# EFFECT OF VEGETAL OIL APPLICATION ON BUDBREAK PHENOLOGY TIMING

Jose Carlos Herrera[1], Robin Knöbl[1], Christoph Gabler[2], Erhard Kührer[2] und Astrid Forneck[1]

[1] University of Natural Resources and Life Sciences Vienna (BOKU)
Division of Viticulture and Pomology, Department of Crop Sciences
A-3430 Tulln, Konrad Lorenz Straße 24
[2] Wein- und Obstbauschule Krems
A-3500 Krems; Wiener Straße 101
E-Mail: jose.herrera@boku.ac.at

Late frost damage is an important threat for Austrian viticulture. Increasing winter air temperatures as a consequence of climate change result in early grapevine budbreak and increased late frost risk. The aim of this work was to investigate the effect of vegetal oil application to dormant buds on budbreak timing. Delayed shoot development is expected to reduce late frost damage. Experiments were carried out in 2017 with the two most important wine grape varieties in Austria, 'Zweigelt' and 'Grüner Veltliner'. The oil application resulted in a budbreak timing shift of 8 days in average compared to non-treated controls for both varieties and without symptoms of phytotoxicity. Although our results are limited to one season observation, promising results advocate further experiments to fine-tune the technique (e. g. timing of applications, number of applications, environmental condition during applications) considering also other varieties and sites of interest.
**Keywords:** frost damage, late frost, budburst delay, *Vitis vinifera*

**Spätfrostschäden sind eine aktuelle Bedrohung für den österreichischen Weinbau.** Erhöhte Durchschnittstemperaturen im Winter als Folge des Klimawandels führen zu einem verfrühten Austrieb und als Folge davon zu einem erhöhten Risiko durch Spätfröste. Das Ziel dieser Studie war, die Auswirkungen von Ölapplikationen auf dormante Knospen bei Reben im Hinblick auf den Austriebstermin und die spätere vegetative und generative Entwicklung zu untersuchen. Im Jahr 2017 wurden Feldversuche an den Rebsorten 'Zweigelt' und 'Grüner Veltliner' durchgeführt. Die Ölapplikation führte zu einer Austriebsverzögerung von durchschnittlich acht Tagen im Vergleich zu nicht behandelten Kontrollen für beide Rebsorten. Symptome von Phytotoxizität konnten bei keiner Versuchsvariante festgestellt werden. Die Ergebnisse sollen sowohl in weiteren Vegetationsperioden als auch an weiteren Standorten im Hinblick auf eine Feinabstimmung der Technik (z. B. Zeitpunkt der Anwendung, Anzahl der Anwendungen, Umweltbedingungen während der Anwendung) und an weiteren Rebsorten reproduziert werden.
**Schlagwörter:** Spätfrostschäden, Spätfrost, Austriebsverzögerung, *Vitis vinifera*

In recent years, probably as a consequence of climate change and global warming, mild winter temperatures are increasingly favoring a premature sprouting in Austrian vineyards which in turn has increased the risk of spring frost damage. On the other hand, the expected risk of temperature drops below zero during April to mid-May has not changed, and therefore the frequency of frost events after budburst is still likely to occur in the near and far future (Molitor et al., 2014). With the advancement of the phenological development, the frost resistance of grapevine buds decreases (Centinari et al., 2016; Johnson and Howell, 1981). Growing organs have a high water content, which makes them susceptible to the formation of ice at freezing temperatures. Air temperatures slightly below zero(-2, -3 °C) can permanently damage green tissues (Keller, 2010); the extent of the damage (from low damage of buds and shoots to 100 % primary bud necrosis) depends on the minimum temperature reached, event duration, and bud development stage. Although the *Vitis* genus is characterized by a compound bud that includes a primary, secondary, and tertiary bud generating spring shoots (Keller, 2010; Mullins et al., 1992), primary bud protection is essential as these buds usually yield 300 to 400 % more fruit than those produced by secondary buds (Loseke et al., 2015). Different direct methods for frost protection have been proposed including air movement, the use of heaters and over-vine irrigation (Evans, 2000), or the use of cryoprotectants such as potassium dextrose (Centinari et al., 2016). However the implementation of such methods is difficult particularly for small growers or the effectiveness remains questionable. Indirect methods to avoid or reduce spring frost damage are delaying grapevine budbreak. Such techniques include pruning strategies (e. g. long pruning or double pruning, late pruning) that take advantage of the apical dominance physiological behavior of grapevines (Friend and Trought, 2007; Frioni et al., 2016; Gatti et al., 2018), or the use of vegetal oils (e. g. soybean oil) capable to delay the bud dormancy release (Dami and Beam, 2004; Loseke et al., 2015; Centinari et al., 2016; Petgen, 2016; Centinari et al., 2017). Here we explored the potential use of vegetal oil (commonly used as coadjutant in organic agriculture) applied to the dormant buds with the aim to delay budbreak. We performed the experiment on two grapevine varieties widely used in Austrian viticulture, 'Zweigelt' (ZW) and 'Grüner Veltliner' (GV).

