IMPACT OF DEFOLIATION ON LEAF AND BERRY COMPOUNDS OF *VITIS VINIFERA* L. CV. RIESLING INVESTIGATED USING NON-DESTRUCTIVE METHODS)

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Abstract

Climate change has a strong impact on the earlier onset of important phenological stages and plant development in viticulture. Hence, the adaptation of plant management is important to reply to climate related changes on a seasonal or long-term scale. In particular, a change in precipitation and higher temperatures entails the risk negatively impacting on fruit quality. An experiment was conducted where different canopy management strategies were applied to Riesling grapevines (*Vitis vinifera* L. cv. Riesling) planted in Winkel (Rheingau, Germany). Leaf removal at different canopy positions using various methods (e.g. manual *vs*. mechanical defoliation practices) led to a reduced photosynthetic active leaf area. Through modifications of the leaf area to fruit weight ratio, the berry ripening can be altered. Leaf removal of the bunch zone impacts fruit parameter and most importantly fruit health. Four different defoliation practices within a VSP trellis system were compared to a non-defoliated control during three growing seasons in an organic treated site: mechanical defoliation above the canopy (MDC); manually defoliation prior to flowering (DpF); defoliation of the bunch zone past flowering: Bunch zone defoliation (BZD) either suction fan plucking (EB490® Binger Seilzug, Germany) and mechanical defoliation or pulsation jetting of compressed air (DmS) (Siegwald®, Germany). Non-destructive measurements using a polyphenolmeter (Multiplex®3, Force-A, Orsay, France) were performed on leaves and berries to estimate the nutrition and ripening stage.

The chlorophyll index showed the lowest values for BZD and highest for control leaves. Additionally, on-the-go measurements were established to determine leaf components achieving vineyard maps in response to nitrogen or chlorophyll index. Furthermore, the data can be used for zoning the vineyard and harvest based on such mapping. When the severity of *Botrytis cinerea* was compared to control all treatments showed lower disease pressure (BZD -5.3 %, DpF -3.0 % and DmS -2.3 % respectively). Yield differed between -16 % (MDC), -8% DpF, -1 % (DmS) and +1 % (BZD) compared to the control having the highest (1.4 g) and BZD the lowest (1.1 g) single berry weight with a lower bunch compactness in 2014. Defoliation treatments influence the number of cluster per vine, where the lowest were found for DpF plants, accompanied with the lowest yield per single vine. These results help understanding the canopy characteristics and offer an opportunity to adapt the vineyard management strategies to seasonal changes.

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Keywords: defoliation, non-invasive determination of leaf components, Multiplex, Plasmopara viticola, Vitis vinifera

1 INTRODUCTION

Adaption of vinicultural strategies in the vineyard, due to changes in vine microclimate (Jones et al. 2005), is of importance for viticulturist to preserve the standards in vine production. Therefor the ratio between vegetative and generative growth can be seen as one solution (Kliewer and Dokoozlian, 2005) to use potentials for changing the microclimate. The changing environmental conditions such as higher temperatures, unexpected heavy rain events, increasing CO_2 concentrations and altered precipitation pattern can result in a modified grapevine physiology, growth and yield (Salinari et al. 2006). The interaction between pathogens and hosts can also alter and the challenge for the next future will be to control this and develop strategies to overcome the negative effect of climate change in viticulture. In years with a low amount of precipitation during the growing season a secondary infection cycle of the zoospore of *Plasmopara viticola* is not given caused by the limiting wetness. Leaf removal of the bunch zone impacts fruit parameter and most importantly fruit health. The leaf removal during flowering and fruit set (called early leaf removal) change the fruit composition, increase the berry skin thickness and reduce in this way the risk of infection (Poni et. al 2008).

