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NanoKremny effect on the quality of grapes and wines

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Abstract:
Introduction. There is still an urgent need in viticulture for studying the effect of tank mixtures of pesticides and bioactive substances on *Vitis vinifera* and, therefore, the quality and composition of wine. We aimed to study the effect of NanoKremny (silicon fertilizer) treatment of the grapevine on the productivity and quality of grape harvest, as well as the quality of dry wines.
Study objects and methods. Grape varieties from three vineyards in Crimea and the wines produced from them. We applied standard methods used in viticulture, plant protection, and oenological practice. Organic acids and volatile components in grapes and wines were determined by high-performance liquid chromatography and gas chromatography.
Results and discussion. We found that the most effective use of NanoKremny was threefold at 0.15 L/ha during the periods of active growth and formation of vegetative and generative organs in grapevines. It had a positive effect on vegetative development, water balance, productivity of grape plants, as well as yield quality and quantity. Also, NanoKremny decreased the development of mildew and oidium diseases, preserved the content of titratable acids in grapes during their ripening, as well as accumulated phenolic compounds, tartaric and malic acids in grape berries.
Conclusion. We found no negative effect of NanoKremny treatment of the grapevine on the physicochemical parameters and sensory characteristics of wines. Thus, this preparation can be used as a bioorganic additive in viticulture.

Keywords: Grapes, NanoKremny, foliar dressing, tank mixture, productivity, yield parameters, wine, chemical composition, quality

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INTRODUCTION

Silicon, whose content in soil is rather high (50–400 g/kg soil), plays a significant role in soil formation and fertility [1, 2]. Back in 1813, Davy established that silicon is concentrated in the epidermal tissues of plants, creating a barrier that protects plants from insect pests. This was the first work on the importance of silicon in plant physiology.

Today, we know a lot about the role of silicon in plant life (Fig. 1). In particular, silicon content determines the level of natural protection against biotic and abiotic stresses [2–8]. Silicon nutrition for plants increases leaf area and creates favorable conditions for photosynthesis [7, 9]. When added to the soil, readily-soluble silica improves the metabolism of nitrogen and phosphorus in tissues, increases the content of phosphates, and facilitates the consumption of boron and other elements. In addition, it reduces the toxicity of excessive heavy metals, neutralizes the negative effects of excessive nitrogen fertilizers, increases the population of ammonifiers, improves nitrification, and helps the soil to absorb mobile forms of nitrogen [10–14].

Silicon fertilizers are increasingly being used in agriculture across the world (the USA, China, India, Brazil, Japan, South Korea, Mexico, Australia, and other countries). Their production increases by 20–30% annually. An ecological alternative to pesticides, they also increase plants' resistance to stress.

