Variable-rate mechanical pruning: a new way to prune vines

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Abstract

Hand pruning is a precise operation, with a visual evaluation of each grapevine to adapt bud load to the vigor. With the advent of mechanical pruning the individual evaluation is lost, and the plant balance relies solely on self-regulation mechanisms. However, precision agriculture provides remote sensing tools for vigor evaluation that allow adapting mechanical pruning to the vine vigor. Variable-rate mechanical pruning (VRMP) could be a way of bringing the best of two worlds: time-efficiency of a mechanized operation and the plant-level accuracy of a hand-made operation. In the present study two different options were investigated as the basis for the bud load prescription map: a) images acquired from the SENTINEL-2 satellite with a spatial resolution of 10 m at processing cost; b) images acquired with a hyperspectral camera from a drone with a spatial resolution of 5 cm at acquisition and processing cost. While the images from SENTINEL-2 allow the individualizing vigor areas, the images from the drone allow evaluating a vegetation index (e.g., NDVI) per single plant. Three different vigor classes were set and, for each, a different cutting distance from the cordon was defined. Two different variable-rate mechanical pruning treatments were established, one with the cutting distance varying between NDVI areas and the other varying between individual plants, both compared with a standard mechanical pruning with a uniform cutting distance. Canopy structure, canopy microclimate, yield and grape composition were assessed to evaluate the performance of each treatment.

Keywords: precision viticulture, satellite imagery, high resolution remote sensing, balanced pruning, yield

INTRODUCTION

Winter pruning is fundamental to regulate grapevine yield and maintain a balance between vigor and capacity. According to Nikov (1987), yield increases with bud load up to a certain level, when the decline in bud burst, fruitfulness, berry set, and berry weight compensate for the increase in the nodes left in pruning. This compensation mechanisms act differently, among other factors, according to the cultivar, water availability (Freeman et al., 1979) and soil fertility (Botelho et al., 2016).

Winkler (1962) reports that the number of nodes left at pruning should be proportional to the vigor observed in the previous year. The number of nodes retained on a vine in relation to its size affects both reproductive and vegetative growth in the following year and, thereby, influences the grape quality (Lider et al., 1975; Byrne and Howell, 1978). The increase in bud load tends to increase yield and reduce vegetative growth, which leads to a decrease in the leaf area to fruit ratio and, consequently, delays ripening (Clingeleffer, 1988; Wessner and Kurtural, 2013), and affects grape quality. There is also a tendency for an increase in canopy density and a reduction in cluster exposure, also affecting grape quality (Smart et al., 1982).

Traditionally, the bud load retained on a mature vine is adjusted empirically by

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pruners. Nowadays, mechanical pruning is a system that blindly cuts canes and, consequently, bud load is independent of vine capacity. However, the development of pruning machines that can maintain a defined distance from the cutting area to the cordon and, consequently, control the spur/cane size, allows creating a mechanical pruning system that, tendentially, can adjust bud load to vine capacity. Dobrowski et al. (2003) showed that normalized difference vegetation index (NDVI) is directly correlated with dormant pruning weight, and Drissi et al. (2009) observed a good correlation between NDVI and leaf area development. Thus, NDVI is a powerful tool to evaluate vine vigor and can be used to define the pruning level in the following year.

MATERIALS AND METHODS

The trial is carried out in a vineyard of *Vitis vinifera* L. 'Trincadeira' in Quinta das Faias, belonging to the wine company José Maria da Fonseca Vinhos, S.A. The vineyard was grafted on 1103P in 2003 and was spaced 1.5×2.5 m. The training system was a cane pruned Guyot, established at 80 cm above the ground surface, with vertical shoot positioning. The vines were converted for mechanical pruning by setting a permanent cordon at 1.50 m height, with no wires above the cordon, with the vegetation growing free with no shoot positioning.

The studied factor is the type of mechanical pruning, with 3 treatments in a completely randomized design with 3 repetitions, each with 120 vines: URMP – mechanical pruning with a constant distance from the cordon; VRMPS – mechanical pruning with a variable distance from the cordon, according to the vigor areas obtained from images acquired from the SENTINEL-2 satellite with a spatial resolution of 10 m at processing cost; VRMPP – mechanical pruning with a variable distance from the cordon, according to the plant vigor images acquired with a hyperspectral camera from a drone with a spatial resolution of 5 cm at acquisition and processing cost. However, since the images to determine the plant vigor were acquired in 2018 – the year of the cordon formation – the plants had no sufficient vegetation to assess the individual NDVI, whereby the treatment VRMPP was not imposed and the plants were pruned following the VRMPS method.

