MedCrave Step into the World of Research
Horticulture International Journal

Research Article
Open Access CrossMark

Delaying bud break in grapevines with various substances as a prophylaxis against spring frost

Abstract

Different substances can be used to delay the development of buds or shoots in grapevines. Such a delay often requires early application, sometimes even during the bud dormancy period. This slows shoot development and reducing susceptibility to late frost events. Once green parts of the shoot become visible, frost resistance significantly decreases. Consequently, a developmental delay increases frost stability for a certain period. Retarded bud break has been primarily standardized using oil spraying. However, variations remain, especially concerning the timing of application. Other substances, particularly phytohormones, have not shown consistent and thus useful effects, although under certain conditions, developmental delay was noticeable with Ethephon application. Standardization in these procedures appears challenging and requires further development. Despite the delayed bud break of few days, frost damage could not be avoided during the spring frost in 2024. It seems essential to prolong the period of retardation.

Keywords: phytohormones, BBCH stages, application

Volume 9 Issue 1 - 2025

Ferdinand REGNER,[1] Erich Ferschel,[1] Christoph Nastl,[2] Ida Brandstätter[1]

[1]Institute of viticulture, Höhere Bundeslehranstalt und Bundesamt für Wein- und Obstbau Klosterneuburg, Austria
[2]Institute of viticulture, Estate Bründlmayer Langenlois, Austria

Correspondence: Ferdinand REGNER, Höhere Bundeslehranstalt und Bundesamt für Wein- und Obstbau Klosterneuburg, Wiener Straße 74 A-3400 Klosterneuburg, Österreich, Austria

Received: January 8, 2025 | **Published:** February 4, 2025

Introduction

Late frost and its impact on Austrian viticulture

Late frost and its impact on grapevines have been a recurring issue in Austrian viticulture.[1,2] Due to global warming, the bud break of grapevines is occurring earlier in many years, increasing the likelihood of late frost damage.[3] A mild winter and early bud break due to changed temperatures increases the risk of damage from late frost events in spring.[4] In Austria, the last major late frost damages of national dimension in viticulture were recorded in 2016 and 2017.[2] In 2024, frost failures occurred again, especially in the Langenlois area but actually in all wine-growing regions in frost-prone areas. However, frost can be technically prevented nowadays, and there are many methods to prevent or at least mitigate late frost damage.[4] The revenue from lower-quality locations does not justify extensive technical measures against frost.[5] The simplest precaution is a good match of variety, rootstock, and location. However, this potential for frost prevention is no longer sufficient for strong climatic changes. Within the species *Vitis vinifera*, the bud break period of various grapevine varieties can extend up to five weeks, depending on the year, climate and location.[6] The bud break time of grapevine varieties will typically occur in Central Europe from the second half of March to the end of April. Basically bud break is controlled by soil temperature.[7]

Frost protection in viticulture through pruning

A good way to achieve frost protection in viticulture can be through delay by pruning.[8,9] Frost sensitivity increases with the development of the bud and shoot length. While closed buds are still very robust and strong frost does not cause damage, stability against frost decreases significantly with bud break and appearance of green parts.[10] As long as the bud is still covered with wool, the protection extends up to about -4°C.[4] Once leaf green appears, the threshold falls to about -2°C, and a fully developed shoot with spread leaves can tolerate a maximum of -1°C for an extended period.[6] Consequently, delaying bud break can reduce or even avoid damage to grapevines.[11] This mainly depends on the stage of vegetative development at the time of the frost event and how low the cold temperature drops. Late pruning brings some delay, but in some years, it disappears after a few days.[12,13] A disadvantage is that late pruning, especially if the vine is already in sap, carries an increased risk of Esca infections.[14] In addition to the timing of pruning, an increased number of developing shoots can also delay the development of the vine.[15] On the one hand, if there is only a partial damage from late frost, sufficient shoots can still be available. On the other hand, the vigor of the shoots is lower, development is slightly delayed, and frost risk is marginally reduced.[16]

Technical possibilities for frost protection

Many technical possibilities for frost protection have been developed. Options range from air mixing with wind machines to heating with resistance cables and frost irrigation with micro-sprinklers.[4] All these technical solutions are associated with high investments. However, a few methods can also be managed with the existing infrastructure of a vineyard. Some methods rely on achieving frost protection immediately before the event.[17] Substances or microorganisms (https://cropaid.com) are applied to achieve slight improvement in frost stability. The efficiency remains rather low, but because the application is simple and well known procedure these methods are popular among practitioners.

