2017-2021 period.

When analyzing the evolution of average temperatures compared to the multiannual data, it has been recorded that in all locations, the values of average annual temperatures for the period 2017-2021 exceeded the multiannual values – within the sector A. I. Cuza the multiannual average constituted 10.0°C, whilst the average during the researched years constituted 12.2°C (+2.2°C); at Purcari: from 9.6°C (multiannual) to 12.1°C during the research period (+2.5°C); at Bugeac: from 8.2°C (multiannual) to 11.7°C during the research period (+3.5°C); at Speia: from 9.5°C (multiannual) to 11.7°C during the research period (+2.2°C); at Leova: from 9.8°C (multiannual) to 11.5°C during the research period (+1.7°C); in Nisporeni: from 9.0°C to 11.3°C (+2.3°C); in Mircesti : from 9.0°C (multiannual) to 10.8°C during the researched period (+1.8°C). Such an uniform increase highlights a general warming trend in all the areas analyzed.

The year 2020, has been the year showing the highest temperatures in all locations (13.1°C - A. I. Cuza, 13.0°C - Purcari), suggesting a particularly warm climatic year. The largest interannual variations (±) have been recorded in Bugeac (±4.54 in 2020), indicating high thermal instability in this very location. The most stable locations (showing small deviations) have appeared to be Mircesti and Leova, especially in 2021 (±0.69 and ±0.74).

When analyzing the ranking of locations by the average temperature within the period 2017-2021, it has been possible to mention: A. I. Cuza - 12.2°C; Purcari - 12.1°C; Speia - 11.7°C; Leova - 11.5°C; Bugeac - 11.7°C; Nisporeni - 11.3°C; Mircesti - 10.8°C. Proceeding from the above mentioned, it can be seen that the southeastern region (Purcari, A. I. Cuza) has recorded the highest temperature values, whilst the central and the northern regions (Mircesti, Nisporeni) have recorded lower temperatures, which corresponds to the altitudinal and geographical gradients of the Republic of Moldova.

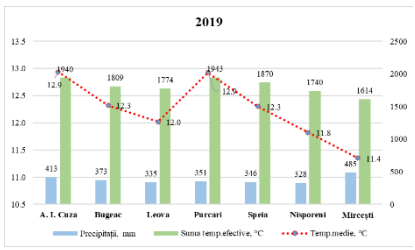


Fig. 2.3. Weather conditions for the year 2019

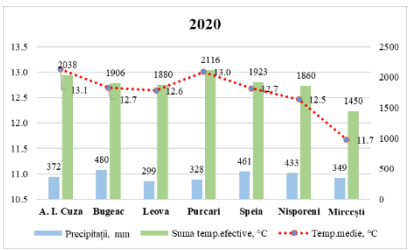


Fig. 2.4. Weather conditions for the year 2020

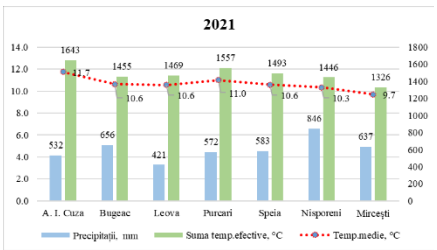


Fig. 2.5. Weather conditions for the year 2021

The increase in the average annual temperature influences the grapevine phenology and requires adapting the cultivation technologies. The data confirm a general warming trend, with increases of approximately 2.0-2.5°C compared to multiannual averages, highlighting the need to adapt the agricultural practices to the climate change.

The sum of effective temperatures (SEFT) differs considerably as year-over-year as among the analyzed experimental allotments, a fact which directly influences the vegetation period and the grapes ripening. In all locations, the SEFT average annual values for the period 2017-2021 have been recorded above the multiannual values, indicating a trend of climate warming, which is a generally favorable aspect for the vine development, however, bearing at the same time some associated risks (drought, sunburn, accelerated ripening).

Together with, it should be mentioned that within all the experimental allotments a significant SEFT increase has been recorded when compared to the multiannual average. The DP (Demonstration Plot) A.I. Cuza (multiannual: 1454.0 °C, and average for the years 2017-2021: 1850.0 °C) recording an increase of approx. 27%. The most favorable experimental vine locations (within the framework of the SEFT average for 2017-2021): DP Purcari - 1889.7 °C (the highest SEFT), indicating a high potential for late-ripening varieties and high-quality wines. DP A.I. Cuza and Bugeac - over 1750 °C, suitable for thermally demanding varieties. Experimental locations with lower thermal potential: DP Mircesti (1535.8 °C) and DP Nisporeni (1698.2 °C) - suitable for early varieties or cooler climates. These locations may require increased attention in colder years, as the year 2021 turned out to be (significantly reduced values).

It is interesting to mention that the analyzed data showed that the highest variability has been recorded at the DP Purcari (±460.7 °C), a fact implying both, a high climatic risk and an opportunity for the *terroir* wines. The DP Leova and the DP Mircesti have registered the lowest standard deviations (±256.5 °C and ±248.8 °C), suggesting a relative thermal stability. High SEFT values (>1800 °C) are known as favorable for grape ripening and crucial for producing high-quality red wines. Colder locations (the DP Leova, the DP Mircesti) could be recommended for producing fresh wines. The years 2018 and 2020 have been the most favorable for all locations, showing a potential for valuable productions. The year 2021, turned up to be atypical due to steep decreases, which could negatively influence the yield and the quality.

The data analysis allows us finding out that during the period 2017-2021, except for the year 2021, the annual precipitation amounts have been recorded as being lower than the multiannual averages within all the studied locations, indicating significant negative deviations, which made it possible highlighting frequent moderate to severe drought conditions. The year 2021, distinguished itself by bringing a generalized pluviometric surplus, thus, contributing to a partial compensation of the previously accumulated water deficit.

It is worth noting that geographically, the DP A.I. Cuza has recorded an average amount of 428.6 mm, with a deviation of -99.4 mm, recording the 2020 as being the most deficient year (-155.6 mm), thus, suggesting a repeated water stress manifestation. The DP Bugeac has offered values close to the multiannual average (473.8 mm; -5.2 mm), indicating a relatively stable precipitation regime.

The DP Leova has stood out for the most pronounced water deficit (301.7 mm; -212.3 mm), indicating a high agronomic risk and the need to implement adaptive measures. The DP Purcari has recorded as well a significant pluviometric deficit (386.4 mm; -141.6 mm), especially during the 2018-2020 period showing a potential impact on the grape ripening processes.

The DP Speia has highlighted a pronounced rainfall variability, while the DP Nisporeni and the DP Mircesti have allowed to record significant negative deviations, characterized by the alternation of deficient periods with excess rainfall episodes.

The repeated water deficit has negatively impacted the physiological vine processes, including the vegetative development, the sugar accumulation and the production quality. The 2021 excess rainfall has led to a partial compensatory effect, however, favored an increase in the risk of cryptogamic diseases. The analyzed rainfall regime emphasizes a regional aridification trend with direct implications for the sustainability of vineyard plantations, requiring the implementation of adaptive technological strategies, here included using drought-resistant rootstocks, applying controlled deficit irrigation and carrying out conservative soil management practices (mulching, minimal work).

2.4.2. Topographic and Pedological Conditions

The pedological survey has been conducted in the framework of the NVWO project High-Quality Grapes by the DIMO Soil Institute of the Republic of Moldova *(starting with 2024, known as INCAAMV).* The vineyard allotments where the experiments and the evidence plots have been located are characterized by the following data presented in the table 2.4.1

It is important to mention that the comparative analysis of the topographic elements of the vineyard plots highlighted a significant variability of the relief conditions among the studied plots, with direct effects on the thermal, hydrological and radiation regime of the plantation. The altitude varied between 68-87 m (Alexandru Ioan Cuza) and 280-309 m (Mircesti), while the slopes inclination degree was between 0-20º, influencing the works mechanization, the drainage and the solar exposure. The slopes exposure, predominantly southern, southwestern or eastern ones, determined differentiations within the thermal accumulation and the grapes ripening. All together, the topographic characteristics have shown up as being the most important factor of the *terroir*, underlying the varieties zoning and the viticultural technologies optimization for obtaining a stable and high-quality harvest.

Table 2.4. Topographic and pedological characteristics of the vineyard parcels

Vineyard parcels	Slope inclination degree	Altitude, m	Slope exposition	Soil types
Alexandru Ioan Cuza				
Feteasca Neagra	1º - 7º	68,00 - 73,00	SV, V	carbonated blacksoil, loose, slightly eroded, loamy
Rara Neagra	3º - 5º	81,00 - 87,00	SV	
Bugeac				
Feteasca Neagra	1º - 5º	149,37 - 154,09	SV, S, V	typical blacksoil, loose, loamy-clayey
Rara Neagra	1º - 5º	147,16 - 152,20	SV, S, V	
Leova				
Feteasca Neagra	0º - 3º	157,00 - 162,00	SV	Common blacksoil, loose, slightly eroded, loamy
Purcari				
Feteasca Neagra	1º - 7º	114,86 - 126,40	E, SE, NE	carbonated blacksoil, loose, clayey-loamy on loamy soil
Rara Neagra	1º - 7º	122,34 - 126,45	E, SE, NE	carbonated blacksoil, loose, clayey-loamy on loamy soil
Speia				
Feteasca Neagra	3º - 10º	131,07 - 135,54	NE, E	leached blacksoil, loose, loamy-clayey
Nisporeni				
Feteasca Neagra	5º - 12º	116,00-126,00	SV	carbonated blacksoil, loose, moderately eroded, loamy
Mircesti				
Feteasca Neagra	5º - 20º	296,14 - 309,25	E, SE	Typical grey soil, loose, slightly eroded, loamy-clay on loamy soil
Rara Neagra	7º - 15º	280,42 - 294,25	E, SE	Typical grey soil, loose, moderately eroded, loamy-clayey, on loamy clay and ochreous deluvial

Within the analyzed vineyards, soil conditions have demonstrated a significant variability,

which have been determined by local pedogenetic factors, by the parent rock nature and by the hydrothermal regime. The soils under investigation clearly differed in type (typical and carbonated blacksoils, typical ashy, ocher, and levigated deluvial soils), in humus content, in carbonate regime, in pH and in texture. The humus and fine fractions distribution indicated a variable capacity for water and nutrient retention, while the adsorption complex, dominated by Ca^{2+}, reflected the differentiated agroproductive potential of Lodi soils. Overall, the natural fertility appeared to be the interaction result of the humus, the carbonate regime, the soil reactivity and the cation composition, thus, such characteristics provided a solid basis aimed at developing differentiated agricultural practices adapted to the specific characteristics of each vineyard and at maintaining the agroecological balance.

3. COMPARATIVE EVALUATION OF THE AGROBIOLOGICAL POTENTIAL OF AUTOCHTHONOUS VARIETIES IN THE CONTEXT OF THE VITICULTURAL *TERROIR*

3.1. Mapping of the Feteasca Neagra and Rara Neagra varieties at the national level

Following the mapping of the Feteasca Neagra variety, carried out based on the data of the Wine Registry (Fig. 3.1.), allowed to established that the total area occupied by this variety in the analyzed territorial units amounted to 424,04 ha.

It is interesting to know that the territorial distribution summarizes a significant variability of cultivated areas. The most extensive plantations have been registered in: the Cahul district - 84.09 ha (19.83%), the UTA Gagauzia - 74.53 ha (17.58%) and the Stefan Voda district - 44.79 ha (10.56%), followed by the Cantemir district - 30.73 ha (7.25%), the Anenii Noi district - 28.08 ha (6.62%), the Criuleni district - 20.57 ha (4.85%), the Straseni district - 20.03 ha (4.72%), the Cimislia district - 19.24 ha (4.54%), the Tiraspol mun. - 16.39 ha (3.87%), the Leova district - 14.49 ha (3.42%), the Chisinau mun. - 14.25 ha (3.36%), the Taraclia district - 13.94 ha (3.29%), the Ialoveni dist. - 10.89 ha (2.57%), the Nisporeni dist. - 8.18 ha (1.93%), the Hancesti dist. - 7.40 ha (1.75%), the Ungheni dist. - 4.49 ha (1.06%), the Basarabeasca dist. - 4.32 ha (1.02%), the Causeni dist. - 3.52 ha (0.83%), the Telenesti dist. - 2.68 ha (0.63%), the Calarasi dist. - 0.72 ha (0.17%), the Orhei dist. - 0.49 ha (0.12%) and the Sangerei dist. - 0,22 ha (0,05%).

