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The impact of dynamic meteorological conditions in the ATU Gagauzia on the growth and development of grapevines

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Abstract

The southern region of the Republic of Moldova, specifically ATU Gagauzia, offers highly favourable conditions for cultivating diverse grape varieties with multiple harvest utilization options, including wine, brandy, juices, and fresh or dried consumption. Grapevines, adaptable yet sensitive to environmental changes, were the focus of our analysis regarding meteorological fluctuations' impact on the growth of grape shoots and the development of leaf surfaces. Our research aimed to assess the changes in meteorological conditions in the ATU Gagauzia and their impact on the growth dynamics of grapevine shoots, as well as the development of leaf surfaces, yields of introduced clones of European selection. Temperature and precipitation levels significantly impacted the growth of grapevine shoots and the development of shoot leaf surfaces, vines, and vineyards. Aligning these factors with the requirements of grapevines optimizes the growth and development of the annual grapevine growth. Meteorological conditions varied across study years, benefiting grapevine growth in certain years (2017-2018) but proving less favourable in others due (2019-2020) to reduced precipitation and higher temperatures during the growing season. The research findings indicate that the growth parameters of shoots, the development of leaf surfaces, LAI, and yield of clone R5 Cabernet Sauvignon in the agroecological conditions of ATU Gagauzia depend on both the rootstock variety and the fluctuating meteorological conditions. It has been established that when grafting the investigated clone onto RxR 101-14, growth indicators, the development of annual shoot growth, leaf surface and yields were lower compared to the vines grafted onto BxR Kober 5BB. This difference was evident throughout the entire research period but was particularly pronounced during periods of adverse meteorological conditions. Specifically, in 2020, these indicators decreased by 1.1-1.2 times compared to the experimental option BxR Kober 5BB.

Keywords: Gagauzia, Grapevines, Growth, Development, Meteorological Conditions

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1. Introduction

The viticulture restoration program at ATU Gagauzia aims to build a contemporary grape industry, focusing on high-quality grape production that can compete in markets while ensuring strong economic viability. Its primary focus is to realign the industry by expanding vineyard areas with superior planting material of enhanced biological value, emphasizing the adoption of innovative techniques for vine plantation establishment (Cara, 2023).

The current viticulture production potential remains underutilized due to various factors, leading to a financial crisis within both the viticulture and winemaking sectors that do not align with their potential. Many viticulture enterprises became unprofitable and shifted to less resource-intensive industries, resulting in a decreased vineyard area in agricultural enterprises. This reduction in vineyard acreage was a consequence of unprofitability, leading to enterprises opting for less labour and energy-intensive alternatives (Parmacli and Cara, 2021).

In the Autonomous Territorial Unit of Gagauzia, as well as in the entire Republic of Moldova, European-introduced clones of grape varieties are actively being implemented. These clones demonstrate their highest productive potential in the areas where they were originally developed. However, when introduced to different locations, they may change their positive and negative characteristics. Therefore, to minimize potential production and economic risks, it is essential to study how these introduced clones adapt to new growing conditions (Cara, 2022).

Physical and geographical factors constantly influence the grapevine (Chisili et al., 2008). Therefore, scientists have repeatedly explored the correlation between grape productivity, harvest quality, and climatic and placement conditions, considering them primary environmental influencers (van Leeuwen et al., 2004).

They aimed to find a precise quantitative expression of this relationship. However, it would be premature to consider this issue definitively resolved, as it continues to be a pertinent subject of research in numerous grape-growing and winemaking countries worldwide (Perstniov and Cara, 2015; Cara, 2021).

Climate change impacts the grape cultivation processes (Küpe and Köse, 2015), affecting growth (Küpe and Köse, 2019), yield, and product quality (Küpe, 2012). Microclimate refers to the fluctuations in climatic elements within a specific area, typically at the plot level or within a canopy. These conditions can be intentionally altered or managed through canopy management techniques (Smart and Robinson, 1991).

The Leaf Area Index (LAI) is one of the most used parameters in viticulture. It is used to assess the vineyard canopy area (Delrot et al., 2010). He is an important indicator since leaf area parameters affect the processes of transpiration, root growth, and the photosynthetic potential of grapevines (Keller, 2015). The LAI is affected by the management of agronomic practices such as irrigation, nutrient and grapevine training systems (Oliveira and Santos, 1995).