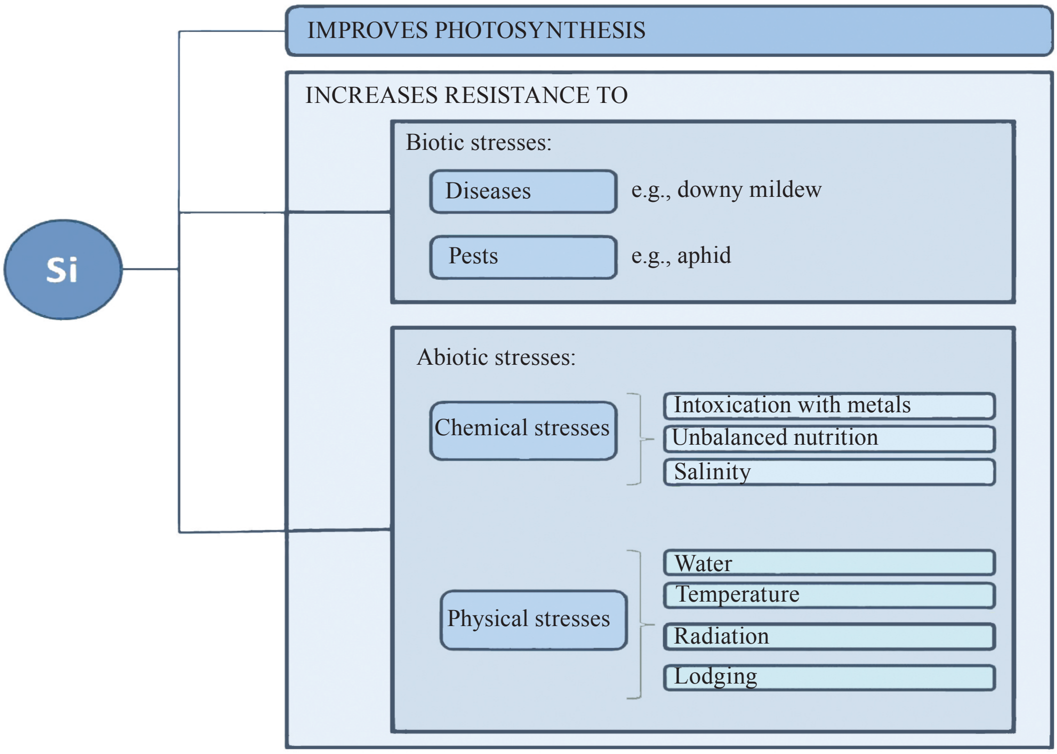


Figure 1 Role of silicon in plant life [12]

Russia-produced silicon fertilizers include natural silicon materials (Diatomite, BIO COMPLEX; Promzeolit, PROMZEOLIT), concentrated monosilicic acid with active colloidal silicon (Akkor, Moscow Region), as well as physiologically active organosilicon biostimulants (FLORA-SI, Moscow). Among them is a unique fertilizer – NanoKremny (NANOCREMNY) – crystalline silicon with a particle size under 0.5 µm, which has no analogues in Russia or other countries.

Silicon fertilizers have a proven positive effect on different soils for the *Leguminosae*, *Gramineae*, *Solanaceae*, *Citrinae*, and *Cruciferae* families, as well as other agricultural crops. However, few studies have looked into tank mixtures of pesticides and bioactive substances in relation to *Vitis vinifera*. In practice, using scientifically unfounded tank compositions often leads to negative phytosanitary and economic consequences [15].

The quantity and quality of grape and wine yield can be increased by using foliar dressing with macro- and microelements. Grape quality is determined primarily by sugar content and acidity of the berry juice. According to State Standard 31782-2012 "Fresh grape of combine and hand harvesting for industrial processing. Specifications", the concentration of sugars in grapes for winemaking must be at least 160 g/L for white varieties and 170 g/L for red varieties. To ensure such high concentrations of sugars and stable grape yield, the grapevine must be provided with sources of microelements [16, 17].

In recent years, scientists have been interested in the role of bioorganic additives in winemaking technology. Silicon-containing preparations, in particular, have a beneficial effect on yeast metabolism and functional activity. They intensify alcoholic fermentation, enrich the wine with volatile components and, therefore, improve its aroma [18–20].

We aimed to substantiate the use of the NanoKremny mineral fertilizer in the Crimean vineyards and to study its effect on crop efficiency, the quality and quantity of grape, as well as the chemical composition and sensory indicators of dry table wines.

STUDY OBJECTS AND METHODS

Our study objects were the grapes of white (Aligoté, Chardonnay) and red (Cabernet Sauvignon) varieties, as well as respective dry wines produced in 2017–2018 in the western piedmont-coastal area of the main viticulture zones of Crimea, namely the South-Western Zone (S. Perovskoy; SVZ-AGRO, Sevastopol), the Central Steppe Zone (Legenda Kryma, Geroyskoye village), and the South Coast zone (Livadiya branch of Massandra Winery, Yalta). Grape cultivation was in line with the technological maps adopted for each variety in each zone.

The technology for dry white table wines (Chardonnay and Aligoté) included the following stages:
- crushing grapes on a manual roll-mill crusher;
- destemming;
- pressing the pulp on a manual basket-type press;

Table 1 Experimental vineyard treatments with NanoKremny

Sample	Number of treatments	Indicators under study
Chardonnay		1. Growth strength and productivity of grapevine bush. 2. Level of disease development. 3. Grape chemical composition and biochemical characteristics. 4. Wine chemical composition and sensory characteristics.
Legenda Kryma, 2017		
Control – vineyard chemical protection system	6	
Experiment – vineyard protection system + NanoKremny treatment during blossom clustering, after florification, and at the beginning of bunch formation	3	
S. Perovskoy, 2017		
Control – vineyard chemical protection system	6	
Experiment – vineyard protection system + NanoKremny treatment during bud pushing, blossom clustering, before and after florification, and at the beginning of bunch formation	5	
Aligoté		
SVZ-AGRO, 2018		
Control – vineyard chemical protection system	6	
Experiment – vineyard protection system + NanoKremny treatment during blossom clustering, before and after florification	3	
Cabernet Sauvignon		
Livadiya branch of Massandra Winery, 2017		
Control – vineyard chemical protection system	6	
Experiment 1 – vineyard protection system + NanoKremny treatment during bud pushing, blossom clustering, and before florification	3	
SVZ-AGRO, 2018		
Control – vineyard chemical protection system	6	
Experiment – vineyard protection system + NanoKremny treatment during blossom clustering, before and after florification	3	

