Mechanical pruning in non-irrigated vineyards: effects on yield and grape composition of cultivar 'Syrah' (*Vitis vinifera* L.)

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Abstract

The effect of mechanical pruning on vine performance and wine quality was evaluated from 2012 until 2015. Two trial fields, with a randomized complete block design, were established on already existing 'Syrah' vineyards in Quinta do Côro and Quinta do Gradil, located in Tejo and Lisboa wine regions respectively. Mechanical pruning (MEC) was simulated by trimming all shoots to a 15 cm square around the cordon. Manual pruning (MAN) treatment was subjected to a traditional spur pruning. MEC tended to increase water consumption due to the higher proportion of exposed leaf area, since the total leaf area per vine was not different from MAN. The transpiration and photosynthetic rates were tendentially lower in MEC, indicating an adaptation to more stressful conditions. Yield was higher in MEC, while the individual shoot vigour and the total amount of pruning wood were lower in MEC. These results led to higher values of the Ravaz index in this treatment, reflecting changes in the partitioning of carbohydrates that were redirected from vegetative to reproductive growth. Total dry matter production (DMP) was mainly not affected by the pruning system, even in years with lower water availability. In 2014, when water was not a limitative factor, the total dry matter production was higher in MEC. The DMP in MEC was not reduced along the trial, suggesting that reserves accumulation have not been restricted. The grape composition, analyzed in 2013 and 2014, has not been significantly affected, with the exception of the total soluble solids content (TSS) and the pH, in 2014, which were lower in MEC. The results indicate that mechanical pruning is a reliable instrument to improve vine performance in non-irrigated vineyards, increasing yield without quality loss, even in dry years.

Keywords: mechanical pruning, water scarcity, dry matter partitioning, yield and quality

INTRODUCTION

With the generalization of mechanical harvest, winter pruning is the operation that demands more hand labor in viticulture (Clingeleffer and Krake, 2002). Furthermore, the availability of skilled vineyard workers is decreasing and the cost of their work is steadily rising. The adoption of mechanized pruning systems leads to reductions of hand labor needed for this task, from 54 to 70% and significant increases in production without loss of quality (Gatti et al., 2011), except where production exceeds the productive capacity of vines, and may even result in increasing quality (Intrieri et al., 2011; Terry and Kurtural, 2011).

Carbonneau (1983) proposes the use of mechanized pruning systems, like hedge pruning, in situations where auto-regulation doesn't affect maturation. According to Clingeleffer (1988), the higher yields and the associated lower leaf area to fruit ratios tend to delay maturation in vines subjected to mechanical pruning. Therefore, the decision of adopting these pruning systems must have in account the ripening period of each cultivar and the objective of the production.

Since bud load drastically increases, changes in carbohydrates production and partitioning occur when mechanical pruning is established. The higher bud load lead to an increase in the shoot number per vine and to a reduction of shoot individual weight (Reynolds and Wardle, 1993; Castro et al., 2010). The total pruning weight per vine is also reduced but, in a global perspective, mechanical pruned vines are more efficient, since they invest less energy in cane formation, redirecting the higher available carbohydrates to reproductive growth and to the formation of reserves (Clingeleffer and Krake, 1992; Weyand and Schultz, 2006).

However, the development of many shoots creates a higher leaf area, particularly during the early part of the season (Smithyman et al., 1997), although this difference may maintain until the end of the cycle (Schmid and Schultz, 2000; Botelho et al., 2012). The increase in leaf area intensifies the water consumption, although some reduction in the transpiration rate per leaf unit area is usually observed (Schmid and Schultz, 2000). The effect of mechanical pruning, under drought conditions, was studied by Martinez de Toda and Sancha (1999) with 'Grenache', an isohydric cultivar according to Schultz (2003). Despite the good results obtained with that cultivar, the application of mechanical pruning, under drought conditions, on an anisohydric cultivar may lead to different conclusions and requires additional study, which is the objective of the present work.

