

Double-Pruning: preventive technique against spring frost damage

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Abstract. The double pruning technique on Sangiovese vines, based on pre-pruning in February and finishing in April, induced a delay of bud break, which is an approach to avoid spring frost damage. The field experiment was conducted on Sangiovese vines mechanically spur-pruned during dormancy in February and manually finished post budburst to test the potential of ‘double-pruning’ approach to prevent the spring frost damage. This technique, associated with the finishing performed when the apical shoots on the mechanically-shortened canes were about 10 cm long, allowed to keep the basal buds in a dormant phase for almost 15 days, extending the resistance period against the spring frosts, particularly important for the cultivars characterized by early bud-break. Yield reduction per vine was -22% due only to the incidence of unsprouted buds, while the grape ripening profile was delayed with an increase of acidity and phenols and a decrease of pH and soluble solids.

1 Introduction

Periodically, in many regions of Italy the vineyards suffer spring frost injury with strong yield loss and severe shoot damage. Such losses are often devastating, especially if experienced frequently. In contrast to many other high-value crops, frost protection methods for wine grapes are less frequently deployed, due to high costs and management challenges. An integrated approach of preventative measures, as management and pruning, can help to mitigate short and long term implications of late-spring frost damage. Preventing cold injury to vines is a key viticulture concern in many grape regions worldwide [1]. Effective vineyard frost protection depends on many factors: type of frost, severity of the frost event, crop sensitivity, relative humidity and dew point, soil conditions, topography, and available resources.

1.1 Types of spring cold events

It is crucial to understand the differences among cold events that can occur in spring. Frost events are caused by radiation, while freeze events are caused by moving air masses that cool surfaces (advection). The radiative frosts are the most common types of frost for many grape growing regions. They occur when a dry, cold air mass moves into an area when there is almost no cloud cover and no wind at night. Because plants and soil are warmer than the sky temperatures, they will emit heat back to their surrounding space and become progressively colder than the air.

Differently, the advective frosts occur when strong, cold winds, colder than the critical temperature, blow into a region. Radiative and advective frosts may occur simultaneously; the classification depends on which one is dominant. The critical temperature is the temperature at which the cells of the tissues will be killed and determines the cold hardiness levels of the plant. Many factors affect the temperature at which damage occurs including the type of plant tissue, stage of phenological development of the bud/shoot, dew point and surface moisture, a probability of an ice nucleation event, and pre-frost environmental conditions [1]. The dew point (DP) temperature is defined as the temperature at which water vapor in the air becomes saturated and then condenses as dew, fog, or frost. A relatively high DP indicates that the lower atmosphere is moist and that there may be potential for a hoar frost [2]. A relatively low DP temperature indicates drier air, and in this scenario, there is potential for a second type of radiational frost called a black frost. Hoar frosts occur when atmospheric water vapor freezes in small crystals on solid surfaces (sublimation), also called white frost for the white layer of ice crystals formed on the ground, grass blades, twigs, and young grape shoots. The black frost does not present ice crystals on plant surfaces because the lower atmosphere is essentially too dry. The black frost is much more dangerous than the hoar frost. This is often the case on cloudless, cooler nights that promote radiation emission from the soil [3].

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1.2 Budbreak: the most susceptible period for cold injury

Growing organs have a high water content, which makes them susceptible to the formation of ice at freezing temperatures. Air temperatures of -2, -3 °C can permanently damage green tissues. In midwinter, grapevines are able to tolerate freezing temperature through a complex process called deep supercooling. For example, the cells within the dormant bud become resistant to lower temperature through dehydration and accumulation of so-called cryoprotectant (e.g. soluble sugars and proteins). Those compounds lower the freezing point of the water within the plant tissue and stabilize cell membranes making the dormant buds able to survive temperatures well below freezing. Also, during the dormant season buds are thought to be disconnected or weakly connected to the vine's vascular tissues, which limit their potential to take up water [4].

On average, in Italy over the last 30 years one frost occurred every four years.