The rate of NanoKremny application – 0.15 L/ha

– sulfitating the must with sulfur dioxide (75–80 mg/L) and stirring;
– clarifying the must at 14–16°C for 18–20 h;
– decanting the clarified must;
– introducing a pure culture of the *Saccharomyces cerevisiae* yeast from the Magarach collection of winemaking microorganisms (strain I-271 for Chardonnay, I-187 and I-525 for Aligoté) and stirring;
– fermenting the must until dry at 20 ± 2°C with stirring 2–3 times a day;
– clarifying the wine; and
– decanting the wine.

The technology for dry red table wines (Cabernet Sauvignon) consisted of the following stages:
– crushing grapes on a manual roll-mill crusher;
– destemming;
– sulfitating the pulp with sulfur dioxide (75–80 mg/L) and stirring;
– introducing a pure culture of the *S. cerevisiae* yeast from the Magarach collection of winemaking microorganisms (strains I-652 and I-250) and mixing;
– fermenting the pulp with a floating cap at 24 ± 2°C, with mixing 7–8 times a day, up to 1/3 of residual sugars;
– pressing the pulp on a manual basket-type press;
– fermenting the must until dry;
– self-clarifying; and
– decanting.

Fieldworks were conducted with common methods of viticulture and plant protection [21, 22]. Foliar dressing was introduced in a tank mixture with pesticides. Experimental treatment schemes are presented in Table 1.

The chemical composition of grapes, must, and wines was analyzed with standard oenological methods [23–25].

The phenolic ripeness of grapes was assessed according to Glories *et al.* [24]. Their method determines the potential amount of anthocyanins that grapes can produce ($ApH_{1.0}$) and the amount of easily extractable anthocyanins ($ApH_{3.2}$). The ratio between these amounts shows the percentage of easily extractable anthocyanins in the grape berry (Ea, %).

The concentration of organic acids was determined in freshly squeezed, centrifuged must (OPN-8 centrifuge, Kyrgyzstan) by HPLC (Shimadzu LC20AD Prominence chromatograph, Japan). The method required preliminary calibration with standard solutions of pure substances on the spectrophotometric detector, taking into account their retention time. Individual components of the organic acid profile were determined at 210 nm. The sample was separated on a Supelcogel C610H column (Supelco®, Sigma-Aldrich) in an isocratic mode of eluent supply (0.1% aqueous solution of phosphoric acid, flow rate 0.5 mL/min). The refractometric detector was additionally calibrated using solutions of carbohydrate standards with the same retention time as organic acids, taking into account their analytical characteristics during analysis.

The concentration of organic acids in the sample was calculated mathematically, using the data obtained on the UV and refractometric detectors.

Volatile components were determined by gas chromatography (Agilent Technology 6890, USA) at an evaporator temperature of 220°C and a thermostat temperature of 50–240°C programmed at 4°C/min. The components were extracted with methylene chloride. The experimental samples were separated on an HP-INNOWAX column (Carbowax 20M or PE-FFAP; 30 m long, 0.25 mm inner diameter). The NIST 2007 database was used to identify the substances.

Experimental data were processed by variational statistical methods using Excel and SPSS Statistica 17 (arithmetic mean, root-mean-square deviation, and error mean square of a singular result). The tables and figures show the mean values of the indicators (standard deviation under 5% at $P \leq 0.005$).

RESULTS AND DISCUSSION

Silicon fertilizers are an innovation in modern intensive agriculture worldwide. NanoKremny is a unique fertilizer that contributes to high-yielding and ecological crops. Its main component is a biologically and chemically active silicon in a chelated form.

Our field experiments showed that NanoKremny produced the best results when applied threefold in the periods of active growth and formation of vegetative and generative organs in grape plants: bud pushing, before florification, after florification, and at the beginning of bunch formation (Table 1). This treatment led to increased stress resistance and yield, as well as reduced fungal diseases. In particular, it contributed to:

– higher productivity of grape plants: for example, the first three spray treatments of Cabernet Sauvignon (Livadiya, Massandra) improved the water balance of grape plants and increased the leaf area (by 13.9%), growth and ripening parameters (by 11.3 and 12.2%), and crop quantity (by 14.7%);

– lower risk of downy mildew disease (1.2–3.6 times, depending on variety) and oidium (protection improved by 10–12%) with threefold spraying during blossom clustering, before florification, and after florification;

– higher crop yield: for example, by 5, 45, and 49% for Aligoté (SVZ-AGRO), Chardonnay (S. Perovskoy), and Cabernet Sauvignon (SVZ-AGRO), respectively [26, 27].