The growth and productivity of vine canopies, operating as an optical-biological system, hinge upon the rhythm of physiological phenomena linked to shoot development and Leaf Area functionality (Amirdzhanov, 1980).

Key life-sustaining processes like photosynthesis, transpiration, and respiration occur predominantly in the leaves. Their efficiency relies on the plant's genetic makeup and adaptability to environmental factors. The cumulative Leaf Surface Area of shoots, vines, rows, and vineyards is a resultant effect of individual leaf activity (Smirnov et al., 1998).

The dimensions, structure, and environmental context influencing Leaf Surface regulate the magnitude of both biological and economic yield, directly impacting grape quality (Stirbu, 2012).

The increase of the Leaf Surface in vine plants throughout their development is crucial for the efficient assimilation of CO_2 during photosynthesis. According to studies by Poenaru and Beznea (1977) and Naumenko (2001, 2004), the rates at which Leaf Area develops in vine plants vary. These disparities are contingent upon the inherent biological traits of the varieties and their adaptability to the prevailing growth conditions.

In this context, it is pertinent to investigate the impact of changing meteorological conditions on the ATU Gagauzia and rootstock varieties on the growth and development of grapevines.

2. Material and Methods

2.1. Plant material and experimental design

The research material was provided by the R5 clone of the Italian-selected Cabernet Sauvignon variety, which was grafted onto the rootstock variety BxR Kober 5BB and RxR 101-14. The experiments were conducted on vineyards planted in 2005 in the village of Tomai, Ceadir-Lunga district. The experimental plot of the vineyard was arranged according to the following scheme: a distance of 2.75 meters between rows, 1.5 meters between vines (density 2424 vines per hectare). The soil of the experimental vineyard is calcareous chernozem. The vines were shaped into a bilateral horizontal cordon form. They were trained in a Vertical Shoot Position and supported by a trellis consisting of four wires positioned at heights of 0.8, 1.0, 1.4, and 1.8 meters above the ground. Pruning the vines was used-cane pruning. The scheme of the experiment consisted of two variants of the experiment - two rootstock varieties. Each experiment variant consisted of four repetitions. In each repetition, there were 10 grapevines, and 80 experimental vines in total.

2.2. Shoot growth

The vine's growth was expressed linearly in m/vine and volumetrically in dm^3/vine. Linear Annual Growth was calculated by multiplying the number of shoots on the vine by their average length, expressed in m/vine. Volume of Annual Growth: for this purpose, the Average Shoot Diameter was used to calculate the Average Shoot cross-sectional area by the equation $S = \pi * d^2/4$, where, d - Shoot Diameter, π - 3.14. The equation determined the Shoot Growth: $G = l * S$, where, G - Shoot Growth, l - Shoot Length, S - Average Shoot Area. The total vine growth - Volume of Annual Growth, was calculated as the sum of all shoots and expressed dm^3/vine (Melnik, 1959).

2.3. Leaf surface area

The Leaf Area of a shoot was calculated by multiplying the Leaf Area – S by the number of leaves on the shoot the Leaf Area – S, expressed in dm^2/shoot. The total Leaf Area of a vine was calculated by multiplying the Shoot Leaf Area by the number of shoots per vine, expressed in m^2/vine. The total Leaf Area of the vineyards was calculated by multiplying the vine Leaf Area by the number of vines per hectare (2424), expressed in thousands of square meters per hectare (thousand m2/ha) (Melnik et al. 1957). The Leaf Area Index was calculated as the ratio of of Leaf Surface Area of a vine to its ground surface area, expressed in m^2/m^2 (Laman et al., 1996).

2.4. Meteorological conditions

The analysis of meteorological conditions during the study years (2015-2021) was conducted using data from the Ceadir-Lunga meteorological station. This included calculating monthly precipitation in mm, calculating the annual sum of precipitation for each study year in mm, computing average monthly air temperature values for each study year in °C, and determining the average annual air temperature for each study year in °C.

2.5. Statistical analysis

Effects of rootstock and year were determined by performing a Two-way Analysis of Variance (ANOVA). Differences between the means of years in each rootstock were evaluated according to Tukey's posthoc test (HSD).

3. Results and Discussion

The research scrutinized the evolving meteorological conditions in ATU Gagauzia and their influence on the development and harvest of grapevines. Temperature and precipitation are environmental factors that influence the development and growth of plants and the quantity and quality of the harvest. The closer these factors align with the requirements of the grapevine at different stages of its development, the better the growth of all its organs will proceed, ultimately resulting in higher crop yields and grape quality.

