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Evaluation of products for *Drosophila suzukii* control and their impact on grape quality

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Abstract

The pest *Drosophila suzukii* also causes significant damage to grapevine berries. Kaolin-based products and biostimulants were tested in an experiment to reduce the development of *Drosophila suzukii* and the development of sour rot, while the effect on grape quality parameters was also investigated. Surround, building kaolin, NovaFerm Orion, NovaFerm Sirius and Hycolat were tested on Riesling, Traminer and Palava varieties between 2023 and 2024. In terms of reducing damage to *Drosophila suzukii* berries, the most effective application was Surround (3%, 5%). From the biostimulants, NovaFerm Orion and Hycolat were the most effective. The same products also showed good efficacy in point of reducing the development of sour rot. In view of the effect on grape quality parameters, the most significant negative impact was on pH values. Riesling and Traminer showed an increase in pH values compared to the untreated control. pH is a very important parameter in the context of grape processing and fermentation.

Keywords: grapevine; *Drosophila suzukii*; sour rot; kaolin; biostimulants; grape quality

1 Introduction

Drosophila suzukii is an invasive Asian species of Diptera that is spreading globally (Asplen et al., 2015; Walsh et al., 2011). It has a wide host range and can adapt well to climatic conditions, which may support its global spread (Tundagi et al., 2023). The interannual variability of *Drosophila suzukii* populations is influenced by changing climatic conditions, particularly air temperature during winter (Leach et al., 2019) and also during the growing season (Wang et al., 2016). Temperatures above 30 °C can reduce the population size of *D. suzukii* and the risk of vineyard infestation (Eben et al., 2018; Gutierez et al., 2016). *D. suzukii* can lay its eggs in healthy berries with intact skin (Entling and Hoffmann, 2020; Kienzle et al., 2020). Vectors from the genus *Drosophila* collect and transport yeasts and acetic acid bacteria (AAB) on their bodies and then deposit them on the berries upon direct contact (Ioriati et al., 2018). Red wine varieties are more frequently infested than white varieties (Weissinger et al., 2021). Poyet et al. (2015) and Lee et al. (2011) also found that *Drosophila suzukii* prefers red berries to green berries. Varieties susceptible to sour rot include varieties with compact bunch and varieties susceptible to berry cracking (Hartman and Kaiser, 2008). Riedle-Bauer et al. (2020) evaluated a wide range of varieties and identified Bluer Portugieser, Frühroter Veltliner, Saint Laurent, Zweigelt and Roesler as varieties with moderate susceptibility. No or almost no eggs were found in the varieties Cabernet Sauvignon, Pinot noir, Veltliner, Blaufraenkisch, Blauer Wildbacher, Pinot Noir, Syrah, Cabernet Franc, Chardonnay, Grüner Veltliner and

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Welschriesling. Sour rot is caused by the simultaneous development of acetic acid bacteria and yeasts. Climate warming may be accelerating the spread of sour rot by directly increasing the population of the vector that carries the pathogens associated with sour rot (Zhu et al., 2023). Barata et al. (2012) reported that acetic acid can be produced by both *Saccharomyces* and non-*Saccharomyces* yeasts.