The quality of grapes and young wines was assessed on the basis of their chemical composition and sensory characteristics. The grape batches under study met the requirements of State Standard 31782. The optimal contents of titratable acids are 6–9 and 5–8 g/L and those of sugar are 170–200 and 180–220 g/L for white and red varieties, respectively [28]. These contents are not standardized and recommended for table wines in scientific literature. We compared the carbohydrate-acid composition of the experimental grape batches against the controls and found an up to 5% increase in sugars for Legenda Kryma's Chardonnay and a 5% decrease in sugars for S. Perovskoy's Chardonnay and SVZ-AGRO's Cabernet Sauvignon (Table 2). This might be associated with a significant (by 45–49%) yield growth. The experimental batches of Aligoté and Livadiya's Cabernet Sauvignon had a similar composition to that of the controls.

The concentration of titratable acids in the experimental samples increased by 7 and 9% for Aligoté

Table 2 Chemical composition of the experimental NanoKremny-treated grape varieties vs. controls

Sample	Concentration, g/L		pH	Technological reserve, mg/L		Ea, %
	sugars	titrable acids		phenolic compounds	anthocyanins	
Chardonnay (Legenda Kryma, 2017)						
Control	194.00 ± 8.73	7.80 ± 0.16	3.44 ± 0.07	1234.0 ± 111.1	–	
Experiment	204.00 ± 9.18	7.70 ± 0.15	3.45 ± 0.07	1316.0 ± 118.4	–	
Chardonnay (S. Perovskoy, 2017)						
Control	194.00 ± 6.79	6.50 ± 0.09	3.33 ± 0.05	1505.0 ± 120.4	–	
Experiment	186.00 ± 6.51	6.90 ± 0.10	3.23 ± 0.03	1675.0 ± 134.0	–	
Aligoté (SVZ-AGRO, 2018)						
Control	183.00 ± 9.15	5.80 ± 0.17	3.16 ± 0.03	891.0 ± 84.6	–	
Experiment	188.00 ± 9.40	6.20 ± 0.19	3.16 ± 0.03	999.0 ± 83.9	–	
Cabernet Sauvignon (Livadiya branch of Massandra Winery, 2017)						
Control	271.00 ± 10.84	6.80 ± 0.27	3.61 ± 0.05	2657.0 ± 252.4	703.0 ± 46.4	59.0 ± 3.0
Experiment	271.00 ± 10.84	7.40 ± 0.30	3.41 ± 0.02	2728.0 ± 259.2	726.0 ± 47.9	56.0 ± 2.8
Cabernet Sauvignon (SVZ-AGRO, 2018)						
Control	201.00 ± 9.05	6.10 ± 0.18	3.30 ± 0.03	2434.0 ± 211.8	565.0 ± 49.7	44.0 ± 2.1
Experiment	191.00 ± 8.59	6.40 ± 0.19	3.24 ± 0.05	2516.0 ± 218.9	520.0 ± 45.8	45.0 ± 2.3

Ea – easily extractable anthocyanins

Control – chemical protection system

Experiment – chemical protection system + NanoKremny treatment and Livadiya's Cabernet Sauvignon, respectively. NanoKremny significantly reduced active acidity (by 0.20) only in the Cabernet Sauvignon samples, compared to the controls. Thus, we did not identify any changes in the carbohydrate-acid complex that would be common for all the experimental samples, regardless of variety or place of growth.

Silicon makes plant more stress-resistant by stimulating the synthesis of phenolic metabolites and the activity of protective enzymes, such as monophenol-monooxygenase (MPMO), peroxidase, and others [29–31]. Important technological characteristics of grapes for winemaking are the content of phenolic compounds, including anthocyanins, phenolic ripeness, and the activity of grape oxidases at the time of their technical ripeness [32].

The experimental treatments increased the technological reserve of phenolic compounds in the experimental samples by 82–170 and 71–82 mg/L for white and red varieties, respectively, compared to the control. We found that the phenolic reserve in the Cabernet Sauvignon and Aligoté samples, both control and experimental, corresponded to the values recommended for table wine production: at least 2000 mg/L for red grapes and under 1000 mg/L for white grapes [28, 32].