MATERIALS AND METHODS

The trial, run over four years (2012 to 2015), was installed in two vineyards of *Vitis vinifera* L. 'Syrah'. Quinta do Côro (QC) experimental site is located in Tejo wine region and the vineyard had been grafted on 99R in 1999 and spaced 1.0×2.5 m. In Quinta do Gradil (QG) experimental site, which is located in Lisboa wine region, the vines, grafted on 1103P, were planted in 2005 and spaced 1.0×2.6 m. The training system was a spur pruned Royat cordon, established at 70 cm above soil surface, with vertical shoot positioning.

The studied factor is pruning and 2 treatments were imposed in a randomized complete block design, with three blocks of 48 vines in each trial field: MAN – manual spur pruning, retaining six to seven 2-bud spurs per vine; MEC – mechanical pruning, simulating the pruning effect of four cutting bars (2 parallel and 2 perpendicular to the ground) working at a distance of 15 cm from the cordon. In MAN treatment, shoots were oriented using mobile wires, while in MEC the wires stayed in the same position (40 cm and 80 cm above the cordon) the whole year, and shoots were not oriented.

The soil water content in the root zone was determined using the predawn leaf water potential (ψ_p), which was assessed with a pressure chamber, as described by Scholander et al. (1965), throughout the growing season until close to harvest. In each pruning system were collected 6 mature leaves from the middle third of the canopy. Photosynthetic and transpiration rates were assessed at solar zenith on 3 mature leaves, from the middle third of the canopy, using an infrared gas analyzer (ADC-LCA4).

In order to determine yield components, the number of clusters per vine and its weight were assessed at harvest. In each treatment, the production of 36 previously selected vines was assessed. During pruning, the number of canes per vine and their weight was measured, in order to evaluate the effect of the different treatments on vegetative growth. The dry matter production was calculated as proposed by Carbonneau and Cargnello (2003): DMP = 0.2 * yield + 0.5 * pruning weight. The vines where the pruning data was collected were the same 36 that were evaluated at harvest. The grape composition was assessed by the laboratorial analysis of 6 samples of 100 berries per treatment to determine: probable alcoholic content (PAC); pH; total acidity; anthocyanins content and total phenols.

The analysis of predawn leaf water potential as well as of photosynthetic and transpiration rates were corrected by the average standard error with M.O. Excel. Statistical analysis was done by one-way analysis of variance (ANOVA), using the general linear model, and F test. Since the experimental site interaction with the pruning system was never significant, its values are not presented.

RESULTS AND DISCUSSION

Looking to the seasonal evolution of photosynthetic and transpiration rates (Figure 1), expressed in a unit leaf area basis, both rates are, tendentially, higher in MAN, even when the differences in soil water content (Figure 2) are few, showing an adaptation of mechanically pruned vines to control water loss and adapt to more stressful conditions. According to Lovisolo and Schubert (2000), downward shoots have lower hydraulic conductivity, what may explain the differences in transpiration rate. Furthermore, Rogiers and Clarke (2013) observed that stomatal conductance decreases when the root zone temperature (15cm depth) is lower and, since in MEC there is a greater area of soil, under the vine, that is shadowed by the foliage, this effect may also contribute for the lower transpiration rates observed in MEC.

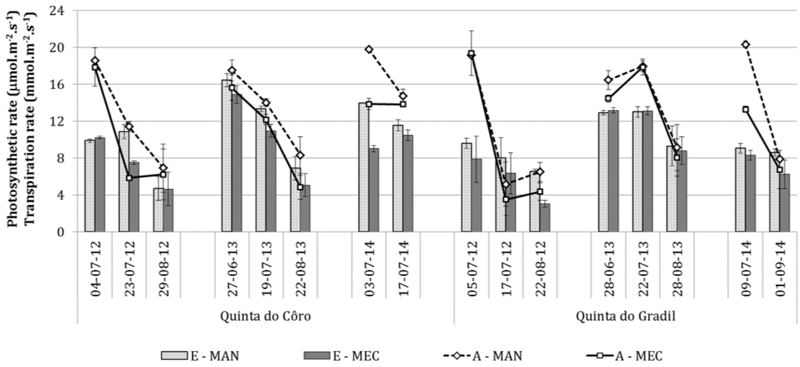

Figure 1. Seasonal evolution of the photosynthetic and transpiration rates of ‘Syrah’ vines subjected to mechanical pruning (MEC) and manual pruning (MAN). Average of 3 leaves ± S.E.

