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Review

Mechanical winter pruning of grapevine: Physiological bases and applications

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ABSTRACT

Since machine introduction in the early 1970s, much work has been expended to adapt pruners to vine trellis and physiological requirements, especially regarding the higher bud load their non-selective cuts leave compared to manual trimming. While units have successfully met the former requirement, efforts to meet the latter have been hampered by a broad range of variables depending on cultivar, machine type, environmental conditions and any manual follow-up. Several examples are instructive here. Winter hedge pruning usually delivers best results with low-to-medium basal node fruitfulness coupled with some hand finishing, two crucial factors for achieving the desired balance of crop yield and quality similar to hand pruning but at lower cost. Minimal pruning has by and large proved unsuccessful in European environments, although some of its good features like looser, less rot-susceptible clusters, earlier canopy filling, lower individual shoot vigor and higher vine capacity can be reproduced using a semi-minimal pruned hedge (SMPH) system to better control over-cropping while maintaining desired grape composition. For instance, the best option for winter mechanical pruning in Italian districts today is the single high-wire cordon managed to maintain upright canopy growth for fast and physiologically sound cutter-bar pruning with little or no manual follow-up. A more comprehensive outlook seems to presage robotics for "precision" pruning to deliver a bud load that is adjusted to vine vigor and desired crop level.

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1. Introduction

Winter pruning in Europe is closely bound to tradition and still considered a primary field skill. Resorting to mechanical pruning is often skeptically regarded because it is typically non-selective and because manual "aesthetics" still count, especially in premium wine production districts (Fig. 1). Yet this attitude is found in both the Old and New World. One example is Italy. While mechanical winter pruning is on the rise, it is practiced erratically and mainly confined to specific areas like the Lambrusco district that relies on Geneva Double Curtain trellising (Intrieri and Poni, 2000). Another is California. The adoption by 2012 of box-hedged pruning with little or no manual follow-up regarded only 5% of total acreage, whereas machine pre-pruning with hand follow-up was employed

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Fig. 1. Hand spur pruning (panels A, B), mechanical pre-pruning followed by hand finishing (panel C) and a detail of a cordon after several consecutive years of mechanical pruning (panel D).

in about 50% of its vineyards (Greenspan, 2007; Dokoozlian, 2013). Yet this comparison must also take into account that, although its skilled vineyard labor pool is shrinking and overhead costs have been steadily rising, California's overall labor supply and overhead remain relatively favorable compared to those in other parts of the country and the world.

The gap between actual adoption of machine winter pruning and the amount of information gathered since the early 1970s on vine physiological and performance responses to it is notable. What is disappointing is that trials carried out in Europe and beyond have shown that the likelihood of a vine reaching an appreciable balance of crop load to grape composition when subjected even to long cycles of mechanical winter pruning is good (Carbonneau and Zhang, 1988; Kliewer and Benz, 1992; Andersen et al., 1996; Martinez de Toda and Sancha, 1999; Intrieri and Poni, 2000; Clingeleffer, 2000; Poni et al., 2004; Gatti et al., 2011). The same papers explain why this happens and, in the few cases where mechanization did not work, adduce the reasons why it failed.

It is thus important to re-assess certain factors in our physiological understanding of the mechanisms winter machine pruning triggers in the vine. Indeed, by including unexpected or negative responses, we shall propose a number of solutions that can accommodate an array of cases depending on cultivar, environment and crop management practices.

2. Physiological bases of winter mechanical pruning

2.1. The gold principles

A good start for explaining the physiological background of a mechanized approach to winter pruning is by asking an apparently naive question: why prune vines in winter? The most obvious answer is "to regulate crop level and achieve the desired grape composition". So, the thinking immediately goes to the need for limiting crop yield and, hence, automatically relating excessive bud load to unacceptably high yield and inadequate grape composition. Yet such a view oversimplifies the gold principles of winter pruning in grapes as cogently summarized in Fig. 2 (Winkler et al., 1974). If it is agreed that an unpruned vine bearing no crop allows maximum

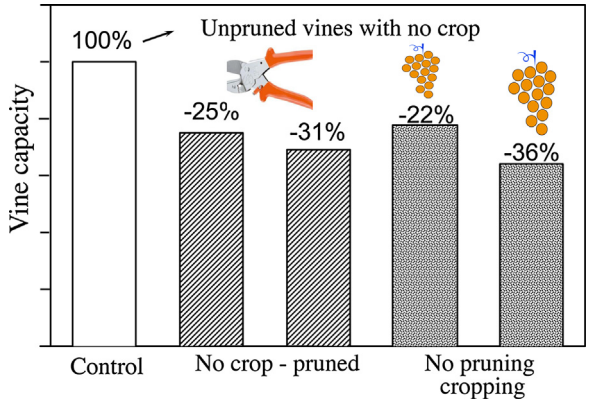

Fig. 2. Changes in vine capacity (*i.e.* total leaf area) depending upon severity of winter pruning and cropping level (redrawn from Winkler et al., 1974).

expression of vine capacity, intended as total leaf area, it follows that the same dormant vine subjected to either light or severe winter pruning will show a significant decrease in vine capacity, *i.e.* off 25% and 30%, respectively, compared to control. Therefore, it should be kept in mind that winter pruning's removal of nodes places constraints not only on yield as well as on vine capacity. To read it backwards, light mechanical pruning may result in increased vine capacity *vs*. traditional hand pruning. If such an increase is roughly proportional to the increased yield, no specific reason is foreseen to predict a worsening in final grape composition. This is the challenge posed by any mechanical approach to winter pruning and our task is to assess case studies providing clarification and matter for rethinking.

2.2. The original trial: early 1970s

In Italy the route towards winter mechanical pruning was laid out in the 1970s by introducing the Geneva Double Curtain training system (Intrieri and Poni, 2000). Once modified subsequently toward horizontal, self-supporting arms, it proved to be an ideal trellis for accommodating a tractor-mounted cutter bar unit per-