Substances for delaying bud break

Delayed bud break measures through the application of active substances are also among the inexpensive frost prevention methods.[18] Substances are applied to the vine to delay shoot development.[19] One of these bud break-retarding measures is the use of plant oils.[20] Phytohormones like abscisic acid or gibberellic acid can also develop bud break-delaying effects.[21] Ethephon delays bud break under certain conditions.[22] A shoot with green parts as reached in BBCH stage 7 is more stable than a shoot already have spread one leaf at stage BBCH 11. (Photograph 1 & 2)

Abscisic Acid (ABA): The influence of ABA on aging processes and dormancy phases is documented. ABA also plays an important role in drought stress. However, the exact functional processes of ABA during dormancy are still unclear. Studies showed that the application of exogenous ABA during the growth phase of the vine can increase winter frost resistance and delay bud break during the bud dormancy phase.[23]

Photograph 1 Shoot at stage BBCH 7 with first nuances of a green shoot tip.

Photograph 2 Shoot at stage BBCH 11 with one spread leaf.

Gibberellins (GA): Gibb 3 is approved in viticulture for thinning during the outgoing bloom. Bioactive gibberellin plays a significant role in many developmental and growth processes in the plant. Gibberellin controls seed germination, elongation growth, cell growth, and the enlargement and multiplication of cells. The relationship between GA and ABA is considered antagonistic.[24] The activity of GA-coding genes in the buds decreases during dormancy. With bud break, gibberellin content increases, and GA-relevant genes are more strongly expressed again.[25] The application of exogenous GA to one-year-old buds during or at the end of winter dormancy can have both promoting and inhibiting effects on bud break. The timing of the application is crucial for how GA application works. If GA is applied before the resumption of meristem growth, bud break is delayed. Application after bud break stimulates growth and development.[24]

Ethephon (Cerone®): Cerone® from Bayer Austria GmbH contains the active ingredient Ethephon. It acts as a growth regulator and is approved for various applications in different crops. Among other uses, it is employed for straw strengthening in cereals, thinning blossoms in apples, and accelerating ripening in tomatoes. There is currently no approval for use in viticulture. Ethephon causes ethylene to be released in the plant, which promotes the formation of abscisic acid, suppressing all growth processes. It is successfully used in stone fruits to delay bloom and thus avoid frost damage.[26] A 2018 study by Labay showed that bud break delay can occur in grapevines with the use of Ethephon.

Trinexapac-ethyl (Alar®): Alar® is a registered trademark offered by Kwizda, containing the active ingredient Trinexapac-ethyl, which shows growth-regulating effects in many applications. This daminozide reduces internode length in many ornamental plants, resulting in compact and robust plants. The leaves become greener, and the plants are more resistant to drought. In some species, Alar® 85 SG can delay bloom under certain application conditions. There is no approval for use in grapevines.

Oil application: The application of oil is among the most well-established methods for delaying bud burst. Micula (Biohelp, AT) and Promanal HP (Biohelp, AT) were originally used to combat overwintering pests through bud burst spraying. Observations of growth and bloom delays led to experiments on grapevines in Virginia (USA).[27] Oils from fossil sources tend to have phytotoxic effects on grapevines. Plant-based oils, such as soybean oil, are more compatible. The mechanism by which oil delays bud burst is based on a reduction in gas exchange, particularly in the buds. Oils clog the vessels and coat the cell surface with a film, allowing only little oxygen to penetrate, which increases the endogenous concentration of carbon dioxide. Reduced gas exchange retards the development of the vine.[27] Two applications of 10% (v/v) rapeseed oil resulted in an average bud burst delay of one week in the Grüner Veltliner and Zweigelt varieties.[28] Multiple applications of soybean oil at concentrations of 8 or 10% (v/v) also caused a significant delay in bud burst compared to the control.[29,30] Centinari et al.,[17] reported that the duration of the delay with soybean oil was variety-dependent, and an application concentration of 10% (v/v) sometimes also showed phytotoxic effects in the Rheinriesling and Blaufränkisch varieties. Wang and Dami[31] also confirmed a varietal influence with soybean oil and observed a discontinuity in the effect.

Syneco AF5 (Syneco, Milan-IT) is approved as a foliar fertilizer. The ingredients potassium and monopropylene glycol are primarily responsible for stabilizing the plant against frost. In addition to frost protection, it is also credited with improving performance due to fertilization. Its effect was tested on apple crops by the University of Bologna. Genol Antifreeze, obtained from the Raiffeisen warehouse, is used as antifreeze for piping systems and plant protection equipment. Its active ingredient is polyethylene glycol. It is not approved for use in viticulture, and there is no literature on its use as a bud burst-delaying substance. Regalis® Plus (BASF, DE) The active ingredient prohexadione-calcium is approved for loosening cluster structure in grapes. In fruit cultivation, Regalis is used against fire blight. Its mechanism of action is to disrupt the plant's phytohormone balance, thereby reducing growth or causing the grape clusters to shatter.[32] Whitewash (Substral-Naturen, Baumanstrich) based on lime was obtained from GBC Vienna. The whitewash was applied with a painter's brush. This method is mainly used in fruit cultivation to protect the trunks from frost cracking.[33] In the presented work, treatment methods were sought that would bring about a significant delay in bud burst and thus be suitable for late frost prophylaxis. The sensitivity against frost is increasing with shoot size. In the event of bud burst already occurring, the application of an active substance should reduce frost damage. The application of oil should become optimized and further substances are tested for their potential to retard shoot development.

