HEAT BERRY: THE INFLUENCE OF ABIOTIC FACTORS ON THE COMPOSITION OF BERRIES, MUST AND WINE IN VITIS VINIFERA L. CV. RIESLING

HEAT BERRY: L'INFLUENCE DE FACTEURS ABIOTIQUES SUR LA COMPOSITION DES BAIES, DES MOÛTS ET DES VINS DE *VITIS VINIFERA* L. CV. RIESLING

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Abstract:

It has been known for a long time that altering microclimate affects fruit composition and wine quality. The research project *Heat Berry* focuses on future scenarios of the climate change regarding higher temperatures and the risk of increasing sun radiation to the fruit. Field experiments were conducted in 2015 and 2016 at an experimental site at Geisenheim (Germany) using Riesling (clone 198-25 grafted to rootstock SO4). The aim of this study was to investigate and separate the effect of higher temperature to the fruit and higher light exposure in the bunch zone. Therefore, an experimental setup was designed to increase temperature inside the bunch zone (up to max. 3 °C on average) as well as defoliation and shading to influence the light exposure of the bunches. In addition, some physiological parameters and maturity measurements (Brix, yeast available nitrogen, organic acids) were determined. Aroma measurements focused on monoterpenes, C_{13}-Norisoprenoids and polyphenols in berries as well as in samples of small scale vinification. A special focus lies on the C_{13}-norisoprenoid TDN (1, 1, 6-trimethyl-1, 2-dihydronaphthalene). It is mostly present in mellow, aging Riesling wines and associated with a petrol taint in the sensory perception. Whether the origin of TDN is connected to viticultural and abiotic factors like temperature or sun exposure will be discussed.

Keywords: climate change, light exposure, *Vitis vinifera*, 1,1,6-trimethyl-1,2-dihydronaphthalene

1. Introduction

The Intergovernmental Panel of Climate Change (IPCC) published in their fifth Assessment Report that the global surface temperature is likely to rise. There are two scenarios given for the end of 21st century, in the lowest emission scenario the temperature will rise between 0.3 to 1.7 °C, in the highest emission scenario the temperature range will be between 2.6 °C and 4.8 °C (Cubasch et al., 2013). The aim of the United Nations Framework Convention on Climate Change (UNFCCC) is to limit the global warming well below 2 °C (UNFCCC, 2015).

The global warming will influence agriculture including viticulture. The higher temperatures are already impacting on phenology in many crops including an early bud burst and an earlier onset of ripening. Higher radiation increases the risk of sunburn to the berries and to the leaves, impacting the yield. The higher radiation and temperatures have strong influence on the aroma of the berries and later to the wine. A loss of some typical aroma for any given region may occur, i.e. changes in the acid composition or alcohol content. All this factors influence the fermentation, the ageing potential and hence the taste of the final product (Mira de Orduña, 2010; Keller and Molitor, 2016).

The aim of this study will be to investigate the impact of increasing temperature and higher sun radiation, to fruit components and wine quality aspects using the white variety of Riesling (*Vitis vinifera* L.).

There have been studies for Riesling about defoliation looking at the phenols (Friedel et al., 2015), monoterpenes (Sasaki et al., 2016; Friedel et al., 2016) and also looking at the C_{13}-norisopreoids (Kwasniewski et al., 2010; Meyers et al., 2013; Schüttler et al., 2015). However, either light conditions or vine´s water status was altered whilst temperature was maintained. There have been studies about direct and indirect treatments to influence the effect of the temperature. However, separating the factors light from temperature is not an easy task. Based on the experience of Sadras and Soar (2009) our aim was to establish a system which will enable to increase the temperature of the fruiting zone within a VSP (vertical shoot positioning) system without influencing the light conditions.

The results of free Linalool, bounded TDN and the ratio of malic acid and tartaric acid will be shown in this manuscript. Linalool is known to be strongly influenced by the amount of sun radiation. Higher sun radiation causes higher amounts of Linalool (Friedel et al., 2016; Sasaki et al., 2016). It's also known that malic acid decreases with higher temperatures (Lakso and Kliewer, 1975; Ruffner, 1982). The results of TDN are presented because they are one of our main research interests. Schüttler et al., 2015 have shown an impact of the defoliation to the increasing amount of bounded TDN in grape juice.