We did not find a single trend in the effect of NanoKremny on the accumulation of monomeric anthocyanins in grapes at that stage. For example, Livadiya's Cabernet Sauvignon showed a 3% increase in monomeric anthocyanins, whereas the same variety from SVZ-AGRO had an 8% decrease. Cabernet Sauvignon growing on the South Coast reaches phenolic ripeness when it has at least 45% of easily extractable anthocyanins [32]. We only used phenolically ripe samples of Cabernet Sauvignon (both control and experimental), with 44–56% of easily extractable anthocyanins. The experimental treatment did not have a significant effect on this indicator.

We found that the effect of NanoKremny on the MPMO activity of the must depended largely on the grape variety (Fig. 2). For example, Chardonnay showed a decreasing trend, regardless of the place of its growth, which is a favorable factor for white table wines. Cabernet Sauvignon showed the opposite trend, while the Aligoté samples were not affected at all. However, we registered a correlation between the MPMO activity and the place of growth. For example, Chardonnay showed a decrease in the MPMO activity by 24 and 33% for Legenda Kryma and S. Perovskoy, respectively, while Cabernet Sauvignon had an increase by 91 and 61% for SVZ-AGRO and Livadiya, respectively, compared to the control.

Organic acids determine the sensory characteristics of wines and the intensity of redox processes, as well as protect them from harmful bacterial microflora [33, 34]. Recent studies have proved the relationship between the metabolism of organic acids and plant resistance to stress [35]. Organic acids are produced during plant respiration due to the incomplete oxidation of carbohydrates, as well as during photosynthesis (mainly in leaves, with further transportation to grape berries). Since silicon fertilizers create favorable conditions for photosynthesis, we can assume that they have an indirect effect on the metabolism of organic acids in the grapevine. As we can see in Fig. 3, NanoKremny contributed to a 9–12% increase in tartaric acid in the grapes, regardless of their variety and growth area. A similar trend was observed with malic acid (especially in Chardonnay), whose concentration increased by 8% in Cabernet Sauvignon and by 25 and 48% in Chardonnay from S. Perovskoy and Legenda Kryma, respectively.

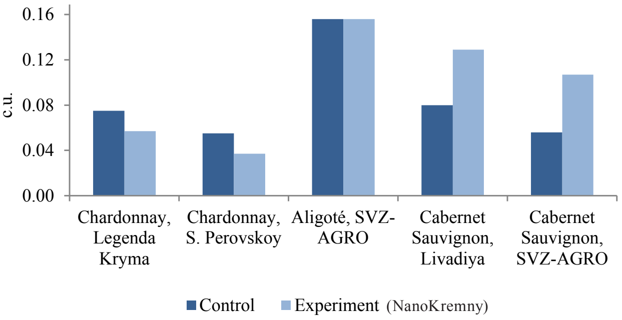


Figure 2 Monophenolmonooxygenase activity of the must obtained with different treatment schemes

The quality assessment revealed that all the white and red dry table wines produced from the grapes treated in different ways met the requirements of State Standard 32030-2013 "Table wines and table winestocks. General specifications" (Table 3).

The chemical composition of wines and their quality result from a combination of factors, including agricultural methods used in the vineyard. To neutralize technological influence, we used the same technology to produce all the wines. The technologically relevant parameters of grape and wine quality were taken from previous studies [10, 28, 32].

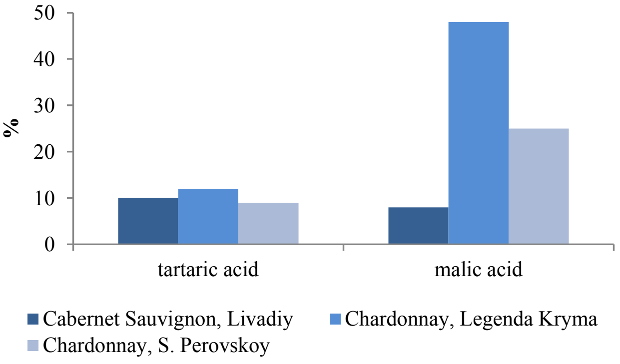


Figure 3 Concentrations of organic acids in NanoKremny-treated grape varieties from different growth areas

Table 3 Chemical composition of dry table wines from grapes exposed to different treatments (average values)