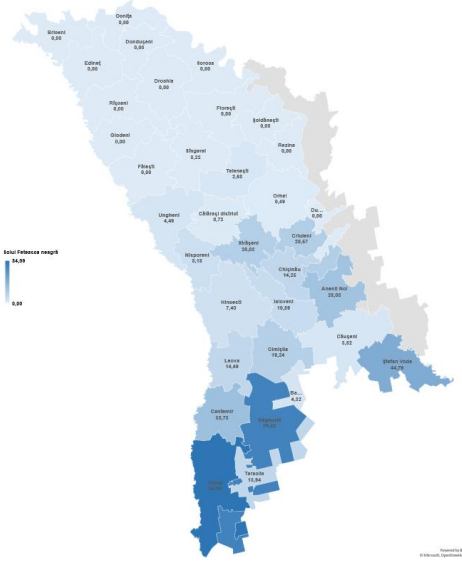


Fig. 3.1. Mapping of the Feteasca Neagra variety in a regional context

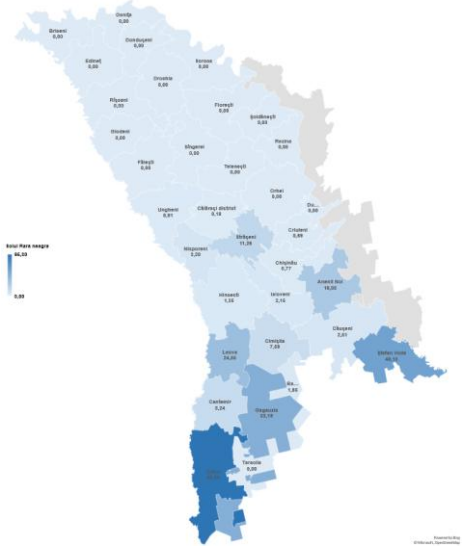


Fig. 3.2. Mapping of the Rara Neagra variety in a regional context

It is worthy noting that the territorial distribution of the Feteasca Neagra variety accentuates a predominant concentration in the southern and southeastern regions of the Republic of Moldova. This fact reflects its adaptability to the soil and climatic conditions which are typical for more arid and relatively dry regions. The observed distribution confirms the importance of the variety in the framework of modern plantations structure revealing its potential for the production of quality red wines and for a sustainable economic benefit of wine-growing areas.

Following the mapping of the Rara Neagra variety (Fig. 3.2), it has been established that the total area occupied by this variety in the analyzed territorial units amounts to 222,76 ha.

The territorial distribution emphasizes a pronounced variability of the cultivated areas, the most extensive plantations being registered in the Cahul dist. - 65.3 ha (29.31%), the Stefan Voda dist. - 40.13 ha (18.01%) and the UTA Gagauzia - 33.19 ha (14.90%), followed by the Leova dist. - 24.55 ha (11.02%), the Anenii Noi dist. - 19.08 ha (8.57%), the Straseni dist. - 11.26 ha (5.05%), the Cantemir dist. - 8.24 ha (3.70%), the Cimislia dist. - 7.59 ha (3.41%), the Nisporeni dist. - 3.20 ha (1.44%), the Causeni dist. - 2.51 ha (1.13%), the Ialoveni dist. - 2.15 ha (0.97%), the Basarabeasca district - 1.65 ha (0.74%), the Hancesti dist. - 1.35 ha (0.61%), the Ungheni dist.- 0.91 ha (0.41%), the Chisinau mun. - 0.77 ha (0.35%), the Criuleni dist. - 0.69 ha (0.31%) and the Calarasi dist. - 0,19 ha (0,09%).

In general, the Rara Neagra variety pas been found to be highly concentrated in the south of the republic, especially in the Cahul dist., in the Stefan Voda dist. and in the UTA Gagauzia. Such a distribution underlines a preference for the southern terroirs bearing a pronounced climatic influence, where the variety best reveals its oenological potential. In the context of the local varieties revival, the Rara Neagra variety has shown an excellent prospect of asserting itself as an emblematic variety for light and fruity red wines with a national wine heritage value.

3.2. Phenological particularities depending on the cultivation region

It must be noted that the global warming phenomenon causes changes within the annual biological cycle of the vine, manifested by the acceleration of the phenophases development from destemming to grape ripening, as well as the shift for the ripening period to higher thermal conditions, with direct implications on the biochemical composition and on the quality of wine production. The climatic parameters, such as the real heliothermal index, the sum of active temperatures and the pluviometric regime do decisively influence the agrobiological behavior of the varieties, of the productivity level and of the must composition. Under the conditions of heat and water balance, the biological potential of varieties is effectively utilized, while the drought and the excessive insolation can negatively affect the yields and the technological characteristics of the grapes [53; 54].

Table 3.1. The phenophases duration of the vegetation period for the Feteasca Neagra variety during the years of experience

Years	Bleeding		Bud break		Shoot and inflorescent-ce growth		Flowering		Berry growth		Berry ripening		Leaf fall		Duration of the vegetation period		
	days	±	days	±	days	±	days	±	days	±	days	±	days	±	days	±	Level of significance
A.I.Cuza Sector																	
2017	32	-13	11	6,6	34	14,6	9	1	56	-5,8	52	-2,8	19	5,2	245	0,8	" - "
2018	9	10	9	8,6	42	6,6	5	5	41	9,2	64	-14,8	26	-1,8	232	13,8	" xxx "
2019	16	3	29	-11,4	41	7,6	11	-1	50	0,2	32	17,2	41	-16,8	260	-14,2	" ooo "
2020	12	7	13	4,6	60	-11,4	11	-1	50	0,2	56	-6,8	26	-1,8	255	-9,2	" ooo "
2021	26	-7	26	-8,4	66	-17,4	14	-4	54	-3,8	42	7,2	9	15,2	237	8,8	" xxx "
average	19	-	17,6	-	48,6	-	10	-	50,2	-	49,2	-	24,2	-	245,8	-	
$DL_{0,95}$															**2,31**		

Years	Bleeding		Bud break		Shoot and inflorescent-ce growth		Flowering		Berry growth		Berry ripening		Leaf fall		Duration of the vegetation period		
	days	±	days	±	days	±	days	±	days	±	days	±	days	±	days	±	Level of significance
Bugeac Sector																	
2017	**30**	-9,6	11	5	34	12,6	9	3,6	56	-6	52	-8,6	19	3	237	-1,4	" - "
2018	13	7,4	14	2	34	12,6	13	-0,4	48	2	37	6,4	35	-13	236	-0,4	" - "
2019	14	6,4	21	-5	46	0,6	11	1,6	37	13	51	-7,6	21	1	237	-1,4	" - "
2020	19	1,4	21	-5	59	-12,4	16	-3,4	45	5	35	8,4	26	-4	241	-5,4	" oo "
2021	26	-5,6	13	3	60	-13,4	14	-1,4	64	-14	42	1,4	9	13	227	8,6	" xxx "
average	20,4	-	16	-	46,6	-	12,6	-	50	-	43,4	-	22	-	235,6	-	
$DL_{0,95}$															**2,38**		
Leova Sector																	
2017	14	0,4	7	3	54	-3,6	8	2	51	2,6	52	-4,2	15	5	237	-7,8	" ooo "
2018	13	1,4	7	3	39	11,4	9	1	45	8,6	60	-12,2	16	4	221	8,2	" xxx "
2019	10	4,4	8	2	41	9,4	11	-1	64	-10,4	49	-1,2	23	-3	229	0,2	" - "
2020	12	2,4	9	1	57	-6,6	16	-6	49	4,6	39	8,8	29	-9	231	-1,8	" - "
2021	23	-8,6	19	-9	61	-10,6	6	4	59	-5,4	39	8,8	17	3	228	1,2	" - "
average	14,4	-	10	-	50,4	-	10	-	53,6	-	47,8	-	20	-	229,2	-	
$DL_{0,95}$															**2,25**		
Purcari Sector																	
2017	15	2,2	15	-3,4	49	-10,6	5	2,6	64	-14,8	48	9,8	10	10	236	-5,4	" oo "
2018	8	9,2	8	3,6	35	3,4	9	-1,4	41	8,2	58	-0,2	39	-19	238	-7,4	" ooo "
2019	21	-3,8	21	-9,4	36	2,4	8	-0,4	47	2,2	41	16,8	17	3	233	-2,4	" - "
2020	14	3,2	7	4,6	36	2,4	8	-0,4	47	2,2	71	-13,2	17	3	216	14,6	" xxx "
2021	28	-10,8	7	4,6	36	2,4	8	-0,4	47	2,2	71	-13,2	17	3	230	0,6	" - "
average	17,2	-	11,6	-	38,4	-	7,6	-	49,2	-	57,8	-	20	-	230,6	-	
$DL_{0,95}$															**2,54**		
Speia Sector																	
2017	11	4,8	11	0	49	-8,6	12	0,2	64	-17,8	48	-2	10	10,8	232	-1,2	" - "
2018	11	4,8	14	-3	34	6,4	7	5,2	43	3,2	45	1	26	-5,2	231	-0,2	" - "
2019	18	-2,2	10	1	34	6,4	9	3,2	43	3,2	41	5	24	-3,2	234	-3,2	" o "
2020	16	-0,2	10	1	37	3,4	15	-2,8	45	1,2	46	0	27	-6,2	225	5,8	" xx "
2021	23	-7,2	10	1	48	-7,6	18	-5,8	36	10,2	50	-4	17	3,8	232	-1,2	" - "
average	15,8	-	11	-	40,4	-	12,2	-	46,2	-	46	-	20,8	-	230,8	-	
$DL_{0,95}$															**2,31**		
Nisporeni Sector																	
2017	14	-0,6	8	-0,4	50	-7,4	7	7,2	50	-6	44	-6,2	11	12,4	234	-25,4	" ooo "
2018	6	7,4	6	1,6	39	3,6	14	0,2	46	-2	46	-8,2	25	-1,6	195	13,6	" xxx "
2019	15	-1,6	10	-2,4	38	4,6	10	4,2	44	0	33	4,8	27	-3,6	203	5,6	" xx "
2020	14	-0,6	7	0,6	43	-0,4	20	-5,8	40	4	33	4,8	27	-3,6	203	5,6	" xx "
2021	18	-4,6	7	0,6	43	-0,4	20	-5,8	40	4	33	4,8	27	-3,6	208	0,6	" - "
average	13,4	-	7,6	-	42,6	-	14,2	-	44	-	37,8	-	23,4	-	208,6	-	
$DL_{0,95}$															**2,42**		
Mircesti Sector																	
2017	11	-2,4	10	-2,2	50	-6,8	7	0,8	50	5,2	44	-0,8	11	1,2	234	-23,6	" ooo "
2018	11	-2,4	11	-3,2	40	3,2	8	-0,2	65	-9,8	37	6,2	12	0,2	209	1,4	" - "
2019	10	-1,4	6	1,8	42	1,2	8	-0,2	56	-0,8	45	-1,8	5	7,2	202	8,4	" xxx "
2020	4	4,6	6	1,8	42	1,2	8	-0,2	56	-0,8	45	-1,8	14	-1,8	197	13,4	" xxx "
2021	7	1,6	6	1,8	42	1,2	8	-0,2	49	6,2	45	-1,8	19	-6,8	210	0,4	" - "
average	8,6	-	7,8	-	43,2	-	7,8	-	55,2	-	43,2	-	12,2	-	210,4	-	
$DL_{0,95}$															**2,11**		

It was interesting to find out that the phenological analysis of the Feteasca Neagra variety (Table 3.1) revealed significant differences within the duration of the vegetation period and the phenophases rhythm depending on the sector and the pedoclimatic conditions. The longest vegetation period has been noted in the A.I. Cuza area (232-260 days, average 245.8 days) and in the Bugeac area (235.6 days), an intermediate period has been registered in the areas of Speia (230.8 days), Purcari (230.6 days) and Leova (229.2 days), whilst the shortest one proved to be in the areas Mircesti (210.4 days)

and Nisporeni (208.6 days). The dispersion analysis ($DL_{0,95}$=2,1-2,5 days) confirmed the significance of annual variations, accentuating a pronounced climatic influence.

The durations of early phenophases varied considerably: Bleeding - 8.6-20.4 days, budding - 7.6-17.6 days, and shot and inflorescence growth - 38.4-50.4 days, with the longest periods within the areas A.I. Cuza and Leova, and the shortest ones in the Purcari and the Nisporeni areas. The reproductive phenophases reflected functional differences: flowering - 7.6-14.2 days, grape berries growth - 44-55.2 days, grape berries ripening - 37.8-57.8 days, and leaf fall - 12.2-24.2 days.

Therefore, the data recieved emphasize the high phenological plasticity of the variety, underlining the importance of adapting the viticultural technologies and the agrotechnical measures both to the climatic particularities and to the oenological potential of each sector.