## MATERIALS AND METHODS

The experiment was carried out in 2017 in an experimental vineyard of the Landesweingut Niederösterreich in Krems/Landersdorf. The vineyard encompasses a total area of 1.6 ha. Within the vineyard, we used four consecutive rows of ZW planted in 2004 and four consecutive rows of GV planted in 2007. Both varieties are grafted on SO4 and inter-row × within-row distance is 2.8 × 1 m for GV and 2.8 × 0.8 m for ZW, with a total row length of 140 m and N-S orientation. Both varieties were trained as single Guyot, canes pruned to 10 buds per cane, and vertical shoot positioned, with the fruiting canes 0.8 m above the ground and with a set of three catch wires separated 0.4 m from each other for a total canopy height of 1.2 m. The vineyard is entirely rain-fed and fertilization and pest management were conducted following the standard practices of the area. Within the experimental vineyard an automated weather station was used to record climatic parameters (Fig. 1).

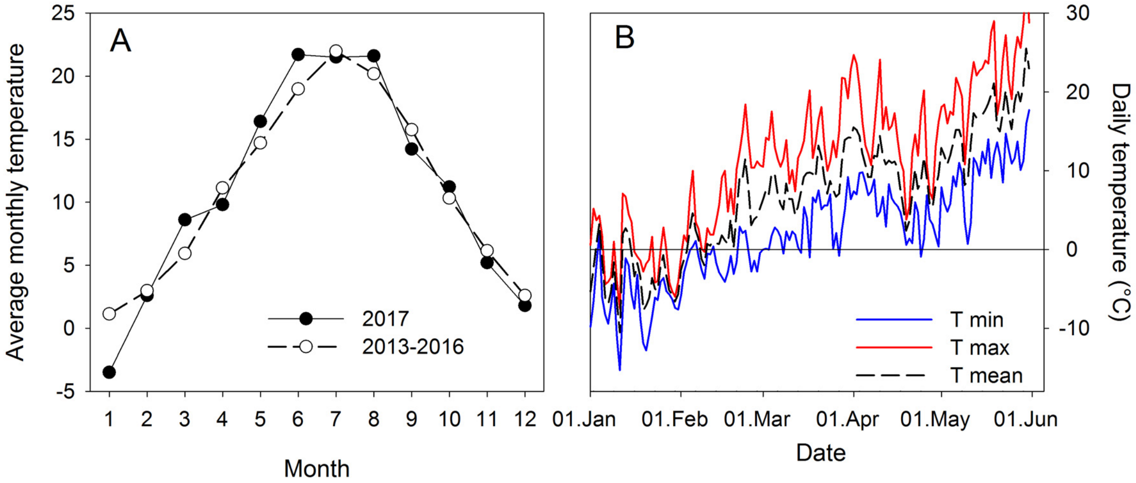


Fig. 1: A) Average monthly temperature in the experimental vineyard during the 2017 season and average during the 2013 to 2016 period; B) Daily temperature in the experimental vineyard during the period January, 1st, to June, 1st, 2017.

## EXPERIMENTAL DESIGN

In January, for each variety a total of 8 experimental plots of 10 m each were randomly selected within the 4 consecutives rows, assigning 2 plots per row. In each experimental row, one plot was used as non-treated control while the second was treated twice with "Micula" rapeseed oil based coadjutant (Biohelp GmbH, Vienna, Austria). The first treatment was performed on March, 14th, and the second on March, 29th. Oil treatment consisted in spraying the oil at 10 % concentration (v/v in water) manually (using a backpack sprayer) on all the buds in the canes until runoff (~0.3 l/vine).

