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The Impact of Shoot Topping Intensity on Grape Ripening and Yield of 'Chardonnay'

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ABSTRACT

In recent decades, the negative effects of climate change have resulted in the premature ripening of grapes and thus inappropriate parameters of grape maturity. The dynamics of ripening and the quality of the grapes can be influenced via the process of topping the leaf wall height. The aim of the study was to analyse the impact of shoot topping intensity on grape ripening and yield parameters. The experiment was performed on the 'Chardonnay' variety in 2018. In the experiment, 540 vines were included and exposed to three treatments: control – shoot topping (length 120 cm), low-topping (length 50 to 60 cm) and no-topping (without topping). The parameters of grape ripening (mass of 100 berries, sugar content and total acidity in grape juice) and grape yield were measured. The results of the study indicate, that leaf wall height has a significant effect on measured parameters of grape ripening and yield ($P \leq 0.05$). The earliest ripening of grapes was found with the highest leaf wall (no-topping). In this treatment, the maximum mass of 100 berries was also measured throughout the ripening period. In the low-topping treatment throughout the entire period of ripening, the mass of 100 berries was lower, sugar content (°Oe) and total acidity (g/L) were also lower in grape juice compared to control and non-topped vines. A low-topping resulted in a lower grape yield. The results showed that the shoot topping intensity can slow down the ripening of the grapes and thereby reduce the negative effects of climate change.

Key words: shoot topping, leaf wall height, climate change, grape ripening, grape yield, 'Chardonnay'

INTRODUCTION

During the last three decades in the wine-growing regions of the world, climate change was most often noticeable as a trend of increasing average vegetation temperatures (Jones et al., 2005; Raifer et al., 2021). In the Podravje wine-growing region, this trend was expressed in an increase of 0.54 °C over the last ten years (Vršič, 2016). The grape maturity is now reached between 22 to 39 days earlier than thirty years ago (Vršič, 2016). Between 1980 and 2014, there has been an increase from 5.8 to 15.1 summer days per year with a maximum daily air temperature above 30 °C (Vršič, 2016). These major climate change for the respective wine-growing area, were also confirmed by the changed Huglin helio-thermal index, which increased in the period from 2001 to 2010 from 1894 to 2002 units in comparison to the period from 1980 to 2010 (Pulko, 2016).

Higher average daily air temperatures and higher daily sun exposure affect the earlier onset of vegetation (Stoll et al., 2013) and an earlier start of all phenological stages in the grapevine (Duchene and Schneider, 2005; Petrie and Sadras, 2008; Keller, 2010; Caffarra and Eccel, 2011). This prolongs the period of intensive assimilation, which in turn affects the early or premature ripening of grapes (Stoll et al., 2013, Raifer et al., 2021). The premature ripening at higher temperatures (1.2 to 1.8 °C) in north-eastern Slovenia (Vršič et al., 2014) decreased the content of total acidity of grape juice by 1.6 to 4.4 g/L in the period from 1980 to 2013 (Vršič, 2016). In wines, however, we can expect disharmony, unbalanced alcohol content, a less fruity character (Stoll et al., 2013) and an atypical varietal aromatic profile (Renner, 2020). Vegetation length is influenced by many factors such as winegrowing region (Jones et al., 2005), rootstock and its vigor (Dias et al., 2012; Pulko et al., 2012; Pulko, 2016), variety and their clones (Raifer et al., 2002; Raifer et. al., 2004).

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In the 1980s and 1990s, the leaf wall height in Austrian (Steiermark region) viticulture was increased to ensure an appropriate ratio between leaf area and grape yield per vine (Renner, 2020). In order to achieve satisfactory photosynthesis for the appropriate grape quality, sufficient leaf surface is required which corresponds to 12-14 well-developed leaves per shoot (Koblet, 1966).

Two of the very important technological measures that can influence the size of the leaf surface during the growing season are targeted defoliation (Kliewer, 1970; Ollat and Gaudillere, 1998; Pulko, 1999; Stoll et al., 2013) and shoot topping (Stoll et al., 2010). During the shoot topping process, the tops of the shoots are removed 20 cm above the last pair of wires. This enables the removal of too long shoots, which allows better machine processing in the vineyard, protection against diseases and prevents shading in the grape zone (Vogt and Götz, 1987).

The stronger intensity of shoot topping reduces the negative effects of premature grape ripening in changed climatic conditions. As stated by Stoll et al. (2010), reducing the leaf area by shoot topping to 0.8 m2 per kg of grapes, can prolong the ripening of the 'Riesling' variety by 20 days. Similar results as with regulating the leaf surface, can also be achieved with the application of an anti-transpirant substance (Palliotti et al., 2010; Di Vaio et al., 2019).