Materials and methods

The experimental site was located in Rüdesheim/Rheingau (49°59´20" N; 7°55´56" E) and planted using *Vitis vinifera* L. cv. Riesling (clone Gm 198-25; grafted on rootstock SO4-Gm47). The vineyard was established in 2007 with a VSP trellis system (row distance 2.10 m; plant distance 1.05 m). The row orientation is North-South. Four different treatments were investigated. Control (CON), an early defoliation (DEF_E), a late defoliation (DEF_L) as well as a chimney construction to increase temperature (HEAT). 75% of the leaves were removed on both sides of the canopy for the defoliation, the time points were pea corn size (DEF_E) and veraison (DEF_L). Every treatment had four replicates in both years (2015 and 2016). For the CON, DEF_E and DEF_L each replicate included eight vines in 2015. In 2016 the experiment was extended that each replicate included 18 vines.

The chimney was set up at the same time as the DEF_E was conducted. The chimney (Figure 1) was built on both sides of the row using greenhouse foil (FVG Sun Saver Clear 5-ST, 180 µm,3-layer Coex film made of polyethylene). The material was mounted on bars from a hail protection system.

In 2015 two chimneys were set up covering twelve vines, respectively. Each chimney had two replicates with four vines each and two buffer vines on either side. In 2016 four chimneys were set up. Each replicate included 18 vines with two buffer vines on either side.

Every replicate had data loggers recording the temperature and humidity in five minute intervals during the experiment.

During the growing season maturity measurements were conducted. 40 berries (20 berries from either side) were collected. Brix, yeast available nitrogen and organic acids were determined of fresh berry samples. The organic acids were analysed by high performance liquid chromatography (HPLC) refractive index detector (RID)/ultraviolet/visible detector (UV/vis).

For aroma analysis of monoterpenes and C_{13}-norisoprenoids 200 berries were collected (100 berries from each side, cut after the stem, freeze dried with liquid nitrogen and flushed with CO_2). The samples were stored at -20 °C until analysis. The berries were blended (Bomann hand blender, SM 384 CB) and kept cool in an ice bath. The blended samples were centrifuged, afterwards the must was analysed. The volatiles released to headspace (HS) were collected using solid phase micro extraction (SPME) and analysed by gas chromatography mass spectrometry (GC-MS). Since monoterpenes and C_{13}-norisoprenoids are present in grapes in free and in glycosidically bounded form, the bounded compounds were concentrated by solid phase extraction (SPE) and released through acid hydrolysis. The released compounds were analysed by HS-SPME-GC-MS like the free compounds (manuscript in preparation). The method is based on the work of Kwasniewski et al., 2010 and Yuan and Qian, 2016.

For statistical analysis a two-way analysis of variance (ANOVA) with subsequent pairwise multiple comparison (Student-Newman-Keuls Method) was carried out (SigmaPlot version 11.0, Germany).

Results and discussion

Figure 2 shows the impact of the chimney construction on temperature during a day course. The effect is based on the passive sunlight at the bunch zone. During sunny days the chimney was able to heat up the bunch zone up to 3 °C on average compared to the control. In the morning the chimney is slightly colder than the control, this is caused by the remaining humidity inside the chimney overnight. During evening and the early morning the treatments have the same temperature levels.

The impact of the four treatments to the ratio of malic acid and tartaric acid are presented in Table 1. In 2015 the ratio of these acids was strongly influenced after mid of September (DOY = 253). The amount of malic acid in the heated treatment decreased strongly compared to the control. When the ratio between malic and tartaric acid was compared the defoliation treatments differed compared to control. Nevertheless, the strongest influence of the ratio between tartaric acid and malic acid occurred within the heated treatment. The same trend was observed during season 2016 (data not shown). The two-way ANOVA showed a significant difference of DOY and treatment with $p < 0.001$.

Linalool is a monoterpene known to be strongly influenced by the light. In 2015 and 2016 the average amount of free Linalool was the highest within the early defoliation treatment. Also in both years the control had the lowest amount of Linalool. In 2015 the late defoliation had the second highest amount of Linalool followed by the heat treatment. In 2016 the heat treatment had slightly more Linalool then the late defoliation. Significant differences of year and treatment with $p < 0.001$ are investigated by means of a two-way ANOVA.

No free TDN was found in the berry samples. After acid hydrolysis the bounded TDN could be released and analysed. The results are summarised in Table 2. In 2015 both defoliation treatments showed the highest amount of bounded TDN. The time point of the defoliation seems to be irrelevant. The heat treatment had the lowest amount. Whether in 2016 the heat treatment and the late defoliation had the highest amount. The control and the early defoliation had comparable results. No significant difference for year and treatment could be investigated for bounded TDN through a two-way ANOVA.

In contrast to the previous year in 2016 no significant pairwise tendencies for the aromas were found.