Acetic acid bacteria are capable of converting glucose and ethanol into acetic acid. The following species of acetic acid bacteria have been reported to cause sour rot: *Gluconobacter cerinus, G. albidus, G. frateurii, Acetobacter aceti* and *A. pasteurianus*. Sour rot occurs by microorganisms that enter the berries when they are damaged. Sugar convert into alcohol in the berries, which the bacteria convert into acetic acid. Berries with sour rot are light brown, oxidise and lose their must. They smell strongly of vinegar. As the insects feed on the must and lay eggs, the yeasts and acetic bacteria enter the berries, triggering the development of sour rot. No plant protection products are available against sour rot (Mackie-Hass, 2024). Products capable of forming a "film" have been successfully applied for decades to control insect pests in various agricultural crops. Applied in suspension in water, they form a film of mineral particles on the plant surface. These films act as physical barriers against infestation and prevent insect movement (Glenn and Puterka, 2004). Kaolin is a white inert aluminosilicate mineral that can be an alternative to chemical insecticides (Glenn et al., 1999) and is also capable of leaving a thin layer on the fruit surface (Yazici and Kaynak, 2006). Kaolin particle film (KPF) can inhibit the adhesion and infection of pests and pathogens through the formation of a physical barrier rather than through chemical toxicity, (Ferrari et al., 2017; Sharma et al., 2015). Application of kaolin to the leaf increases the photosynthetic activity of vines (Teker, 2023; Frioni et al., 2019; Dinis et al., 2018). Kaolin application has a stimulatory effect on the primary and secondary metabolism of grapevine and improves berry quality (Conde et al., 2016; Dinis et al., 2016). Biostimulants are substances or microorganisms that, when applied to the plant or root zone, naturally stimulate processes that improve the efficiency of nutrient uptake and assimilation, stress tolerance, and product quality (Cataldo et al., 2022). Biostimulants are different from fertilizers because they act on plant metabolism and their nutrient concentration is negligible (Bulgari et al., 2015). The role of biostimulants is to improve natural processes in plants, with the aim of stimulating nutrient uptake and utilization, tolerance to abiotic stresses and crop quality (De Vasconcelos and Garofalo-Chaves, 2019; Saavedra et al., 2020). Biostimulants based on beneficial fungi or growth-promoting bacteria affect plant metabolism, leading to improved plant growth, resistance to stress conditions, improved nutrient utilization and production quality (Teklic et. al., 2021). The use of microbial biostimulants is a sustainable strategy to enhance plant traits and increase fertility, under stress conditions caused by climate change (Sangiorgio et al., 2020; Yalkin et al., 2017). Hydrolysable proteins are also considered biostimulants. Hydrolysed proteins regulate gene expression involved in nutrient transport, signalling and reactive oxygen species metabolism, thereby increasing plant tolerance to stress (Meggio et al., 2020). They also have the ability to influence the development of fungal pathogens in plants. They act as signal compounds to trigger plant defence responses (Boller, 1995). Products that promote plant defence against fungal pathogens may be a suitable alternative to pesticides. They contain large amounts of bioactive peptides that can act as plant growth regulators, antioxidants and biostimulants (Colla et al., 2014).

The aim of this research is to evaluate the effect of the different products on the reduction of berry infestation by *Drosophila suzukii* and also to evaluate the effect of the applied products on grape quality parameters.

2 Materials and methods

2.1 *Site description, grapevine varieties, tested preparations*

The experiment was realized in the vineyards of the Faculty of Horticulture, Mendel University in Brno. The vineyards are located in the Mikulov wine sub-region, Lednice wine-growing village and the vineyard site "Na Valtické". The evaluation took place in 2023 and 2024. The evaluation was carried out for the varieties Riesling, Traminer and Palava. The following products were applied in the individual trials, as shown in Table 1.

2.2 *Methods of evaluation* Drosophila suzukii *and sour rot damage*

For the evaluation of *Drosophila suzukii* berry damage, the method according to Weißinger et al. (2019) was used: 25 grape parts were randomly collected in the vineyard. From all these grape parts, 50 berries were collected and evaluated for the presence of ovules using a binocular microscope. Monitoring was conducted at harvest of grapes.

The average percentage of berries with deposited ovules was determined from the obtained data. The evaluation took place during the ripening of the grapes on 15 September 2023 and 1 September 2024.