Table 3.2. The phenophases duration of the vegetation period for the Rara Neagra variety during the years of experience

Years	Bleeding		Bud break		Shoot and inflorescen-ce growth		Flower-ing		Berry growth		Berry ripening		Leaf fall		Duration of the vegetation period		
	days	±	days	±	days	±	days	±	days	days	±	days	±	days	±	days	Level of significance
A.I. Cuza Sector																	
2017	20	-3,2	11	2,6	54	0	9	1	56	-5,8	52	7,8	19	3,4	245	1,6	" - "
2018	9	7,8	9	4,6	44	10	5	5	49	1,2	92	-32,2	36	-13,6	244	2,6	" - "
2019	17	-0,2	9	4,6	46	8	11	-1	42	8,2	57	2,8	22	0,4	252	-5,4	" o "
2020	12	4,8	13	0,6	60	-6	11	-1	50	0,2	56	3,8	26	-3,6	255	-8,4	" oo "
2021	26	-9,2	26	-12,4	66	-12	14	-4	54	-3,8	42	17,8	9	13,4	237	9,6	" xx "
average	16,8	-	13,6	-	54	-	10	-	50,2	-	59,8	-	22,4	-	246,6	-	
$DL_{0,95}$															**4,25**		
Bugeac Sector																	
2017	22	-2	11	5	36	15,4	6	6,6	59	-8,4	45	-1,8	19	3	235	1	" - "
2018	19	1	14	2	56	-4,6	16	-3,4	48	2,6	43	0,2	35	-13	240	-4	" o "
2019	14	6	21	-5	46	5,4	11	1,6	37	13,6	51	-7,8	21	1	237	-1	" - "
2020	19	1	21	-5	59	-7,6	16	-3,4	45	5,6	35	8,2	26	-4	241	-5	" oo "
2021	26	-6	13	3	60	-8,6	14	-1,4	64	-13,4	42	1,2	9	13	227	9	" xxx "
average	20	-	16	-	51,4	-	12,6	-	50,6	-	43,2	-	22	-	236,0	-	
$DL_{0,95}$															**2,56**		
Purcari Sector																	
2017	13	4,8	15	-2	50	-9	7	1,8	55	-5	33	19,4	10	10	232	-1	" - "
2018	13	4,8	15	-2	47	-6	13	-4,2	54	-4	46	6,4	39	-19	244	-13	" ooo "
2019	21	-3,2	21	-8	36	5	8	0,8	47	3	41	11,4	17	3	233	-2	" - "
2020	14	3,8	7	6	36	5	8	0,8	47	3	71	-18,6	17	3	216	15	" xxx "
2021	28	-10,2	7	6	36	5	8	0,8	47	3	71	-18,6	17	3	230	1	" - "
average	17,8	-	13	-	41	-	8,8	-	50	-	52,4	-	20	-	231,0	-	
$DL_{0,95}$															**4,37**		
Mircesti Sector																	
2017	10	0,2	10	-2,2	50	-6,6	8	0	45	7,2	49	-3,8	11	2,2	231	-17,2	" ooo "
2018	10	0,2	11	-3,2	41	2,4	8	0	55	-2,8	33	12,2	17	-3,8	219	-5,2	" o "
2019	10	0,2	6	1,8	42	1,4	8	0	56	-3,8	45	0,2	5	8,2	202	11,8	" xxx "
2020	4	6,2	6	1,8	42	1,4	8	0	56	-3,8	45	0,2	14	-0,8	197	16,8	" xxx "
2021	17	-6,8	6	1,8	42	1,4	8	0	49	3,2	54	-8,8	19	-5,8	220	-6,2	" oo "
average	10,2	-	7,8	-	43,4	-	8	-	52,2	-	45,2	-	13,2	-	213,8	-	
$DL_{0,95}$															**3,71**		

It should also be stated that the phenological analysis of the Rara Neagra variety (Table 3.2) has made it possible to discover clear variations within the duration of the vegetation period and the succession of phenophases depending on the sector and the pedoclimatic conditions. The vegetation period has turned out to be the longest in the areas of A.I. Cuza (237-255 days, average 246.6 days) and Bugeac (236 days), an intermediate tendency has been traced in the Purcari area (231 days), whilst the shortest one has been registered in the area of Mircesti (213.8 days), reflecting ecoclimatic differences between the southern, the central and the northern sectors.

It is worth noting that the early phenophases varied significantly: Bleeding - 10.2-20 days, budding - 7.8-16 days, and shots and inflorescence growth - 41-54 days, with the longest periods revealed in the areas of A.I. Cuza and Bugeac while the shortest ones belonged to the areas Purcari and Mircesti. Blooming lasted the longest in the Bugeac Sector (12.6 days) and the shortest in the Mircesti Sector (8 days). The grape berries growth have shown similar values among the sectors (approximately 50-52 days), whereas grape berries ripening has turned up to last significantly longer in the vineyards areas of A.I. Cuza (59.8 days) and the Purcari Sector (52.4 days), suggesting favorable conditions for accumulation of sugars, phenolic and aromatic compounds, whilst a shorter period has been discovered to be in the area of Bugeac (43.2 days). The leaf fall phenophase has shown similar durations in the areas of A.I. Cuza and Bugeac (approx. 22 days), but has been considerably shorter in the Mircesti area (13.2 days), indicating a reduced period of the leaf apparatus functioning, which is to be considered as the risk of accumulating reserve substances in the canes.

Together with, the statistical analysis confirmed the significance of annual variations ($DL_{0,95}$=2,56-4,37 days), highlighting the influence of climatic conditions on the duration of the vegetative cycle. The inter-sectoral comparison indicates that the A.I. Cuza and Bugeac sectors, characterized by higher thermal resources, favor long vegetation periods and an intense vegetative development. The Purcari sector presents a balanced regime, standing out through a prolonged berry ripening associated with a high oenological potential. In contrast, Mircesti is characterized by a shorter growing season and an accelerated ripening, reflecting thermal limitations and more restrictive climatic influences.

Overall, the Rara Neagra variety demonstrates a high phenological plasticity, but also a phenological dynamic sensitive to environmental conditions, adapting the duration and succession of phenophases to the local pedoclimatic conditions. These particularities provide scientific support for adapting viticultural technologies, optimizing the timing of agrotechnical interventions and valorizing the productive and oenological potential specific to each viticultural area.

3.3. Physiological particularities of the Feteasca Neagra and Rara Neagra varieties depending on the cultivation region

As the study continued, it has been revealed that the LAI values have shown to be strongly correlated with the shoot and the bush leaf area [58]. The optimal ratio between the leaf and the grape production has proven to ensure a favorable vegetative-productive balance for berry ripening and organic compound accumulation [59].

Within the Feteasca Neagra variety, the leaf area per shoot, depending on the sector, obtained values between 776.91 - 1857.77 cm2, the average value reaching 1440.45 cm2. The average number of leaves per shoot ranged between 9.5 - 17.5 leaves, the average value constituted 14.21 leaves. The average leaf area of the Feteasca Neagra variety has been recorded between 81.66 - 116.50 cm2, while the average value equaled to 100,46 cm2.

As to the Rara Neagra variety, the leaf area per shoot, depending on the sector, has registered values between 1143.76 - 1522.18 cm2, the average value being 1394.02 cm2. The average number of leaves per shoot ranged between 11.5 - 17.5 leaves, the average value approached to 14.25 leaves. The average area of a leaf in the Rara Neagra variety has shown values between 79.62 - 121.57 cm2 whilst the average value recorded 99,51 cm^2.

The chlorophyll content index (CCI) may fluctuate depending on the variety, the sun exposure and the sector. Within the Feteasca Neagra variety (Fig. 3.3.), the CCI depending on sun exposure and the sector have obtained the following values: for leaves exposed to the sun between 18.55 - 33.35, the average value registering 28.09. For leaves exposed to the shade between 14.95 - 19.90, the average value recording 17.83. In general, the average CCI value for variety Feteasca Neagra has demonstrated values between 16.75 - 26.63, the average value being 22,96.

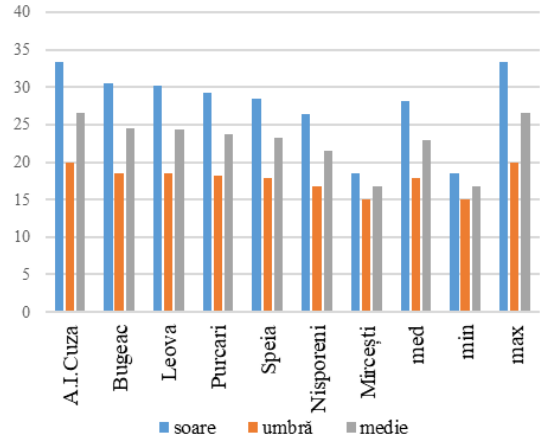


Fig. 3.3. The value of the chlorophyll content index (CCI) of the Feteasca Neagra variety

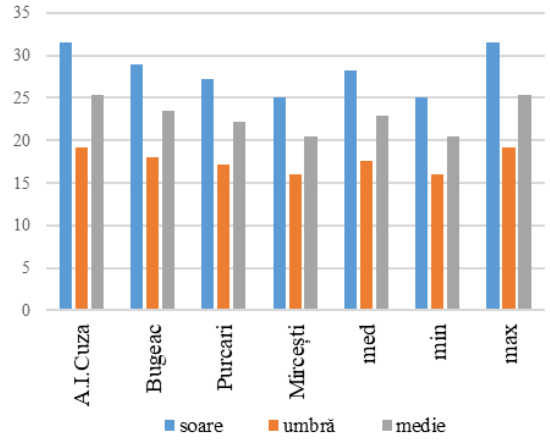


Fig. 3.4. The value of the chlorophyll content index (CCI) of the Rara Neagra variety

It is interesting to note that all the varieties presented higher CCI values in 2021 compared to 2020, especially in the southern regions (Alexandru Ioan Cuza, Bugeac, Leova), reflecting higher temperatures and longer sunny days, factors which favor the photosynthesis and leaf development.

Within the Rara Neagra variety (Fig. 3.3.2.), the CCI depending on sun exposure and the sector obtained the following values: for leaves exposed to the sun between 25 - 31.5, the average value being 28.18. For leaves exposed to shade between 16.05 - 19.2, the average value registering 17.6. In general, the average CCI value for the Rara Neagra variety oscillated between 20.53 - 25.35, the average value recording 22.89.

Noteworthy, all varieties recorded higher CCI values in 2021 compared to 2020, reflecting more favorable climatic conditions for the photosynthesis and the leaf development. Such a correlation being characteristic for all the sectors. The southern regions (Alexandru Ioan Cuza, Bugeac, Leova) presented higher CCI values.

Along with, the PAR values interpretation and the distribution photosynthesis in the two analyzed varieties, has made it possible to observe that the maximum RAF value has appeared to be constant in the upper part of the shoot (h1), regardless the location. Meanwhile, the PAR values in the upper part (h1) have shown a variability range between 1222.95 and 1308.65 µmol $m^{-2}s^{-1}$, indicating a high photosynthetic intensity in that very region due to direct exposure to light. The middle part of the shoot (h2) has offered significantly lower values (approx. 785-847 µmol $m^{-2}s^{-1}$), but still high enough to support an active photosynthetic activity. The lower part of the shoot (h3) has recorded very low values, generally between 66-163 µmol $m^{-2}s^{-1}$, indicating a minimal photosynthetic contribution due to the internal shading of the leaf apparatus.

3.4. Fertility and productivity indicators

A fact to be mentioned is that the vine fertility and the productivity are essential characteristics of grape production, moreover, they are interdependent and get influenced by both the genetic characteristics of the varieties and ecological factors. Equally, evaluating the embryonic fertility of winter buds allows estimating the shoots productive potential and forecasting the harvest, substantiating the planning of the stump load, the pruning method and the technologies specific to each variety. [55]

3.4.1. Analysis of the fertility and productivity indices of the Feteasca Neagra variety

It must be pointed out that following a comparative analysis of the average fertility index values presented in the Table 3.4.1.1, has revealed differences in the number of buds per stem and in the

fertility indicators, depending on the winegrowing area studied. The average bud load per stem varied from low values in the Mircesti sector (14.3 eyes) to high values in the Alexandru Ioan Cuza sector (47.4 eyes), these being determined by the management form of the bush vine. The percentage of starting to grow buds has appeared to be the lowest within the DP Alexandru Ioan Cuza (45.32%) while the highest values have been recorded in the Mircesti sector (91.05%), indicating a physiological compensation through a more intense start under the conditions of a reduced load.

Table 3.3. The average value (2017-2021) of the Feteasca Neagra variety fertility indices

Sector	Number of buds during pruning, on average per vine, pcs.	buds, during growth, %	Normally developed shoots, pcs.	Normally developed fertile shoots, pcs.	Normally developed fertile shoots, %	Inflorescen-ces, pcs.	RFC	AFC
A.I. Cuza	47,40	45,32	21,48	17,56	81,75	23,72	1,10	1,35
Bugeac	20,18	82,66	16,68	12,12	72,66	16,98	1,02	1,40
Leova	21,02	76,59	16,10	12,55	77,95	16,68	1,04	1,33
Purcari	26,04	85,18	22,18	17,00	76,65	22,76	1,03	1,34
Speia	26,56	81,33	21,60	18,32	84,81	23,68	1,10	1,29
Nisporeni	21,00	85,71	18,00	16,00	88,89	20,20	1,12	1,26
Mircesti	14,30	91,05	13,02	11,02	84,64	15,90	1,22	1,44

The proportion of fertile shoots ranged between 72.66% in the Bugeac and 88.89% in the Nisporeni areas, however, within the most areas falling between 75-85% and thus, reflecting a stable productive potential. The RFC values ranged between 1.02 (Bugeac) and 1.22 (Mircesti) while the AFC values ranged between 1.26 (in the Nisporeni area) and 1.44 (in the Mircesti area), confirming a good to very good variety fertility in all the areas.