Material and methods

For the application trials, a plantation of the HBLAuBA Klosterneuburg at Bisamberg in Langenzersdorf (NW of Vienna) was selected. Three varieties were used: Grüner Veltliner (GV), Weißburgunder (WB), and Gelber Muskateller (MU). At the beginning of the trials, the plants were as follows: WB 7 years old, GV 13 years old, and MU 15 years old. The soil of the trial area is

Citation: REGNER F, Ferschel E, Nastl C, et al. Delaying bud break in grapevines with various substances as a prophylaxis against spring frost. *Horticult Int J.* 2025;9(1):17‒23. DOI: 10.15406/hij.2025.09.00318

a brown soil weathered from flysch sandstone conglomerates with medium depth and adequate nutrient supply. The site is a south-facing slope with an incline of approximately 25%. The average annual temperature during the trial period was 11.4°C, and 16.5°C during the growing season, measured by an Adcon weather station (Adcon Telemetry- Klosterneuburg). The heat sum according to Winkler during the growing period in recent years averaged 1406°C/h. During the trial years, no late frost occurred at Bisamberg when there were green shoots on the vines (Table 1). Plant protection was carried out according to integrated production guidelines, with 8 applications, including the use of a botryticide. The soil was usually covered with vegetation but was plowed at least twice to allow new seeding of a green coverage. The cultivation method was a local high culture training system with approximately 90 cm cordon height and cane pruning. The spacing was generously arranged at 3x1.1m. The trials were mostly conducted over three years (2020-2022). At least two sets of 10 vines from each variant were treated and compared with an untreated control. Treatment involved twice spraying or coating to the tied canes. The coated variants were mixed with a thickening polymer (gum arabicum) to ensure a paste-like consistency that adhered well to the cane by brushing.

Table 1 Climate data for Langenzersdorf from March to May 2020-2022

	Climate 2020			**Climate 2021**			**Climate 2022**		
Criteria	**March**	**April**	**May**	**March**	**April**	**May**	**March**	**April**	**May**
Average T.	7,2	12,8	13,9	5,7	8,4	13	6,2	9,1	17,3
Max. T	20,6	24,3	26,5	24	24,4	28,8	20,8	22,2	31,4
Min. T	-4	-3,9	3,6	-4,6	-0,7	4,3	-4,7	-0,5	7,3
Precipitation	19,2	3,2	73	12,4	17,8	74,6	13,4	25,6	46

For the oil application, another site in a frost-prone area at Kamp municipality, Zöbing, Riede Steinwand, was selected. This site has historically experienced frost damage. The plantation covers more than two hectares, and the oil (Schädlingsfrei) was applied in 4 variants using a standard vineyard sprayer (Table 2). The first application was set to occur at BBCH 1, with the second application conducted 10 days later. A wetting agent was necessary to ensure solubility in water. The size of the plantation allowed for a 4-fold repetition in a row format. Each variant involved evaluating 4 sets of 10 vines. Wine was processed from vines treated with oil under same conditions to illuminate influence of quality by retarding development.

Table 2 Trial variants for oil application in Zöbing in 2020 labeled 1 to 4, and in 2021 and 2022 labeled A to D, control without any application K

K	**Control 2020**	**K**	**Control 2021+22**
1	2x 10% oil	A	2x 10% oil
2	1x10%, 1x15% oil	B	1x10%, 1x15% oil
3	1x15%, 1x15% oil	C	1x15%, 1x10% oil
4	1x 15%, 1x 10% oil	D	2x 15% oil

Abscisic Acid (ABA): was obtained from two manufacturers (Protone - Valent Biosciences, USA, and IRIS-Biotech, Germany). The product from the USA was already in solution, while the product from IRIS was obtained as a powder. Gibberellin (GA): Gibb 3 was sourced from Globachem (Globachem, Netherlands).The product Cerone from Bayer Austria GmbH contains the active ingredient Ethephon. The product Alar is a registered trademark: Alar® 85 SG and was offered by Kwizda. The active ingredient is Trinexapac-ethyl, which exhibits growth-regulating effects in many applications. The application of oil (Micula, Promanal) is one of the best-established methods for delaying bud burst. Micula (Biohelp, AT) and Promanal HP (Biohelp, AT). Syneco AF5 (Syneco, Milan-IT) is approved as a foliar fertilizer. Genol Antifreeze was obtained from Raiffeisen Lagerhaus and is used as antifreeze for piping systems and plant protection equipment. It contains the active ingredient polyethylene glycol. Regalis Plus (BASF, DE) contains the active ingredient prohexadione-calcium and is approved for loosening cluster structure in grapes. Whitewash (Substral-Naturen, Baumanstrich) based on lime was obtained from GBC Vienna. The whitewash was applied with a painter's brush.