During the first week of April 2021, after about 2 months without rainfalls and with high temperatures in the last weeks of March (with peaks of over 25-26 °C), many regions in Italy have been affected by the spring frosts, in particular on the nights of the 6th, the 7th and the 8th of April. For several hours, vines suffered from temperatures below 0 °C with minimum peaks below -6 °C and relative humidity lower than 35-40%. The high temperatures of March favored the sprouting and the speed of development of the new shoots, making them more vulnerable to the frost attack (Figure 1).



Figure 1. Radiative and advective frosts effect on Sangiovese vines.

In Figure 1, radiative and advective frosts occurred simultaneously and affecting mostly early bud-burst varieties, such as Chardonnay, Grechetto, Sangiovese, Colorino, Glera, Nebbiolo and Primitivo. The choice of vineyard site also has a large impact on the occurrence of frost injury. In fact sites like North facing soils, valley floors, humid areas and areas near woods should be avoided.

The aim of this work was to avoid the spring frost damage through the postponement of bud-burst induced with the double pruning technique.

2 Materials and Methods

The trial was carried out in 2014, 2015 and 2016 in a vineyard near Perugia (42°58'N; 12°24'E, elevation 405 m a.s.l.) in Umbria region (central Italy) in mature Sangiovese grapevines grafted on 420 rootstocks. The vines were planted at 2.5 × 1.0 m inter- and intra-row spacing and trained to a vertically shoot-positioned spur-pruned cordon trellis. Vines were not irrigated. The cordon was trained 0.9 m above ground with three pairs of trellis canopy wires on a canopy wall extending 1.2 m above the permanent cordon. Five adjacent rows were selected to form a completely randomized block design, with each row as a block. Using a rotary pre-pruner (Volentieri-Pellenc Visio TLV20), all rows were subjected to winter mechanical pre-pruning in late winter (mid-February). The pre-pruner was set to shorten the canes to a uniform length of about six to seven nodes each. Within each row groups of 25 adjacent vines (sub-replicates) were randomly assigned to the following hand-finishing (HF) treatments: (1) standard (SHF), performed right after mechanical pre-pruning in mid-February with all buds still dormant; (2) late (LHF), performed when the first two apical shoots on the mechanically-pruned canes were at phenological stage BBCH-14, ~10 cm long with three to four unfolded leaves, applied on 14, 28 and 11 April in 2014, 2015 and 2016, respectively. In all treatments, HF consisted of cutting back all canes of the test vines to standard two-node spurs.

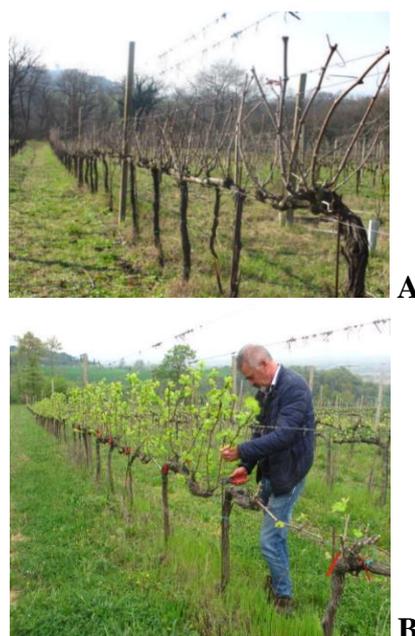


Figure 2. Vines just after the pre-pruning treatment in winter (A), and worker during the hand-finishing (B).

A two-way analysis of variance (ANOVA) on the complete randomized block design was used to analyze the timing of HF and year effects on yield components and grape composition at harvest. ANOVA was performed with block as replications (degree of freedom = 4). Mean separation was performed using the Student-Newman-Keuls test ($p \leq 0.05$ and 0.01). All the statistical analyses were performed with the SigmaStat 3.5 software package (Systat Software Inc.).

3 Results and Discussions

As reported by Palliotti *et al.* (2017), from 2014 to 2016, SHF vines reached budburst (green shoot tips clearly visible = 50% of total buds) during the third week of March, while budburst in LHF was postponed by about two weeks (Table 1). The phenology difference among treatments at budburst ranged between +14 days in 2014 and in 2016 and +17 in 2015. In this way there has been an extension of the freezing tolerance period against the impending low temperatures.