Table 3.4. Productivity indices of the Feteasca Neagra variety

Years	Average weight of a grape			RPI			API			Average yield per vine	
	gr.	±	Level of significance	gr.	±	Level of significance	gr.	±	Level of significance	kg/vine	±
Alexandru Ioan Cuza Sector											
2017	238,50	-30,60	" o "	205,11	21,95	" - "	269,51	9,76	" - "	4,31	0,65
2018	249,20	-41,30	" oo "	249,20	-22,14	" - "	318,98	-39,71	" - "	5,73	-0,77
2019	188,90	19,00	" - "	243,68	-16,62	" - "	298,46	-19,19	" - "	3,51	1,45
2020	150,80	57,10	" xx "	176,44	50,62	" x "	186,99	92,28	" xx "	3,18	1,78
2021	212,10	-4,20	" - "	260,88	-33,82	" - "	322,39	-43,12	" - "	8,09	-3,13
average	207,90	-		227,06	-		279,27	-		4,96	-
$DL_{0,95}$	**21,87**			**42,99**			**56,77**				
Bugeac Sector											
2017	242,40	-18,59	" - "	169,68	48,51	" xx "	346,63	-47,10	" - "	2,99	0,53
2018	366,90	-143,09	" ooo "	337,55	-119,36	" ooo "	366,90	-67,37	" - "	4,05	-0,53
2019	163,18	60,63	" xx "	205,61	12,58	" - "	303,51	-3,98	" - "	3,04	0,48
2020	118,36	105,45	" xxx "	138,48	79,71	" xxx "	165,70	133,83	" x "	2,49	1,03
2021	228,20	-4,39	" - "	239,61	-21,42	" - "	314,92	-15,39	" - "	5,03	-1,51
average	223,81	-		218,19	-	-	299,53	-		3,52	-
$DL_{0,95}$	**35,77**			**26,09**			**104,74**				
Leova Sector											
2017	149,90	37,37	" x "	109,43	85,21	" xx "	161,89	85,37	" - "	1,35	1,73
2018	280,27	-93,00	" ooo "	327,92	-133,28	" ooo "	355,94	-108,68	" o "	3,94	-0,86
2019	176,56	10,71	" - "	199,51	-4,87	" - "	300,15	-52,89	" - "	3,43	-0,35
2020	105,60	81,67	" xxx "	123,55	71,09	" xx "	138,34	108,92	" x "	2,22	0,86
2021	224,00	-36,73	" o "	212,80	-18,16	" - "	280,00	-32,74	" - "	4,47	-1,39
average	187,27	-		194,64	-		247,26	-		3,08	-
$DL_{0,95}$	**27,02**			**35,69**			**99,85**				
Purcari Sector											
2017	237,80	-39,44	" o "	114,14	85,76	" xx "	316,27	-38,01	" - "	2,20	2,13

Years	Average weight of a grape			RPI			API			Average yield per vine	
	gr.	±	Level of significance	gr.	±	Level of significance	gr.	±	Level of significance	kg/vine	±
2018	139,40	58,96	" xx "	129,64	70,26	" xx "	139,40	138,86	" x "	3,63	0,70
2019	228,30	-29,94	" o "	223,73	-23,83	" - "	347,02	-68,76	" - "	4,65	-0,32
2020	126,80	71,56	" xx "	166,11	33,79	" - "	186,40	91,86	" - "	3,74	0,59
2021	259,50	-61,14	" oo "	365,90	-166,00	" ooo "	402,23	-123,97	" o "	7,43	-3,10
average	198,36	-		199,90	-		278,26	-		4,33	-
$DL_{0,95}$	**27,49**			**41,21**			**115,29**				
Speia Sector											
2017	200,10	-4,87	" - "	302,15	-88,84	" oo "	368,18	-114,68	" o "	5,62	-1,05
2018	176,80	18,43	" - "	203,32	9,99	" - "	228,07	25,43	" - "	4,13	0,44
2019	196,46	-1,23	" - "	196,46	16,85	" - "	208,25	45,25	" - "	4,48	0,09
2020	127,20	68,03	" xxx "	155,18	58,13	" x "	181,90	71,60	" - "	3,03	1,54
2021	275,60	-80,37	" ooo "	209,46	3,85	" - "	281,11	-27,61	" - "	5,61	-1,04
average	195,23	-		213,31	-		253,50	-		4,57	-
$DL_{0,95}$	**19,09**			**36,35**			**103,54**				
Nisporeni Sector											
2017	210,30	-28,42	" o "	258,67	-56,81	" oo "	290,21	-63,72	" - "	5,48	-1,84
2018	171,20	10,68	" - "	162,64	39,22	" x "	181,47	45,02	" - "	3,27	0,37
2019	147,90	33,98	" xx "	180,44	21,42	" - "	204,10	22,39	" - "	2,60	1,04
2020	104,82	77,06	" xxx "	126,83	75,03	" xx "	145,70	80,79	" - "	2,31	1,33
2021	275,20	-93,32	" ooo "	280,70	-78,84	" oo "	310,98	-84,49	" - "	4,52	-0,88
average	181,88	-		201,86	-		226,49	-		3,64	-
$DL_{0,95}$	**19,74**			**29,91**			**95,81**				
Mircesti Sector											
2017	310,20	-61,50	" o "	164,41	104,10	" xxx "	310,20	10,44	" - "	1,74	1,81
2018	350,23	-101,53	" oo "	322,21	-53,70	" o "	350,23	-29,59	" - "	3,87	-0,32
2019	178,30	70,40	" xx "	253,19	15,32	" - "	272,80	47,84	" - "	3,49	0,06
2020	163,56	85,14	" xx "	269,87	-1,36	" - "	300,95	19,69	" - "	3,81	-0,26
2021	241,20	7,50	" - "	332,86	-64,35	" oo "	369,04	-48,40	" - "	4,86	-1,31
average	248,70	-		268,51	-		320,64	-		3,55	-
$DL_{0,95}$	**41,54**			**35,69**			**93,82**				

The comparative analysis of both the productivity indices and the average grape weight of the Feteasca Neagra variety (Table 3.4.) has revealed significant differences between the wine-growing sectors, determined by the local ecoclimatic and agrobiological conditions.

The average grape weight varied considerably among the sectors. The highest values have been recorded in the Mircesti sector, where the multiannual average reached 248.7 g (163.56-350.23 g), indicating favorable conditions for the grape mass development. High values have also been observed in the sectors of Bugeac (223.81 g) and Alexandru Ioan Cuza (207.9 g). The Purcari (198.36 g) and the Speia (195.23 g) sectors have presented intermediate values, while the Leova (187.27 g) and the Nisporeni (181.88 g) sectors have recorded the lowest average values. The variation analysis ($DL_{0.95}$ ≈ 19-41 g) confirms the significance of the annual differences, bringing into the light the climatic conditions influence on the grape mass.

The productivity indices comparison have proven a significant variability among the sectors. In the Alexandru Ioan Cuza sector, the RPI has presented an average of 227.06 g, while the API constitued 279.27 g, with an average production of 4.96 kg/bush, the maximum values being associated with the favorable climatic years. The Bugeac sector has recorded similar API values (299.53 g), but a lower average yield per bush (3.5 kg/bush), indicating a moderate productive efficiency. In the sector of Leova, the API has reached an average of 247.26 g, whilst the average yield per bush has amounted to 3.08 kg/bush.

The Purcari sector has stood out with a high API (278.26 g) and an average yield of 4.33

kg/bush, suggesting a balance between both the fertility and the production quality. In the Speia sector, the average yield per bush has recorded 4.57 kg/bush, being altogether associated with an API reaching 253.50 g, thus, indicating a higher productive potential under favorable conditions. The Nisporeni sector has recorded an average yield of 3.64 kg/bush, demonstrating a good productive potential, despite moderate API values (226.49 g). In contrast, the Mircesti sector has put on paper the highest API (320.64 g), but a lower average production per bush (5.55 kg/bush).

The statistical significance analysis highlighted annual variations determined by climatic factors. Significant positive differences have been observed during the years especially within 2019 - 2020 in the Alexandru Ioan Cuza sector and in the 2020 within several sectors at once, whereas the year 2021 has frequently been characterized by negative deviations.

Being characterized by high temperatures and severe water stress, the year 2020, has determined a reduction in the average mass of grapes, thus, the lowest values have been recorded that very year. The factors mentioned have negatively influenced the plants growth and their development, and respectively, the harvest quantity and quality. [56]

Along with, the inter-sectoral differences have confirmed the influence of pedoclimatic conditions and agrobiological factors on the productivity of the Feteasca Neagra variety. The results obtained constitute a scientific basis for adapting the viticultural technologies, optimizing the production management and capitalizing on the quantitative and qualitative potential specific to each wine-growing area.

The statistical analysis of the agrobiological and climatic factors influence on the average grape harvest per vine ($\mathbf{Y_{Harvest}}$, kg/vine), carried out based on 35 observations (2017-2021; 7 vineyard locations), has proven the existence of a strong and statistically significant linear relationship between the explanatory variables and the production obtained.

The mathematical model of multiple regression is expressed by a general equation estimated by the ordinary least squares (OLS) method, presenting the following:

$$\mathbf{Y_{Harvest} = 7{,}2519 + 0{,}0350X_1 + 0{,}0154X_2 - 0{,}0669X_3 + 0{,}1819X_4 - 0{,}6939X_5 - 0{,}0008X_6 + 0{,}0022X_7 + 0{,}0005X_8 + 0{,}0389X_9 - 0{,}0006X_{10}} \quad (3.1)$$

where: X_1 – buds on the vine; X_2 - shoots on the vine; X_3 – fertile shoots; X_4 – inflorescences on the vine; X_5 - average annual temperature; X_6 - sum of the effective temperatures; X_7 - rainfall; X_8 - leaf surface; X_9 - chlorophyll coefficient index (CCI); X_{10} - photosynthetically active radiation (PAR)

The developed multiple regression model aimed at estimating the average harvest, has demonstrated high a statistical significance ($p < 0{,}0001$) and an explanatory capacity of 82,33% ($R^2 = 0{,}8233$; R^2 adjusted = 0,7496), confirming its suitability for interpreting the production. Therethrough, the results show a significant positive effect of the inflorescences number per vine and a negative influence of the average annual temperature on the yield, emphasizing the decisive role of both the vegetative-generative structure and the temperature conditions.

3.4.2. Analysis of the fertility and productivity indices of the Rara Neagra variety

It is important to state that as a result of the fertility indices analysis for the Rara Neagra variety (Table 3.5.), it has been possible to mention that within the Alexandru Ioan Cuza experimental sector, during the years of research the average number of buds per vine has ranged within the limits of 55.3-61.8 buds per bush with an average of 58.78 buds per bush, out of which approximately 73.56% started growing. The fertile shoots have reached approximately 82.61%. The average value of RFC=0.61, and AFC=0.73

The research over the mentioned years has shown that in the Bugeac wine region the average number of buds per vine has amounted within the limits of 16-35.15 buds/vine, the average being

26.07 buds/vine, out of which approx. 86.84% started growing. Fertile shoots constituted an average of approx. 70.67%, and the average value of RFC=1.01 and AFC=1.43

During the same research years, the Purcari sector has recorded an average number of buds per bush within the limits of 21-36.2 buds/bush, the average being 29.56 buds/bush, out of which about 84.51% started growing. Fertile shoots constituted about 79.02%, whilst the average value of RFC=0.93 and AFC=1.18.

Table 3.5. The average value (2017-2021) of the Rara Neagra variety fertility indices

Sector	Number of buds during pruning, on average per vine, pcs.	buds, during growth, %	Normally developed shoots, pcs.	Normally developed fertile shoots, pcs.	Normally developed fertile shoots, %	Inflorescen-ces, pcs.	RFC	AFC
A.I. Cuza	58,78	73,56	43,24	35,72	82,61	26,22	0,61	0,73
Bugeac	26,07	86,84	22,64	16,00	70,67	22,88	1,01	1,43
Purcari	29,56	84,51	24,98	19,74	79,02	23,32	0,93	1,18
Mircesti	20,60	82,04	16,90	14,18	83,91	17,52	1,04	1,24

In the Mircesti sector the average number of buds per bush ranged within the limits of 14-25, the average being 20.6 buds/bush, out of which an average of approx. 82.04% started growing. Fertile shoots constituted an average of approx. 83.91%, while the average value of RFC=1.04 and AFC=1.24.

The comparative analysis carried out allows us to conclude that the Alexandru Ioan Cuza sector has been characterized as showing the highest load of buds per bush, which has led to lower RFC and AFC indices values, thus, suggesting a slight overload on the grape vine. Contrariwise, the sectors with moderate or low load (Bugeac, Purcari and Mircesti) have presented higher fertility indices and a high biological efficiency.

The Bugeac sector has stood out for its highest capacity for the vegetation starting and for the highest AFC value, therefore, indicating a high productive potential.

The Mircesti sector has revealed the highest percentage of fertile shoots and a higher RFC value, reflecting a biological stability and a reproductive efficiency.

The Purcari sector shows intermediate values, confirming a good balance between growth and fruit-bearing. The results show that optimising the bud load per vine is a determining factor for increasing fertility allowing an efficient use of the production potential with in all the sectors analyzed.

The experimental data presented (Table 3.6.) and the productivity indices comparative analysis together with the information provided as to the average grape weight o for the Rara Neagra variety, it was possible to observe the following: The average grape weight recorded multiannual average values ranging placed between 246.29 g in the Alexandru Ioan Cuza sector and 356.12 g in the Mircesti sector. The Bugeac sector has pointed out an average of 295.51 g, whilst the sector of Purcari - 302.63 g. Following the dispersion analysis at different confidence levels, the year 2020 has recorded distinctly significant positive differences within the sectors Alexandru Ioan Cuza, Bugeac and Purcari, whereas the 2021 presented distinctly significant negative differences. As to the Mircesti sector, it has been only the year 2021, when an insignificant difference was recorded;

The relative productivity index (RPI) has ranged between 153.01 g in the Alexandru Ioan Cuza sector and 365.17 g in the Mircesti one. The significance level has shown considerable positive differences in 2020, in the Alexandru Ioan Cuza sector, while the Bugeac sector has recorded a very significant negative difference in 2018, and a very positive difference in 2019. The Purcari sector has revealed a very significant positive difference in 2017 and a distinctly negative difference in 2019 and 2021. Within the Mircesti sector, a distinctly significant negative difference has been recorded in

2019 and 2020, reflecting the sensitivity of the RPI to the specific climatic conditions of the year.