Applications in 2020

The following substances (Table 3) were applied to test their effectiveness in delaying bud burst: abscisic acid ABA (two different products and two different concentrations) and gibberellin GA3 with only a single concentration. Alar, and Cerone were applied once as a solution with a hand sprayer and once as a paste using a brush with two concentrations. As a reference for comparison, Promanal oil was applied as a 10% solution. All applications were performed twice within a distance of ten days.

Table 3 Application sheme in 2020 (H means high concentration in contrast to L low concentration)

Substance	**Conc.**	**Appl.**	**Content**	**Product**	**Application**	
ABA 1	L	2x	100mg/l	Protone	spray	
ABA 2	H	2x	500 mg/l	Protone	spray	
ABA 3	L	2x	100mg/l	Iris	brush	
ABA 4	H	2x	500 mg/l	Iris	brush	
GA 3		2x	500 mg/l	Gibb3	brush	
Ethephone	L	2x	0,05%	Cerone	spray	brush
Ethephone	H	2x	0,50%	Cerone	spray	brush
Daminozide	L	2x	0,05%	Alar	spray	brush
Daminozide	H	2x	0,50%	Alar	spray	brush

Applications in 2021

The following substances (Table 4) were applied twice to test their effectiveness in delaying bud burst: Gibberellin GA3, Promanal oil, Alar, Cerone, and Regalis. Each substance was applied once as a solution with a hand sprayer and some of them (GA3, Cerone and Alar) were coated also as a paste. Additionally, two whitewash variants were tested. The trunk was painted with a white plant-compatible lime paint, and in the second variant, a white reflective foil was also applied. The idea was to reflect infrared radiation and keep the plant cooler means to slow down the development of shoots.

2022

The following substances (Table 5) were applied twice to test their effectiveness in delaying bud burst: Gibberellin GA3, Micula oil, Syneco AF5, Alar, Cerone, and Genol antifreeze. Each substance was applied once as a solution with a hand sprayer and Cerone and Alar were also applied as a paste. Additionally, two whitewash variants were tested. The trunk was painted with a white plant-compatible lime paint, and in the second variant, a white reflective film was also applied. As a new approach, cold water treatment was included, where the vines were watered three times with 10 liters of cold water (approx. 6°C). It is known that a soil saturated with water brakes the development and shoots need longer time to reach a frost sensitive stage.

Table 4 Application sheme in 2021 (H means high concentration in contrast to L low concentration) White T+F means white trunk and white foil

Substance	Conc.	Appl.	Content	Product	Application	
White Trunk		1x		chalky	brush	
White T + F.		1x		chalky	brush	
GA3	H	2x	1g/l	Gibb3	spray	
GA3	H	2x	1g/l	Gibb3		brush
Oil	H	2x	15%	Promanal	spray	
Ethephone	H	2x	1%	Cerone	spray	brush
Daminozide	H	2x	1%	Alar	spray	brush
Prohexadion Ca	H	2x		Regalis	spray	

Table 5 Application sheme in 2022 (H means high concentration in contrast to L low concentration) White T+F means white trunk and white foil

Substance	Conc.	Appl.	Content	Product	Application	
White Trunk		1x	pure	chalky	brush	
White T + F.		1x	pure	chalky	brush	
GA3	H	2x	3g/l	Gibb3	brush	
PEG	H	2x	10%	Syneco AF5	spray	
oil	H	2x	15%	Micula	spray	
Ethephone	H	2x	3%	Cerone	spray	brush
Daminozide	H	2x	2%	Alar	spray	brush
Glykol	H	2x	10%	Genol	spray	
Cold water		3x	10 l	water	irrigation	

At the Zöbing site, only oil applications were used to delay bud burst. Based on preliminary trials, only concentrations of 10% and 15% were used. We observed that oil longer sticks to the canes in the case of application with 15% oil concentration. Despite the risk to provoke phytotoxic reaction we involved these sprays within our strategy. It was also more tricky to get a perfect solution at this oil concentration level.