## BUDBREAK PHENOLOGY

Following the treatments, periodic observations (every 5 days) were performed to visually assess the phenological stage of the buds in each treatment using the modified E-L system (Coombe, 1995). For each plot 25 buds were observed (for a total of 100 buds per treatment) and the E-L stage of each one was recorded and expressed as rounded percentage values.
After all buds in the control treatments reached the stage 9 in the E-L scale (2 to 3 leaves separated; shoots 2 to 4 cm long), visual scouting was concluded.

## STATISTICAL ANALYSIS

For each date of observation, a histogram of frequency for each E-L stage category was calculated for controls and oil-treated vines. The proportion of buds at a given E-L stage in oil-treated vs. non-treated control vines was then analyzed for statistical differences using a Chi-square test ($P < 0.05$) using R software (R Foundation for Statistical Computing, Vienna, Austria).

## RESULTS AND DISCUSSION

In general, an earlier budbreak than the average (ca. 20 days before the expected time point) was observed in the season 2017, probably in relation to relatively high temperatures during March that were higher than in other years (Fig. 1A). Also, whereas in several European winegrowing regions spring frost resulted in severe damage in 2017, in our experimental vineyard no late frost events were recorded (Fig. 1B) and thus no freeze damage was observed in the growing shoots. Regardless, oil application successfully induced a delay in the budbreak process on both the varieties tested here, without any symptom of phytotoxicity. In particular, the oil treatment delayed the budbreak date in ZW and GV, respectively, in average by 12 days and 5 days as compared with the non-treated controls (Fig. 2). This result is in agreement with previous experiences in other varieties (*V. vinifera* and hybrids) and with other oils (such as soybean) where budbreak was delayed from 4 to 17 days compared with non-treated controls (Centenari et al., 2017; Losecke et al., 2015; Dami and Beam, 2004).

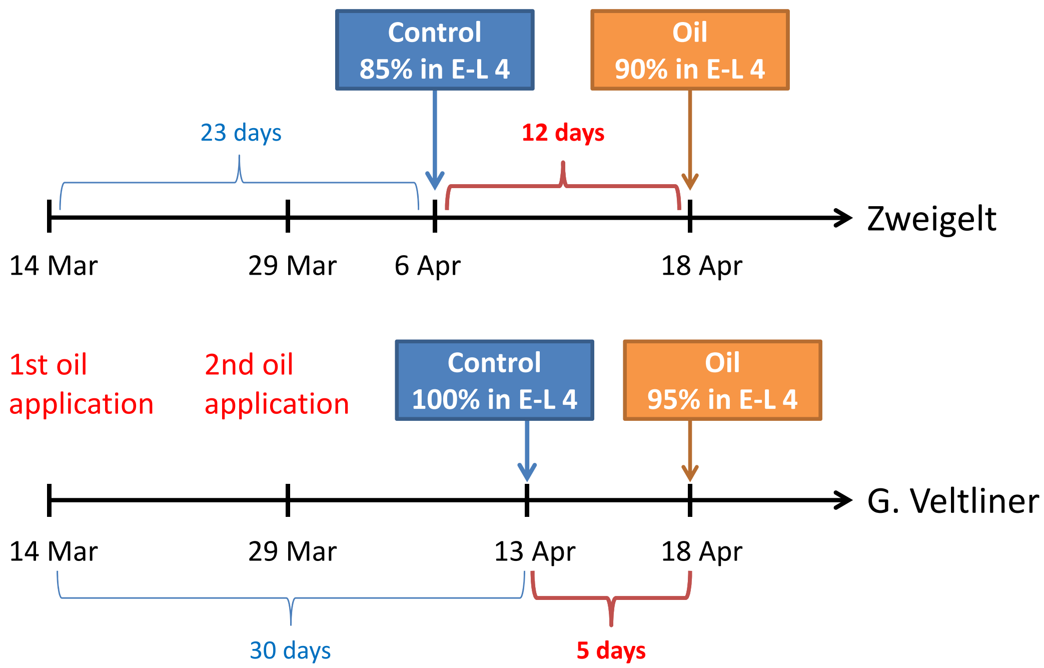


Fig. 2: Timing of oil application and 100 % budbreak (E-L stage 4) in oil-treated vs. non-treated control vines of 'Zweigelt' and 'Grüner Veltliner'

In the used scale, E-L stage 4 indicates that the bud tip has expanded and the first green leaf tissue is visible and thus could be considered as the standard stage to indicate budbreak. On April, 6th, 85 % of ZW control buds had reached or surpassed the E-L stage 4, while 90 % of the buds of oil-treated vines were at E-L stage 2 (bud scales opening). Similar results were observed in GV (that started bud growth in control vines around one week after ZW) as on April, 13th, 100 % of the buds in control vines had reached or surpassed the E-L stage 4, while only 30 % had reached stage 3 (wooly bud) in oil-treated vines. The entire evolution of the budbreak phenology is presented in detail in Figure 3, where it can be observed, that in almost each date of observation, the proportion of buds at a given stage was statistically different ($P < 0.05$) between control and oil-treated vines in ZW and GV.