The absolute productivity index (API) has recorded multiannual average values ranged between 194.06 g in the Alexandru Ioan Cuza sector and 507.2 g in the Bugeac sector. Significant differences, both positive and negative, have been noted in the sectors of Bugeac, Purcari except for the year 2018, while the Mircesti sector has only in 2018 noted a distinctly significant positive difference.

Table 3.6. Productivity indices of the Rara Neagra variety

Years	Average weight of a grape			RPI			API			Average yield per vine	
	gr.	±	Level of significance	gr.	±	Level of significance	gr.	±	Level of significance	kg/bush	±
Alexandru Ioan Cuza Sector											
2017	254,20	-7,91	" - "	134,73	18,28	" - "	165,23	28,83	" - "	6,55	-0,04
2018	245,30	0,99	" - "	152,09	0,92	" - "	179,07	14,99	" - "	7,62	-1,11
2019	239,40	6,89	" - "	169,97	-16,96	" - "	275,31	-81,25	" - "	3,33	3,18
2020	198,16	48,13	" xx "	116,91	36,10	" x "	138,71	55,35	" - "	5,80	0,71
2021	294,40	-48,11	" oo "	191,36	-38,35	" o "	211,97	-17,91	" - "	9,24	-2,73
average	246,29	-		153,01	-		194,06	-		6,51	-
$DL_{0,95}$	**21,61**			**34,97**			**108,81**				
Bugeac Sector											
2017	298,00	-2,49	" - "	298,00	11,98	" - "	715,20	-208,00	" oo "	3,58	3,10
2018	285,97	9,54	" - "	431,81	-121,83	" ooo "	466,13	41,07	" - "	6,05	0,63
2019	290,10	5,41	" - "	205,97	104,01	" xxx "	687,54	-180,34	" oo "	5,97	0,71
2020	240,28	55,23	" xx "	276,32	33,66	" - "	307,56	199,64	" xx "	8,32	-1,64
2021	363,20	-67,69	" oo "	337,78	-27,80	" - "	359,57	147,63	" x "	9,49	-2,81
average	295,51	-		309,98	-		507,20	-		6,68	-
$DL_{0,95}$	**25,82**			**34,97**			**108,81**				
Purcari Sector											
2017	268,20	34,43	" x "	150,19	140,28	" xxx "	268,20	101,94	" x "	3,75	3,35
2018	314,53	-11,90	" - "	289,37	1,10	" - "	314,53	55,61	" - "	6,94	0,16
2019	305,30	-2,67	" - "	393,84	-103,37	" oo "	506,80	-136,66	" oo "	6,62	0,48
2020	251,44	51,19	" xx "	256,47	34,00	" - "	279,10	91,04	" x "	7,82	-0,72
2021	373,70	-71,07	" ooo "	362,49	-72,02	" oo "	482,07	-111,93	" o "	10,37	-3,27
average	302,63	-		290,47	-		370,14	-		7,10	-
$DL_{0,95}$	**25,82**			**41,54134**			**81,43**				
Mircesti Sector											
2017	426,30	-70,18	" ooo "	353,83	11,34	" - "	532,88	-86,89	" - "	4,25	1,85
2018	274,20	81,92	" xxx "	246,78	118,39	" xxx "	274,20	171,79	" xx "	4,94	1,16
2019	308,10	48,02	" xx "	440,58	-75,41	" oo "	471,39	-25,40	" - "	6,78	-0,68
2020	407,40	-51,28	" ooo "	423,70	-58,53	" oo "	484,81	-38,82	" - "	7,54	-1,44
2021	364,60	-8,48	" - "	360,95	4,22	" - "	466,69	-20,70	" - "	6,97	-0,87
average	356,12	-		365,17	-		445,99	-		6,10	-
$DL_{0,95}$	**18,91**			**32,87**			**97,01**				

It should be emphasized that the average yield per vine and per hectare presented values between 6.1-7.1 kg/bush and 17.35-21.32 t/ha, varying significantly between the sectors. Within the Alexandru Ioan Cuza sector, the average yield per bush varied between 3.33 and 9.24 kg, with a multi-annual average of 6.51 kg, and the production per hectare between 10.66 and 29.57 t, the average being 20.83 t/ha ($DL_{0.95}$=2.13). With that said, the values have indicated a good productive potential, with moderate annual variations and a relative yield stability.

The Bugeac sector has recorded an average harvest of 6.68 kg/vine highlighting a constant production, but slightly lower than in the Alexandru Ioan Cuza sector. The variations between the years have been moderate, ($DL_{0.95}$ =2.13) which suggests a good resilience of the sector to the local conditions.

The Purcari sector has reached an average harvest per vine equal to 7.10 kg, the values being slightly higher than those in the Bugeac sector, thus, indicating a balance between the grapes weight

and the productive potential of the plantation.

Within the Mircesti sector, the average harvest per bush amounted to 6.10 kg, indicating a high total yield, even if the individual mass of grapes per bush has not been registered as being the highest. The sector presents a very good production potential due to the density of the vine.

Analysing the data on the average harvest per vine within the mentioned research years one can notice that the values appeared to be decreasing in the following regions: Purcari - 7.10 kg/vine; Bugeac - 6.68 kg/vine; Alexandru Ioan Cuza - 6.51 kg/vine; Mircesti - 6.10 kg/vine. The values obtained can be mainly explained by the crop load particularities and by the fertility of the vines.[57]

The comparative analysis among the sectors have emphasized that the Mircesti and the Purcari sectors present the highest grape weight harvested per vine (Purcari), followed by the Bugeac sector, with a good stability, whereas the Alexandru Ioan Cuza and the Bugeac sectors have provided average values, sensitive to extreme climatic conditions. The years 2017 and 2020, being characterized by high temperatures and water shortages, have determined a reduction of grape mass in most of the sectors, meanwhile, the high productive potential has highlighted the variety adaptability to extreme pedoclimatic conditions, of course with the adaptation of technological management to optimize the production quantity and quality.

It must be outlined that he statistical analysis of the agrobiological and the climatic factors influence on the average yield per bush (kg/vine) of the Rara Neagra variety has been implemented based on 20 experimental observations (2017-2021), proceeding from four representative wine-growing areas (A.I. Cuza, Bugeac, Purcari, Mircesti). The multiple regression model aimed to quantify the relationship between the dependent variable Y (average yield per vine) and the 10 explanatory factors (X_1-X_{10}), representing the structural parameters of the vine, the photosynthetic indicators and the climatic variables.

The equation estimated by the ordinary least squares (OLS) method is as follows:

$$\mathbf{Y_{Harvest}=1,5362-0,0351X_1-0,0194X_2+0,0114X_3+0,3329X_4+0,3150X_5-0,0049X_6+0,0019X_7+0,0026X_8-0,2013X_9+0,0035X_{10}} \quad (3.2)$$

The developed multiple regression model (3.2) for estimating the average yield is globally statistically significant (F = 3.6731 > Fcritical = 3.1373; p = 0.0316) and explains 80.32% of the variation within the production (R^2 = 0.8032; R^2adjusted = 0.5845), therefore, indicating a moderately-high explanatory capacity. Among the variables analyzed, the inflorescences per vine (X_4) exerts a significant positive influence on the yield, whilst the sum of the effective temperatures (X_6) and the chlorophyll index coefficient (CCI, X_9) show negative effects. The results confirm the determining structural and climatic factors role in achieving the production and highlight the existence of a high multicollinearity between the photosynthetic variables, without compromising the overall significance of the model.

3.5. Uvological and biometric particularities of the Feteasca Neagra and Rara Neagra varieties depending on the cultivation region

Following the analysis of the uvological and biometric indices of the Feteasca Neagra variety, cultivated in the A.I. Cuza, Bugeac, Leova, Purcari, Speia, Nisporeni and Mircesti sectors, has underlined significant variations with the grapes mass and dimensions, which have been determined by the pedoclimatic conditions and the annual climatic variability. The average grape weight varied between 181.88 g in the Nisporeni sector and 248.70 g in the Mircesti sector, with high values recorded as well in the sectors of Bugeac (223.81 g) and A.I. Cuza (207.90 g), and with intermediate values registered in the sectors of Purcari (198.36 g), Speia (195.23 g) and Leova (187.27 g). The average grapes dimensions varied between 14.62-17.46 cm in length and 8.60-11.69 cm in width, the

maximum values being recorded in the Mircesti and Speia sectors.

Along with, the grape berries weight and the mass of a single grape berry followed the same trend, with the maximum values being recorded in the Mircesti sector (239.61 g and 1.30 g/berry), and the minimum ones in the Nisporeni and the Leova sectros, confirming the direct correlation between the mass of the grape, its dimensions and the accumulation of organic substances in the berries.

As to the annual variability, it has been noted being significant in all the sectors, the years 2019-2020 being characterized by lower biometric parameters values, correlated with unfavorable climatic conditions, while the years 2017, 2018 and 2021, presented values above average, suggesting a hydrothermal regime favorable to the grapes development. The Mircesti, the Bugeac and the Purcari sectors stood out for higher values of biometric parameters, indicating favorable conditions for cultivating the Feteasca Neagra variety, while the Nisporeni and the Leova sectors presented lower values, suggesting the limiting influence of local pedoclimatic factors.

The uvological and biometric indices analysis of the Rara Neagra variety, cultivated in the A.I. Cuza, the Bugeac, the Purcari and the Mircesti sectors, has highlighted significant variations within the grapes mass and dimensions. The average weight of the grape varied between 246.29 g in the A.I. Cuza sector and 356.12 g in the Mircesti sector, with intermediate values being recorded in the sectors Bugeac (295.51 g) and Purcari (302.63 g). The average dimensions varied between 16.19-17.11 cm in length and 12.39-14.29 cm in width, confirming the superior morphological development in the Mircesti and Purcari sectors.

Accordingly, the average berry weight and the mass of a single berry followed the same trend, the maximum values being recorded in the Mircesti sector (346.65 g and 2.04 g/berry), and the minimum ones in the A.I. Cuza sector (237.20 g and 1.82 g/berry).

It should be stated that the annual variability has been pronounced in all the sectors, whereas the year 2020, being characterized by the lowest values of biometric parameters, while the 2017 and the 2021 have recorded favorable conditions for grape development. The Mircesti sector stood out as the most favorable for the cultivation of the Rara Neagra variety, followed by the sectors Purcari and Bugeac, while the A.I. Cuza sector presented lower values of biometric parameters, suggesting the limiting influence of local pedoclimatic factors.

3.6. Quality of Grapes as Raw Material and of the wines obtained

3.6.1. Quality indices of the Feteasca Neagra variety

During the research years, the reducing sugars content in the Feteasca Neagra variety cultivated in the Alexandru Ioan Cuza sector has recorded values between 195.6-229 g/dm^3, and an average value of - 215 g/dm^3. Based on the dispersion analysis at the 95% confidence level, it has been revealed that the limit difference obtained the values $DL_{0.95}$=56.77 g/dm^3. The above mentioned allows concluding that the significance level for all the research years proved to be insignificant.

The titratable acidity content has reached the values between 6.46 - 6.81 g/dm3, while the average value has approached to 6.64 g/dm^3. At the same time, it is possible to state that the must yield turned out to be 76.5 -83.5%, and the average value - 79.74%. The gluco-acidometric index (GAI) obtained values between 28.85-35.23, and an average value - 32,44.

In the Bugeac sector, the sugar content has oscillated between 196 - 270 g/dm^3 (average 241 g/dm^3), showing significant differences in 2021. The titratable acidity varied between 5.47 - 10.1 g/dm^3 (average 7.89 g/dm^3), the average must yield value - 81.98%, whit a GAI average value of 32,6.

In the Leova sector, the sugar content ranged between 186 - 265 g/dm^3 (average 227.6 g/dm^3), with significant differences in the years 2020 and 2021. The acidity varied between 6.3 - 10.6 g/dm^3 (average 8.36 g/dm^3), the average must yield value being 80.44%, and the GAI average value reaching 28,63.

The sugar content in the Purcari sector varied between 199 - 261 g/dm^3 (average 231.2 g/dm^3), with significant positive differences in 2017. The titratable acidity obtained the values between 6.3 - 9.6 g/dm^3 (average 8.07 g/dm^3). At the same time, we conclude that the must yield presented an average value of 82.32%, whilst the average GAI value registered 29.85.

During the research years, the Speia sector has offered sugar values between 176 - 263 g/dm³ (average 215.34 g/dm^3), with significant differences in the years 2019 and 2021. The content of titratable acids registered values between 6.1 - 9.1 g/dm^3 (average 7.2 g/dm^3), the average value of the must yield - 80.6% whilst the average GAI value approached - 30,71.

In the Nisporeni sector, the sugar concentration varied between 216.3 - 274 g/dm^3 (average 242.38 g/dm^3), with insignificant differences in between the years. The titratable acidity registered values between 5.95-6.12 g/dm^3 (average 6.04 g/dm^3), the average value of the must yield being 79.02% and the average GAI value showing - 40,14.