Assessment

To evaluate the effectiveness, all buds on a cane or all developing shoots were assessed, and their developmental stage (BBCH) was determined.[34] The data were collected from weeks 11 to 19 (and sometimes week 20). Control vines were always included among the treated ones to minimize the influence of location. The average value of all shoots on a vine was represented as the BBCH stage. Statistical analysis was performed using SPSS (IBM, Statistics 26). The data were checked for normal distribution using the Kolmogorov-Smirnov test and analyzed using ANOVA. Means were assessed using the LSD test ($P < 0.05$) or with Kruskal Wallis test. The graphical representation of the data was created using SPSS and Microsoft Excel (Microsoft Austria GmbH, Vienna, Austria).

Results

Vintage 2020

The applications of the various substances did not show any significant difference in terms of developmental delay in 2020. Only the oil 1 variant was able to delay budding. Neither ABA and GA3 nor Cerone and Alar showed any lag effect**.** The retard in development already was diminished at the week 20. The oil 2 application showed no effect (Table 6).

Table 6 Average value of the BBCH stages. More than 7 means green parts available, 9 means shoot tip visible, 11 means one leaf is fully developed, 15 shoot has 5 spread leaves. (Concentrations see material and methods)

Method	Week 12	Week 13	Week 15	Week 18	Week 20
Control	1,9	2,6	3,5	10,2	13,4
Oil 1	**1,8**	**2,2**	**2,7**	**8,6**	**12,9**
ABA 1	2,2	2,3	3,3	10,4	13,5
ABA 2	2,5	2,8	3,6	10,8	14,2
ABA 3	1,9	2,1	2,9	10,5	13,8
ABA 4	1,9	2,1	2,7	10,8	14,1
Control	2,1	2,6	2,9	10,3	14,1
Oil 2	2,2	2,5	3,5	11,3	14,8
ABA 1	2,7	2,8	3,4	10,8	15,0
ABA 2	2,4	3,0	3,5	12,2	15,3
ABA 3	2,4	2,9	3,9	11,8	14,7
ABA 4	2,1	2,4	3,2	11,0	14,0
GA 3	2,0	2,5	3,0	10,6	13,6
Control	2,0	2,3	2,9	10,7	13,9

Vintage 2021

The applications of the different substances showed a significant difference in 2021 in terms of developmental delay (Table 7). The oil variant was able to significantly delay budding. This time, the difference was in the concentration, which was increased to 15% and had already produced better results at the Zöbing site. Neither GA3, Regalis, Alar nor the white paint (including foil) showed any delay effect. Nevertheless the application of Etephon (Cerone) by means of brushing resulted in a significant delay (Figure 1) between weeks 15 and 18, but the difference weakened already in week 19.

Table 7 Average value of the BBCH stages. More than 7 means green parts available, 9 means shoot tip visible, 11 means one leaf is fully developed, 15 means shoot has 5 spread leaves

Method	Week 12	Week 13	Week 15	Week 18	Week 19
control	1,1	1,19	4,43	9,53	13,4
Oil	**1**	**1,1**	**1,1**	**2,6**	**5,1**
Cerone H br	**1**	**1**	**1,8**	**7,1**	**12,2**
Alar	1	1,1	3	9,2	13,7
Regalis	1	1,2	2,7	8,5	13,3
White trunk	0,9	1	2,9	9,8	13,8
White T + F.	1,2	1,2	2,7	7,7	12,8
Ga 3	1	1,2	4,1	9,7	13,6
Control	0,9	1,1	2,9	9,4	13,4

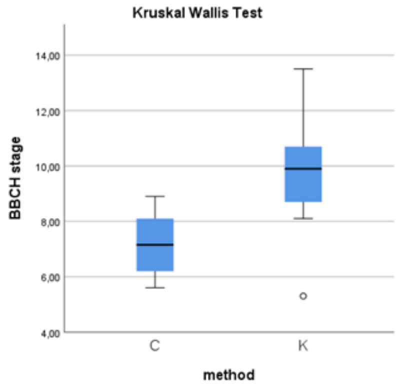

Figure 1 BBCH developmental stage of Cerone (C) and control (K) shows significant differences.

Vintage 2022

The applications of the various substances did not show a significant difference in terms of developmental delay in 2022 (Table 8). Only the oil variant (here Micula) was able to delay budding. Neither ABA and GA3 nor Cerone and Alar showed any lag effect. The white trunk coloration variant was covered with a white foil in the understock area. It could be observed that the variability within one method was much higher in this season as the years before.