Conclusion

The results of the temperature monitoring as well as the temperature sensitive organic acid analyses during two seasons proofed a successful design of the experiment. Regarding the aroma analysis differences can be seen but more results need to be considered. The differences between the years might have a larger effect compared to the influence of the treatments. 2015 was a hot and dry year, whereas 2016 was wet in the early ripening stages and hot in the end.

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References

CUBASCH, U., WUEBBLES, D., CHEN, D., FACCHINI, M. C., FRAME, D., MAHOWALD, N. AND WINTHER, J.-G. (2013), Introduction. In: *Climate Change 2013* The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

FRIEDEL, M., FROTSCHER, J., NITSCH, M., HOFMANN, M., BOGS, J., STOLL, M. AND DIETRICH, H. (2016) Light promotes expression of monoterpene and flavonol metabolic genes and enhances flavour of winegrape berries (*Vitis vinifera* L. cv. Riesling), *Australian Journal of Grape and Wine Research*, vol. 22, no. 3, pp. 409–421.

FRIEDEL, M., STOLL, M., PATZ, C. D., WILL, F. AND DIETRICH, H. (2015) Impact of light exposure on fruit composition of white 'Riesling' grape berries (*Vitis vinifera* L.), *Vitis*, vol. 54, pp. 107–116.

KELLER, M. AND MOLITOR, D. (2016) Yield of Müller-Thurgau and Riesling grapevines is altered by meteorological conditions in the current and previous growing seasons, *OENO One*, vol. 50, no. 4.

KWASNIEWSKI, M. T., VANDEN HEUVEL, J. E., PAN, B. S. AND SACKS, G. L. (2010) Timing of cluster light environment manipulation during grape development affects C13 norisoprenoid and carotenoid concentrations in Riesling, *Journal of agricultural and food chemistry*, vol. 58, no. 11, pp. 6841–6849.

LAKSO, A. N. AND KLIEWER, W. M. (1975) The Influence of Temperature on Malic Acid Metabolism in Grape Berries, *Plant Physilogy*, pp. 370–372.

MEYERS, J. M., SACKS, G. L. AND VANDEN HEUVEL, J. E. (2013) Glycosylated Aroma Compound Responses in 'Riesling' Wine Grapes to Cluster Exposure and Vine Yield, *HortTechnology*, vol. 23, no. 5.

MIRA DE ORDUÑA, R. (2010) Climate change associated effects on grape and wine quality and production, *Food Research International*, vol. 43, no. 7, pp. 1844–1855.

RUFFNER, H. P. (1982) Metabolism of tartaric and malic acids in *Vitis*: A review, *Vitis*, no. 21, pp. 247–259.
SADRAS, V. O. AND SOAR, C. J. (2009) Shiraz vines maintain yield in response to a 2–4°C increase in maximum temperature using an open-top heating system at key phenostages, *European Journal of Agronomy*, vol. 31, no. 4, pp. 250–258.
SASAKI, K., TAKASE, H., MATSUYAMA, S., KOBAYASHI, H., MATSUO, H., IKOMA, G. AND TAKATA, R. (2016) Effect of light exposure on linalool biosynthesis and accumulation in grape berries, *Bioscience, biotechnology, and biochemistry*, vol. 80, no. 12, pp. 2376–2382.
SCHÜTTLER, A., GUTHIER, C., STOLL, M., DARRIET, P. AND RAUHUT, D. (2015) Impact of grape cluster defoliation on TDN potential in cool climate Riesling wines, *BIO Web of Conferences*, vol. 5, p. 1006.
UNFCCC (2015) Adoption of the Paris Agreement: Report No. FCCC/CP/2015/L.9/Rev.1 [Online]. http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.
YUAN, F. AND QIAN, M. C. (2016) Development of C13-norisoprenoids, carotenoids and other volatile compounds in Vitis vinifera L. Cv. Pinot noir grapes, *Food chemistry*, vol. 192, pp. 633–641.

Table 1: Means (n = 4) ± standard deviation of the ratio between malic acid and tartaric acid during the growing season 2015. Different letters indicate significant differences for treatments according to Student-Newman-Keuls Method ($p < 0.05$).