We have analyzed meteorological conditions from 2003 to 2022 (Figure 1). It was revealed that the climate in ATU Gagauzia is warm, with temperatures of 10 °C and above lasting for 179-187 days, significantly longer than in other parts of the Republic of Moldova. The sum of active temperatures is 3300 °C. The annual amount of atmospheric precipitation varies from 258.9 mm (in 2022) to 569.3 mm (in 2016). It is noted that meteorological conditions in recent years of the study have changed towards an increase in the average annual temperatures and a decrease in precipitation. Thus, compared to the long-term average temperature of 9.8 °C, there has been an increase of this indicator by 2.8 °C in the last years of the study. In 2016, the average annual temperature was 13.2 °C, 12.5 °C in 2017, 11.5 °C in 2018, 12.5 °C in 2019, 13.1 °C in 2020, 11.1 °C in 2021, and 12.3 °C in 2022.

We have established that recent years are also characterized by a lower amount of precipitation compared to the long-term averages. For example, in 2018, the annual precipitation amounted to 431.4 mm, in 2019 it was 380.6 mm, and in 2022, it was 258.9 mm, which is less than the long-term average values by 34.6 mm, 85.6 mm, and 207 mm, respectively. Along with this, there has been a change in the distribution of precipitation during the grapevine's growth and dormancy periods. It has been noted that grapevines experienced a moisture deficit during critical growth and development stages, which hurt the growth, development, and yield of the plants.

It is important to highlight that meteorological conditions varied throughout the study years. They favoured the growth and development of grapevines in 2003, 2004, 2005, 2010, 2013, and 2017 but were less conducive in 2011, 2019, and 2020. This was attributed to a notable reduction in precipitation and elevated temperatures during the summer growing seasons.

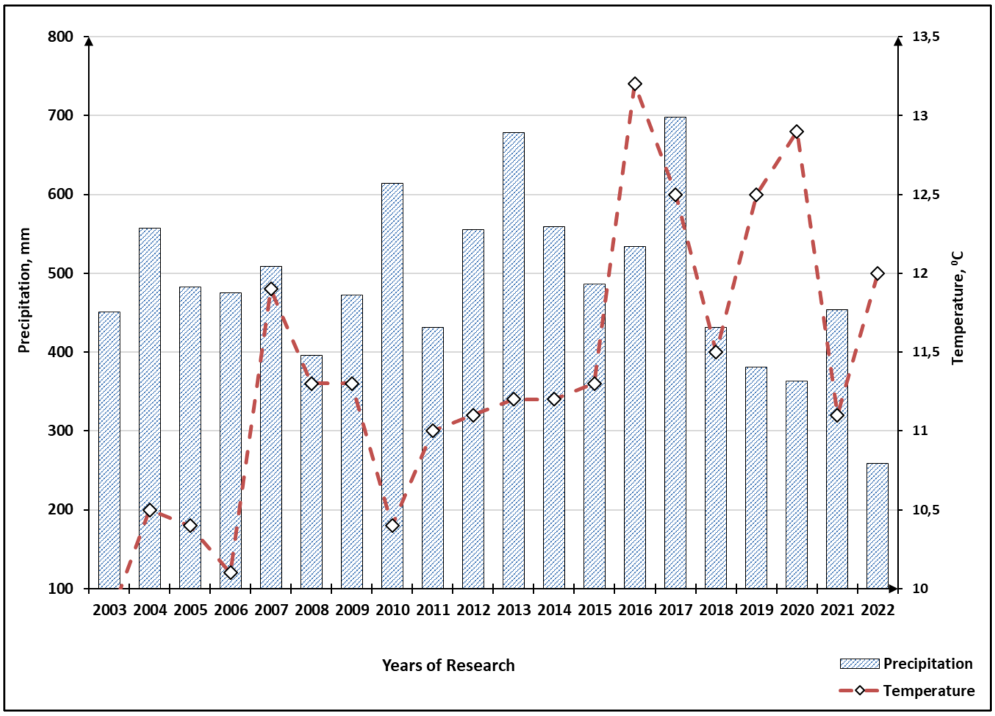

Figure 1. Meteorological conditions during the study years (according to the Ceadir-Lunga Meteorological Station data)

Table 1. Growth and development parameters of grapevine shoots in the conditions of ATU Gagauzia