Table 1 *Products used in the research*

Product	Dosage of the product	Characteristics of the product
Surround	3%, 5%	Active ingredient: 950 g.kg^{-1} KAOLIN, Surround protects plants in three ways and promotes higher yields and harvesting of more commercial fruits and vegetables. First, a film of kaolin particles protects fruit from sunburn and heat stress damage. It can reduce losses due to sunlight by up to 50%. Second, Surround keeps the leaf surface of plants cooler, leading to more efficient photosynthesis and higher yields in environments with intense sunlight and heat. Finally, carefully timed treatments reduce the activity of certain insect pests, delaying or even eliminating the need for conventional insecticide applications.
Building kaolin	5%, 10%	
NovaFerm ORION	5.0 l.ha^{-1}	NovaFerm Orion is a functional microbial blend that uses spore-forming bacteria and produced phytoactive substances and enzymes. The microorganisms contained: *Bacillus thüringiensis* spp. *kurstaki*, *Bacillus thüringiensis* spp. *tenebrionis*, *Photorhabdus luminescens*. Eliminates pest damage in plants.
NovaFerm SIRIUS	5.0 l.ha^{-1}	NovaFerm® SIRIUS contains an exceptional microbial strain of bacteria that is applied to the leaf. The phytoactive substances and enzymes produced enhance health and significantly eliminate phytopathogenic fungi. Microbial strain: *Bacillus licheniformis* (min. 1×10^7 cfu.ml^{-1}) – max. 5%.
Hycolat	5.0 l.ha^{-1}	Hycolat is a plant biostimulant. It was primarily developed for the treatment of vineyards. The amide nitrogen comes from hydrolysed collagen. The resulting collagen derivatives are natural oligopeptides and amino acids that favourably influence a number of biochemical reactions in plants, promoting their growth, development and the formation of reproductive organs. This increases the resistance of plants to abiotic stress and the influence of adverse conditions.

2.3 Analysis of qualitative parameters of grapes

The evaluation of sour rot was carried out on the same range of grape varieties. The incidence of sour rot was evaluated on 50 grapes of each variety, as a percentage of berries with symptoms of sour rot, within a bunch. The evaluation was carried out before harvest of each variety.

The grape harvest dates for the determination of analytical parameters are: Riesling: 3. 10. 2023, 18. 9. 2024, Traminer – 18. 9. 2023, 5. 9. 2024 and Palava – 18. 9. 2023, 9. 9. 2024.

The grapes were sampled using the method described by Iland et al. (2000). The following parameters were evaluated in this study: total soluble solids (SSC), pH value (pH), titratable acids (TA), content of assimilable nitrogen (YAN).

2.3.1 Determination of the total soluble solids of must by refractometry

The soluble solids concentration (SSC) of must was determined using a digital refractometer (model PR-100, Atago) at 22 °C.The value in Brix was measured. To convert to degrees of the standardised must meter, it is necessary to use the formula: °NM = °Brix × 1.15768 – 4.26.

2.3.2 Estimation of titratable acids

The estimation of all titratable acids contained in must was performed with 0.1 M solution of NaOH in an automatic Schott TitroLine easy titratator (SI Analytics GmbH, Mainz, Germany) with a preset potentiometric point of equivalence of pH 7.0. The reference factor of NaOH solution was determined with potassium hydrogen phtalate (KPH). The results are expressed in equivalents of tartaric acid (g.l^{-1}).

2.3.3 Estimation of pH-value

pH-value was estimated by means of a table pH-meter WTW (Weiltheim, Germany) with a combined glass and argent chloride gel electrode.

2.3.4 Determination of yeast assimilable nitrogen

The Formol titration procedure used was described by Gump et al. (2002). 100 ml of sample was poured into a 200 ml beaker and pH was adjusted to 8.0 using 1M NaOH and pH meter. The sample was transferred into a 200 ml volumetric flask, made up to the volume with deionised water and thorough mixed. The solution was filtered through filter paper. 100 ml aliquot of the sample was transferred into a beaker and the pH was readjusted to 8.0 with 1M NaOH, if necessary. 25 ml of neutralised formaldehyde (pH 8.0) was added, the mixture was stirred and titrated to pH 8.0 using 0.1M NaOH. The results can be calculated using the general equation: mg nitrogen.l^{-1} = [(vol NaOH) × (conc. NaOH) × 14 × (dilution factor) × 1000]/(sample vol).

2.4 Statistical evaluation

The results obtained were statistically analysed using the statistical package UNISTAT. Means and standard deviations were evaluated using ANOVA followed by the minimum detectable difference method at significance levels of P>0.95. These data were further analysed by means of Pearson´s correlation.

