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CHALLENGES CAUSED BY CLIMATE CHANGE IN ORGANIC GRAPE PRODUCTION IN THE SOUTHWESTERN WINE-GROWING REGION

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Abstract

In recent years, the adverse effects of climate change on agricultural productivity have been increased drastically. As a result of this change, in the Southwestern wine-growing region, which has a transitional Mediterranean climate, the possibilities for organic grape production are hampered. Productivity and profitability decrease due to uncontrollable events caused by climatic anomalies. Rainfalls of 119 mm, and 218.2 mm, per m^2 were recorded during the study period. These rainfalls accumulated during the autumn-winter period in combination with the low temperatures of the atmosphere and the soil create prerequisites for stopping rhizogenesis and suction activity of the root system in the spring, and this reflects on the growth processes of the vines. All this has a direct impact on the accumulation of biomass, which has a direct impact on the duration of the growing season. These components lead to significant changes in the intensity of growth processes in the vine. From here follows the formation of yields with inappropriate technological quality.

Key words: *climate, organic viticulture, phenology, Shiroka Melnishka loza.*

INTRODUCTION

According to statistical data, Southwestern Bulgaria occupies about 30% of the total area of the vineyards in the country (Bulgarian Ministry of Agriculture, 2020). Although organic viticulture still represents a small share of the total wine production in the region, recent years have seen a high growth of interest in this direction. Of the total agricultural area in the country, about 8% is cultivated organically, and approximately 3% of them are vineyards.

Sustainable development and the green economy is a key priority at the international level, especially in the context of climate change and environmental protection. In this regard, the EU Green Deal is an ambitious initiative that aims to transition to sustainable and climate-neutral economic development by 2050. Within this strategy, organic viticulture plays a key role. The EU aims for 25% of agricultural areas to be cultivated organically by 2030, which provides significant opportunities for the development of organic viticulture in Bulgaria.

Climatic conditions have key importance for the growth of vines (Roychev, 2012). According to the research of Lazarevskiy (1946), the temperature threshold at which the vine begins its active vegetation is very close to the temperature at which all biological activity stops, known as "biological zero degree". After conducting research in different but geographically limited areas, Arnaudova & Popov (2010) found that temperature plays a key role in the growth and fruiting of grapevines. As a result, when developing schemes for zoning and optimal distribution of vines, temperature is taken as the main and decisive factor. This highlight the importance of climatic conditions and their impact on the successful development of the viticulture industry. In this regard, the grower must take measures to reduce the risks of climate change and maintain agricultural productivity and the profitability of the agricultural holdings. This seems important for the overall sustainability of the vine and wine sector and agriculture in general (Filippo & Sciancalepore, 2022).

Global warming causes many disturbances in the viticultural ecosystem, grape varieties are forced to change their annual cycle of vegetation, with consequences, most often negative for the quality and quantity of grape production and also for the produced wines (Tănase et al., 2019).

The European Environment Agency indicates that the overall impact of climate change could significantly reduce EU agriculture (up to 16%

revenue loss by 2050), with large regional variations (Fetting, 2020).

Even in regions that do not have a decrease in precipitation, an increase in air temperature will lead to higher evapotranspiration (Seneviratne et al., 2010).

For this reason, the agricultural sector must build capacity to adapt to the increasingly dry and warm conditions brought about by climate change.

In the complex soil-plant relationship, plants play a key role as solar energy converters. Proper tillage of the soil creates favorable conditions for appropriate biological processes to take place, to improve the work of soil microorganisms and nutrients to be in an easily digestible form, to reduce weed vegetation and maintain fertility.

Organic fertilization and comprehensive plant protection are key components in sustainable viticulture, which focus on the healthy and sustainable development of vines. Organic fertilizers are designed to enrich the soil and plants with natural nutrients, thus supporting healthy growth and resistance of vines to stressful conditions (Coll et al., 2011).

This not only reduces the risk of environmental pollution, but also supports the development of biodiversity in the vineyards (Muneret et al., 2019).

Modern research highlights the importance of combining organic fertilization and total plant protection to achieve optimal results in viticulture. Such methods not only improve the quality of the grapes, but also contribute to the long-term sustainability of the vineyards (Provost & Pedneault, 2016; Volanti et al., 2022).

Weed control in organic viticulture requires an integrated approach that combines different methods and practices to ensure healthy vine growth without the usage of herbicides. By planting certain types of grasses or cover crops between the rows of vines, a competitive environment is created for weeds. These plants can compete with weeds for light, water and nutrients, thus reducing their spread (Novara et al., 2018; 2021; Guerra et al., 2022).