Sample (yeast strain)	Volume rating of ethyl alcohol, %	Concentration, g/L					Concentration, g/L			pH	DE*, point
		sugars	titratable acids	volatile acids	total dry extract	total sulphurous acid	free sulphurous acid	phenolic compounds	anthocyanins		
Values according to State Standard 32030											
	8.5–15	≤ 4	≥ 3.5	≤ 1.1 for white wine; ≤ 1.2 for red wine	≥ 16 for white wine; ≥ 18 for red wine	≤ 200	not standardized				
Chardonnay (Legenda Kryma, 2017)											
Control: chemical protection system (st. I-271)	10.8	1.0	7.2	0.29	20.1	94	50	257	–	3.19	7.60
Experiment: chemical protection system + NanoKremny treatment (st. I-271)	10.6	1.3	7.3	0.79	16.3	100	50	274	–	3.22	7.55
Aligoté (SVZ-AGRO, 2018)											
Control: chemical protection system (st. I-187)	11.9	0.7	6.1	0.43	16.5	86	51	161	–	3.24	7.75
Experiment: chemical protection system + NanoKremny treatment (st. I-187)	10.9	0.5	7.6	0.48	18.3	70	32	114	–	3.24	7.74
Control: chemical protection system (st. I-525)	10.8	0.4	7.2	0.53	16.5	75	33	166	–	3.24	7.78
Experiment: chemical protection system + NanoKremny treatment (st. I-525)	11.5	0.4	7.4	0.34	16.4	68	31	123	–	3.29	7.65
Cabernet Sauvignon (Livadiya branch of Massandra Winery, 2017)											
Control: chemical protection system (st. I-652)	14.8	1.8	5.1	0.43	26.1	120	38	2474	301	4.00	7.69
Experiment: chemical protection system + NanoKremny treatment (st. I-652)	13.9	1.7	5.2	0.26	25.9	110	38	2427	401	3.85	7.57
Cabernet Sauvignon (SVZ-AGRO, 2018)											
Control: chemical protection system (st. I-250)	11.0	1.4	7.2	0.49	20.2	68	27	1563	385	3.50	7.84
Experiment: chemical protection system + NanoKremny treatment (st. I-250)	11.0	1.1	7.9	0.37	20.5	90	45	1446	319	3.38	7.74
Control: chemical protection system (st. I-652)	11.1	0.4	7.6	0.38	21.5	77	35	1322	339	3.40	7.80
Experiment: chemical protection system + NanoKremny treatment (st. I-652)	11.2	1.8	6.7	0.29	20.4	86	43	1593	314	3.54	7.75

*DE – TE – tasting evaluation

We found that the Chardonnay and Aligoté experimental wines showed various trends in relation to titratable acids and active acidity. In the Aligoté wines, the concentration of titratable acids was determined by the yeast strain. For example, strains I-187 and I-525 increased titratable acids by 1.5 and 0.2 g/L, respectively, compared to the control.

Just as the experimental batches of Chardonnay grapes, the experimental wines from them had a high content of phenolic compounds – 7% higher than in the controls. Their technological reserve in the Aligoté wines, however, remained the same. On average, the concentration of phenolic compounds in the experimental wines amounted to 114–123 mg/L, which was 26–29% lower than in the controls (Fig. 4).

It was impossible to determine the exact effect of NanoKremny on the chemical composition of Cabernet Sauvignon wines at that stage of research. Only 33% of the wine samples showed an 0.7 g/L increase in titratable acids. In 33% of the tested wines, the concentration of titratable acids decreased by 0.9 g/L. In other cases, this indicator was the same for both the experimental wines and the controls.