3 Results and discussion

3.1 *Damage to berries by* Drosophila suzukii *and the occurrence of sour rot on grapes*

Drosophila suzukii causes yield losses in vineyards and, above all, negatively affects grape and wine quality. Encouraging the development of the acetic acid bacteria leads to a higher production of volatile acids already in the grapes in the vineyard and thus to a deterioration of the harvest.

The effect on reducing berry damage by *Drosophila suzukii* was most effective among the kaolin-based formulations for the Surround (3% and 5%) variants. Results were highly variable for the building kaolin because the building kaolin is more easily washed off the berry surface by precipitation. From the biostimulants, berry damage through *Drosophila suzukii* was minimal in NovaFerm Orion and Hycolat. Also, Linder et al. (2018) found that kaolin application significantly reduced *D. suzukii* oviposition, compared to an untreated control. However, inconclusive differences were observed between different kaolin concentrations. A kaolin concentration of 2% seems to be the most suitable as it provides better adhesion after rainfall and consequently higher sustainability on grapes. Pérez-Guerrero and Molina (2016) evaluated the effect of kaolin on *D. suzukii* under laboratory conditions. However, kaolin caused insignificant reductions in infestation and adult mortality. Kaolin does not have a lethal effect on adults. Similar results were also obtained when evaluating the infestation of berries by sour rot, with the lowest infestation in the Surround (5%), NovaFerm Orion and Hycolat variants. The correlation between berry damage by *Drosophila suzukii* and berry sour rot infestation showed a strong correlation, with Riesling (r = 0.8757), Traminer (r = 0.8979) and Palava (r = 0.9511) showing the highest correlation. In terms of the effect of reducing *Drosophila suzukii* infestation and the development of sour rot, Surround, Hycolat and NovaFerm Orion showed good efficacy. The active ingredients of Hycolat are hydrolysed proteins. Hydrolysed proteins are mixtures of polypeptides, oligopeptides and amino acids that are produced from protein sources, through hydrolysis. Hydrolyzed proteins can be considered as elicitors. Elicitors are substances that are non-toxic to the plant and are recognized by plant membrane receptors, which means that they are often able to freely mobilize a number of plant defense mechanisms (Boller and Felix, 2009). The use of Hycolat is based on the content of hydrolyzed proteins with biostimulatory action and, in relation to *Drosophila suzukii*, also on the ability of Hycolat to form a "protective" layer on the surface of plant tissues. NovaFerm Orion is a functional microbial mixture that uses spore-forming bacteria and the phytoactive substances and enzymes produced. Contained microorganisms: *Bacillus thüringiensis* spp. *kurstaki, Bacillus thüringiensis* spp. *tenebrionis, Photorhabdus luminescens*. Eliminates pest damage in plants. It is therefore a microbial biostimulant that is claimed to eliminate pest damage to plants. In this research, the effect on reducing berry infestation by *Drosophila suzukii* was also confirmed.

Table 2 *Damage to the berries of* Drosophila suzukii *and occurrence of sour rot on grape*

Variant	Riesling				Traminer				Palava			
	Damage to the berries by *Drosophila suzukii*		Occurence of sour rot on grapes		Damage to the berries by *Drosophila suzukii*		Occurence of sour rot on grapes		Damage to the berries by *Drosophila suzukii*		Occurence of sour rot on grapes	
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
Surround (3%)	5%	5%	10%	10%	25%	0%	30%	0%	0	0%	0	0%
Surround (5%)	5%	0%	15%	5%	10%	0%	10%	5%	0	0%	0	0%
Building kaolin (5 %)	15%	5%	40%	5%	15%	0%	10%	5%	0	0%	0	0%
Building kaolin (10%)	15%	0%	40%	2%	10%	0%	5%	5%	0	0%	0	0%
NovaFerm ORION (5.0 $l.ha^{-1}$)	0%	0%	20%	5%	3%	5%	3%	5%	0	0%	0	0%
NovaFerm SIRIUS (5.0 $l.ha^{-1}$)	25%	0%	40%	10%	5%	3%	10%	5%	5%	0%	10%	5%
Hycolat (5.0 $l.ha^{-1}$)	0%	5%	5%	15%	15%	5%	15%	10%	0	0%	0	0%
control	20%	10%	40%	10%	20%	10%	20%	10%	10%	0%	20%	5%