In the Mircesti sector, the sugar concentration values ranged between 225.3 - 268 g/dm³ (average 244.26 g/dm^3), with significant positive differences in the years 2017 and 2021, while in 2020 there was a significant negative difference. The acidity content reached values between 5.7 - 7.5 g/dm^3 (average 6.79 g/dm^3), the average must yield being 81.5%, and the GAI indicating - 36,41.

It is noteworthy that the results obtained have confirmed the presence of differences between the grapes biochemical parameters depending on the sector and the annual climatic conditions, therefore, highlighting the influence of terroir on the accumulation of sugars, titratable acidity and on the must yield.

The statistical modeling results dealing with the influence of the agrobiological and the climatic factors on the sugar content in the Feteasca Neagra variety, during the period 2017-2021, in seven localities from three wine-growing regions, have been coherently integrated into the general objective of the thesis, confirming the systemic nature of the relationship between the terroir, the biological structure of the bush and the qualitative production expression.

The estimated multiple linear regression model for Feteasca Neagra variety is:

$$\mathbf{Y=-35,615-1,5697X_1-3,7452X_2+5,3368X_3-0,8782X_4+22,839X_5-0,0034X_6+0,0832X_7-0,0226X_8+0,154X_9+0,0358X_{10}} \quad (3.3)$$

The multiple linear regression model (3.3) developed for estimating the sugar content of the Feteasca Neagra variety is statistically significant (F=3,6633; p=0,0044) and explains 60,42% of this parameter variation (R^2 = 0.6042; R^2adjusted = 0.4393), indicating a moderate explanatory capacity. It must be stressed that the results highlight as the negative influence of the buds and shoots number per bush as well as the positive effect of the fertile shoots and of the average annual temperature, thus, confirming the role played by the vegetative-generative balance and by the thermal resource within the glucose accumulation. The high VIF values for the photosynthetic indicators point to a multicollinearity between these parameters, without compromising the overall significance of the model.

The integration the statistical analysis results on the titratable acidity (A.T.) of the Feteasca Neagra variety into the research makes it possible to underline the fundamental aspect of the research: the qualitative expression of grapes is being differently determined by the agrobiological and the climatic factors, whereas the sensitivity of biochemical parameters to the *terroir* influences is not uniform.

The multiple regression model (3.4) created for estimating titratable acidity, has shown a reduced and statistically insignificant explanatory capacity ($R^2 = 0.3699$; R^2adjusted = 0.1073; p = 0.2354), thus, indicating the lack of a robust linear relationship between the titratable acidity and the set of agrobiological and climatic variables analyzed. Compared to the sugar model ($R^2 = 0.6042$; p = 0.0044), the results emphasize that the acidity is less dependent on the bush structural factors and on the average climatic parameters. This suggests that the acidity variability is mainly determined by the metabolic processes and the microclimatic conditions, which are not fully reflected within the variables included in the model. The estimated equation for the titratable acidity is:

$$\mathbf{Y=16,2859+0,0012X_1+0,1430X_2-0,0229X_3-0,0939X_4-0,6138X_5-0,0002X_6-0,0039X_7+0,0016X_8-0,0144X_9-0,0018X_{10}} \quad (3.4)$$

It is to be mentioned that the comparative analysis of physico-chemical indices of Feteasca Neagra wine among the sectors brings to light the differences between the wine-growing sectors under study, which have been determined by both the pedoclimatic conditions and the technological cultivation factors.

It is necessary to underline that the alcoholic content for the Feteasca Neagra wines has varied between 12.85% vol. (Speia) and 14.06% vol. (Nisporeni), the titratable acidity between 4.37 and 5.10 g/dm³, while the pH has registered values between 3.38 and 3.61. The total extract has shown a maximum in the sectors Bugeac (30.41 g/dm³) and Purcari (29.62 g/dm³), and lower indices in the Leova and the Mircesti sectors (28.6-28.8 g/dm³). The total phenolic substances concentrated the highest in the sectors Nisporeni (2127 mg/dm³) and Mircesti (2044 mg/dm³), the highest anthocyanins values have turned up to be in the Purcari (332 mg/dm³) and the Mircesti sectors (319 mg/dm³), therefore, conferring a chromatic stability. The color intensity reached maximum values within the sectors of Mircesti (0.834) and Purcari (0.801), whilst the total polyphenolic index has registered a maximum in the Bugeac (64.3) and the Nisporeni (62.9). The results provide a basis to confirm the significant influence of the *terroir* on the physicochemical profile and the maturation potential of the wines, thus, highlighting the variety adaptability to the local conditions.

It is significant to note that the multiple regression analysis (3.5) has revealed that 50.19% of the variation in the content of phenolic substances within the Feteasca Neagra wine is to be explained by 10 agrobiological, photosynthetic and climatic factors ($R^2 = 0.5019$; adjusted $R^2 = 0.2944$; F = 2.4186; p = 0.0371), having, thus, demonstrated their real influence on the phenolic expression. The estimated multiple linear regression model is:

$$\mathbf{Y = 1705,753 + 1,667X1 - 82,584X2 + 81,110X3 - 5,881X4 - 51,106X5 + 0,816X6 - 0,530X7 - 0,010X8 - 21,215X9 + 0,442X10} \quad (3.5)$$

It should be also emphasized that the negative coefficient for the "shoots on the vine" (b = -82.584; p = 0.007) and the positive coefficient for the "fertile shoots" (b = 81.110; p = 0.052) underline the importance of the vegetative-generative balance within the phenolic accumulation. The sum of effective temperatures has positively correlated with the phenolics (r = 0.438), whilst the precipitation has proven to show a slightly negative effect (r = -0.269). Altogether, the photosynthetic indicators (leaf area, CCI, PAR) have revealed a high multicollinearity, indicating an integrated influence on phenolic maturation.

It is appropriate to indicate that the model has confirmed the phenolic expression to depend on the interaction between the biological structure of the bush, the thermal resource, the water availability and the functionality of the photosynthetic apparatus, manifesting itself specifically in the local *terroir*. Appliedly, the results support the differentiated management of the crop load and the vine vigor to capitalize on the qualitative potential of the variety.

3.6.2. Quality indices of the Rara Neagra variety

Analysing the grape quality indices, one could be able to witness see that in the Alexandru Ioan Cuza Sector, the sugar content has reached the values between 195.6 - 226 g/dm^3, with an average of 208.82 g/dm^3, the differences being statistically insignificant, except for the year 2020. The titratable acid content varied between 6.23 - 7.33 g/dm^3 (average 6.79 g/dm^3), the must yield between 76.8 - 81.34% (average 79.35%), and the average GAI value being 30.95.

In the Bugeac sector, the sugar content ranged between 151 - 223 g/dm^3 (average 195.66 g/dm^3), with significant differences in the years 2019 - 2021. The titratable acidity presented the highest values, between 8.7 - 14.4 g/dm^3 (average 11.02 g/dm^3), the average must yield value being 81.52%, whilst the GAI = 18.84, indicating a lower technological maturation.

As to the Purcari sector, the reducing sugar content varied between 181-222 g/dm^3, with an average of 202.86 g/dm^3, without statistically significant differences. The acidity ranged between 7.92-11 g/dm^3 (average 9.2 g/dm^3), the average must yield value - 81.33%, and the GAI = 22.63.

The Mircesti sector has recorded the sugar content between 194-221 g/dm^3, with an average of 208.26 g/dm^3, without significant differences between the years. The titratable acidity varied between 8.6-10.7 g/dm^3 (average 9.46 g/dm^3), the must yield between 73.6-87.3% (average 79.04%), and the GAI obtained values between 19.07-24.83, while the average value reached - 22.16

Summing up it needs to be specified that the Alexandru Ioan Cuza sector has stood out presenting the highest GAI and a moderate acidity, indicating a favorable sugar-acidity balance, while the sector of Bugeac has rgistered the highest acidity and the lowest IGA, reflecting a weaker technological maturation.

The statistical analysis of the agrobiological and the climatic factors influence on the grape berry sugar content in the Rara Neagra variety, carried out based on 20 observations (2017-2021; four locations), aimed to quantify the relationship between the structural parameters of the bush, the photosynthetic indicators and the climatic variables on the accumulation of carbohydrates during the ripening period.

$$\mathbf{Y_z=276,226+0,6979X_1-0,7970X_2-0,4601X_3+0,4981X_4-1,6261X_5+0,0159X_6-0,1162X_7+0,0075X_8+3,0254X_9-0,0997X_{10}} \quad (3.6)$$

The equation estimated using the ordinary least squares (OLS) method (3.6) has demonstrated that the model is not globally statistically significant (F = 1.1198; p = 0.4373), having a coefficient of determination $R^2 = 0.5544$ and adjusted $R^2 = 0.0593$, which indicates a low explanatory power. Among the variables, only photosynthetic active radiation (PAR) has proven to be significant (p = 0.0479), suggesting indirect influences of the radiative stress or water imbalances on the glucose accumulation. The results obtained tend to indicate that the sugar content depends more on thermal and water conditions than on the vegetative bush structure, the high multicollinearity between photosynthetic indicators reducing the stability of the individual coefficients (VIF = 18,6-36,9).

It was interesting to discover that the multiple regression analysis for titratable acidity (A.T.) for the Rara Neagra variety (20 observations, 2017-2021, four locations) showed that the model is globally statistically significant (F = 3.6731; p = 0.0316), with a coefficient of determination $R^2 = 0.8032$ and R^2adjusted = 0.5845, indicating that approximately 80% of the variation in acidity could be explained by the included agrobiological and climatic factors. The equation estimated using the ordinary least squares (OLS) method is:

$$\mathbf{Y_{AT}=7,3333-0,1119X_1+0,1012X_2-0,0207X_3-0,0848X_4-0,3589X_5+0,0024X_6+0,0125X_7-0,0046X_8-0,1366X_9+0,0084X_{10}} \quad (3.7)$$

Out of the variables, the photosynthetically active radiation (PAR) has proven to be positively significant (p = 0.0253), while the average annual temperature has negatively influenced the acidity, meanwhile the precipitation has shown a positive effect.

After all the above taken into consideration, the results suggest that the titratable acidity mainly depends on the thermal factors, the radiative and water regime, being more directly correlated with the environmental conditions than with the vegetative bush structure.

The comparative analysis of the quality indices for the Rara Neagra wine has revealed differences between the wine-growing sectors, determined by the pedoclimatic conditions and the applied viticultural technologies. The alcohol content has turned up to present similar values between the sectors, with a slight upward trend within the sectors A.I. Cuza (11.94 %vol) and Mircesti (11.89 %vol), indicating a relatively uniform degree of grapes maturation. The titratable acidity has proven to be higher in the sector of Bugeac (5.41, g/dm3), which suggested a more pronounced freshness. In contrast, the sectors A.I. Cuza and Purcari present slightly lower pH values, suggesting a higher potential for stability.

The average content of total phenolic substances has reached the maximum in the Mircesti sector (1436.83 mg/dm^3), followed by the sectors Purcari (1403.33 mg/dm^3), A.I. Cuza (1327.00 mg/dm^3) and Bugeac (1297.01 mg/dm^3). The average concentration of anthocyanins has registered its highest in the Purcari sector (234.90 mg/dm^3), followed by the sectors Bugeac (208.20 mg/dm^3), Mircesti (188.00 mg/dm^3) and A.I. Cuza (178,50 mg/dm^3).

The multiple regression model for the Rara Neagra variety (2017-2021, within the A.I. Cuza, Bugeac, Purcari and Mircesti areas) explains 28.64% of the variation in phenolic substances content ($R^2 = 0.2864$), not confirming the global significance ($F = 0.3613$; $p = 0.9358$). The stated above indicates a complex determinism of phenolic expression, insufficiently captured by the vegetative-generative, climatic and photosynthetic variables included in the multiple linear regression model (3.8).

$$\mathbf{Y=1749,983+14,127X_1-12,652X_2-16,108X_3+25,356X_4-92,364X_5+0,369X_6-0,303X_7+0,158X_8-12,754X_9-0,016X_{10}} \quad (3.8)$$

The bush structure coefficients (buds, shoots, inflorescences) have proven to be insignificant ($p > 0.4$), while the simple correlations have confirmed weak links, a fact showing that the phenolic maturation depends on the fine balance between the photosynthetic source, the metabolic consumption and the maturation conditions, and not only on the amount of vegetative elements. The climatic factors (average temperature, sum of temperatures, precipitation) and the photosynthetic parameters (leaf area, CCI, PAR) have registered limited effects and a high collinearity, thus, highlighting complex interdependencies.

3.7. Analysis of the economic efficiency of cultivating grapevine varieties depending on the cultivation region

It must be noted that analyzing the economic efficiency of the Feteasca Neagra variety cultivation in different sectors has highlighted significant variations as to the profitability, (Fig. 3.5.) which have been determined mainly by the level of harvest per hectare and the annual climatic conditions.

It is useful to note that analyzing the data for the Alexandru Ioan Cuza sector, it has turned out that the profitability of cultivating the Feteasca Neagra variety has ranged between 52-178%, with an average of 107.7%. The average harvest registered 15.89 t/ha, the average production cost 22.94 thousand lei/ha, whilst the average income has approached to 47.66 thousand lei/ha, resulting in an average profit of 24.72 thousand lei/ha.