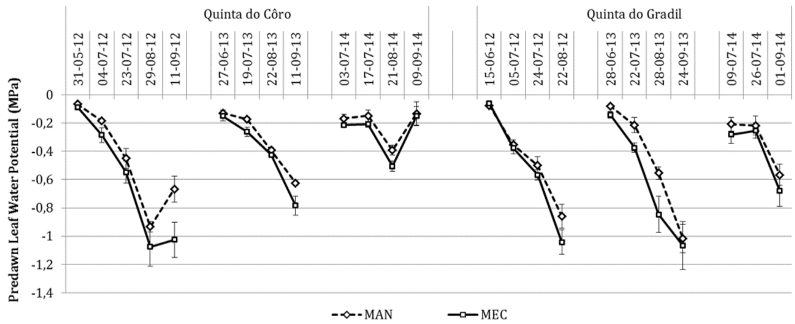

Figure 2. Seasonal evolution of the predawn leaf water potential of ‘Syrah’ vines subjected to mechanical pruning (MEC) and manual pruning (MAN). Average of 6 leaves ± S.E.

The seasonal evolution of predawn leaf water potential (Figure 2) shows a decrease of water availability in soil along the season, except in 2012 and 2014 in QC, when some rainfall in late season increased the water content in the root zone. The values attained in 2012 and 2013 (-0.8 to -1.2 MPa) are indicative of severe water stress, according to Deloire et al. (2004). Analyzing the differences between treatments, there is a tendency for lower soil water content in the root zone in MEC, revealing higher water consumption by the plants subjected to mechanical pruning. Schmid and Schultz (2000) also observed higher water consumption in vines mechanically pruned, attributing this result to their higher leaf area, since the transpiration rate was lower. In this study, the difference in total water consumption cannot be attributed to the leaf area per vine, since it was equal between systems (data not shown). However, the lack of shoot positioning, in MEC, led to a sparser canopy, where the proportion of exposed leaves was higher.

The number of clusters per vine (Table 1) was significantly higher in MEC, while the cluster weight was significantly lower in this treatment. Due to the higher bud load left by hedge pruning, the cluster number in MEC was 53% higher, when compared to MAN, while the cluster weight was only 38% lower. As result, the yield was higher in MEC in three of the four years of the study and, in an overall analysis, this treatment produced significantly more than MAN. These results were also obtained by Freeman and Cullis (1981), Martinez de Toda and Sancha (1999) and Intrieri et al. (2011).

Table 1. Yield components of 'Syrah' vines subjected to mechanical pruning (MEC) and manual pruning (MAN). Data are means of 36 vines from both experimental sites. The interaction between pruning and experimental site was never significant.

	Clusters per vine				Cluster weight (g)				Yield (kg vine^{-1})			
Year	1	2	3	4	1	2	3	4	1	2	3	4
MAN	33.3	28.8	27.7	45.7	137	140	163	142	18.2	15.7	18.1	25.1
MEC	58.8	67.0	78.4	86.0	99	76	100	86	22.3	20.2	31.7	29.1
Sig.	***	***	***	**	*	**	***	**	*	**	**	*n.s.*

Sig. – Significance level; n.s. – non-significant at 5% level by F test; significant at 5% (*), 1% (**) and 0.1% (***) by F test.

The number of shoots per vine (Table 2) was significantly higher in MEC, while shoot weight was lower. However, in this case, the pruning weight per vine was significantly lower in MEC since the difference in shoots number was 38% and in shoots weight was 53%. Pellegrino et al. (2014) found similar results, but Martinez de Toda and Sancha (1999), working with a non-irrigated vineyard in a Mediterranean climate, did not observe different pruning weight per vine, nevertheless in this case the total leaf area per vine was significantly higher in mechanical pruning. In the present work the total leaf area per vine was equal between pruning treatments, so the available carbohydrates were preferably redirected to the reproductive growth, reducing the vegetative expansion.

