Technical Abstract Nº 2

CLIMED-FRUIT

Improving vineyard resilience: agricultural frost damage mitigation techniques

The Mediterranean region is experiencing some of climate change's most intense effects of climate change on European agriculture, including more frequent extreme heat, droughts, loss of biodiversity and increasing water needs. This is particularly concerning for perennial fruit crops such as grapevines, which cover substantial areas and are increasingly affected by these changes. Farmers are adjusting their practices to cope, but many of these solutions remain confined to specific regions or agricultural sectors. The EU-funded CLIMED-FRUIT [1] project is working to bridge this gap by collecting and sharing innovative, climate-adaptive practices from various European agricultural operational groups (OGs) to enhance resilience and promote effective climate change adaptation and mitigation.

Global warming has led to pronounced shifts in vine phenology, especially in the Mediterranean, resulting in earlier flowering and fruiting events. Studies indicate that approximately 78% of flowering and fruiting cycles now occur earlier, with 30% of these shifts showing significant advances. Similarly, late autumn frosts have an adverse effect on plants that have not yet entered a dormant phase, collectively resulting in significant yield losses. This article outlines best practices for mitigating frost risk and adapting vineyard management to withstand these climatic challenges.

This article presents a non-exhaustive list of experimental results from projects carried out across Europe and identified in the framework of the CLIMED-FRUIT project.

Late winter pruning: example in viticulture

In vine growing, adopting late winter pruning — a cheap technique — has the potential to protect lower buds and, in certain instances, delay grape ripening. This technique was implemented in Italy by the OG VIRECLI [2] and represents a strategy against spring frost.

It is implemented at the winter pruning stage and is an adaptation of regular winter pruning based on grape acrotony. It consists of the following steps:

- Performing a pre-pruning operation to optimise the organisation of the final pruning steps (reducing the time needed for final pruning): the shoots must be long and kept upright (Fig. 1). This operation will help preserve lower buds through the potential spring frost stage; however, it might not always have an effect on ripening delay at harvest time.
- Performing the late pruning step (when frost risk is over) to remove the correct leaf area, which is not more than two unfolded leaves on the apical shoots, so the buds located in the basal position are thereby protected in case of spring frosts (Fig. 2). It is crucial to remove the correct leaf surface area, and if the operation is performed at a later point, it will cause a yield loss (Fig. 3).

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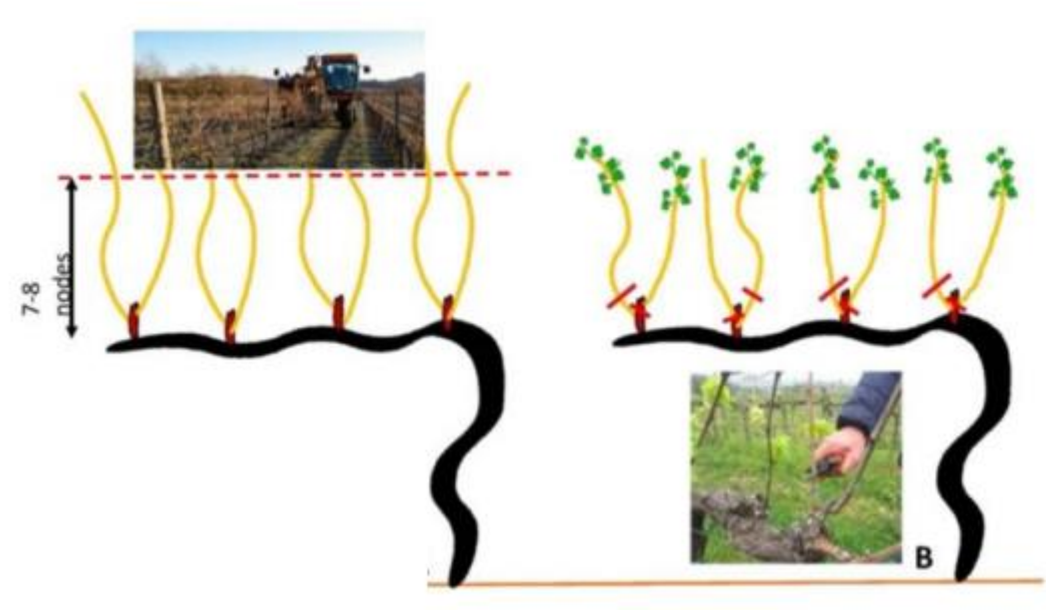