The NDVI of the vineyard was assessed and different areas were classified according to the obtained values: 1 (low) – values between 0.20 and 0.25; 2 (medium) – values between 0.25 and 0.30; 3 (high) – values between 0.30 and 0.35. In this first year of the trial and since the cordon was formed in 2018, the pruning level was reduced, to avoid over cropping, and, consequently, the differences between NDVI classes in VRMP were less than they will be in the next years: URMP – mechanical pruning at 5 cm from the cordon; VRMP – mechanical pruning at 3 cm (NDVI 1), 5 cm (NDVI 2) and 7 cm (NDVI 3) from the cordon.

To determine yield components, the number of clusters per vine and its weight were assessed at harvest. In each treatment and NDVI class, the production of 6 previously selected vines was assessed. The grape composition was assessed by the laboratory analysis of 3 samples of 100 berries treatment^{-1} and NDVI class to determine potential alcoholic content, pH, total acidity, total anthocyanins, and total phenols.

The analysis of the collected data was adjusted by the average standard error with Microsoft Excel.

RESULTS AND DISCUSSION

The pruning system influenced the bud load per vine (Figure 1). In URMP, bud load was not different between different NDVI classes. On the other hand, in VRMP, the bud load was different between NDVI classes, with the higher NDVI classes having higher bud loads. Since the cordon was formed in the previous year, the differences in bud load, between NDVI classes, in VRMP, are few and that influence the obtained results, which are not as expressive as expected in the next years.

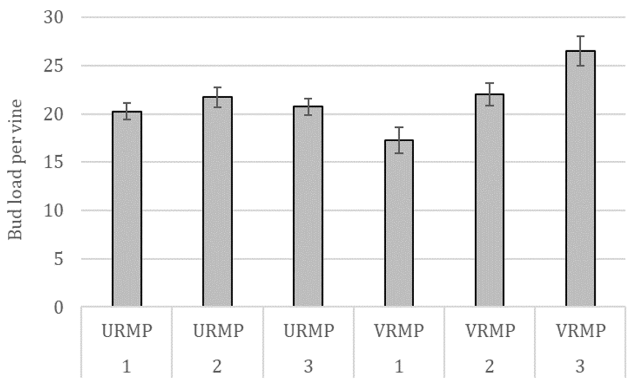

Figure 1. Influence of pruning system and NDVI areas on bud load per vine. Average of 6 vines ± S.E. NDVI classes: 1, low; 2, medium; 3, high. URMP, uniform-rate mechanical pruning; VRMP, variable-rate mechanical pruning.

The cluster number per vine (Figure 2a) was significantly different between areas with different NDVI values. As expected, vines in areas with lower NDVI values originated less clusters and, on the contrary, in the areas with the highest NDVI values vines had more clusters. On the other hand, the pruning treatment had not a significant effect on the cluster number per vine. However, there was a tendency for a higher discrepancy, between the highest and the lowest NDVI classes, in the VRMP compared to the URMP. Small differences were expected between pruning treatments, since the differences in bud load were low. Furthermore, since the initiation and differentiation of inflorescences occurred in the previous year, when no different pruning systems were imposed, the differences will likely tend to change in the following years.

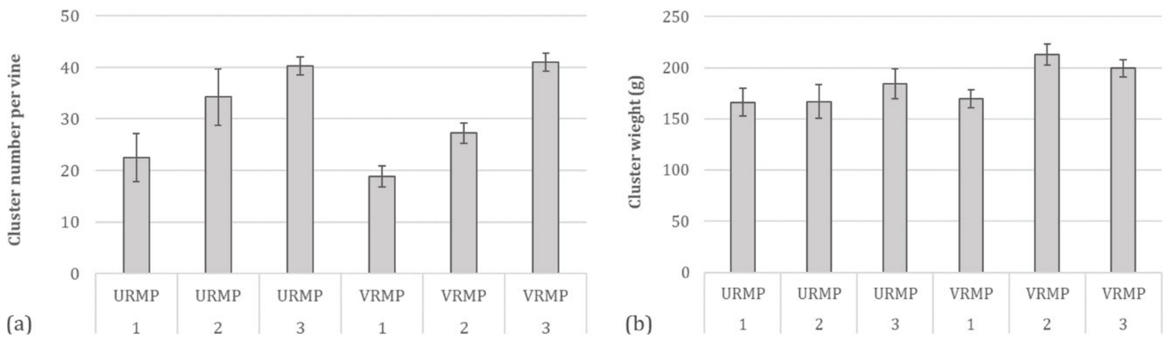

Figure 2. Influence of the pruning system and NDVI areas on cluster number per vine (a) and cluster weight (b). Average of 6 vines ± S.E. NDVI classes: 1, low; 2, medium; 3, high. URMP, uniform-rate mechanical pruning; VRMP, variable-rate mechanical pruning.