Table 2. Vine growth of 'Syrah' vines subjected to mechanical pruning (MEC) and manual pruning (MAN). Data are means of 36 vines from both experimental sites. The interaction between pruning and experimental site was never significant.

	Shoots per vine				Shoot weight (g)				Pruning weight (kg vine^{-1})			
Year	1	2	3	4	1	2	3	4	1	2	3	4
MAN	19.4	20.2	21.5	21.8	40.8	46.5	58.4	48.5	0.812	0.943	1.219	1.065
MEC	27.1	33.6	37.2	36.2	26.2	21.3	22.2	18.6	0.710	0.738	0.838	0.697
Sig.	***	***	***	***	**	***	***	***	n.s.	*	**	**

Sig. – Significance level; n.s. – non-significant at 5% level by F test; significant at 5% (*), 1% (**) and 0.1% (***) by F test.

Although there is a tendency for higher total dry matter production in MEC (Table 3), the difference, between treatments, is significant only in 2014 when water availability in soil was higher. However, in an overall analysis MEC produced significantly more dry matter in clusters and canes, than MAN. Since mechanically pruned vines direct carbohydrates preferably to perennial wood, rather than to canes (Clingeleffer and Krake, 1992), there is a clear increase in vine capacity with this pruning system.

Table 3. Annual dry matter production of 'Syrah' vines subjected to mechanical pruning (MEC) and manual pruning (MAN). Data are means of 36 vines from both experimental sites. The interaction between pruning and experimental site was never significant.

	Dry matter production (t ha^{-1})			
Year	1	2	3	4
MAN	5.23	5.00	6.00	7.12
MEC	5.86	5.49	7.99	7.18
Sig.	n.s.	n.s.	*	n.s.

Sig. – Significance level; n.s. – non-significant at 5% level by F test; significant at 5% (*) by F test.

The dry matter production did not decrease along the years, what shows that mechanical pruning did not reduce the vine capacity over time, even in dryness conditions. Martinez de Toda and Sancha (1999) found the similar results in an 11-year trial with Grenache.

The grape composition (Table 4), analyzed in 2013 and 2014, has not been significantly affected, with exception of the total soluble solids content (TSS) and the pH, in 2014, which were lower in MEC. The lower sugar content and pH reflect a delay in ripening in 2014, when the difference in yield was higher. According to Clingeleffer (1988), the higher yields and the associated lower leaf area to fruit ratios tend to delay ripening, in vines subjected to mechanical pruning. So, it is conceivable that if the two treatments were harvested at different dates, the results would be different. The total sugar production per vine was higher in MEC in both years, as observed by Martinez de Toda and Sancha (1999). In terms of anthocyanins content and total phenols, two characteristics that have a strong influence in the wine quality, no significant differences were observed between treatments.

Table 4. Grape composition of 'Syrah' vines subjected to mechanical pruning (MEC) and manual pruning (MAN). Data are means of six 100-berries samples from both experimental sites. The interaction between pruning and experimental site was never significant.

	PAC (% vol.)		pH		Total acidity (g L^{-1})		Anthocyanins (mg L^{-1})		Total phenols	
Year	2	3	2	3	2	3	2	3	2	3
MAN	13.6	13.0	3.48	3.54	5.08	5.83	1344	1133	49.3	43.1
MEC	13.4	11.9	3.44	3.45	5.19	5.70	1461	903	54.2	34.5
Sig.	n.s.	*	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Sig. – Significance level; n.s. – non-significant at 5% level by F test; significant at 5% (*) by F test.

PAC – probable alcoholic content.

CONCLUSIONS

Although mechanical pruning showed a tendency for lower transpiration and photosynthetic rates, in an overall analysis it increased total water consumption as well as total carbohydrate production. Mechanical pruning increased yield and with 20% of difference, between systems, grape composition was similar. When the difference in yield was about 40%, a delay in maturation was observed. However, anthocyanins and total phenols were never significantly affected. No decrease in vine capacity was observed along the 4-years in study.

The present results indicate that mechanical pruning is a reliable instrument to improve vine performance in non-irrigated vineyards, increasing yield without quality loss, even in dry years.

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