Experiment Options	Year	Number of Shoot, pcs.	Annual Growth, m/vine	Volume of Annual Growth, dm^3/vine
Cl R5 Cabernet Sauvignon onto Kober 5 BB	2015	40.4±0.34 cde	129.1±2.10 d	2.72±0.02 e
	2016	41.0±0.31 bcd	134.8±2.34 cd	2.99±0.02 d
	2017	44.2±0.26 a	152.3±2.04 a	4.47±0.03 a
	2018	43.1±0.20 a	149.8±1.92 ab	3.49±0.03 c
	2019	41.2±0.19 bc	125.5±1.90 def	2.73±0.03 e
	2020	31.5±0.25 h	63.5±0.60 h	0.51±0.01 i
	2021	37.5±0.20 f	76.2±0.65 g	1.13±0.02 g
Cl R5 Cabernet Sauvignon onto RxR 101-14	2015	37.3±0.23 f	119.2±2.14 ef	2.35±0.02 f
	2016	40.0±0.20 de	126.7±2.41 de	2.68±0.02 e
	2017	41.9±0.24 b	141.5±2.42 bc	3.77±0.03 b
	2018	41.0±0.24 bcd	139.8±2.12 c	3.03±0.03 d
	2019	39.5±0.23 e	117.1±2.02 f	2.38±0.02 f
	2020	28.2±0.22 i	61.1±1.45 h	0.42±0.01 i
	2021	34.2±0.21 g	73.9±1.76 g	0.97±0.02 h
Options	Kober 5 BB	39.8±0.48 A	118.7±3.96 A	2.58±0.15 A
	RxR 101-14	37.4±0.54 B	111.3±3.60 B	2.23±0.13 B
Years	2015	38.9±0.41 D	124.2±1.85 C	2.54±0.05 D
	2016	40.5±0.21 C	130.8±1.88 B	2.83±0.04 C
	2017	43.1±0.32 A	146.9±1.97 A	4.12±0.08 A
	2018	42.1±0.29 B	144.8±1.80 A	3.26±0.06 B
	2019	40.4±0.24 C	121.3±1.66 C	2.55±0.04 D
	2020	29.9±0.41 F	62.3±0.81 E	0.47±0.01 F
	2021	35.9±0.40 E	75.1±0.95 D	1.05±0.02 E
ANOVA	$F_{Options}$	347.30^{***}	51.62^{***}	785.06^{***}
	F_{Year}	703.74^{***}	594.74^{***}	5785.82^{***}
	$F_{Options*Year}$	6.69^{***}	1.72ns	35.77^{***}

*Different letters in the same column indicates signifcant differences according to Tukey's HSD ($p \leq 0.05$). ns: not significant ($p > 0.05$), *** indicates significance at $p < 0.001$.*

The number of shoots varied throughout the research period (Table 1). We found that during the study period, an average of 39.8±0.48 shoots formed per vine of the Clone R5 Cabernet Sauvignon onto the Kober 5 BB when grafted onto RxR 101-14 decreases to 37.4±0.54 shoots per vine. The highest average number of shoots was observed in 2017 (43.1±0.32), while the lowest was in 2020 (29.9±0.41). Statistically significant differences were found in the number of shoots depending on the rootstock variety (347.30***), the year of study (703.74***), and the interaction between rootstock and the year of study (6.69***).

It has been established that the R5 clone of the Cabernet Sauvignon variety grafted onto Kober 5 BB rootstock is characterized by the formation of a larger Volume of Annual Growth, which amounts to 2.58±0.15 m/vine. It was found that the meteorological conditions prevailing during the study years systematically influence the development of the Volume of Annual Growth. For instance, higher precipitation in 2017 leads to an increase in this indicator to 4.12±0.08 m/vine, while in the drought year of 2020, this indicator significantly decreases to 0.47±0.01 m/vine.

Significant differences in the development of the Annual Growth Volume of vines were found depending on the rootstock variety, the year of the study, and the interaction between these factors. Furthermore, these variations were indicative of distinct impacts on the growth patterns of the vine stock, showcasing the nuanced influence of rootstock variety and annual conditions of study on their development. The observed significant differences in the growth patterns of vine stock based on rootstock variety, study year, and the interaction between these factors emphasize the dynamic and intricate nature of their influence on the overall growth and development of the vines.