Applying organic mulch helps retain soil moisture, provides additional organic matter as it breaks down, and increases soil temperature. (Fraga & Santos, 2018).

Providing nutrients to organically grown vines requires a specific and well-thought-out approach. In the rhizosphere, the zone around the roots of plants, the microflora produces biologically active substances that stimulate plant growth and development, facilitating the exchange of substances. Soil color affects vegetative processes, root growth and reproductive functions. Dark soils help the grapes ripen faster (Keller, 2010). In the Northern regions, when the grapes are positioned further from the earth's surface, there is a lower content of anthocyanins and aromatic substances.

From a practical point of view, there is a clear relationship between soil and air temperatures that directly influence and govern the nutrition of vine plants and the quality of grape production.

The aim of the present study is to determine the influence of “Humat Rost“ on the stress of drought and high temperatures on the vegetative and reproductive characteristics of the vine.

MATERIALS AND METHODS

A vineyard of the the Bulgarian red wine cultivar ‘Shiroka Melnishka’, located in Petrichko-Sandanski basin, was used as the object of this research.

The vines are 30 years old with planting distances 2.5/1.2 m.

The variants, which are included in this research are: V_0 – control; V_1 – 30 cm length of the shoots with control of 10 inflorescences and V_2 – Phase of berry growing with control of 10 bunches.

All variants without the control were treated with “Humat Rost” in dosage of 0.400 mL per decare, four times, 8 days before flowering, after mass flowering, in the phase of berry growth and 15 days after the berry growth phase.

“Humat Rost” is organic product which contains: 78-82% organic matter; 5.5-7.8% humic and fulvic acids; 1.2-4% nitrogen; 2% potassium; 1.9% humic and fulvic hydrocarbons; 1.2% phosphorus; 0.06% magnesium and 0.15% calcium.

The vineyard is grown under non-irrigated conditions.

The research was conducted in 2022-2023.

The phenological observations for each variant were collected from 40 vines, arranged in 4 replicates of 10 vines.

The data for temperature (ºC) and precipitation (mm) was taken from a Meteobot automatic weather station located 1 km from the vineyard. The correlations between the studied variables are obtained by regression analysis in MS Excel.

RESULTS AND DISCUSSIONS

The orography directly affects the formation of the climate in the area. The average altitude of the basin is about 200 m. Its length is 42 km, and its width reaches 13 km.

Petrichko-Sandanski basin has a transitional Mediterranean climate and is one of the warmest in Bulgaria. Here are the highest average annual temperatures for the country. For 2022, the average annual temperature in Sandanski was 14.8°C, with summer temperature between 26.8 -28.1 (Table 1). The maximum temperature measured being 39.6°C, in the month of July (Table 2). The lowest temperature was recorded in the month of January -8.7°C (Table 3).

In the second year of the experiment, differences in seasonal temperature dynamics were found for 2023. The average annual temperature in the area of the Sandanski station is set to be higher, and we assume that this will be due to the warmer winter, spring, summer and autumn.

Table 1. Average air temperatures (ºC) by season in Sandanski

Year	Winter temperature °C	Spring temperature °C	Summer temperature °C	Autumn temperature °C	Total temperature sum	Average annual temperature °C	Amplitude °C
2022	3.2	13.7	26.8	15.7	5292	14.8	28.1
2023	7.0	12.1	28.1	21.0	6937	17.0	34.0

Table 2. Maximum monthly air temperatures (ºC) in Sandanski

Year	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2022	16.8	18.5	22.8	27.7	34.6	35.9	39.6	38.2	33.8	27.2	25.8	7.9
2023	18.2	21.3	23.5	22.8	28.1	34.3	40.8	33.5	30.7	29.1	24.9	17.4

Table 3. Minimal monthly air temperatures (ºC) in Sandanski

Year	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2022	-8.7	-4.1	-5.3	1.5	7.5	13.3	14.0	12.0	5.9	0.2	0.1	-3.2
2023	-1.2	-6.6	-0.4	1.3	8.9	12.0	13.5	16.1	14.4	5.7	-5.4	-3.4

The average winter temperature in 2023 is 7.0°C, (Table 1), and the maximum temperature measured was 40.8°C, in the month of July (Table 2). The lowest temperature was recorded in the month of February - 6.6°C (Table 3). Weather data also shows also shows one change that is being observed, which is the formation of low temperatures in inappropriate phases of rest in the vine.