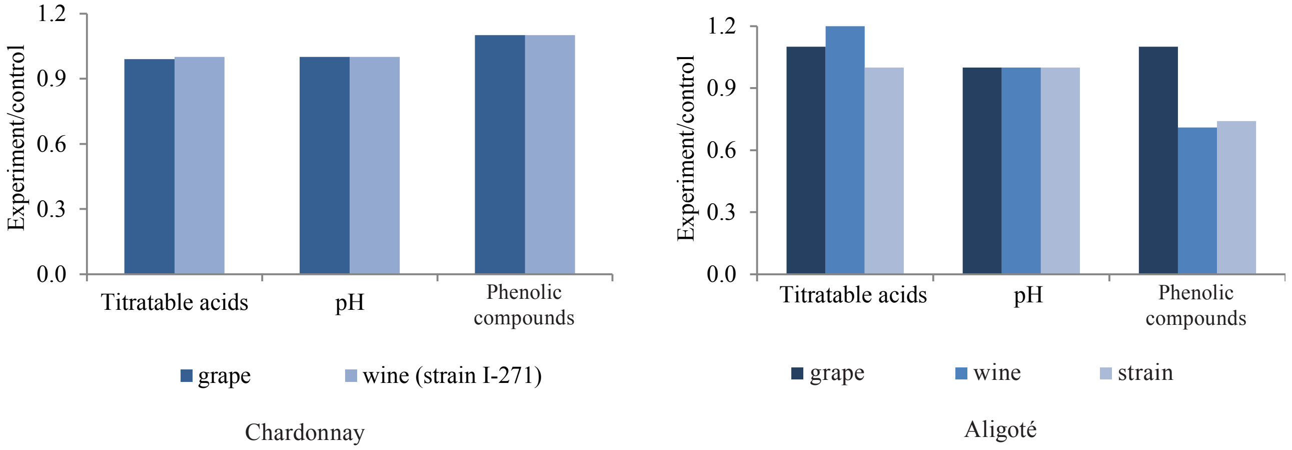


Figure 4 Concentrations of titratable acids, phenolic compounds (technological reserve in grapes), and pH in wines and grapes exposed to different treatments

The profile of organic acids in the "grapes-wine" chain showed the dominance of tartaric acid, whose concentration in the control and experimental samples did not differ, averaging 1.4 g/L (Fig. 5). Malic acid, however, did not show the same increasing trend in the wines as it did in the experimental grape samples. Its average concentration in the experimental wines was 33% lower than in the controls. This might be due to malolactic fermentation, which also led to higher concentrations of lactic and succinic acids, mostly expressed in the experimental wine samples (Fig. 5).

Although NanoKremny contributed to the accumulation of phenolic compounds in the grapes, their concentration averaged 1446–2427 mg/L in 67% of the experimental wines, which was 2–7% lower than in the controls. The only exception was the wines from SVZ-AGRO where the concentration of phenolic compounds averaged 1593 mg/L – 20% higher than in the control. This might be due to the initial composition of raw materials and the physiological and biochemical properties of the strains used. Compounds produced from fermentation can affect the speed of redox processes initiated and mediated by phenolic compounds.

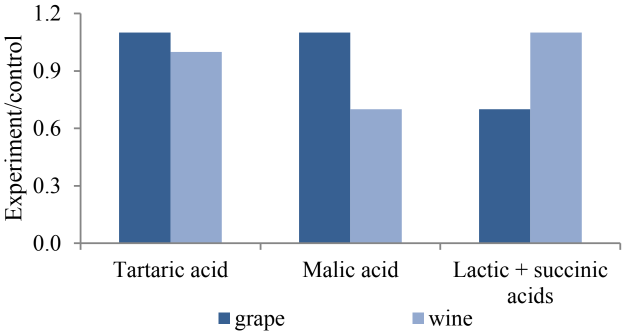


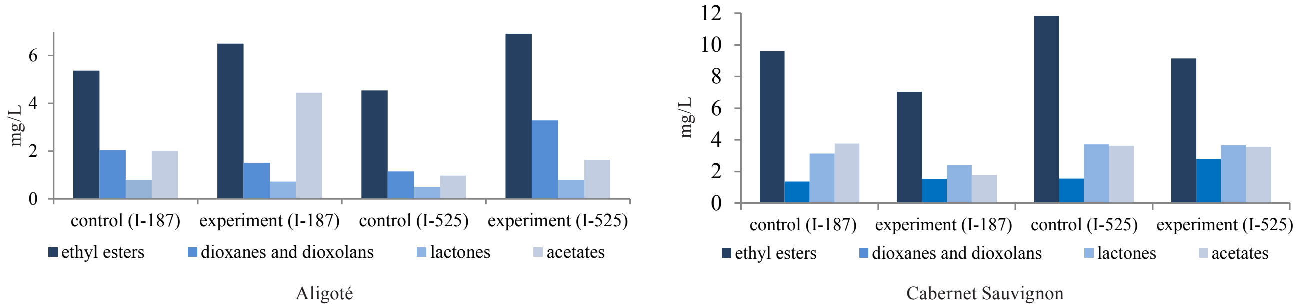
Figure 5 Concentrations of organic acids in the control and experimental samples of grapes and wines (for Cabernet Sauvignon)

The concentration of monomeric anthocyanins was 301–385 and 314–401 mg/L in the control and experimental wines, respectively. In Livadiya's wines, monomeric anthocyanins accounted for 12–17% of phenolic compounds, only half of their proportion in the grapes. In the wines from SVZ-AGRO, they amounted to 20–26%, almost the same as in the grapes (21–23%). This might be due to their ability to bind with other compounds, form complex structures, and precipitate [36]. This assumption could be supported by a lower content of acetaldehyde in the wine materials in 2017 (8–40 mg/L) compared to 2018 (90–133 mg/L).