3.2 The effect of applied products to limit the development of Drosophila suzukii *on the quality of grapes*

When using products to reduce the damage to berries by *Drosophila suzukii*, the extent to which the products used affect the quality of the grapes should also be addressed. The following quality parameters were assessed for each variety in 2023 and 2024: total soluble solids, pH, titratable acids and assimilable nitrogen.

pH. The Table 5 shows the specific differences between the variants on average 2023–2024 using the method of minimum significant difference. The most significant differences relative to the untreated control can be found in pH.

For the Traminer, the highest values for total soluble solids were for Surround (3%), Surround (5%), building kaolin (10%) and Hycolat. In case of pH, higher values were found in all the varieties compared to the untreated control. Traminer is a variety that quite regularly shows values higher than 3.50, which are less favourable for the release of aromatic compounds from the berries and promote the development of undesirable microorganisms. Extremely high pH values were found in NovaFerm Orion (2024: 3.99), Surround 5% (2024: 3.90) and Surround 3% (2024: 3.87). There were no conclusive differences in assimilable nitrogen content in relation to the untreated control, where the content was even highest in 2023. Stably higher contents in both years were evaluated for Surround (3%), Surround (5%) and Hycolat.

Table 3 *Quality parameters (total soluble soilds, pH, titratable acids and assimilable nitrogen) of Riesling*

Variant	Year	Total soluble soilds (°NM)	pH	Titratable acids ($g.l^{-1}$)	Assimilable nitrogen ($mg\cdot l^{-1}$)
Surround (3%)	2023	20.15±0.35	3.28±0.03	9.38±2.01	193.58±2.04
	2024	18.25±0.78	3.30±0.04	7.52±0.28	124.46±10.11
Surround (5%)	2023	18.90±0.57	3.21±0.01	7.68±0.81	143.74±3.06
	2024	17.40±0.14	3.22±0.01	7.88±0.81	115.05±3.06
Building kaolin (5%)	2023	20.80±0.42	3.23±0.01	7.71±0.21	173.36±46.99
	2024	19.95±0.21	3.37±0.00	7.99±0.94	162.08±30.54
Building kaolin (10%)	2023	20.05±1.91	3.23±0.05	8.58±1.43	151.69±28.60
	2024	16.90±0.42	3.25±0.04	7.77±0.50	108.53±30.60
NovaFerm ORION (5.0 $l.ha^{-1}$)	2023	18.15±0.92	3.20±0.03	7.91±0.42	140.85±7.15
	2024	16.60±1.12	3.26±0.04	8.04±0.08	156.31±8.34
NovaFerm SIRIUS (5.0 $l.ha^{-1}$)	2023	19.45±1.48	3.27±0.02	10.15±0.43	205.14±28.60
	2024	15.65±0.64	3.25±0.01	8.03±0.53	138.79±33.12
Hycolat (5.0 $l.ha^{-1}$)	2023	17.90±0.85	3.19±0.11	8.99±0.53	187.80±2.04
	2024	15.40±0,54	3.23±0.08	8.96±1.65	148.13±4.67
control	2023	19.70±0.14	3.11±0.06	9.38±0.60	157.50±3.54
	2024	18.05±1.06	3.19±0.04	7.57±0.66	79.59±24.48

Table 4 *Analysis of variance of quality parameters for the effect of variant, year and variant × year for Riesling*

Parameter	Variant	Year	Variant × year
Total soluble solids	0.0253	0.0003	0.7837
pH	0.0070	0.0154	0.3538
Titratable acids	0.3591	0.0322	0.3086
Assimilable nitrogen	0.0192	0.0001	0.1174