Fig. 1. Late winter pruning in two steps – OG VIRECLI

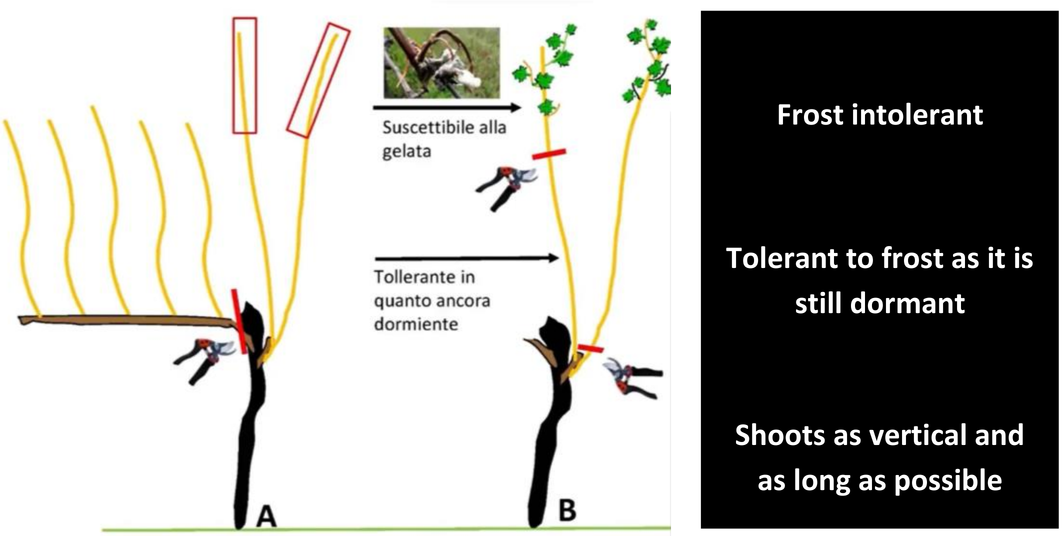

Fig. 2. Bud frost tolerance versus bud position on the shoots – OG VIRECLI

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Fig. 3. Right way to perform late pruning – OG VIRECLI

In France, trials have been carried out [3] on the Merlot grape variety in the Gaillac PDO to study the effect of different pruning dates after budburst. The main results include:

- ✓ Carried out at the budburst stage, pruning results in a phenological delay of one week at the flowering and veraison stages.
- ✓ Carried out at the four- to six-leaf stage, the delay can be up to two weeks.
- ✓ At the harvest time, no matter the date of pruning (January or March for example), slight differences are observed in terms of maturity parameters.
- ✓ Out of three trials, the yield was only significantly affected in one vintage.

Other results: late pruning can be carried out at an even later stage (eight to 12 leaves). In this case, the reduction in grape sugar can be more than 1% by volume of probable alcohol, but significant yield reductions can be observed.

Soil management practices

A study was carried out [4], focusing on avoiding the increasing frost risks in French vineyards through soil management practices. It was observed that unploughed soil in vineyards significantly decreased the humidity near the buds — by 33% compared to ploughed vineyards (Fig. 4, 5). Higher humidity increases the damage caused by frost to the buds: at the same temperature, 20% more humidity leads to a 50% increase in bud damage. It was concluded that if frost is forecast, the atmosphere around the buds needs to be as dry as possible by avoiding tillage or mowing practices five to six days before the frost event. The volume of soil moved also impacts the number of days it takes to reach the same humidity around the buds as in the case of untilled soils.

