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Study on the drought resistance of the grape variety Storgozia grafted onto different rootstocks

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Abstract

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The study, conducted between 2017 and 2022, in the experimental vineyards of the Institute of Viticulture and Enology, Pleven, identified significant climatic changes in the region. The annual accumulated temperature consistently exceeded 4400°C, peaking at 4827.1°C in 2019. The period from 2019 to 2022 was the warmest of the decade, characterized by prolonged heatwaves and summer droughts. Precipitation during the growing season exhibited a persistent declining trend, reaching its lowest recorded value in the past 15 years (266.6 mm in 2022). A pattern of uneven rainfall distribution was observed, with a maximum between April and June and a minimum between August and October.

An analysis of the response of the Storgozia grape variety, grafted onto four different rootstocks, revealed high to very high-water stress, varying in intensity across years and experimental variants. Concurrently across all experimental years, the control combination Storgozia/SO 4 exhibited the greatest vulnerability to drought, whereas the Storgozia/110 R combination consistently exhibited significantly greater drought tolerance. During the hot growing seasons of 2017, 2020 and 2022, various visual symptoms of water deficit were observed, and these symptoms were most pronounced in the Storgozia/SO 4 control variant and less severe in the Storgozia/Fercal variant. Statistical analysis confirmed the significantly higher drought resistance of vines grafted onto the 110 R rootstock, with statistically significant differences compared to the other rootstocks. The study highlights the increasing water stress in the Pleven region and emphasizes the suitability of the 110 R rootstock for the Storgozia grape variety in mitigating the adverse effects of drought.

Keywords: vine; cultivar; rootstock; climate; resistance; drought

Introduction

Recent significant climate changes have profoundly impacted agriculture, natural resources, and human health (Orlandini et al., 2008; IPCC, 2019; Rockström et al., 2021; IPCC, 2022; Tomalka et al., 2024). Empirical research in this domain demonstrates an accelerating warming trend, with atmospheric temperature increases spanning the late 20th century and establishing critical baseline shifts for systemic adaptation (Myneni et al., 1997; Howden et al., 2007). Simulated projections of future climate patterns, based on various spatial models and the temporal evolution of temperature indicators, confirm that warming and drought will persist across all seasons, with the most severe effects occurring during summer (Valcheva and Spiridonov, 2021; NIMH, 2023).

Thermal and moisture regimes are among the key climatic factors determining the geographical distribution of plant species and their ability to reach full maturity in a specific region (Beck et al., 2023). Temperature conditions define the length of the growing season, directly influencing the growth, development, and yield of agricultural crops, as well

as the quantity and quality of production (Houghton, 1996; Orlandini et al., 2008; Mbow et al., 2019; NIMH, 2023; Tomalka et al., 2024).

In the context of global climate change and pessimistic future projections, increasing the ecological plasticity of plants to adapt to changing environmental conditions is becoming an increasingly relevant issue.

Grapevine cultivation thrives when water requirements are met throughout the entire vegetative period (Behboudian and Singh, 2001). The drought tolerance of grapevines is directly influenced by soil type, rootstock, the biological characteristics of the variety, and applied agricultural practices. Beyond selecting an appropriate terroir and grape variety, choosing a suitable variety/rootstock combination is crucial for mitigating the adverse effects of unfavorable climatic conditions. Modern viticulture is unthinkable without the use of phylloxera-resistant rootstocks, which are adapted to diverse soil and climatic conditions, protect the scion from environmental stresses, and enhance resistance to abiotic stress factors (Katerov et al., 1990; Carbonneau, 1985; Ezzahouani and Wiliams, 1995; Kocsis et al., 1998).

Rootstocks with high adaptive potential and low requirements for specific soil and climatic conditions are particularly valuable in viticultural practice, especially when combined with excellent affinity to the cultivated grape variety. The harmonious interaction between the rootstock and the scion determines vine vigor, fertility, grape yield, fruit quality, and vine longevity (Lilov, 1979; Pouget, 1984; Jaquinet and Simon, 1989; Egger and Graseli, 1993; Bettiga, 2003; Boso et al., 2008). Selecting a grapevine rootstock should be based on its affinity and adaptability to specific environmental conditions (Trifonova, 2002), ensuring optimal vine growth and minimizing the negative impact of abiotic stress factors.