Here we must emphasize that a temperature such as -6.6°C is suitable for the period of vernalization at the buds of the vine, which coincides with the dormancy period in the month of January. Lower temperature conditions create conditions for prolonging periods of dormancy, and this prevents the passage into the phase of forced dormancy. These temperatures are not typical for the region of the Petrichko-Sandanski basin, creating prerequisites for intervention and change in the phenological cycles of the grapevine varieties that are grown in this region of the country. This trend was observed throughout the 2023 growing season within the study area and would affect the phenolic maturity and yield potential of the grape. The climate in Sandanski municipality is characterized by large diversity. It is characteristic of the winter months that the average monthly temperatures in the plain and foothills are higher. Therefore, the precipitation in the winter months is mostly rain. Spring comes early in this part of the country. The whole area in summer has the longest sunshine in our country. Precipitation and relative air humidity in the Sandanski region are the lowest in the country. Autumn is relatively mild. It is characterized by sunny days that last until the end of November, and very often throughout the winter. In the distribution of precipitation by season, a trend characteristic of the Mediterranean climate is also noticeable. The most significant amount of precipitation is formed in autumn, winter and spring. At least they are during the summer months, which creates conditions for longer droughts. This trend persists until the beginning of autumn. The annual amount of precipitation for 2022 is only 349 mm in Sandanski, which characterizes the year as extremely dry (Table 4).

Table 4. Precipitation regime in Sandanski for 2022-2023, mm

Year	Average rainfall winter	Average rainfall spring	Average rainfall summer	Average rainfall autumn	Annual rainfall	Month with maximum rainfall	Month with minimal rainfall
2022	78	68	84	119	349	XI	X
2023	126	92	52	196	767	I	IX

The maximum amount of precipitation was recorded in autumn – 119 mm. Compared to the precipitation for the winter-spring period of 2023, 218.2 mm is distinguished by a significant increase, as values compared to the previous year 2022. This increased water condition is positive for the grapevine in the upcoming vegetation, but from a phenological point of view, this huge water content in combination with the low temperatures of the atmosphere and the soil, create conditions for instability around the rhizosphere capsule. Water molecules displace the air via a capillary route by settling around the root hairs. All this leads to a momentary suspension of rhizogenesis and suction activity of the root system, and this reflects on the growth processes.

The data from the conducted phenological observations show that between the individual phases in the experience in the two years, significant differences are demonstrated between them (Table 5).

Table 5. Timings of the phenological phases of development in 2022-2023

Variants	Year	Bud burst	Appearance of 1st leaf	Appearance of 1st inflorescence	Flowering	Pea size berry	Veraison	Maturity	Leaf fall
V_0	2022	14 Apr.	25 Apr.	29 Apr.	04 Jun.	01 Jul.	17 Aug.	24 Sept.	05 Nov.
	2023	18 Apr.	28 Apr.	01 May	09 Jun.	08 Jul.	20 Aug.	-	02 Dec.
V_1	2022	14 Apr.	25 Apr.	29 Apr.	04 Jun.	02 Jul.	17 Aug.	24 Sept.	05 Nov.
	2023	18 Apr.	28 Apr.	04 May	09 Jun.	06 Jul.	18 Aug	-	02 Dec.
V_2	2022	16 Apr.	25 Apr.	29 Apr.	04 Jun.	01 Jul.	17 Aug.	24 Sept.	05 Nov.
	2023	18 Apr.	28 Apr.	04 May	09 Jun.	06 Jul.	20 Aug.	-	02 Dec.

The duration of the budburst phase is 4 days apart, and that of the flowering phase – 9 days in 2022, while in 2023 this was done in 14 days. A difference in the phase of berry growth was observed. For variants V_1 and V_2, it occurred two days earlier. A similar dependence was also observed during berry veraison in the second year of the experiment. As the difference that is formed is 5 days for V_1 and three days for V_2 compared to the control. The results of the phenological observations give us reason to summarize that the reason for the occurrence of the phenophases is due to three main factors, and these are the greater amount of precipitation in the winter-spring period combined with low temperatures, as well as reducing the yield by more than half compared to the vines in the control.

One of the main factors that directly affect the accumulation of biomass are: the different periods of controlling the yields, the availability of food resources and, last but not least, the duration of the growing season. These components lead to significant changes in the intensity of growth processes. This also has an effect on the amount of vine canes that are obtained after the pruning in autumn (Figure 1).

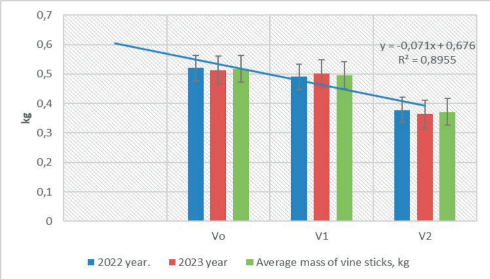

Figure 1. Mass of the vine canes, kg

The data show that the early shoot thinning V_1 has influenced within the experiment a reduction in the mass of the mature cane growth (Figure 2).