Table 2. The development of grapevine Leaf Surface in the conditions of ATU Gagauzia

Experiment Options	Year	Number of Leaves on Shoot	Leaf Area			
			cm^2/leaf	dm^2/shoot	m^2/vine	th.m^2/ha
Cl R5 Cabernet Sauvignon onto Kober 5 BB	2015	26.4±0.16 cd	116.6±0.56 d	30.8±0.50 e	12.4±0.23 f	30.2±0.36 f
	2016	27.5±0.11 bc	133.1±0.41 bc	36.6±0.20 c	15.0±0.15 d	36.4±0.19 d
	2017	31.1±0.25 a	144.6±0.43 a	45.0±0.18 a	19.9±0.11 a	48.2±0.29 a
	2018	30.6±0.29 a	138.6±0.35 abc	42.4±0.31 b	18.3±0.13 b	44.3±0.32 b
	2019	25.6±0.22 de	116.5±0.41 d	29.8±0.50 ef	12.3±0.23 f	29.8±0.36 f
	2020	22.6±0.23 gh	85.1±0.31 f	19.2±0.19 i	6.1±0.07 j	14.7±0.18 j
	2021	26.0±0.34 cde	97.8±0.31 e	25.4±0.25 h	9.5±0.08 h	23.1±0.32 h
Cl R5 Cabernet Sauvignon onto RxR 101-14	2015	24.4±0.35 ef	115.7±1.92 d	28.2±0.42 fg	10.5±0.33 gh	25.5±0.37 g
	2016	25.9±0.53 cde	131.8±2.38 c	34.1±0.55 d	13.7±0.27 e	33.1±0.61 e
	2017	28.9±0.50 b	141.0±2.57 ab	40.7±0.16 b	17.1±0.17 c	41.4±0.26 c
	2018	28.6±0.42 b	131.6±3.25 c	37.7±0.53 c	15.4±0.26 d	37.4±0.39 d
	2019	23.9±0.35 fg	115.3±2.67 d	27.6±0.31 g	10.9±0.25 g	26.4±0.29 g
	2020	21.8±0.38 h	84.1±2.96 f	18.3±0.32 i	5.2±0.23 j	12.5±0.39 k
	2021	25.2±0.28 def	96.7±2.59 e	24.4±0.41 h	8.3±0.07 i	20.2±0.45 i
Options	Kober 5 BB	27.1±0.34 A	118.9±2.43 A	32.7±1.03 A	13.4±0.54 A	32.4±1.31 A
	RxR 101-14	25.5±0.32 B	116.6±2.47 B	30.1±0.88 B	11.6±0.47 B	28.1±1.13 B
Years	2015	25.4±0.30 C	116.2±0.98 C	29.5±0.43 D	11.4±0.30 D	27.9±0.59 D
	2016	26.7±0.32 B	132.4±1.19 B	35.3±0.41 C	14.3±0.21 C	34.8±0.49 C
	2017	30.0±0.37 A	142.8±1.33 A	42.9±0.51 A	18.5±0.34 A	44.8±0.80 A
	2018	29.6±0.34 A	135.1±1.78 B	40.0±0.62 B	16.9±0.36 B	40.9±0.83 B
	2019	24.7±0.28 C	115.9±1.32 C	28.7±0.38 D	11.6±0.23 D	28.1±0.46 D
	2020	22.2±0.24 D	84.6±1.45 E	18.8±0.21 F	5.7±0.15 F	13.6±0.32 F
	2021	25.6±0.23 C	97.3±1.28 D	24.9±0.26 E	8.9±0.15 E	21.7±0.43 E
ANOVA	$F_{Options}$	80.15***	5.20*	174.63***	276.06***	513.27***
	F_{Year}	135.64***	248.06***	1067.65***	999.15***	1851.12***
	$F_{Options*Year}$	1.36ns	1.72ns	7.98***	7.87***	14.06***

*Different letters in the same column indicates signifcant differences according to Tukey's HSD ($p \leq 0.05$). ns: not significant ($p>0.05$), * and *** indicate significance at $p<0.05$ and $p<0.001$, respectively.*

In the course of our research, we established the fluctuations in Leaf Blade development data related to inconsistent meteorological conditions observed during the study period (Table 2). The Leaf Area during growth on different rootstocks varies from 116.6±2.47 cm^2/leaf to 118.9±2.43 cm^2/leaf. Favorable years (2017-2018) saw Leaf Areas of 135,1±1,78 cm^2/leaf - 142,8±1,33 cm^2/leaf. Subsequently, a steady decline in the Leaf Area occurred, attributed to reduced precipitation and higher average monthly air temperatures during the growth season. For instance, in 2020, Leaf Areas decreased by 1.6-1.7 times compared to 2017-2018.