The aim of this study was to determine the influence of rootstock on the drought resistance of the red wine cultivar Storgozia, and to establish the optimal timing for the implementation of hydro-ameliorative measures in the vineyard.

Material and Methods

The research work was carried out in the period 2017–2022, in an experimental plantation of the Institute of Viticulture and Enology – Pleven, Bulgaria. The plantation was established in 2009 on an area of 2.6 da (0.26 ha), with a planting distance of 2.20 m between rows and 1.30 m inside the row. The object of study was the reaction to a drought of the red wine cultivar with interspecific origin Storgozia (Buket x Seyve Villard 12 375) (Roychev, 2012), grafted on the following rootstocks:

American-American hybrids (Roychev, 2012):
Berlandieri x Riparia SO 4 – main for the Bulgaria (control) – (SO 4);
Berlandieri x Rupestris 110 Richter – (110 R);
Riparia grand glabre x 144 M (Cordifolia x Rupestris) 44-53 Malegue – (44-53 M).
European-American hybrids (Roychev, 2012)*:*
Fercal (BC_1 /Berlandieri x Colombard № 1 A/ x 333 E. M. /Cabernet Sauvignon x Berlandieri/) – (Fercal).

Each cultivar-rootstock combination consists of 75 vines, divided into 4 replications of 15 vines, formed by a medium stem (0.80 m), type double Guyot training system. The pruning and loading of the vines are the same in all variants – 28 buds (winter eyes), realized with 2 fruit shoots with 8 buds and 6 knots with 2 buds each.

To determine the ecological plasticity of all studied cultivar-rootstock combinations, the climatic indicators – total annual temperature sum (°C), average daily and total temperature sum in the months of July and August (°C) and precipitation during the growing season (mm) were monitored annually from a meteorological station located in the experimental area. To determine the need of vine plants for water annually during the growing season, the hydrothermal coefficient, HTC (Selyaninov, 1958) was calculated.

The susceptibility of the studied cultivar-rootstock combinations to drought was determined by taking into account visual symptoms of moisture deficiency and leaf water potential (Ψ) of the vines measured at midday (Scholander et al., 1965; Naor, 1998). The visual observations of moisture deficit (twisting of the leaves, leaf wilting, yellow or dead leaves, necrotic edges on the leaves, suppressed growth, withered grains in the bunches and others) were performed regularly, every week from the beginning of grape ripening until harvest. The Ψ of the vines was determined annually, in July and /or August, during the beginning of grape ripening, using a pressure chamber (PCI, model 600). The measurements were performed at noon when the water potential is in a relatively static position from the daily maximum deficit. Cloudless and windless days were chosen between 13.00 and 14.30 p.m., at an air temperature not higher than 35°C. Samples of 3 fully developed leaves located on the sunlit side of 5 vines of equal growth strength from each cultivar-rootstock combination were measured. The measurement of water stress was performed in negative (-) bars on the scale of Naor (1998), according to which at established pressure up to -10 bars – no stress, from -10 to -12 bars – mild stress, from – 12 to -14 bars – moderate stress, from -14 to -16 bars – high stress and higher than -16 bars – severe water stress.

Statistical processing of the experimental results was processed by the method of dispersion analysis (Dimova and Marinkov, 1999).

Results and Discussion

The main climatic indicators in the Pleven region, relevant to the objectives of the study, were monitored (Table 1).

The results show permanent retention of the total temperature sum (t > 10°C) in the Pleven region above 4400°C, which is an increase of more than 500°C from the multiyear norm (1904-1955, 3908°C) for the region (Katerov et al., 1990). The highest value of the indicator was reported in 2019 (4827.1°C). Average daily air temperatures in July were within the normal range for this period, and in August an increase in values of more than 1°C was found compared to the norm. The last four years of the study (2019–2022) were characterized as the warmest of the last decade. A significant increase in the accumulated temperature sum and the average daily temperature during the summer months of July and August has been observed.

Precipitation was moderate, the average annual amount for the study period was 739.8 mm. During the study period, a gradual decrease in the amount of precipitation during the vegetation period was observed. In 2022, the absolute minimum precipitation for the last 15 years was recorded – 266.6 mm. The maximum during the vegetation period was in April – June, and the minimum was in August – October (Table 2). Single but heavy precipitation events were increasingly common, as well as long periods without precipitation, lasting from mid-July to the second half of September.