Within the Bugeac Sector, the profitability of cultivating the Feteasca Neagra variety varied between 6.44% and 81.98%, with an average of 40.14%, influenced by the production per hectare (6.47-13.06 t/ha, average 9.14 t/ha). The average costs registered 19.57 thousand lei/ha, the average

income constituted 27.43 thousand lei/ha, and the average profit equalled to 7.86 thousand lei/ha.

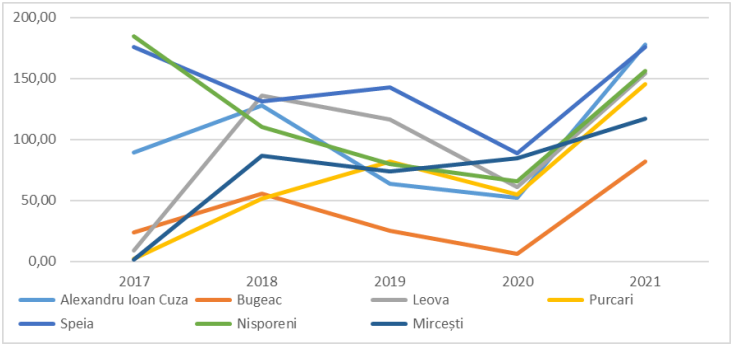


Fig. 3.5. The level of grape production profitability for the Feteasca Neagra variety depending on the cultivation region (2017-2021)

Regarding the Leova sector, the profitability of cultivating the Feteasca Neagra variety varied between 9.14% and 154.31%, with an average of 101.95%, influenced by the production per hectare (6.67-22.07 t/ha, average 15.22 t/ha). The average expenses constituted 22.61 thousand lei/ha, the average income recorded 45.66 thousand lei/ha, and the average profit reached 23.05 thousand lei/ha.

As to the Purcari sector, the profitability of the Feteasca Neagra variety ranged between 2.07% and 145.53%, with an average of 72.55%, influenced by the average harvest of 12.11 t/ha. The average expenses constituted 21.06 thousand lei/ha, the average income reached 36.33 thousand lei/ha, and the average profit registered 15.27 thousand lei/ha.

For the Speia sector, the profitability of the Feteasca Neagra variety ranged between 88.76% and 175.91%, with a high average of 145.59%, supported by an average productivity of 20.79 t/ha. The average expenses came up to 25.39 thousand lei/ha, the average income reached 62.36 thousand lei/ha, and the average profit constituted 36.97 thousand lei/ha.

In the Nisporeni District, the profitability of the Feteasca Neagra variety ranged between 65.32% and 184.54%, with an average of 124.66%, supported by an average harvest of 17.96 t/ha. The average expenses reached 23.98 thousand lei/ha, the average income constituted 53.87 thousand lei/ha, and the average profit registered 29.89 thousand lei/ha.

In the Mircesti Sector, the profitability of the Feteasca Neagra variety ranged between 1.11% and 117.02%, with an average of 75.73%, supported by an average harvest of 12.43 t/ha. The average expenses constituted 21.21 thousand lei/ha, the average income recorded 37.28 thousand lei/ha, and the average profit reached 16.065 thousand lei/ha.

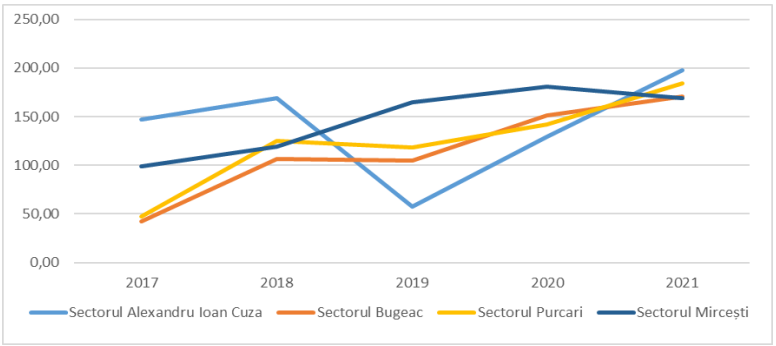


Fig. 3.6. The level of grape production profitability for the Neagra Rara variety depending on the cultivation region (2017-2021)

It is necessary to mention that the analysis of the economic efficiency as to cultivating the Rara Neagra variety in the Alexandru Ioan Cuza sector (Fig. 3.6.) has forecasted a profitability of grape production ranging between 57.30% and 197.83%, with an average of 145.85%. The above

mentioned has been correlated with the productivity per hectare between 10.66 and 29.57 t/ha, with an average of 20.83 t/ha. The expenses per hectare ranged between 20.33 and 29.79 thousand lei, with an average of 25.413 thousand lei, while the revenues oscillated between 31.98 and 88.71 thousand lei, with an average of 62.48 thousand lei. Under such conditions, the profit per hectare varied between 11.65 and 88.71 thousand lei, with an average profit reaching 37.07 thousand lei.

In the Bugeac sector, the profitability of cultivating the Rara Neagra variety varied between 41.98% and 170.63%, with an average of 119.88%, influenced by the harvest of 9.30-24.65 t/ha (average 17.35 t/ha). The average expenses constituted 23.68 thousand lei/ha, the average income reached 52.06 thousand lei/ha, and the average profit registered 28.39 thousand lei/ha.

In the Purcari sector, the profitability of cultivating the Rara Neagra variety varied between 47.06% and 183.82%, with an average of 128.39%, influenced by the harvest of 9.74-26.93 t/ha (average 18.44 t/ha). The average expenses constituted 24.22 thousand lei/ha, the average income reached 55.31 thousand lei/ha, and the average profit recorded 31.10 thousand lei/ha.

In the Mircesti sector, the profitability of cultivating the Rara Neagra variety varied between 98.75% and 180.68%, with an average of 149.25%, supported by a harvest of 14.86-26.37 t/ha (average 21.32 t/ha). The average expenses constituted 25.66 thousand lei/ha, the average income reached 63.95 thousand lei/ha, and the average profit recorded 38.30 thousand lei/ha.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the research related to the doctoral thesis "The Potential of *Terroir*-Based Autochthonous Vine Varieties Within the Conditions of the Republic of Moldova", the following conclusions and scientific recommendations can be formulated:

1. The *terroir* evaluation by integrating pedoclimatic, topographic and ampelographic data allows correlating the environmental conditions with the performance of autochthonous varieties, highlighting the importance of interdisciplinary methods in defining viticultural typicity and in adapting to climate change.
2. The national mapping of the Feteasca Neagra and Rara Neagra varieties highlights their uneven distribution, with high concentrations in the south of the country; the cultivated areas amount to 424.0 ha for Feteasca Neagra and 222.7 ha for Rara Neagra. The data obtained highlight the need for a differentiated valorization of autochthonous varieties, depending on the eco-pedoclimatic particularities of the viticultural sectors and on their oenological and biological potential.
3. The analysis of agroecological conditions revealed regional differences among the seven wine-growing areas studied. The Alexandru Ioan Cuza, Purcari, Bugeac and Speia sectors recorded the highest average temperatures and sums of effective temperatures, influencing the extension of the vegetation period. The data reflect a clear warming trend in all the analyzed regions, with an increase in the average annual temperature compared to the multiannual averages ranging from 1.8°C (Mircesti) to 3.5°C (Bugeac).
4. For the Feteasca Neagra and Rara Neagra varieties, the longest vegetation period was recorded in the Alexandru Ioan Cuza sector, approx. 247 days, which confirms the direct influence of the *terroir* on the course of phenophases. The accumulation of thermal resources can shorten the grape ripening phenophase, as demonstrated by the duration of only 32 days recorded for the Feteasca Neagra variety in the Alexandru Ioan Cuza sector in 2019, at a SEFT value of 1940.3°C.
5. The evaluation of physiological parameters revealed differences between varieties and sectors regarding the development of the leaf system and the intensity of photosynthesis. The average leaf area was 1440.45 cm²/shoot for the Feteasca Neagra variety and 1394.02 cm²/shoot for Rara

Neagra, while the average chlorophyll content index recorded close values of 22.96 and 22.89, respectively. In all the analyzed sectors, a decreasing distribution of the photosynthetically active radiation intensity towards the base of the vine was found, especially for the Rara Neagra variety. These results emphasize the need to differentiate the green operations and the canopy management.

6. The inter-sectoral comparative analysis of the Feteasca Neagra variety revealed differences in fertility and productivity. Shoot fertility ranged between 72.66% in Bugeac and 88.89% in Nisporeni, while the RFC (1.02–1.22) and AFC (1.26–1.44) values confirmed a good reproductive potential. The highest calculated average yields were recorded in the Speia (20.79 t/ha), Nisporeni (17.96 t/ha) and Alexandru Ioan Cuza (15.89 t/ha) sectors, while Mircesti stood out with the highest average grape weight (248.7 g) and the highest API (320.64 g). The multiple regression model explained 82.33% of the yield variation for the Feteasca Neagra variety ($R^2 = 0.8233$). The variables included in the model with statistical significance and positive correlation are the inflorescences per bush ($b = 0.1819$; $p = 0.0006$), while the average annual temperature showed a significant negative association ($b = -0.6939$; $p = 0.0279$), which demonstrates the limiting effect of thermal stress on the harvest quantity.

7. The Rara Neagra variety stood out through a high level of fertility and productivity in most of the studied viticultural sectors, confirming a high adaptability to the agroecological conditions of these areas. The Mircesti sector stood out with the highest average grape weight (356.12 g) and yield per hectare (21.32 t/ha), the Purcari sector with the maximum yield per vine (7.10 kg), and Bugeac with the high values of the maximum percentage of buds started in growth (86.84%), AFC (1.43) and API (507.2 g). The multiple regression model is statistically significant ($F = 3.6731$; $p = 0.0316$), explaining 80.32% of the yield variation ($R^2 = 0.8032$) and confirming the cumulative contribution of agrobiological and climatic factors to yield formation.

8. The uvological analysis of the Feteasca Neagra variety demonstrated the existence of morphological and structural differences between sectors, influenced by the terroir. The Bugeac, Mircesti and Speia sectors stood out with the highest bunch structure index (22.04; 20.13; 20.11), while the average mass of a berry ranged between 1.03 g in Speia and 1.48 g in Alexandru Ioan Cuza. The statistical analysis demonstrates that 60.42% of the variation in grape sugar content ($R^2 = 0.6042$) is explained by the factors included in the model. In the case of titratable acidity, the model did not show statistical significance ($R^2 = 0.3699$), which does not allow confirming a significant statistical relationship with the analyzed factors.

9. The uvological and biometric characteristics of the Rara Neagra variety highlighted the Mircesti sector with the highest bunch structure index (18.59), followed by Bugeac (17.50), Purcari (16.20) and Alexandru Ioan Cuza (14.57). The average mass of a berry ranged between 1.80 g in Bugeac and 2.04 g in Mircesti. The Alexandru Ioan Cuza sector stood out with the highest GAI. The statistical analysis of the relationship between the agrobiological and climatic factors and the grape sugar content of the Rara Neagra variety showed moderate positive correlations with the average annual temperature ($r = 0.4274$) and the sum of effective temperatures ($r = 0.3844$), as well as a moderate negative correlation with precipitation ($r = -0.4322$); at the same time, the multiple regression model was not statistically significant ($p = 0.4373$), and the low value of the adjusted coefficient of determination (adjusted $R^2 = 0.0593$) limits its explanatory capacity. For titratable acidity, the mathematical model is globally statistically significant ($p < 0.05$), and the coefficient of determination is $R^2 = 0.8032$.

10. The evaluation of the oenological potential of the wines obtained from the Feteasca Neagra variety reflects the specificity of the local *terroir*. The pedoclimatic factors directly influenced the content of alcohol, extract and phenolic compounds, contributing to the formation of wines with a

distinct regional typicity. The average alcohol concentration ranged between 12.85% vol. in the Speia sector and 14.06% vol. in Nisporeni. The average content of total phenolic substances ranged from 1663.31 mg/dm³ in Speia to 2127.06 mg/dm³ in Nisporeni. The average anthocyanin content ranged between 238.30 mg/dm³ in Leova and 265.55 mg/dm³ in Mircesti. The multiple regression analysis shows that 50.19% of the variation in the content of phenolic substances is explained by the set of the 10 variables included in the model ($R^2 = 0.5019$).

11. The alcohol content of the Rara Neagra wines showed close values across sectors, with a slight upward tendency in the A.I. Cuza (11.94% vol.) and Mircesti (11.89% vol.) sectors, indicating a relatively uniform degree of grape ripening. The average content of total phenolic substances is highest in the Mircesti sector (1436.83 mg/dm³), followed by Purcari (1403.33 mg/dm³), A.I. Cuza (1327.00 mg/dm³) and Bugeac (1297.01 mg/dm³). The average anthocyanin concentration is highest in Purcari (234.90 mg/dm³), followed by Bugeac (208.20 mg/dm³), Mircesti (188.00 mg/dm³) and A.I. Cuza (178.50 mg/dm³), reflecting the superior chromatic potential of the Purcari wines. The multiple regression for phenolic substances in this variety does not confirm a globally statistically significant relationship among the set of analyzed factors. The model explains 28.64% of the total variation in the content of phenolic substances ($R^2 = 0.2864$).