Table 8 Average value of the BBCH stages. More than 7 means green parts available, 9 means shoot tip visible, 11 means one leaf is fully developed, 15 means shoot has 5 spread leaves

Method	Week 12	Week 13	Week 15	Week 18	Week 19	Week 20
Control	1,3	2,2	3,9	9,9	14,6	17,5
Oil	**1,1**	**2,1**	**3,4**	**8,3**	**12,9**	**15,5**
Cerone H br	1	2,5	4,4	12,1	15	16,7
Alar	0,8	1,7	3,2	11,6	14,4	16,3
Syneco AF5	0,8	1,8	3,5	10,9	13,9	16
White trunk	0,9	1,8	4,1	11,7	14,2	15,6
White T + F.	0,9	2,0	4,0	12,5	14,8	18,4
Ga 3	1,4	2	3,2	9,4	14,1	16,6
Control	0,7	1,2	3,0	11,4	14,0	15,2
Water	0,8	2,1	4,3	10,3	15,4	17,2

Trials in Zöbing

Vintage 2020

Only two of the oil applications showed a significant difference in development compared to the control (Figure 2). Variants 2 (first 10% and later 15%) and 3 (both times 15%) significantly delayed the development of shoots. While the untreated control reached BBCH stage 13 variants 2 and 3 still were at stage 11. Therefore the risk of damages by spring frost is diminished.

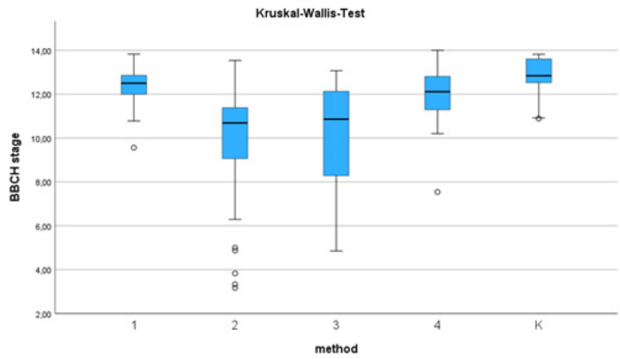

Figure 2 BBCH developmental stage vintage 2020 of grapevine shoots control (K) and variants 1, 2, 3 and 4 (see material and methods).

Vintage 2021

Three of the oil applications showed a significant difference in development compared to the control (Figure 3). The variants B (10% and 15%), C (first 15% and later 10%) and D (both times 15%) significantly delayed the development of shoots (Figure 4). This evaluation reflects the developmental stages at an earlier time point. The untreated control reached BBCH 3,1 while variant A (BBCH 2,9) could not be differentiated in a clear manner, variants B and C (BBCH 2,7) and D (BBCH 2,6) showed significant lower values.

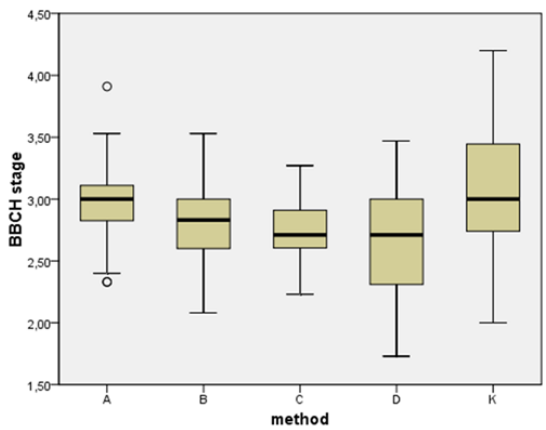

Figure 3 BBCH developmental stage vintage 2021 of grapevine shoots control (K) and variants A, B, C and D (see material and methods)

Vintage 2022

All oil applications showed a significant difference in development compared to control. The variants A (10% and 10%), B (10% and 15%), C (first 15% and later 10%) and D (both times 15%) significantly delayed the development of shoots (data not shown).

Citation: REGNER F, Ferschel E, Nastl C, et al. Delaying bud break in grapevines with various substances as a prophylaxis against spring frost. *Horticult Int J.* 2025;9(1):17‒23. DOI: 10.15406/hij.2025.09.00318

In summary, it can be stated that the continuity of the developmental delay was significantly more pronounced with 15% than with a 10% oil treatment. Factors that have an influence here are both the weather conditions and the timing of application. Heavy rainfall can partially remove the oil film and consequently reduce the effect. Overall, the development delay due to oil application is a measure to be taken early, the necessity of which is only confirmed much later, or not.

Vintage 2024

Oil application was done as a routine work with 10% at the BBCH stage 1 at beginning of March. Hence to the higher temperatures end of April vines reached BBCH 13- 15. When early morning temperatures of 22. and 23. April was fallen to -4°c and lower most shoots were damaged by frost.