The speed of bud development and opening is an important factor to consider since the sensitivity to freezing temperatures increases with the phenological advancement (Centinari et al., 2016; Fuller and Telli, 1999; Johnson and Howell, 1981). It is therefore important to know what percentage of the buds are open at a certain date as compared to the control variant (Fig. 3). For instance, on April, 21st, (when a frost event occurred in other European regions such as Bordeaux) all the control buds in ZW and GV were between stages 5 (post-budbreak, elongating green tip) and 7 (first leaf separated from shoot tip). At the same date, 50 % and 25 % of buds in oil-treated ZW and GV, respectively, were beyond the E-L stage 4 (budbreak). Moreover, in that day 45 % of ZW control buds were at stage 7 (first leaf separated from the shoot). Clearly, these differences would have resulted in different injury severity, buds at stage 4 being less vulnerable than the ones at stage 5 or 7.

Differences in budbreak also resulted in a delay during early shoot elongation and leaf area formation (data available in Forneck et al., 2018). However, these differences were reduced with time, and by veraison no differences were observed between treatments regarding the canopy. Shoots of oil-treated vines developed later in the season under warmer temperatures, which may have reduced the time the leaves needed to reach full size and maximum photosynthetic capacity (Gatti et al., 2018; Centinari et al., 2017). Since flower development was also delayed by the treatments, veraison starting date was also slightly shifted in oil-treated vines and some differences were observed at the beginning of ripening for sugar accumulation and titratable acidity (Fig. 4). Nevertheless, such differences disappeared with time and by harvest no differences were observed in terms of sugar accumulation, acidity or berry weight, similar to the results obtained by Centinari et al. (2017). The final yield per vine, average cluster-weight, and average number of clusters per vine (Fig. 4) were not impacted by oil treatments, advocating for absence of phytotoxicity of rapeseed oil, different from what observed with soybean oil by Centenari et al. (2017).

Although the experiment succeeded in delaying budbreak, fine-tuning of the technique is desirable, particularly in terms of timing of application. Because the budbreak delay is thought to happen as a result of reduced respiration rates of the treated buds (Dami and Beam, 2004), very early application (buds not yet metabolically active) or too late (buds already resumed metabolism) could compromise the effectiveness and the total delay; presumably, this could play a role (together with other pivotal environmental variables such as temperature and water availability, as well as specific genotype response) on the big variability in terms of timing of delay observed in previous studies. Optimization of the technique could be achieved with the possibility of modeling estimating the date of budbreak. The expected budbreak time is related to the site heat accumulation in turn impacting also the soil temperature in the previous weeks