In terms of quality parameters, a significant effect of the variant on total soluble solids, pH and assimilable nitrogen content was found for Riesling. The highest total soluble solids were in the Surround (3%), building kaolin (5%) and building kaolin (10%) variants. In the case of pH, the lowest value was in the untreated control. Treatment with building kaolin and Surround statistically significantly increased pH and most significantly for building kaolin (5%) (2023: 3.23, 2024: 3.37). Treatments also affected assimilable nitrogen content, with the highest levels for Surround (3%), building kaolin (5%), NovaFerm Sirius and Hycolat. Surround (3%) and building kaolin (5%) had the most significant effect on grape quality in Riesling.

The influence of variant and year on quality parameters was demonstrated for Riesling. No correlation was found between the combination of variant × year (Table 4). The most significant effect of variant was found for

Table 5 *Statistically significant differences in quality parameters of Riesling by the method of minimum significant difference. Letter indicated significant differences at significance levels of P>0.95.*

Variant	Total soluble solids (°NM)	pH	Titratable acids ($g.l^{-1}$)	Assimilable nitrogen ($mg.l^{-1}$)
Surround (3%)	bc	cd	n.s.	ab
Surround (5%)	abc	abc	n.s.	ab
Building kaolin (5%)	c	d	n.s.	ab
Building kaolin (10%)	abc	bcd	n.s.	ab
NovaFerm ORION (5.0 $l.ha^{-1}$)	ab	bcd	n.s.	ab
NovaFerm SIRIUS (5.0 $l.ha^{-1}$)	ab	bcd	n.s.	b
Hycolat (5.0 $l.ha^{-1}$)	a	ab	n.s.	ab
Control	abc	a	n.s.	a

Table 6 *Quality parameters (total soluble solids, pH, titratable acids and assimilable nitrogen) of Traminer*

Variant	Year	Total soluble solids (°NM)	pH	Titratable acids ($g.l^{-1}$)	Assimilable nitrogen ($mg.l^{-1}$)
Surround (3%)	2023	24.70±0.99	3.59±0.11	5.68±0.17	143.63±39.41
	2024	22.65±0.07	3.87±0.12	4.71±0.45	247.52±46.81
Surround (5%)	2023	24.90±0.99	3.66±0.08	4.96±0.00	137.91±17.18
	2024	22.95±0.64	3.90±0.04	4.46±0.23	215.14±41.72
Building kaolin (5%)	2023	25.10±0.42	3.78±0.03	5.11±0.45	133.71±15.18
	2024	21.60±0.57	3.42±0.10	7.70±2.00	186.36±17.30
Building kaolin (10%)	2023	25.55±1.34	3.50±0.17	8.26±1.73	144.34±22.23
	2024	22.20±1.27	3.67±0.24	7.08±2.95	216.58±45.79
NovaFerm ORION (5.0 $l.ha^{-1}$)	2023	22.15±1.06	3.61±0.08	5.75±1.50	174.35±64.68
	2024	23.90±0.14	3.99±0.08	4.16±0.34	238.17±15.26
NovaFerm SIRIUS (5.0 $l.ha^{-1}$)	2023	23.90±1.41	3.58±0.13	5.10±0.01	125.76±6.06
	2024	22.55±0.07	3.84±0.25	4.66±0.73	243.20±52.91
Hycolat (5.0 $l.ha^{-1}$)	2023	25.50±1.13	3.54±0.20	8.44±1.33	199.36±56.32
	2024	22.90±0.42	3.73±0.11	5.03±0.41	212.26±27.47
Control	2023	23.70±1.13	3.47±0.06	6.37±0.43	227.23±34.36
	2024	23.80±0.57	3.66±0.16	5.33±0.62	164.77±9.16

In Traminer, there was no conclusive effect of the variant on grape quality parameters. In the case of total soluble solids content and pH, the effect of year was demonstrated.