Discussion

The test results can be used to improve oil applications for practical use. It is also possible to use Ethephon to stimulate delays in development. As can be seen from the frost damage in 2024, there is still a need to optimize applications in practical viticulture. In practice, oil application has the advantage that the products are known, approved and easy to use. All other substances would first have to be registered and approved. Although the small delay in maturity observed in some years could not be distinguished sensorially within the wine. Retard of development could be a way to mitigate the influence of global warming on maturity. In the different vintages and applications, no phytotoxic effects could be detected with oil application, although both Herrera et al.[28] and Persico et al.[30] reported problems with leaf symptoms. In addition to the sensitivity of the variety, the weather and the soil are also likely to have a significant influence. In any case, variability is repeatedly discussed.[31] It seems that an accelerated development due to higher temperatures and more intensive rainfall weaken the advantages of this method.

Although the concentration of the oils was reduced, Zheng et al.[24] were able to achieve a prolongation of the delay. We have actually observed the opposite effect, that the increase from 10% to 15% has resulted in a greater delay. One possible reason for the different results could be the lack of or low rainfall. The oil film is washed away by rainfall and therefore higher concentrations are not necessary in dry regions. Diluted oil suspensions penetrate the tissue more easily and can therefore increase the effect. Variety dependence was diagnosed by Wang et Dami,[35] although they had carried out their experiments with hybrid varieties. In our experiments, the difference in varieties was of secondary importance and showed no significant deviations in the comparison of varieties. One explanation for this would be the general short transition from hibernation to budding under the conditions of a continental climate. The use of Ethephon in the form of the preparation Cerone showed a potential that should be clarified in further trials. The effect was significantly more favorable in the coated form, which would indicate a longer exposure time. Iwasaki[35] suggested smaller amounts for a greater delay, while Labay[22] advised higher concentrations. In any case, Ethephon can also be used to achieve a developmental delay in this regions with established varieties. One option could be to apply phytohormones late in the season that they will be stored in the wood in higher concentration as it is possible to reach with spraying early in spring.

However, in 2024 at the Zöbing location despite a one week retard by oil application frost damage could not be avoided. As shoot development already reached BBCH 13 (3 open and developed leaves) the detrimental low temperatures at morning of 22. and 23. of April caused a loss of 93% of the potential harvest. Therefore the advantage of this method has close limits. It would be necessary to investigate methods enlarging the lag periode for some more days.

Conclusion

In summary, it can be said that the delay in shoot development in grapevines could be improved with a slightly increased concentration, making its applicability as a practical frost prophylaxis more important. The use of the improved application might have provided more efficient protection. Optimization tests will still be necessary for the use of ethephon as a retarding substance.

Acknowledgements

This work was supported by the Ministery of Agriculture within the “Froststrat” project in EIP-AGRI frame.

Conflicts of interest

All authors declare that there is no conflict of interests.

References

1. Soja G, Zehetner F, Rampazzo–Todorovic G, et al. Weinbau im Klimawandel: Anpassungs– und Mitigationsmöglichkeiten am Beispiel der Modellregion Traisental. Online Fachzeitschrift des Bundesministeriums für Land– und Forstwirtschaft. 2010:1–20.
2. Kothgasser M. Frostabwehr im Obst– und Weinbau: Die Vielfalt der Methoden und ihre Wirksamkeit unter besonderer Berücksichtigung der Bewindung. Diplomarbeit, Karl–Franzens–Universität Graz; 2018.
3. Formeyer H, Goler R. *Auswirkung des Klimawandels auf die Eignung für den Weinbau in* Österreich *und Europa.* In: Prettenthaler P, Formeyer H, eds. Weinbau und Klimawandel. Medienfabrik Graz; 2013:117–148.
4. Poni S, Sabbatini P, Palliotti A. Facing spring frost damage in grapevine: recent developments and the role of delayed winter pruning. *Am J Enol Vitic*. 2022;73(4):211–226.
5. Petgen M. Schutz vor Spätfrost. Der Winzer. 2016;3:20–23.
6. Hoppmann D, Stoll M, Schaller K. Terroir: Wetter, Klima, Boden. 2nd ed. Verlag Ulmer; 2017.
7. Kartschall T, Wodinski M, Von Bloh W, et al. Changes in phenology and frost risks of Vitis vinifera (CV. Riesling). *Meteorol Zeitsch.* 2015;24:189–200.
8. Archer WJ, Schalkwyk P. The effect of alternative pruning methods on the viticultural and oenological performance of some wine grape varieties. *S Afr J Enol Vitic.* 2007;28(2):107–139.
9. Morgani M, Pena J, Fanzone M, Prieto J. Pruning after budburst delays phenology and affects yield components, crop coefficient, and total evapotranspiration in *Vitis vinifera* L. cv. ‘Malbec’ in Mendoza, Argentina. *Scientia Horticulturae.* 2022;296:110886.
10. Moran MA, Bastian SE, Petrie PR, et al. Late pruning impacts on chemical and sensory attributes of Shiraz wine. *Aust J Grape Wine Res.* 2018;24:469–477.
11. Regner F, Ferschel E, Brandstätter I, et al. Frostprophylaxe durch alternative Rebschnittverfahren. *Mitteilungen Klosterneuburg.* 2023;73:244–262.
12. Frioni T, Tombesi S, Silvestroni O, et al. Post–budburst spur pruning reduces yield and delays fruit sugar accumulation in Sangiovese in Central Italy. *Am J Enol Vitic.* 2016;67:419–425.
13. Friend AP, Trought MCT. Delayed winter spur–pruning in New Zealand can alter yield components of Merlot grapevines. *Aust J Grape Wine Res.* 2007;13(3):157–164.