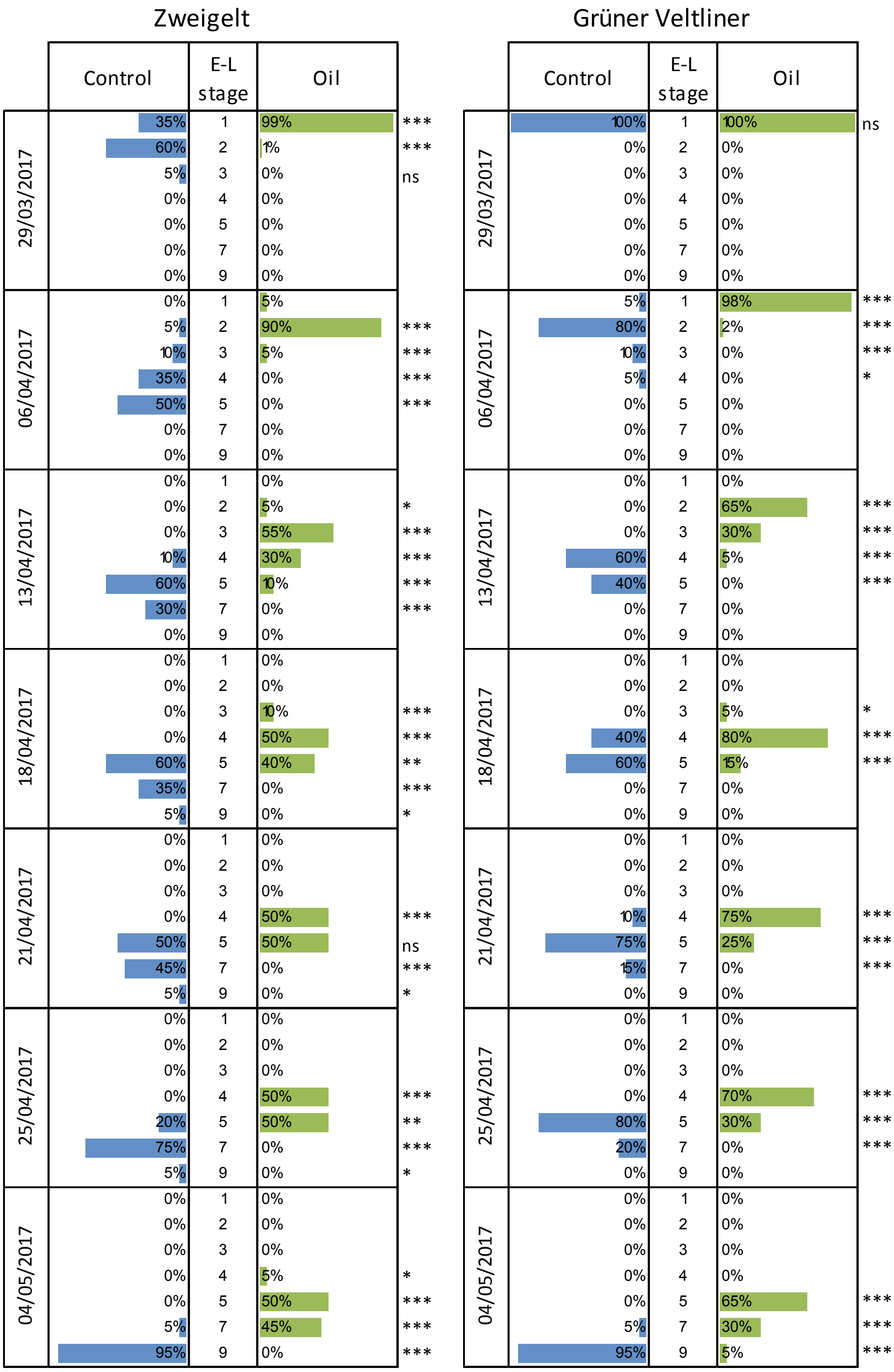


Fig. 3: Budbreak phenology evolution in oil-treated vs. non-treated control vines of 'Zweigelt' and 'Grüner Veltliner' in 2017. At each date of observation a total of 100 buds per treatment were assessed for the phenology stage according to the modified E-L scale (Coombe, 1995) (*, **, *** or ns, significant at $P < 0.05$, 0.01, 0.001 or not significant, respectively, as tested by Chi-square)