Table 7 *Analysis of variance of quality parameters for the effect of variant, year and variant x year for Traminer*

Parameter	Variant	Year	Variant × year
Total soluble solids	0.5975	0.0001	0.0097
pH	0.1754	0.0033	0.0530
Titratable acids	0.2470	0.2017	0.5211
Assimilable nitrogen	0.8636	0.0044	0.2295

The highest total soluble solids content in Palava in both years was found in the untreated control. In the kaolin-based variants: Surround (5%), building kaolin (5% and 10%), total soluble solids were stable in the comparison between the two vintages. It was also higher in 2023 than the other products that can be classified as biostimulants. The pH was lower in all kaolin-based variants than in the untreated control. The lowest pH values were for the building kaolin (5%). The highest pH values were found for the biostimulant Hycolat. There is a large variability in titratable acid content between the variants and no clear effect of variant can be demonstrated. In assimilable nitrogen content, the highest values were found in the variants Surround (3%), building kaolin (5% and 10%).

Table 8 *Quality parameters (total soluble solids, pH, titratable acids and assimilable nitrogen) of Palava*

Variant	Year	Total soluble solids (°NM)	pH	Titratable acids (g.l^{-1})	Assimilable nitrogen (mg.l^{-1})
Surround (3%)	2023	22.70±0.99	3.32±0.04	5.47±0.26	83.76±4.02
	2024	23.65±1.91	3.29±0.03	7.88±0.50	118.72±9.16
Surround (5%)	2023	23.30±0.14	3.32±0.01	5.12±0.52	69.56±22.08
	2024	24.40±1.41	3.33±0.04	6.66±0.29	84.19±17.30
Building kaolin (5%)	2023	23.40±1.27	3.27±0.03	5.73±0.09	90.86±12.05
	2024	23.50±1.98	3.28±0.08	8.01±0.49	125.92±33.58
Building kaolin (10%)	2023	23.25±0.49	3.30±0.04	5.18±0.15	86.60±2.01
	2024	23.65±0.35	3.43±0.06	6.91±0.23	153.26±5.09
NovaFerm ORION (5.0 l.ha^{-1})	2023	22.65±0.21	3.31±0.06	4.82±0.34	80.21±5.02
	2024	23.05±0.07	3.26±0.01	7.05±0.05	59.84±7.29
NovaFerm SIRIUS (5.0 l.ha^{-1})	2023	22.75±0.21	3.35±0.00	5.06±0.05	120.67±56.22
	2024	25.25±0.21	3.22±0.01	7.27±0.07	61.28±5.26
Hycolat (5.0 l.ha^{-1})	2023	23.05±0.35	3.39±0.05	5.09±0.46	88.02±2.01
	2024	25.65±0.07	3.43±0.03	6.31±0.11	95.27±2.45
Control	2023	23.45±0.78	3.27±0.04	5.59±0.47	91.57±5.02
	2024	25.35±0.21	3.39±0.01	6.72±0.04	79.35±2.33

The effect of the variant on pH, titratable acidity and assimilable nitrogen content was demonstrated for the variety Palava. However, in the case of pH, there was no significant difference between the experimental variants and the untreated control, and the same was true for assimilable nitrogen.

Table 9 *Analysis of variance of quality parameters for the effect of variant, year and variant × year for Palava*

Parameter	Variant	Year	Variant × year
Total soluble solids	0.2511	0.0015	0.3904
pH	0.0032	0.4112	0.0052
Titratable acids	0.0009	0.0000	0.0522
Assimilable nitrogen	0.0279	0.2222	0.0064

Table 10 *Statistically significant differences in quality parameters of Palava by the method of minimum significant difference. Letter indicated significant differences at significance levels of P>0.95.*