The cluster weight (Figure 2b) did not differ significantly with none of the factors. Hall et al. (2011) observed a consistent and significant correlation between NDVI and berry weight. However, in the present study, the NDVI had a good correlation with the cluster number (r=0.88) and was not significantly correlated with the cluster weight.

Yield (Figure 3) was significantly different between different NDVI areas, showing a good correlation with this index (r=0.89). Hall et al. (2011), Serrano et al. (2012), Romboli et al. (2017) and Sun et al. (2017) also found good correlations between NDVI and yield. For what concerns the pruning system, this factor did not significantly affect yield. However, as in cluster number, there was a tendency for a higher discrepancy between the extreme NDVIs in VRMP, when compared to URMP. These results were mainly a consequence of the differences observed in the cluster number per vine, since there is a good correlation between these two variables (r=0.89), and the correlation with the cluster weight is weaker (r=0.59).

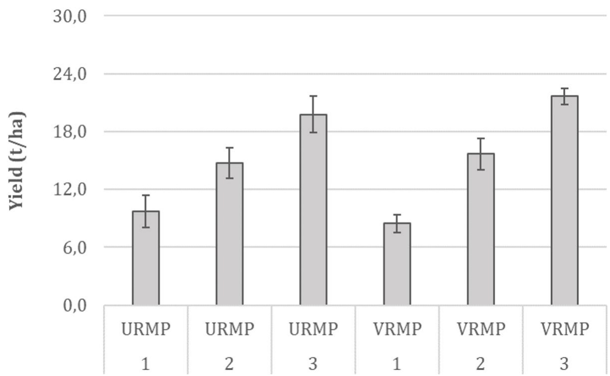

Figure 3. Influence of the pruning system and NDVI areas on yield. Average of 6 vines ± S.E. NDVI classes: 1, low; 2, medium; 3, high. URMP, uniform-rate mechanical pruning; VRMP, variable-rate mechanical pruning.

The grape potential alcoholic content (Figure 4) was not significantly affected either by NDVI or by the pruning system. However, interesting tendencies show a decrease in the potential alcoholic content with the increase in NDVI in URMP, while that decrease does not occur in the VRMP. Fiorillo et al. (2012) and Romboli et al. (2017) also found a reduction of the sugar content with increasing NDVI. However, in VRMP, that decrease does not seem to occur, possibly related to the balance between reproductive and vegetative growth affected by the pruning level. The results show a tendency for higher homogeneity, in terms of sugar content, of the grapes produced by VRMP compared to URMP.

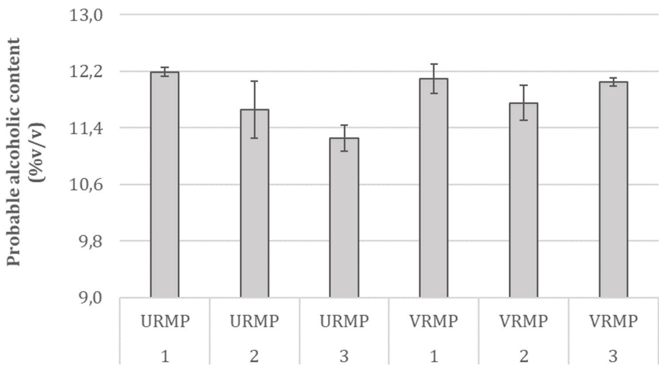

Figure 4. Influence of the pruning system and NDVI areas on potential alcoholic content. Average of 3 samples of 100 berries ± S.E. NDVI classes: 1, low; 2, medium; 3, high. URMP, uniform-rate mechanical pruning; VRMP, variable-rate mechanical pruning.

The grape pH (Figure 5a) and total acidity (Figure 5b) was not significantly affected by none of the studied factors. Fiorillo et al. (2012) also report a weak correlation between NDVI, assessed at several stages of berry development, and pH. On the other hand, Serrano et al. (2012) and Romboli et al. (2017) found increased total acidity with increasing NDVI. Concerning the pruning system, although the differences were not significant, there seems to be a tendency for a higher homogeneity in VRMP compared to URMP, which must be confirmed in the next years.