Table 1. Bud-burst dates in spur-pruned Sangiovese vines mechanically pre-pruned in February and subjected to hand-finishing (HF) at different times: in February (SHF, standard HF) and after bud-burst, when apical shoots on canes retained during pre-pruning were about 10 cm long (LHF, late HF).

	Treatment	
	SHF	LHF
2014	20 March	3 April (+14)
2015	18 March	4 April (+17)
2016	23 March	6 April (+14)

At harvest, LHF vines had 22% lower yields per vine than SFH (Table 2), this was due to a 20% reduction in clusters per vine and a 2.6% reduction in clusters weight. Total must soluble solids at harvest was significantly lower in LHF than SHF, but titratable acidity increased and must pH lowered. An increase in phenols concentration (+18%) was recorded in LHF, whereas total anthocyanins were unaffected (Table 3).

Postponing spur-pruning of cordon-trained vines until well after winter mechanical pruning delayed the budburst up to two weeks. The reduction of clusters per vine (about -2.5) found on LHF compared to SHF vines was probably linked to limitation in the photoassimilate pool necessary to permit the flower primordia development. Severe source limitation caused by LHF (-0.21 m²/vine) may have caused pre-developed inflorescence primordia to revert into tendrils.

Table 2. Crop weight and yield composition at harvest 2014, 2015, and 2016 on spur-pruned Sangiovese vines mechanically pre-pruned in February and subjected to hand-finishing (HF) at different times: February (SHF, standard HF) and after budburst, when apical shoots on canes retained with pre-pruning where ~10 cm long (LHF, late HF).

	Treatment		Sign. F
	SHF	LHF	
Clusters/shoot	1.09	1.06	*
Yield/vine (kg)	2.80 a	2.18 b	**
Clusters/vine (n)	12.2 a	9.7 b	**
Cluster weight (g)	228 a	222 a	*
Berry weight (g)	110	115	ns

Means within columns noted by different letters are different by Newman-Student-Keuls test. *, **, and ns indicate significant differences between treatment and years at $p \leq 0.05$, $p \leq 0.01$, and not significant respectively.

Table 3. Grape composition at harvest in 2014, 2015, and 2016 on spur-pruned Sangiovese vines mechanically pre-pruned in February and subjected to hand-finishing (HF) at different times: February (SHF, standard HF) and after budburst, when apical shoots on apical canes retained with pre-pruning were ~10 cm long (LHF, late HF).

	Treatment		Sign. F
	SHF	LHF	
Total soluble solids (°Brix)	22.1 a	21.1 b	
Titratable acid (g/L)	6.66 b	7.67 a	
Must pH	3.40 a	3.20 b	
Total anthocyanins (mg/kg)	362	402	
Total phenols (mg/kg)	2668 b	3158 a	

Means within columns noted by different letters are different by Newman-Student-Keuls test. *, **, and ns indicate significant differences between treatment and years at $p \leq 0.05$, $p \leq 0.01$, and not significant respectively.

4 Conclusions

Late-spring frosts are a challenge for viticulture especially in the central and northern part of Italy. Injury caused by such frost events can lead to uneven ripening and yield loss, many of which could be expensive and / or labor intensive. Double pruning based on pre-pruning during the dormant period and hand finishing of winter pruning after canes apical bud-burst, can be a tool useful to induce a delay of phenological phases. This technique allows to take advantage of the acrotony and the apical dominance of the vines to preserve the integrity of the basal buds and therefore their overall productivity. In such cases, frosts will only damage the sprouted apical shoots, which will be removed later keeping the basal buds vital. The pre-pruning used on the spur pruned cordons simplifies and accelerates the HF that will take place after the spring frost. In 2021, many Italian vine growers testified that double-pruning has been a very useful practice against the spring frost damage. The latter can especially help on early varieties such as Grechetto, Sauvignon blanc, Chardonnay, Primitivo, Glera, etc. and in vineyards with higher risks of frost.

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