14. Travadon R, Lecomte P, Diarra B, et al. Grapevine pruning systems and cultivars influence the diversity of wood–colonizing fungi. *Fungal Ecol.* 2016;24:82–89.

15. Main GL, Morris JR. Impact of pruning methods on yield components and juice and wine composition of Cynthiana grapes. *Am J Enol Vitic.* 2008;59(2):179–187.

16. Schiefer HC, Thim G. Wundarmer Rebschnitt: So können Reben gesund altern. Rebe & Wein. 2020;01:30–33.

17. Centinari M, Smith MS, L. Jason P. Assessment of freeze injury of grapevine green tissues in response to cultivars and a cryoprotectant product. *Hort Science.* 2016;51(7):856–860.

18. Poling BE. Spring cold injury to winegrapes and protection strategies and methods. *Hort Science.* 2008;43(6):1652–1662.

19. Dami I, Hamman R, Stushnoff C. Delay of bud break and deacclimation in grapevines to overcome spring frost. *Am J Enol Vitic.* 1997;48(3):376.

20. Dami I. *Delaying grapevine bud burst with oils.* In: Proc inst continental climate viticulture and enology—understanding and preventing freeze damage in vineyards. University of Missouri–Columbia; 2007:89–93.

21. Pérez FJ, Noriega X. Sprouting of paradormant and endodormant grapevine buds under conditions of forced growth: similarities and differences. *Planta.* 2018;248:837–847.

22. Labay YE. Evaluating the impact of Ethephon on bud break and delayed pruning on cluster count in wine grapes. MA thesis, A&M University of Texas; 2018.

23. Kovaleski AP, Londo J. Tempo of gene regulation in wild and cultivated Vitis species shows coordination between cold deacclimation and budbreak. *Plant Sci.* 2019;287:110178.

24. Zheng W, Galdo V, García J, et al. Minimal pruning as a tool to delay fruit maturity and improve berry composition under climate change. *Am J Enol Vitic.* 2016;68:136–140.

25. Guillaumie S, Decroocq S, Ollat N, et al. Dissecting the control of shoot development in grapevine: genetics and genomics identify potential regulators. *BMC Plant Biol.* 2020;20(43):1–15.

26. Hendgen M, Günther ST, Schubert S, et al. Ethephon activates the transcription of senescence–associated genes and nitrogen mobilization in grapevine leaves (Vitis vinifera cv. Riesling). *Plants (Basel).* 2021;10(2):333.

27. Dami I, Beam B. Response of grapevines to soybean oil application. *Am J Enol Vitic.* 2004;55(3):269–275.

28. Herrera J, Knöbl R, Gabler Ch, et al. Effect of vegetal oil application on budbreak phenology timing. *Mitteilungen Klosterneuburg.* 2018;68:172–180.

29. Loseke BA, Read PE, Blankenship EE. Preventing spring freeze injury on grapevines using multiple applications of Amigo oil and naphtaleneacetic acid. *Scientia Horticulturae.* 2015;193:294–300.

30. Persico MJ, Smith DE, Centinari M. Delaying bud break to reduce freeze damage: seasonal vine performance and wine composition in two Vitis vinifera cultivars. *Am J Enol Vitic.* 2021;72:346–357.

31. Wang H, Dami I. Evaluation of budbreak delaying products to avoid spring frost injury in grapevines. *Am J Enol Vitic.* 2020;71:181–190.

32. Böll S, Lange T, Hofmann H, et al. Correspondence between gibberellin–sensitivity and pollen tube abundance in different seeded vine varieties. *Mitteilungen Klosterneuburg.* 2009;59(3):129–133.

33. Hageman B. Protecting your fruit trees from frost damage. 2024.

34. Bauer K, Regner F, Friedrich B. Weinbau. 13th ed. Cadmos Verlag; 2017.

35. Iwasaki K. Effects of bud scale removal, Ca Cyanamide, GA3, and Ethephon on bud break of Muskat Alexandria grape. *J Hortic Sci.* 1980;48(4):395–398.