The aim of the experiment was to determine the impact of leaf wall height by different shoot topping intensities on grape ripening parameters as well as yield, and whether this technological measure can have an impact on reducing the negative effects of climate change.

MATERIAL AND METHODS

Experimental Vineyard

The field experiment was conducted during the vegetation period of 2018 with *Vitis vinifera* L. 'Chardonnay', which was grafted onto a 'SO4' rootstock in a vineyard located in Gornja Radgona Slovenia (46° 67 N, 15° 96 E, 200 m a. s. l.). The average slope of the terrain in the experimental vineyard was 20% with southern exposure, an inter-row distance of 2.4 m, inner-row distance of 1 m, planting density of 4150 vines per ha and trained by using the double Guyot system. During the experimental period, the natural permanent green cover was used as the soil management system and the surface around the grapevines (a 0.6 m strip) was treated with herbicide.

In the experiment, 540 vines were included in three different treatments. Each treatment consisted of three repetitions, with 60 vines in each repetition. Throughout the experiment, the young shoots were inserted vertically into the wire system. The shoot topping was carried out when most of the shoots had outgrown the last pair of wires by 30 to 50 cm. Three treatments were included in the experiment. The first treatment was the control (length of shoots after topping 120 cm), the second treatment included a low-topping (length of shoots after topping 50-60 cm) and the third treatment was non-topping.

The grape ripening process was monitored between 13th and 20th of August when the berries were in the final stages of grape ripening; already sufficiently soft and appropriately coloured (yellow). In the vineyard, samples of 100 berries were collected three times on the designated sampling dates, at each replication and at different cluster positions. The samples were transferred to the laboratory in a cooling bag, where the mass of 100 berries (g) was weighed. By mashing and pressing we obtained grape juice from the berries. The sugar content (°Oe) and total acidity (g/L) were measured for each grape juice sample via refractometry and titration with NaOH. On the day of harvest, the mass of grapes per vine (yield) was weighed.

Data analysis

The data obtained in the experiment were statistically analysed using the statistical program IBM SPSS Statistical Data Editor (Version 25). An analysis of variance (ANOVA) was performed for all measured parameters. The significances of differences between means at $P \leq 0.05$ were tested using the Tukey test.

RESULTS AND DISCUSSION

Mass of 100 berries

While monitoring the grape ripening process, there were statistically significant differences in the weight of 100 berries in all treatments in all three sampling terms (Figure 4). In all three terms, the average mass of 100 berries was the highest in the non-topped treatment, followed by the control treatment, and the lowest weight of 100 berries was in low-topping ($P \leq 0.05$). In the first term (13th of August), the average mass of 100 berries was 200 g in no-topping, 179 g in the control, and 160 g in the low-topping treatment. In the second sampling period, the masses of 100 berries were higher in all treatments, and in the third sampling period, the masses of 100 berries were slightly lower in all treatments due to lack of water (drought). Similar results are also reported by Stoll et al. (2013), who found that at low-topping, the average mass of berries was 5 % lower compared to the control. The results showed that the leaf wall height reduction affected a smaller mass of berries.

Sugar content in grape juice

Figure 5 shows the dynamics of the increasing sugar content in grape juice. At all sampling dates, the highest grape juice sugar content was found in the no-topping treatment.

Figure 1: Control – topping length of shoots: 120 cm (Photo by Frangež, 2018)

Figure 3: No topping (Photo by Frangež, 2018)

Figure 2: Low-topped – length of shoots after topping: 50-60 cm (Photo by Frangež, 2018)