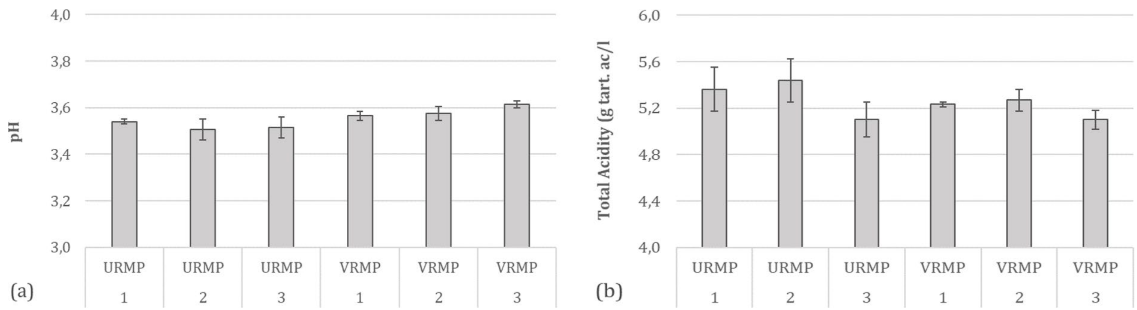

Figure 5. Influence of the pruning system and NDVI areas on grapes pH (a) and total acidity (b). Average of 3 samples of 100 berries ± S.E. NDVI classes: 1, low; 2, medium; 3, high. URMP, uniform-rate mechanical pruning; VRMP, variable-rate mechanical pruning.

Total anthocyanins (Figure 6a) and total phenols (Figure 6b) were not significantly affected either by NDVI areas or by pruning system. However, both variables tend to decrease with increasing NDVI and, concerning the sugar content, the differences between NDVI classes tended to be smaller in VRMP when compared to URMP. Nevertheless, this homogenization effect was more pronounced in probable alcoholic content than in these two variables. Hall et al. (2011) and Fiorillo et al. (2012) also observed a decrease in anthocyanins and polyphenols with increasing NDVI.

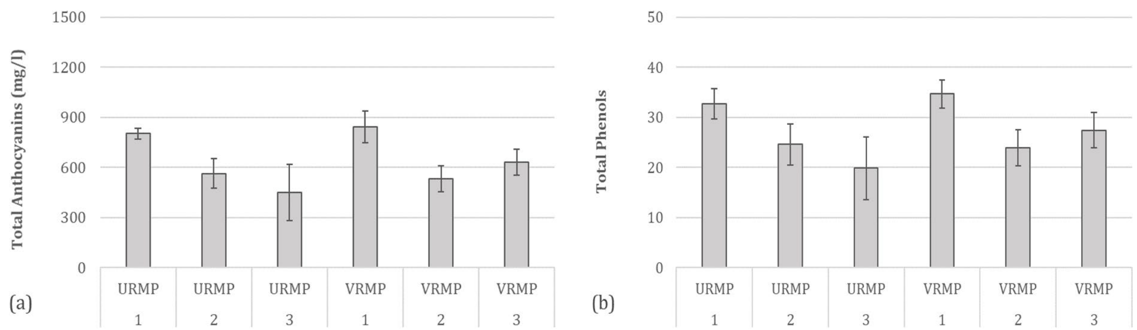

Figure 6. Influence of the pruning system and NDVI areas on grape total anthocyanins (a) and total phenols (b). Average of 3 samples of 100 berries ± S.E. NDVI classes: 1, low; 2, medium; 3, high. URMP, uniform-rate mechanical pruning; VRMP, variable-rate mechanical pruning.

CONCLUSIONS

So far, mechanical pruning is a system that does not adapt the pruning level to the vine capacity, as hand pruning usually does. However, in the last years, the development of more sophisticated machines that can maintain the distance from the cutting zone to the cordon, allows regulating that distance to adapt the pruning level to the vine vigor.

Variable-rate mechanical pruning tended to increase yield in the most vigorous areas and reduce it in the least vigorous ones, balancing the vines by adapting the crop load to their capacity. While the yield differences between NDVI classes tended to be higher, the grape quality tended to be more uniform. The higher NDVI areas produced grapes with improved quality, while the lower NDVI areas maintained the quality standards.

Globally, the yield in VRMP tended to be slightly higher than in URMP. However, a more important difference is the overall grape quality, which was tendentially improved by VRMP. The first results of this trial, which must be validated in the next years, are promising and VRMP seems to be a reliable method to balance mechanical pruning.

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