Aroma is an important characteristic of wine quality. According to the chromatographic analysis, the concentrations of aroma-producing components in the Aligoté and Cabernet Sauvignon wines averaged 104–108 and 120–149 mg/L in the controls, and 96–104 and 112–141 mg/L in the experimental samples, respectively. Aliphatic and aromatic alcohols were predominant among aromatic substances, with the same total concentrations in the experimental and control samples averaging 27–31 and 25–32 mg/L for Aligoté and 35–47 and 27–35 mg/L for Cabernet Sauvignon, respectively.

All experimental wines from Aligoté grapes, regardless of the yeast strain used, showed an increase in ethyl esters 1.2–1.5 times (Fig. 6). They also had high concentrations of acetic acid esters – 2.2 times and 1.6 times higher when treated with the I-187 and I-525 yeast strains, respectively (Fig. 6). The I-525 strain raised the concentration of dioxanes and dioxolans to an average of 3.29 mg/L, which was 2.9 times higher than in the controls.

The experimental wines from Cabernet Sauvignon grapes showed lower (1.2–1.5 times) concentrations of ethyl esters, averaging 7–9 mg/L. As we can see in Fig. 6, the samples treated with the I-652 strain had 1.3 and 2.1 times lower concentrations of lactones



Aligoté

Cabernet Sauvignon

Figure 6 Aroma-producing complexes of the control and experimental wines

and acetates than in the controls, averaging 3.14 and 3.76 mg/L, respectively. The I-250 strain increased the concentration of dioxanes and dioxolans 1.8 times compared to the control. These compositions of the aroma-producing complex might be determined by the physiological and biochemical abilities of the yeast strains used.

The assessment of the influence of grape treatment on the sensory quality of wines showed that young white table wines from Chardonnay grapes contained some shades of medicinal herbs, absent in the control samples. The control Aligoté wines were characterized by a light straw color, a floral aroma, with hints of meadow herbs, candy and spicy tones, and a harmonious taste. In contrast, the experimental wines had a straw color, a fruity aroma, with herbal, spicy and candy tones, as well as a fresh, slightly astringent taste. The average tasting scores of Aligoté wines were 7.70 and 7.77 points for the experimental and control samples, respectively.

The control red table wines from Cabernet Sauvignon grapes had a dark ruby color, a varietal berry aroma with hints of spices, nightshade, morocco leather, and milk cream, as well as a moderate velvety flavor with light astringency. Their average tasting scores were 7.69 and 7.82 points for the 2017 and 2018 grape harvests, respectively. The experimental wines (chemical protection + NanoKremny treatment) had a dark ruby color, a berry aroma with light herbal tints, and a somewhat simple palate with moderate tannins. Their average tasting scores were 7.57 and 7.74–7.75 for the 2017 and 2018 grape harvests, respectively. Different yeast strains had no significant effect on the tasting scores of the experimental red wines.

Thus, the differences in the sensory scores of the control and experimental wines were statistically insignificant ($P < 0.05$).

CONCLUSION

Our study showed that the optimal treatment of grapevines is a threefold application of NanoKremny (0.15 L/ha) during the periods of active growth and formation of vegetative and generative organs in the grape plant. This scheme has a positive effect on vegetative development, water balance, grape plant productivity, as well as yield quality and quantity. Also, it prevents the development of mildew and oidium diseases.

The NanoKremny treatment of the grapevine preserves the content of titratable acids during grape ripening and accumulates phenolic compounds, tartaric and malic acids in the berries. We found no significant differences in the physicochemical parameters of the wines from NanoKremny-treated grapes and the control wines from grapes that underwent standard chemical protection.

The sensory evaluation of young wine samples showed that the NanoKremny treatment enhanced the expression of herbal (grassy) shades in the aroma of both white and red wines. Although it somewhat simplified their taste, NanoKremny did not have a negative effect on the wine quality.

CONTRIBUTION

N.V. Aleinikova studied the effect of NanoKremny on the grape plant and was involved in approving the final version of the manuscript. I.V. Peskova processed experimental data about the effect of NanoKremny on the quality of grapes and wines, and was involved in writing the manuscript. E.V. Ostroukhova studied the effect of NanoKremny on the quality of grapes as raw materials for winemaking and on the quality of wines; she was also involved in approving the final version of the manuscript. Ye.S. Galkina processed experimental data about the effect of NanoKremny on the grape plant. P.A. Didenko conducted fieldworks to identify the effect of foliar dressing on the grape plant. P.A. Probeigolova and N.Yu. Lutkova analyzed the chemical composition of grapes and wines.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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