The amounts and distribution of precipitation cannot alone be used to estimate wetting conditions. A relatively more accurate idea is given by the hydrothermal coefficient (HTC) of Selyaninov (1958), which represents the difference between the amount of precipitation and evaporated water for a given period. It was found that when the HTC is below 1, the moisture during the period was insufficient for the vine. The results show that at the beginning and end of the growing season, during the months of April, May and June, the water supply was very good, and during certain periods it was critically high. During the remaining months, most often the water supply of the vines is insufficient and they experience water stress. Hydrothermal coefficient (HTC) for August was 0.27 (2022), 0.35 (2017), 0.45 (2021), 0.46 (2018) and 0.69 (2019) and 0.12 (2020), respectively, which defines them as exceptional dry periods of the annual plant cycle. With the exception of July 2017 and 2018, the hydrothermal coefficient (HTC) remained at very low levels during July, August, and September, indicating insufficient moisture and severe water deficit for the vines sustained and gradual decrease in the HTC during July has been observed, exerting a negative impact on grape growth and quality (Table 3).

During the beginning of ripening of the grapes of the

Table 1. Values of climatic indicators in the region of Pleven for the period 2017–2022

Year	Total temperature sum, t ºC > 10 °C	Temperature sum, °C		Average daily air temperature,°C		Sum of precipitation for the vegetation period, mm
		July	August	July	August	
2017	4428.6	734.9	744.7	23.7	24.1	759.2
2018	4573.7	712.3	740.1	22.9	23.8	593.4
2019	4827.1	726.3	770.8	23.4	24.9	451.4
2020	4752.8	731.7	767.8	23.6	24.8	452.8
2021	4389.4	787.3	775.4	25.4	25.0	526.0
2022	4539.8	784.3	740.2	25.3	23.9	266.6

Source: Authors' own elaboration

Table 2. Monthly amount (mm) of precipitation during the vegetation for the period 2017–2022

Year/Month	March	April	May	June	July	August	September	October
2017	80.8	56.0	135.2	66.0	210.4	25.8	37.6	147.4
2018	90.2	38.6	38.6	170.0	189.6	21.6	19.4	25.4
2019	29.0	84.4	121.2	86.0	47.4	62.8	3.2	17.4
2020	92.4	13.2	74.2	58.4	58.6	8.6	19.8	127.6
2021	102.4	84.8	112.6	61.2	1.0	34.8	7.6	121.6
2022	15.0	43.8	68.2	48.8	24.8	19.6	34.2	12.2

Source: Authors' own elaboration

Table 3. Hydrothermal coefficient (HTC) during the vegetation for the period 2017–2022

Year/Month	April	May	June	July	August	September	October
2017	1.55	2.58	0.96	2.86	0.35	0.65	3.84
2018	0.77	0.64	2.61	2.66	0.46	0.43	0.77
2019	2.33	2.31	1.47	0.65	0.69	0.53	0.41
2020	0.38	1.41	0.92	0.81	0.12	0.31	2.91
2021	2.86	2.08	0.97	0.01	0.45	0.14	5.54
2022	1.23	1.23	0.73	0.32	0.27	0.70	0.34

Source: Authors' own elaboration

cultivar Storgozia, studies were carried out to determine the drought tolerance of the cultivar-rootstock combinations. Due to unfavorable weather conditions in the months of July and August, 2018 (a large number of precipitations, cloudiness, and low average daily air temperatures), no readings were carried out. In the remaining five years, the control (SO 4) was characterized by the highest water stress of the studied variants, followed by the variants grafted on Fercal, 44-53 M and 110 R rootstocks (Table 4).

The values of midday leaf water potential (Ψ midday) vary widely. In all survey years (except 110 R in 2019 and 2021 and 44-53 M in 2021), as well as on average for the period, the reported values define the water stress as "very high" (above -16 bars). The water stress recorded in 2019 and 2021, for the rootstock 110 R and 2022 for the rootstock 44-53 M, was "high" (-14 to -16 bars) in terms of its intensity. In 2017, the variation was in the range of -21.5 bars (110 R) to -24.5 bars (SO 4), in 2019 from -15.2 bars (110 R) to -17.8 bars (SO 4) in 2020 from -16.0 bars (110 R) to -20.3 bars (SO 4), in 2021 from -14.5 bars (110 R) to -17.13 bars (SO 4) and in 2022 from -18.5 bars (110 R) to -21.17 bars (SO 4). On average for the period, the results follow the same direction, defining the control as the most drought-sensitive variant (-20.19 bars), and the cultivar-rootstock combination Storgozia/110 R (-17.04 bars) as the most resistant.