The Leaf Area of shoots, vines, and vineyards gradually expands, influenced by the number of shoots (load) and the corresponding leaf growth on these shoots. The growth of the Leaf Area on the vines shows variations due to a myriad of internal and external factors. These include the number of shoots developed on the vines, the number of leaves that have emerged on these shoots, the area occupied by the leaf blades, and the spatial arrangement of the vines, among other factors. The Leaf Area of the R5 clone of the Cabernet Sauvignon variety grafted onto BxR Kober 5BB measured 45.0±0.18 dm^2 per shoot and 19.9±0.11 m^2 per vine by the conclusion of the 2017 growing season.

Interestingly, the increase of the Leaf Area on vines is notably influenced by the specific rootstock variety they are grafted onto. For instance, when grafted onto RxR 101-14, the Leaf Area of both the shoot and vine decreases by 1.1-1.2 times compared to BxR Kober 5BB, amounting to 40.7±0.16 dm^2 per shoot and 17.1±0.17 m^2 per vine.

The Leaf Surface Area stands as a pivotal factor influencing the photosynthetic activity within plants. The growth in biomass and productivity of plant organs hinges upon its robust development. Measurements of the Leaf Surface Area within the vineyard plots of the examined clone grafted onto BxR Kober 5 BB and RxR 101-14, revealed variations influenced by the rootstock variety and the amalgamation of meteorological factors during their growth. In 2017, the Leaf Area indicator of the grapevine plantations reached 44.8±0.80 thousand m^2 per hectare; in 2018, it decreased to 40.9±0.83 thousand m^2 per hectare, and in 2020, it dropped to 13.6±0.32 thousand m^2 per hectare, which is 3.3 times less than in 2017.

When considering the experiment options, it was established that under favourable conditions, particularly in 2017, the Leaf Area peaked at 48.20±0.29 thousand m^2 per hectare when grafted onto BxR Kober 5 BB. Conversely, when grafted onto RxR 101-14, this area reduced to 41.40±0.26 thousand m^2 per hectare.

It has been established that the inhibition of Leaf Area growth occurred due to high temperatures and insufficient moisture during unfavourable years (2020-2021). This resulted in a reduction in the Leaf Area across the shoot, vine, and vineyard plantations.

It has been established that the Leaf Area Index (LAI) parameters of the R5 clone of the Cabernet Sauvignon vary when grafted onto different rootstocks (Figure 2a).

Specifically, this indicator is higher when grafted onto BxR Kober 5BB, ranging from 1.47 to 4.82 m^2/m^2, and when grafted onto RxR 101-14, it ranges from 1.25 to 4.14 m^2/m^2. Research has shown that LAI varies over the study years and is influenced by the amount of annual precipitation. The highest values for this parameter were recorded in 2017. As the annual precipitation decreases, there is a decline in LAI to 1.25 m^2/m^2 (RxR 101-14) and 1.47 m^2/m^2 (BxR Kober 5BB) in 2020.

The clone R5 Cabernet Sauvignon, when grafted onto BxR Kober 5BB rootstock and cultivated in the agro-ecological conditions of ATU Gagauzia, demonstrates a yield ranging from 1.82 to 6.11 kg/vine (Figure 2b). When grafted onto RxR 101-14, the yield ranges from 1.48 to 5.69 kg/vine. It has been observed that the grapevine yield of the R5 Cabernet Sauvignon clone is also influenced by the rootstock variety and meteorological conditions during the years of the research.

Direct correlational dependence has been established between the development of the LAI and the yield of the grapevines. The correlation coefficient of 0.98±0.27 demonstrates a high level of association between the LAI and the yield of grapevines. This indicates that the development of leaf area directly impacts grape production, serving as a key factor in optimizing and enhancing grape cultivation techniques. The data obtained, showing a strong correlation between the LAI and grapevine yield, suggests that effective leaf area development is crucial for ensuring a good harvest. Therefore, the LAI of the vine can be considered an indicator for predicting grape yield. Such relationships can be utilized in developing vineyard management strategies, including optimizing canopy management and selecting rootstocks to improve grape yields.