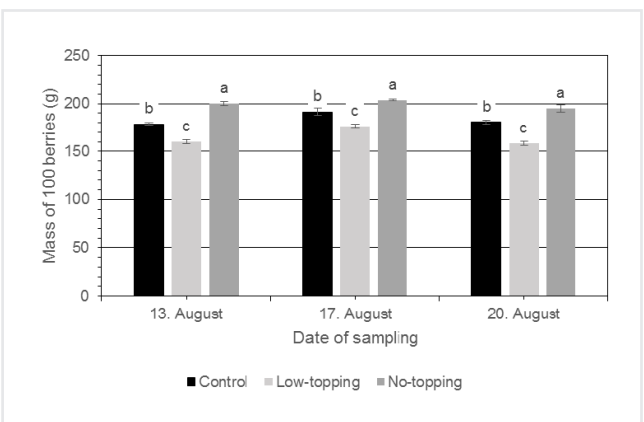


Figure 4: Mass (g) of 100 berries in ripening period

In all sampling terms, the grape juice sugar content was statistically significantly lower in the control and low-topping treatments ($P \leq 0.05$). In the no-topping treatment, the sugar content of grape juice in the first term (13th of August) was 68 °Oe and increased to 80 °Oe by the last sampling date (20th of August). At low-topping, the sugar content was 15 °Oe lower in all sampling periods compared to the no-topping treatment. When comparing the increase in sugar content during grape ripening within each treatment, it was observed that the largest difference in sugar content in grape juice between the first and last sampling period, was in the low-topping treatment (Δ 13 °Oe), followed by the no-topping treatment (Δ 12 °Oe) and the control (Δ 11 °Oe). Poni and Giachino (2000) and Stoll et all. (2013) also state that topping affects the dynamics of grape ripening and sugar accumulation in berries. Stoll et al. (2013) report that low-topping resulted in a 35 % slower grape ripening. Rodrigues da Silva et al. (2018) found that in the table grape variety ('Niagara Rorada'), with a topping of 7 to 8 leaves above the last cluster, the sugar content was higher compared to the lower topping. Renner

(2020) finds that in the 'Chardonnay' variety, when the leaf wall was reduced by 1/3, the sugar content decreased by 0.3 to 0.6 °KMW compared to the control. The results of our experiment confirmed the findings of the aforementioned research, regarding the leaf wall height reduction effect on the sugar content of grape juice.

Total acidity in grape juice

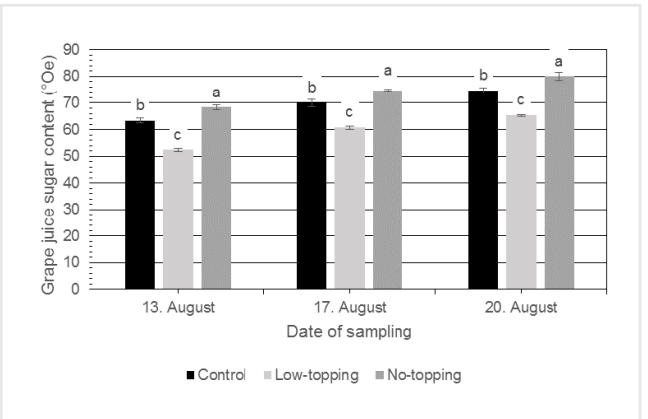
As shown in Figure 6, at the first and second sampling date (13th and 17th of August), the low-topping and no-topping treatments differed statistically significantly in the content of total acidity in grape juice. At the third sampling (20th of August), all three treatments differed statistically significantly ($P \leq 0.05$). In all sampling terms, the highest content of total acidity in grape juice was found in the low-topping treatment. In this treatment, the total acidity content in the first sampling period (13th of August) was 13 g/L and decreased to 10.4 g/L (Δ 2.6 g/L) by 20th of August. In the control treatment, the total acidity decreased from 11.6 g/L to 9.9 g/L (Δ 1.7 g/L). In the no-topping treatment, the lowest total acidity was measured at all sampling dates, the difference between the first and last term being 0.9 g/L. The results of Poni and Giachino (2000) also confirm that the intensity of the topping affects the content of malic and tartaric acid in grape juice. The same was observed by Renner (2020), where he states that the content of total acidity at low topping was 0.4 g/L higher than in the control. The leaf wall height reduction caused a slowing down of the organic acid decomposition in grape juice, which resulted in the highest values of total acidity in the low-topping treatment.

Grape yield

The results in Figure 7 show, that the average mass of grapes ranged from 3.5 kg to 5.4 kg per vine. The extreme reduction in leaf wall height in the low-topping treatment had a negative effect on grape yield. At the time of harvest, the mass of grapes per vine was statistically significantly lower in this treatment, compared to the control and no-topping treatment ($P \leq 0.05$). As stated by Stoll et al. (2013), the low-topping resulted in higher yield of 'Riesling' grapes compared to the control. The authors explain that the reason for such a difference in yield was grey mold on the grapes in the control treatment (no-topping treatment). Part of the grapes were therefore not included in the total mass of grapes. We can assume, that the yield of grapes is highly dependent of the leaf wall height. A larger mass of grapes can be expected from vines where the shoots are not topped during the growing season. A stronger reduction of the leaf wall results in a lower grape yield.