All these statements are also confirmed by the mathematical analysis of the data, where the differences between the SO 4 control and the 110 R, 44-53 M and Fercal rootstocks are, respectively, "very well ensured", "well ensured" and "proven". Differences with a positive direction were found between the vines grafted on the 110 R rootstock and all other variants in the experiment. With the SO 4 control and Fercal they are "very well ensured", and with 44-53 Malegue they are "well ensured". These results define the Storgozia/110 R rootstock combination as the most drought tolerant of all others. In the other variants, the 44-53 M rootstock has a "proven" higher dry resistance than Fercal and "well ensured" against the control (Table 5).

In parallel visual readings and evaluation of the impact

Table 4. Leaf water potential (Ψ midday) for Storgozia cultivar, grafted on different rootstocks

	Rootstocks	Leaf water potential (Ψ midday), /-/ bar					
		2017	2019	2020	2021	2022	average
Storgozia	SO 4 (control)	-24.5	-17.83	-20.31	-17.13	-21.17	-20.19
	Fercal	-22.90	-17.25	-19.77	-16.55	-20.67	-19.43 +
	44-53 Malegue	-22.80	-16.75	-19.33	-15.44	-19.67	-18.80 +++
	110 Richter	-21.50	-15.22	-16.00	-14.50	-18.50	-17.04 +++

GD(5.0%) = t*S~d = 0.636; GD(1.0%) = t*S~d = 0.891; GD(0.1%) = t*S~d = 1.259

Source: Authors' own elaboration

Table 5. Proof of the differences in determining the leaf water potential (Ψ midday), compared to the control, when comparing between the different rootstocks

Storgozia	Ψ, /-/ bar	SO4 (control)		Fercal		44-53 Malegue		110 Richter	
	average	difference	proof	difference	proof	difference	proof	difference	proof
SO4 (control)	-20.19	x	x	0.760	+	1.390	++	3.144	+++
Fercal	-19.43	-0.760	-	x	x	0.630	n.s	2.384	+++
44-53 Malegue	-18.80	-1.390	--	-0.630	n.s	x	x	1.754	++
110 Richter	-17.04	-3.144	---	-2.384	---	-1.754	--	x	x

GD(5.0%) = t*S~d = 0.636; GD(1.0%) = t*S~d = 0.891; GD(0.1%) = t*S~d = 1.259

Source: Authors' own elaboration

of drought on the vines of the individual cultivar-rootstock combinations were carried out.

As a result of the prolonged summer droughts in 2017, 2020 and 2022, some visual symptoms of water deficit, such as twisting of the leaves, necrotic edges on the leaves and withered grains in the bunches were observed in the cultivar-rootstock combination – Storgozia/SO 4, and to a lesser extent in the combination Storgozia/Fercal. In the variants Storgozia/110 R and Storgozia/44-53 M, the visual symptoms of moisture deficiency were significantly less pronounced (Figure 1).

Conclusions



Fig. 1. Drying of leaves and wilting of clusters and berries in the cultivar-rootstock combination Storgozia / Berlandieri × Riparia SO 4
Source: Authors' own elaboration

A tendency towards significant warming and drying in the region of Pleven has been established, expressed in an increase in the values of the total temperature sum, and a decrease in the total amount and number of precipitations during the growing season.

Under the specific climatic conditions for each year, „high" and „very high" water stress in terms of its intensity was found for all cultivar-rootstock combinations of the Storgozia cultivar. The vines grafted on the 110 Richter rootstock have the relatively highest drought resistance, and the lowest those on the Berlandieri x Riparia SO 4 rootstock (control).

Under the critical drought conditions in 2017, 2020 and 2022, the Storgozia/Berlandieri x Riparia SO 4 rootstock combinations and, to a lesser extent, Storgozia/ Fercal showed visual symptoms of water deficit.

Conflict of interest

The authors of the article declare that there is no conflict of interest.

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