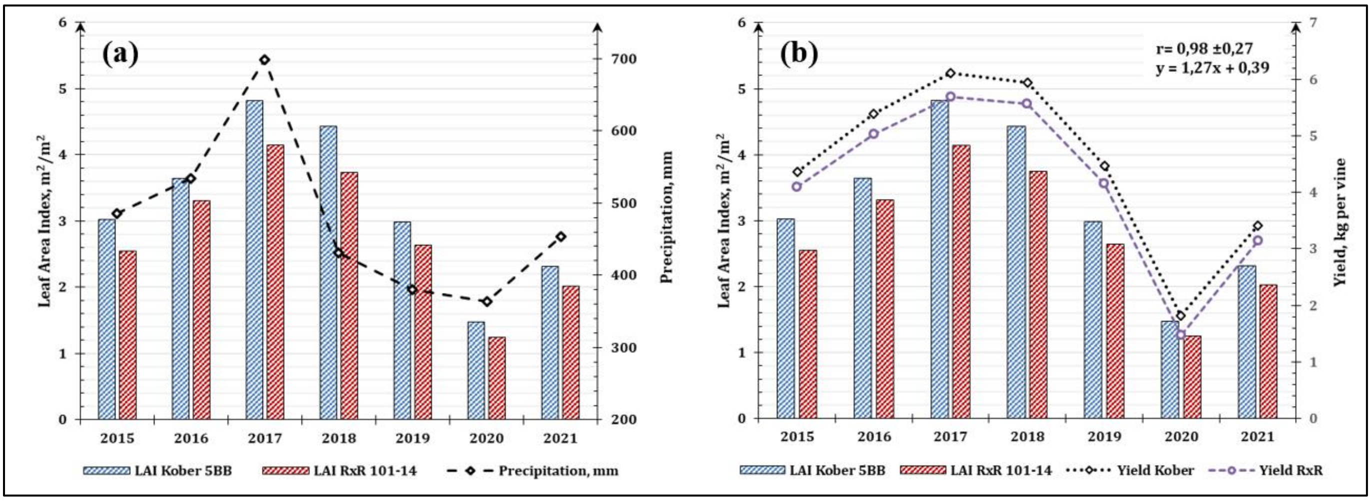

Figure 2. Leaf Area Index, a) Dependence of the LAI on the amount of precipitation, b) Dependence of the yield grapevines on the LAI

4. Conclusion

The meteorological conditions across the ATU Gagauzia, fluctuated significantly throughout the research period. The years 2017-2018 were notably more favourable, contrasting with the less conducive conditions experienced in 2019-2020. These shifts were characterized by a considerable decline in rainfall and soaring temperatures during the growth season. Consequently, this natural phenomenon directly impacted the growth and development of grapevines, on the Annual Growth, Leaf Area and Yields parameters.

The study revealed noteworthy disparities in the Annual Growth volume of vines linked to rootstock variety and study year interactions. These significant differences emphasize the complex influence these factors wield over the overall growth and development of vines, showcasing the dynamic nature of their impact.

The development of Leaf Area in clone R5 Cabernet Sauvignon is reliant upon both the rootstock variety and prevailing meteorological conditions. In more favourable meteorological years, exemplified by 2017, the Leaf Area of clone R5 Cabernet Sauvignon onto BxR Kober 5BB achieves 144.6±0,43 cm^2/leaf, 45.0±0.18 dm^2/shoot, 19.9±0.11 m^2/vine and 48.2±0,29 thousand m^2 per hectare, LAI of 4.82 m^2/m^2. However, when cultivated onto RxR 101-14 in the arid conditions of ATU Gagauzia, there is a significant reduction of 1.1-1.2 times in the Leaf Area parameters.

The R5 Cabernet Sauvignon clone, in the agroecological conditions of ATU Gagauzia, exhibits a high yield during favourable years, ranging from 5.69 to 6.11 kg per vine. A direct correlation relationship of 0.98±0.27 has been established between LAI and the yield of vines. It has been established that the yield of the investigated clone is influenced by the rootstock variety and meteorological conditions, which vary throughout the study years. Grapevines of the R5 Cabernet Sauvignon clone grafted onto BxR Kober 5BB demonstrate increased resilience to unfavourable environmental conditions compared to those grafted onto RxR 101-14. This is evident in the better development of Annual Shoot Growth and Leaf Area, ultimately contributing to higher grapevine yields.

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Conflict of interest

The author declares that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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