Variant	Total soluble solids (°NM)	pH	Titratable acids (g.l^{-1})	Assimilable nitrogen (mg.l^{-1})
Surround (3%)	n.s.	ab	c	ab
Surround (5%)	n.s.	ab	b	a
Building kaolin (5%)	n.s.	a	c	ab
Building kaolin (10%)	n.s.	bc	b	a
NovaFerm ORION (5.0 l.ha^{-1})	n.s.	ab	b	a
NovaFerm SIRIUS (5.0 l.ha^{-1})	n.s.	ab	bc	ab
Hycolat (5.0 l.ha^{-1})	n.s.	c	a	ab
Control	n.s.	abc	bc	ab

n.s. – not significant

In terms of the influence of the applied preparations on the quality parameters, differences between varieties are shown. In view of the number of applications, three applications were made in each year, the first being made after the end of flowering, at the berry size stage (BBCH 73). The application was essentially controlled by washing the kaolin layer off the berries. Once the kaolin layer was washed off, the next application was made. Three applications proved sufficient for both 2023 and 2024. In an overall assessment of the effect of the application of kaolin-based products across varieties, it can be concluded that stable total soluble solids content values were achieved with the Surround and building kaolin applications, indicating suitability for wine production. Very good values of total soluble solids content were also shown for Hycolat in Traminer and Palava.

Other experiments with kaolin-based preparations have also shown a positive effect on increasing sugar content. Shelie and Gleen (2008) found an increase in sugar content in the variety Viognier, followed by Cao et al. (2022) and Wang et al. (2020). Shellie and Glenn (2008) and Shellie and King (2013) reported a variety-dependent effect on sugar accumulation with kaolin treatment. However, in other experiments, the effect of kaolin on sugar accumulation was very inconsistent, depending on the variety and the date of application (Luzio et al., 2021; Kok and Bal, 2018; Lobos et al., 2015). On the contrary, Bernardo et al. (2022) found that kaolin treatment caused lower sugar content than the control. The application of the products affected the pH value, with an increase in Riesling and Traminer compared to the untreated control, while Palava had a lower pH. The high pH value is less favourable from the point of view of grape processing. Higher pH was common especially for Surround and building kaolin. Different experiences with kaolin application can also be found in relation to the effect on pH. For Sauvignon blanc, there were non-significant differences in pH with kaolin treatment (Cataldo et al., 2022). Lobos et al. (2015) found higher pH and lower titratable acids in Cabernet Sauvignon, but no statistical differences were found. Sangiorgio (2024) found no effect of kaolin treatment on pH. Frioni et al. (2019), Brillante et al. (2016) and Lobos et al. (2015) reported that there was no effect on pH in blue varieties.

In many cases, the application of the preparations had a positive effect on increasing the assimilable nitrogen content. Higher assimilable nitrogen contents were shown for kaolin-based preparations (Surround and building kaolin). The biostimulants NovaFerm Orion, NovaFerm Sirius and Hycolat were also effective in increasing assimilable nitrogen content. From the point of view of the complex effect on the quality parameters of the grapes, the greatest risk can be regarded as the increase in pH during treatment with kaolin-based products. The risk of pH increase was observed in Riesling and Traminer. pH is of major importance in wine production and is one of the most considered values for supporting harvest and winemaking decisions (Jackson, 2008) and has been shown to have a direct impact on wine taste, much more important than total acidity (Ribéreau-Gayon et al., 2012). The pH value influences the buffering power of berry juice and wine, which is an effect of major importance in winemaking (Plantevin et al., 2024). Agrotechnical influence on pH to make it lower and more stable is important in the context of climate change (van Leeuwen et al., 2024). In relation to the increase in pH, Riesling and Traminer showed a statistically significant effect of year and, in the case of Traminer, a variant × year interaction. pH may therefore be influenced by the climatic conditions of the year in question, with 2023 and 2024 being characterised by periods of high day and night temperatures during the ripening of the grapes. This weather trend resulted in a more significant decrease in acidity. In particular, malic acid showed a significant dependence on temperature but was not monitored in this research.

4 Conclusion

Reduction of berry damage by *Drosophila suzukii* was achieved not only with kaolin-based products (Surround), but also with the microbial biostimulant NovaFerm Orion and the biostimulant Hycolat. In terms of the impact on the quality parameters of the grapes, the negative effect of the products applied was in relation to pH. In Riesling and Traminer, there was an increase in pH in relation to the untreated control, which can have a negative effect on the quality of the wine. However, this effect may also be related to the weather during the growing seasons.

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