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Fig. 4. Sensors monitoring humidity and temperature near the buds in three different soil management treatments – SICTAG EU

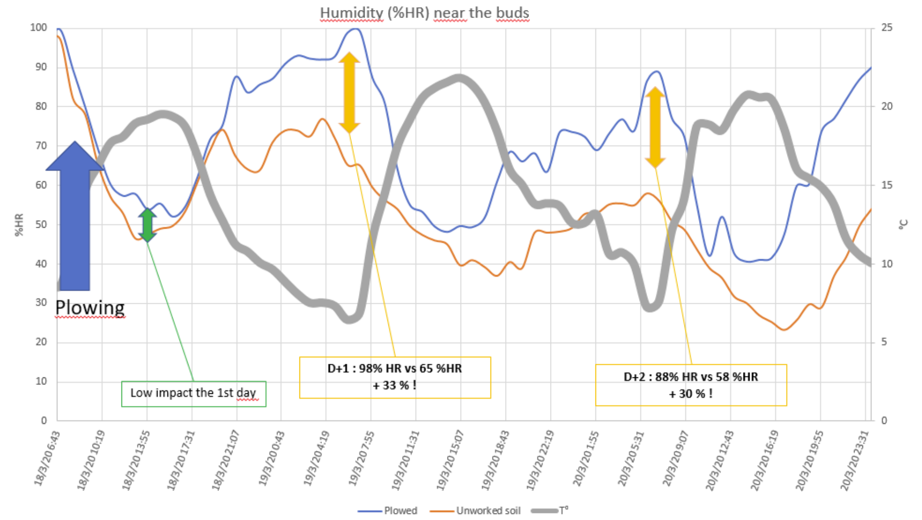

Fig. 5. Effect of soil management (plowing depth) on the humidity variation near the buds – SICTAG EU

Application of biostimulants and supplementary nutrients

Applying biostimulants and supplementary nutrients is a key measure to enhance cold hardiness. Products based on seaweed extracts, in particular, a 0.8% *Ascophyllum nodosum* (brown seaweed) extract formulation, improved freezing tolerance in grapes [5]. Regarding bacteria, the grapevine plantlets' cold tolerance was enhanced with a *Burkholderia phytofirmans* rhizobacterium root application [6]. To support the productive vineyards' resilience to cold, there are foliar application products containing *Thiobacillus spp*. bacteria available on the market. A recent study on cryoprotectants [7] showed that spraying 22% glycine betaine 72 hours before frost occurs delayed intracellular ice

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formation and reduced osmotic damage during freezing. The treatment's effectiveness varied depending on grape cultivar, dormancy stage and year. The greatest benefit was observed in the Michele Palieri cultivar, where frost tolerance improved by 3.07°C during the deacclimation. Elements such as zinc, boron, copper, manganese and iron are vital for cold tolerance. Foliar treatments with potassium oxide (K_2O) and other micronutrient mixes — such as calcium chloride ($CaCl_2$) applications three times between 15 September and 15 October— have proven effective. Notably, K_2O has been identified as particularly successful in enhancing frost resistance when applied regularly [8][9].

Conclusion

Improving grapevine resilience to frost involves a combination of cultural, biological and chemical approaches. Late winter pruning can protect lower buds and delay phenological stages, minimiszing frost damage. Soil management practices, such as avoiding tillage or mowing before frost events, help reduce humidity around buds, which decreases frost susceptibility. The foliar application of biostimulants, such as seaweed extracts (Ascophyllum nodosum) and cryoprotectants such as glycine betaine, has been shown to enhance cold hardiness by delaying ice crystal formation and mitigating osmotic stress. Additionally, micronutrient treatments with elements such as potassium, calcium and trace minerals play a crucial role in boosting frost tolerance by strengthening plant tissues. These integrated methods offer practical solutions for adapting vineyards to the increasing risks posed by climate change.

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