DOY	226	240	253	267	275
CON	1.28 ± 0.11 a	0.93 ± 0.13 a	0.59 ± 0.1 a	0.46 ± 0.07 a	0.43 ± 0.04 a
HEAT	1.20 ± 0.05 ab	0.82 ± 0.04 b	0.43 ± 0.08 b	0.31± 0.07 b	0.28 ± 0.07 b
DEF_E	1.12 ± 0.03 b	0.77 ± 0.07 b	0.45 ± 0.06 b	0.35 ± 0.05 ab	0.31 ± 0.03 b
DEF_L	1.16 ± 0.04 b	0.82 ± 0.06 b	0.51 ± 0.02 ab	0.36 ± 0.04 ab	0.33 ± 0.04 b

Table 2: Means (n = 4) ± standard deviation of the mount of free Linalool [µg/L] and bounded TDN [µg/L] in must used for the small scale vinification (02.10.2015 /05.10.2016), analysed by HS-SPME-GC-MS. Different letters indicate significant differences for treatments according to Student-Newman-Keuls Method ($p < 0.05$).

	free Linalool [µg/L]		bounded TDN [µg/L]	
	2015	2016	2015	2016
CON	32.04 ± 13.62 b	32.27 ± 11.39	10.21 ± 1.58 ab	9.97 ± 2.68
HEAT	59.97 ± 30.06 a	32.80 ± 4.60	8.04 ± 2.82 b	14.60 ± 1.13
DEF_E	81.97 ± 8.23 a	48.16 ± 14.75	13.99 ± 3.32 a	10.80 ± 2.06
DEF_L	65.98 ± 13.40 a	46.84 ± 7.50	13.52 ± 2.55 a	14.56 ± 4.33

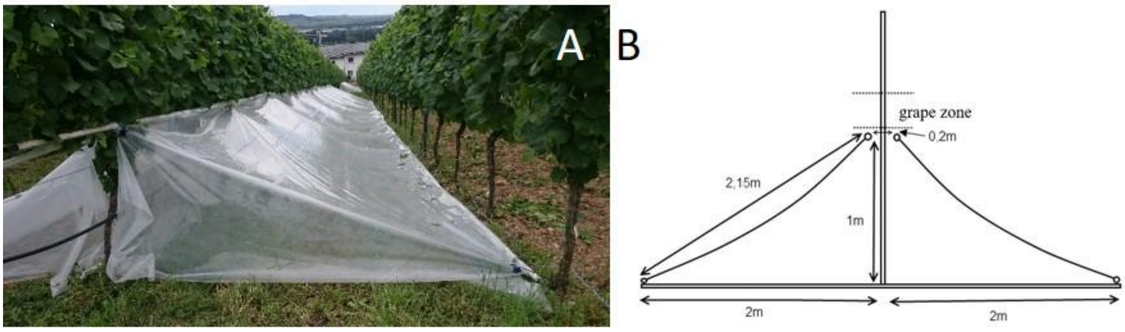

Figure 1: A: chimney construction in the vineyard (05.07.2016); B: scheme of the chimney construction.

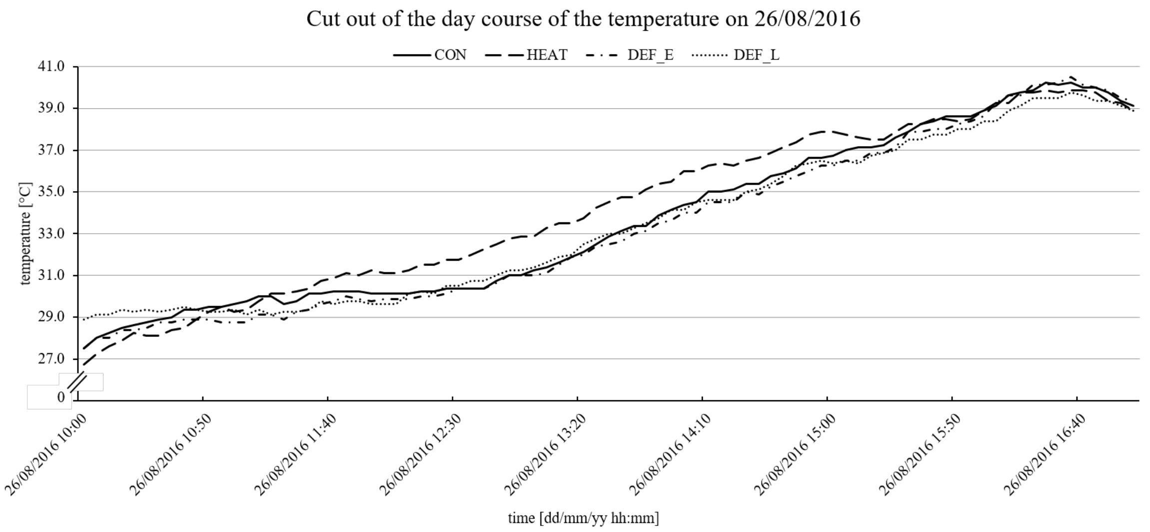

Figure 2: Day course of the temperature for the treatments control and chimney on the 26th August 2016, data points are means of the four field replicates; data points were recorded every five minutes.