12. The economic evaluation demonstrated that valorizing autochthonous varieties can ensure a high economic efficiency in favorable sectors. The Feteasca Neagra variety showed a superior adaptability in the Speia, Nisporeni and Purcari sectors; the average profitability exceeded 120% in Speia and Nisporeni, and the profit per hectare reached, in certain cases, values of over 30 thousand lei. For the Rara Neagra variety, the average profitability exceeded 140% in Alexandru Ioan Cuza and Mircesti, and the profit per hectare exceeded, in some cases, 38 thousand lei. These findings demonstrate the need for an integrated evaluation of productivity, grape and wine quality and production costs in order to identify the sectors with economic advantage and to guide the decisions regarding the placement and management of plantations.

Recommendations for production:

1. For the production of premium Feteasca Neagra wines, with phenolic structure, chromatic intensity and ageing potential, the priority valorization of the Mircesti, Purcari and Alexandru Ioan Cuza *terroirs* is recommended. Mircesti has the advantage of a high accumulation of phenolic substances and anthocyanins, Purcari combines a well-expressed acidity with a superior chromatic and polyphenolic potential, while Alexandru Ioan Cuza is suitable for structured and balanced wines.

2. For the production of Feteasca Neagra wine with a favorable ratio between oenological quality and economic efficiency, the Nisporeni sector is recommended, the wine being characterized by a high alcohol and phenolic concentration, a low pH and an average profitability of over 120%. The Speia sector can be oriented towards producing suppler and more elegant red wines, intended for the commercial segment.

3. For the valorization of the Rara Neagra variety aimed at obtaining high and stable yields, with a well-expressed acidity and a gastronomic character, the Alexandru Ioan Cuza and Bugeac sectors are recommended, which showed favorable productivity indices and a high average yield. The phenological stability of the sector also supports this orientation.

4. For Rara Neagra with added value and terroir identity, the Purcari and Mircesti sectors are recommended. Purcari can be oriented towards premium wines with structure and phenolic expression, while Mircesti towards wines with a distinct expression of origin, supported by the climatic particularities and by the favorable values of the qualitative and productive parameters. This differentiation allows valorizing the variety not only through the harvest quantity, but also by associating the origin with a distinct oenological profile.

Recommendations for science:

1. Further in-depth research is recommended on the relationships between terroir factors, the physiological indices of the leaf apparatus (CCI, PAR, leaf area) and the phenolic expression of the wines obtained from Feteasca Neagra, as well as the development of predictive models for assessing the productive and oenological potential of the variety under climate change conditions.

2. It is recommended to continue the studies on the agroecological and physiological adaptability of the Rara Neagra variety in different viticultural areas of the Republic of Moldova, including research on the influence of pedoclimatic conditions on the accumulation of phenolic compounds, acidity and wine typicity, with a view to optimizing viticultural and oenological technologies differentiated by terroir.

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9. **MOGÎLDEA O**., COCIORVA S., Diversitatea regiunilor vitivinicole în Republica Moldova. In: *Programul simpozionului științific internațional, Sectorul agroalimentar-realizări și perspective.* UTM, Chișinău, 2023. pag 131. ISBN: 978-9975-165-51-8.
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12. **MOGÎLDEA, O.**, VOINESCO, C., *Terroir*-actualitate și perspectivă.În: *Tezele celei de-a 75-a conferință științifică a studenților, masteranzilor și doctoranzilor.* Chișinău, UASM, 2022. pag.44, ISBN: 978-9975-64-336-8

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14. **MOGÎLDEA, O.** Caracteristica uvologică a soiului *Fetească neagră* și factorii ecologici de influență asupra calității strugurilor pentru producerea vinurilor IGP. In: *Tezele celei de-a 74-a conferință științifică a studenților, masteranzilor și doctoranzilor.* Chișinău, UASM, 2021. p. 44.

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4. Patents and other intellectual property objects (IPO)

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1. GRIZA, I., BOGATÎI, E., MELNIC, N., **MOGÎLDEA, O**., PRIDA, I., VACARCIUC, L. Procedeu de prelucrare a strugurilor cu boabe negre. Brevet de invenție MD nr. 4864 (13) B1. A23L 2/00; A23L 2/04; C12G 1/02; C12G 1/028; A23B 7/06; A23B 7/16; C01B 7/14; C08L 3/00; C12G 1/10, nr. depozit: a 2021 0021, data depozit: 2021.04.12, data acordării: 2023.07.31. Universitatea Tehnică a Moldovei. 31.07.2023. *Buletinul Oficial de Proprietate Intelectuală.* 2023, nr. 7, p. 32. https://www.agepi.gov.md/sites/default/files/bopi/BOPI_07_2023.pdf

ADNOTARE

Mogîldea Olga. Potențialul soiurilor autohtone de viță de vie în funcție de *terroir* în condițiile Republicii Moldova. Teză de doctor în științe agricole, specialitatea 411.07 - Viticultură. Universitatea Tehnică a Moldovei, Chișinău, 2026.

Structura tezei: Teza este elaborată în limba română și include introducere, trei capitole, concluzii generale și recomandări, bibliografie și anexe. Volumul lucrării este de 130 pagini partea principală, conținând 20 tabele, 27 figuri și 12 anexe. Bibliografia cuprinde 214 surse. Rezultatele sunt valorificate în 19 publicații științifice.

Cuvinte-cheie: Calitate, Factori climatici, Fetească Neagră, Fenologie, Fertilitate, Productivitate, Rară Neagră.

Scopul cercetării: constă în evaluarea comparativă a influenței factorilor de terroir (specifici regiunilor vitivinicole Codru, Ștefan Vodă, Valul lui Traian) asupra potențialului agrobiologic, tehnologic și economic al cultivării soiurilor autohtone Fetească neagră și Rară neagră, în vederea optimizării calității producției și valorificării potențialului oenologic al acestora în Republica Moldova.

Obiectivele principale ale cercetării: Determinarea influenței factorilor de terroir asupra creșterii și fructificării soiurilor Fetească Neagră și Rară Neagră; analiza parametrilor agrobiologici și productivi; stabilirea relațiilor dintre factorii de mediu și calitatea strugurilor și vinurilor; elaborarea recomandărilor de optimizare a amplasării și tehnologiilor.

Problema științifică abordată și noutatea cercetării: Problema științifică soluționată constă în elucidarea influenței complexe a factorilor de *terroir* (sol, climă, topografie) asupra comportamentului agrobiologic și a calității oenologice a soiurilor autohtone, oferind o bază științifică pentru zonarea ecologică și amplasarea optimă. Noutatea constă în abordarea integrată a relației soi-*terroir*, cartografierea distribuției soiurilor *Feteasca Neagra* și *Rara Neagra* și evidențierea influenței condițiilor agroecologice asupra potențialului productiv și oenologic.

Rezultatele principale: Au fost evidențiate particularitățile agrobiologice ale soiurilor în diferite condiții de *terroir*; s-a demonstrat influența factorilor climatici și pedologici asupra fertilității, productivității și calității; au fost stabilite relații între parametrii fiziologici și indicatorii productivi; s-a determinat variabilitatea potențialului oenologic în funcție de zona de cultivare; au fost fundamentate criterii de zonare și valorificare a soiurilor autohtone.

Semnificația teoretică și valoarea aplicativă: Rezultatele contribuie la fundamentarea științifică a relației soi-*terroir* și a zonării viticole. Valoarea aplicativă constă în utilizarea acestora pentru optimizarea amplasării plantațiilor, creșterea productivității și îmbunătățirea calității producției vitivinicole.

Implementarea rezultatelor științifice: Rezultatele științifice obținute sunt implementate în plantațiile viticole ale entităților din sectorul vitivinicol - Vinăria Purcari, Crama Mircești, ȘP Leova, Ș.P. Nisporeni, Vinăria Chateau Vartely, Castel Mimi

АННОТАЦИЯ

Могылдя Ольга. Потенциал местных сортов винограда в зависимости от терруара в условиях Республики Молдова. Диссертация на соискание ученой степени доктора сельскохозяйственных наук, специальность 411.07 - Виноградарство. Технический университет Молдовы, Кишинэу, 2026.

Структура диссертации: Диссертация выполнена на румынском языке и включает введение, три главы, общие выводы и рекомендации, библиографию и приложения. Общий объем работы составляет 130 страниц, включая 20 таблиц, 27 рисунков и 12 приложений. Библиография содержит 214 источников. Результаты исследования опубликованы в 19 научных работах.

Ключевые слова: Качество, Климатические факторы, Плодоношение, Продуктивность, Рара нягрэ, Фенология, Фетяска нягрэ.

Цель исследования: заключается в сравнительной оценке влияния факторов терруара (характерных для винодельческих регионов Кодру, Штефан-Водэ и Валул луй Траян) на агробиологический, технологический и экономический потенциал выращивания местных сортов Фетеаска нягрэ и Рара нягрэ с целью оптимизации качества продукции и реализации их энологического потенциала в Республике Молдова.

Основные задачи исследования: Определение влияния факторов терруара на рост и плодоношение сортов Фетяска Нягрэ и Рара Нягрэ; анализ агробиологических и продуктивных показателей; установление взаимосвязей между факторами среды и качеством винограда и вин; разработка рекомендаций по оптимизации размещения и технологий возделывания.

Научная проблема и новизна исследования: Научная проблема заключается в выявлении комплексного влияния факторов терруара (почва, климат, рельеф) на агробиологическое поведение и энологическое качество местных сортов винограда, что обеспечивает научную основу для экологического районирования и оптимального размещения. Новизна исследования состоит в комплексном подходе к системе «сорт-терруар», детальной картографической оценке распределения сортов Фетяска Нягрэ и Рара Нягрэ и выявлении влияния агроэкологических условий на продуктивный и энологический потенциал.

Основные результаты: Установлены агробиологические особенности сортов в различных условиях терруара; доказано влияние климатических и почвенных факторов на плодовитость, продуктивность и качество; выявлены взаимосвязи между физиологическими параметрами и продуктивными показателями; определена вариабельность энологического потенциала в зависимости от зоны выращивания; обоснованы критерии районирования и рационального использования автохтонных сортов.

Теоретическая значимость и практическая ценность: Результаты способствуют научному обоснованию взаимосвязи «сорт-терруар» и виноградарского районирования. Практическая ценность заключается в использовании результатов для оптимизации размещения виноградников, повышения продуктивности и улучшения качества винодельческой продукции.

Внедрение научных результатов: Полученные научные результаты внедряются на виноградниках предприятий винодельческого сектора - винодельни «Пуркари», винодельни «Мирчешти», учреждения СПО «Леова» и «Ниспорены», винодельни «Шато Вартели» и «Кастель Мими»

ANNOTATION

Mogîldea Olga. The potential of local grapevine varieties in the Republic of Moldova depending on *terroir*. PhD thesis in agricultural sciences, specialty 411.07 - Viticulture. Technical University of Moldova, Chișinău, 2026.

Thesis structure: The thesis is written in Romanian and includes an introduction, three chapters, general conclusions and recommendations, the bibliography and annexes. The volume of the thesis constitutes 130 pages, including 20 tables, 27 figures and 12 annexes. The bibliography comprises 214 sources. The results are disseminated in 19 scientific publications.

Keywords: Climate factors, Fertility, Feteasca Neagra, Phenology, Productivity, Quality, Rara Neagra.

Aim of the research: to comparatively assess the influence of terroir factors (specific to the wine-growing regions of Codru, Ștefan Voda, and Valul lui Traian) on the agrobiological, technological and economic potential of cultivating of the autochthonous Feteasca neagra and Rara neagra grape varieties, in order to optimize production quality and enhance the valorization of their oenological potential in the Republic of Moldova.

Research objectives: Determining the *terroir* factors influence on the growth and fruiting of *Feteasca Neagra* and *Rara Neagra* varieties; analyzing the agrobiological and the productive parameters; establishing relationships between the environmental factors and the grape and wine quality; developing recommendations intended to optimize the vineyard placement and the technologies.

Scientific problem addressed and research novelty: The scientific problem consists in elucidating the complex influence of the *terroir* factors (soil, climate, topography) on the agrobiological behavior and oenological quality of native grapevine varieties, thus, providing a scientific basis for carrying out an ecological zoning and an optimal placement. The novelty of the study lies in its integrated approach to the "variety-*terroir*" system, in a detailed cartographic assessment of the *Feteasca Neagra* and *Rara Neagra* varieties distribution, and in identifying the influence of agroecological conditions on the productive and oenological potential.

Main results: The agrobiological particularities of the varieties under different *terroir* conditions have been identified; the influence of climatic and soil factors on the fertility, the productivity and the quality has been demonstrated; the relationships between the physiological parameters and the productive indicators have been established; the variability of oenological potential depending on cultivation area has been determined; the criteria for zoning and native varieties valorization have been substantiated.

Theoretical significance and practical value: The results contribute to the scientific substantiation of the variety-*terroir* relationship and viticultural zoning. The practical value consists in applying the results so that to optimize the vineyard placement, increase the productivity and improve the quality of vitivinicultural production.

Implementation of scientific results: The scientific findings have been implemented in vineyards belonging to wine sector entities - Purcari Winery, Mircesti Winery, Vocational Education and Training institutions in Leova and Nisporeni, Chateau Vartely and Castel Mimi.

MOGÎLDEA OLGA

THE POTENTIAL OF LOCAL GRAPEVINE VARIETIES DEPENDING ON *TERROIR* IN THE REPUBLIC OF MOLDOVA

411.07 - Viticulture

Summary of the Doctoral Thesis in Agricultural Sciences

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