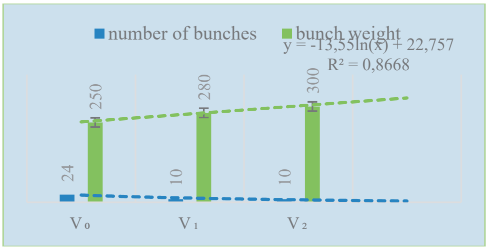

Figure 2. Number and mass of grapes (g)

As the effect was manifested on the average weight of a grape, which is 280 g and outperforms the control on this metric. Controlling the yield in the phase of grain growth in variant V_2 led to a greater mass of grapes of 300 g., which gives us reason to recommend the variants with controlled yield in the production of grapes. In the control, the average mass of the bunch remains the smallest. The data on the quantitative changes of the indicators that characterize the yield of grapes is shown below (Figure 3).

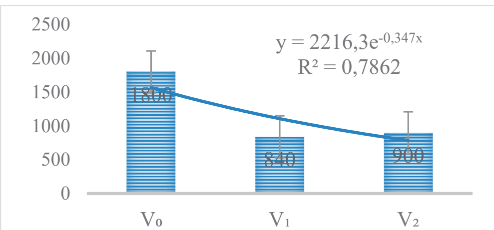

Figure 3. Grape yields, kg/decare

The yield of grapes according to variants is in the range from 840 kg to 1800 kg per decare.
The grape yield was highest at V_0, followed by V_2 as the lowest at and V_1. The yield difference between V_0 and V_1 is significant. In all variants, the yield is formed by spurs. The bunches average mass changes depending on the yield reduction and the phenophase, and also on the application of "Humat Rost". Bunches at V_2 had the largest mass, followed by V_1, and control V_0 had the smallest bunches. An increase in average vine yield leads to an increase in average decare yield, but not in average grape mass, this depends on the phenophase of yield reduction and vine nutrition.
Plant protection products approved for organic production were used to protect the plantation from diseases. They are described in the EU Regulation (2019).
In 2022, 8 plant protection treatments were done on the vines (Table 6).
Least costs to protect the vines from the causative agents of downy mildew and powdery mildew were made in 2023. The main reason for this is that, climatically, the year was rainy and the grape harvest was not reached.
The implemented scheme for the treatment of the vines and the summer pruning operations carried out have had a beneficial effect on the general state of the vineyard and in particular on the vegetative and generative organs of the vines. In the second year of the experiment, an attack from downy mildew and powdery mildew was found, which had a negative effect on the yield of grapes.
The production of organic grapes is only possible if we have a year with a normal distribution of rainfalls. The proposed plant protection scheme will have a positive effect on the vineyard. But in years with cataclysms like 2023, it will be necessary to notify the controlling authority and temporarily put the plantation into a transition period and treat it with synthetic products to protect the grapes from the two economically important vine diseases - downy mildew and powdery mildew.

Table 6. Scheme of treatments

2022	Treatments	2023	Treatments
15 April	Funguran – 0.2% Cosavet – 0.4% Airone – 0.3%	22 April	Funguran – 0.2% Cosavet – 0.4%
09 May	Cosavet – 0.4% Airone – 0.3%	03 May	Funguran – 0.2% Cosavet – 0.4%
20 May	Cosavet – 0.4% Airone – 0.3%	15 May	Airone – 0.3% Cosavet – 0.4%
29 May	Cosavet – 0.4% Airone – 0.3%	23 May	Airone – 0.3% Cosavet – 0.4%
10 June	Cosavet – 0.4% Airone – 0.3%	02 June	Airone – 0.3% Cosavet – 0.4%
23 June	Cosavet – 0.4% Funguran – 0.2%	18 June	Airone – 0.3% Cosavet – 0.4%
06 July	Cosavet – 0.4% Funguran – 0.2%	29 June	Airone – 0.3% Cosavet – 0.4%
20 July	Cosavet – 0.4%	-	-

CONCLUSIONS

The results obtained from the phenological observations give us reason to summarize that the reason for the occurrence of the phenophases is due to three main factors, which are the greater amount of precipitation in the winter and spring period combined with low temperatures, as well as the reduction of the yield by more than half relative to vines in the control. One of the main factors that directly affect the accumulation of biomass is the different periods of yield control in the vines, the availability of food resources and, last but not least, the duration of the growing season. These components lead to significant changes in the intensity of growth processes. An increase in average vine yield leads to an increase in average decare yield, but not in average grape mass, this depends on the phenophase of yield reduction and vine nutrition.

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