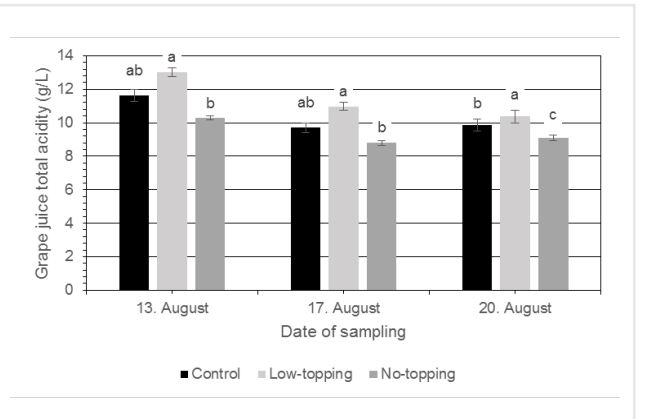
CONCLUSION

Shoot topping is a well-established technological process in viticulture for leaf area management. The past tendency to keep as high a leaf wall as possible, has led to a too rapid grape maturation in changed climatic conditions. Our experiment indicates, that by reducing the height of the leaf wall by topping, we can slow down the process of grape ripening and thus obtain grape juice with a higher total acidity, but this process also negatively impacts the grape yield at the same time.



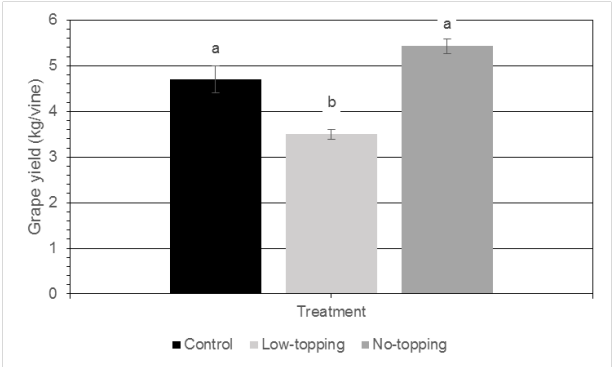
a, b, c – different letters represent statistically significant differences between treatments within a term ($P \leq 0.05$), values are shown as means ± standard errors

Figure 5: Sugar content in grape juice in ripening period (°Oe)



a, b, c – different letters represent statistically significant differences between treatments within a term ($P \leq 0.05$), values are shown as means ± standard errors

Figure 6: Total acidity of grape juice in ripening period (g/L)



a, b, c – different letters represent statistically significant differences between treatments within a term (P ≤ 0.05), values are shown as means ± standard errors

Figure 7: Grape yield at harvest (kg/vine)

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Vpliv intenzitete vršičkanja na dozorevanje in pridelek grozdja sorte 'Chardonnay'

IZVLEČEK

Negativni vplivi klimatskih sprememb so v zadnjih desetletjih rezultirali v prezgodnjem dozorevanju grozdja in s tem neustreznimi parametri zrelosti grozdja. Na dinamiko dozorevanja in kakovost grozdja lahko vplivamo z regulacijo višine listne stene s postopkom vršičkanja. Namen poskusa je bil analizirati vpliv intenzitete vršičkanja na parametre pridelka in dozorevanja grozdja. Poskus smo izvedli pri sorti 'Chardonnay' v letu 2018. V poskus je bilo vključenih 540 trsov v treh obravnavanjih: kontrola (vršičkano pri dolžini mladik 120 cm), nizko vršičkano (dolžina mladik 50 do 60 cm) in nevršičkano. V poskusu smo merili parametre dozorevanja grozdja (masa 100 jagod, vsebnost sladkorja in skupnih titracijskih kislin v grozdnem soku) ter pridelek grozdja. Na osnovi rezultatov meritev lahko potrdimo, da ima višina listne stene statistično značilen vpliv na merjene parametre dozorevanja grozdja in količino pridelka ($p \leq 0,05$). Ugotovimo lahko, da zniževanje višine listne stene upočasni dozorevanje grozdja in vpliva na zmanjšanje pridelka grozdja. Najzgodnejše dozorevanje grozdja je bilo pri obravnavanju z najvišjo listno steno (nevršičkano). Pri tem obravnavanju je bila ves čas dozorevanja grozdja izmerjena tudi največja masa 100-tih jagod. Pri obravnavanju nizko vršičkano je bila v času spremljanja dozorevanja grozdja manjša masa 100 jagod, v grozdnem soku pa je bila manjša vsebnost sladkorja (°Oe) in največja vsebnost skupnih titracijskih kislin (g/L) v primerjavi z nevršičkanimi trtami in kontrolo. Nizko vršičkanje je vplivalo na zmanjšanje pridelka grozdja. Rezultati so pokazali, da lahko z intenziteto vršičkanja upočasnimo zorenje grozdja in s tem zmanjšamo negativne učinke klimatskih sprememb.

Ključne besede: vršičkanje, višina listne stene, podnebne spremembe, dozorevanje grozdja, pridelek, 'Chardonnay'