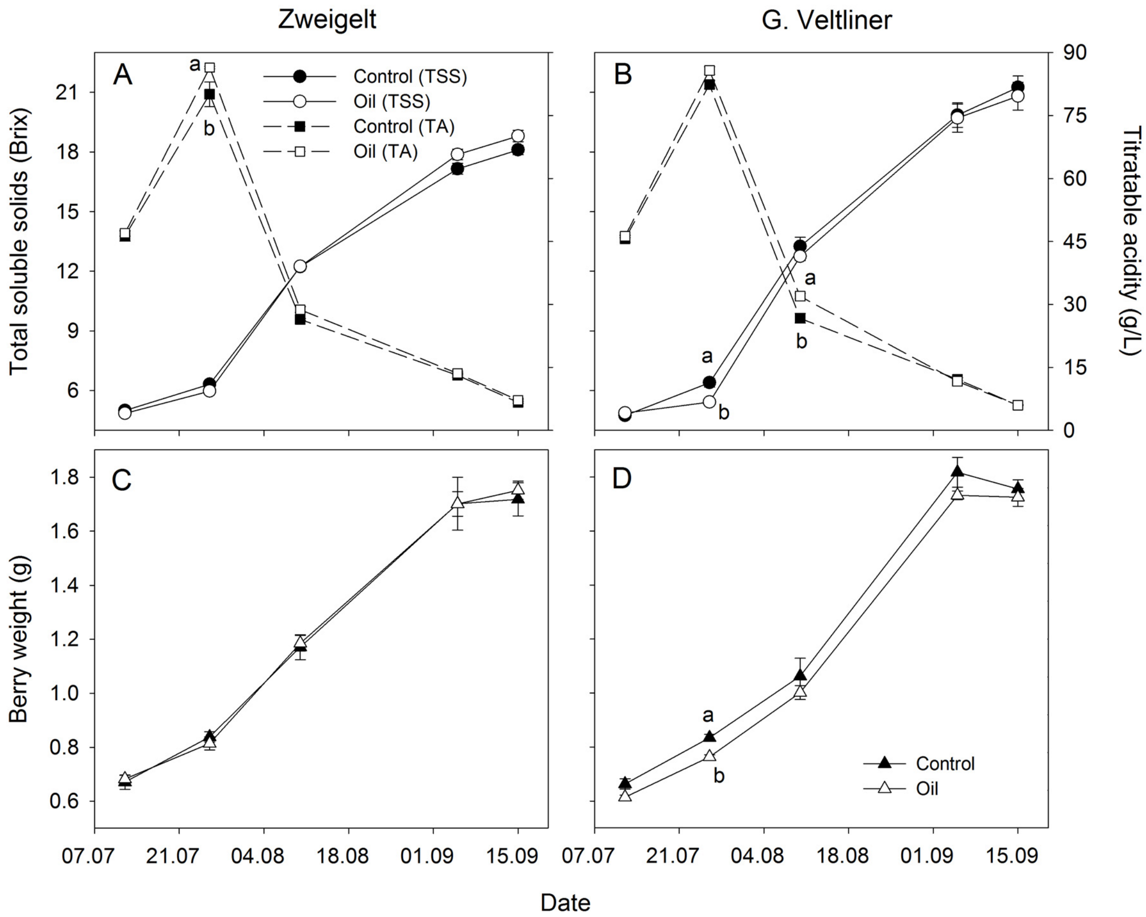


Fig. 4: Grape berry total soluble solids (TSS; °Brix) accumulation and titratable acidity (g/l tartaric acid) during ripening (A, B) and the berry weight (C, D) in 'Zweigelt' and 'Grüner Veltliner' grapevines treated with oil (open symbols) and non-treated controls (closed symbols); different letters in leaf area bars indicate statistical differences tested by T-Student (P < 0.05)

and base temperature specific for the genotype. However, available models to predict grapevine budburst date (Garcia de Cortazar-Atauri, 2009; Molitor et al., 2014) mostly rely on the heat accumulation during March. The oil application should disturb bud metabolism resumption by decreasing oxygen availability in order to slow down the de-acclimation process (Dami and Beam, 2004). Therefore, the oil product should be applied some days before this happens (around 30 to 40 days before the starting of the E-L stage 2). However, predicting such timing is not possible with the current models available and an alternative solution should be pursued. Moreover, no specific budbreak model exists for ZW and GV in Austria, thus we based our treatments on historical average budbreak dates in the experimental site. However, as observed here, the average budbreak date can suffer from big variability from year to year. Field observations of real dormancy break date are urgently required to test the reliability of phenological models under future climatic conditions in Austria and to possibly develop new ones. For this experiment we decided to standardize the timing of the oil treatments for both varieties. However, variety-specific treatments could be performed depending on varietal characteristics. For instance, ZW budbreak occurred earlier than with GV (Fig. 2). In our case, ZW treatment could have been performed some days earlier and maybe result in slightly better results (in terms of total delaying of the budbreak). Finally, although in our trial no phytotoxicity effect was observed in the varieties treated, this effect cannot be excluded, since, first of all, we report on only one season observations, and because in previous research some degree of phytotoxicity was reported for *V. vinifera* and hybrid genotypes (Centinari et al., 2017; 2016; Dami and Beam, 2004; Loseke et al., 2015).

## CONCLUSION

Oil spraying successfully delayed budbreak in ZW and GV while no effects were observed in vine yield components or in the berry chemical parameters analyzed here. Overall, using oil applications to delay budbreak could represent a cost-effective way to reduce frost damage risk in Austrian vineyards without impacting the yield and quality of the production, but multi-season observations and carry-over effects should be assessed. Finally, fine-tuning the application dates is necessary to optimize the effectiveness of the results obtained. Future research efforts should go on that direction.

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