Early detection of stress symptoms caused by deficits and diseases help to react adequate with measures preserving grape quality (Stoll et al. 2011). Indicator for changes in leaf and berry compounds are chlorophyll fluorescence and nitrogen linked to photosynthetic activity and maturity level in berries (Kolb et al. 2006). Non-invasive measurement methods are suitable for the detection of changes of components in leaves and berries during the vegetation period measured in the field and during maturity control (Stoll et al. 2011). In order to determine the influence of different defoliation systems in terms of sanitary situation and phenological development linked to leaf and berry components non-invasive measurements with a phenolmeter were performed (Multiplex®3 [Mx3], Force-A, Orsay, France). The aim of the study was to investigate the influence of canopy manipulation at different canopy height with different techniques to reduce the pathogen pressure.

2 MATERIALS AND METHODS

The field site was located Schloss Vollrads (50°00'45.8"N 7°59'59.3"E, Germany). The experiment was conducted on Riesling (*Vitis vinifera* L. grafted on *V. berlandieri* x *V. riparia* cv. SO4, clone Steinberg 7 Gm). Grapevines were trained in a VSP trellis system with growing space 2.2 m². For the leaf removal four different defoliation treatments were applied at different canopy positions, manual *vs.* mechanical compared to grapevines grown under control conditions. The vineyard at Schloss Vollrads site is an organic treated vineyard. In three seasons (2013-2015) all leaves until the third inflorescence were removed prior flowering manually (DpF). The following mentioned treatments were performed mechanically: defoliation of the bunch zone after flowering with suction fan plucking (BZD, EB490 Binger Seilzug, Germany), or via pulsation jetting of compressed air (DmS, Siegwald, Germany) and defoliation above the bunch zone (MDC).
A polyphenolmeter (Multiplex FORCE-A, France) was used to measure non – invasively the leaf components such as nitrogen or chlorophyll index, anthocyanin or flavonol. The sample was illuminated with ultraviolet (UV) and red-green-blue (RGB) LED´s to excite the corresponding ingredients. Photodiodes, which are placed in the instrument, recording the emission of the sample and this gives a good correlation of the plant performance in sense of nutrition and in special cases also for leaf infection with pests (only using the Mx330). Three leaves per vine, 24 plants per replicate and treatment were measured. A further used tool was a version of the Multiplex mounted on a carrier vehicle, which allows driving through the vineyard, determining the leaf parameters and summarizing the information in a vineyard map. This information can be used for grouping for example to harvest comparable grapes.
Not only leaves but also berries were measured with this system to estimate the nitrogen and ripening status of the samples. Therefore three times nineteen berries were measured and afterwards the samples were analyzed. For berry sampling hundred berries were taken per replicate and treatment (50 berries from each canopy site). The berries were crushed using a press to determine ripening parameters like soluble sugars, total acidity, pH, N-OPA. Close to harvest disease assessment for botrytis (*Botrytis cinerea*) and three to five times for downy mildew (*Plasmopara vitiocola*) were conducted in both vineyards. The yield per single plant was determined for all replications and the total yield per treatment were determined.

3 Results and discussion

The ripening measurements of all three seasons showed a different picture: whereas in 2013 grapevines of MDC treatment had the significant lowest TSS while in 2014 for control plants and 2015 grapevines defoliated with the Sigwald (DmS) a lower TSS was observed. The level of yeast available nitrogen in the samples was in 2014 (maximum 60 mg l^{-1}) and 2015 (maximum 80 mg l^{-1}) relatively low compared to 2013 (140 mg l^{-1}). The yeast available nitrogen showed close to harvest in 2014 and 2015 relatively low values compared to 2013. Only for the harvesting date in 2013 significant higher N-OPA for DmS and significant lower for MDC defoliated grapevines were found. In 2014 a similar trend was observed whereas MDC plants showed more nitrogen in the must compared to control and bunch zone defoliation. In 2015 nearly all treatments show the same nitrogen content in the berry must.
Comparable low single grapevine yield for all treatments in 2013 was achieved; whereas the grapevines defoliated mechanically above the bunch zone (MDC) and defoliated manually (DpF) reached the lowest. No differences between the control and the other mechanically defoliated treatments were determined. In 2014 each single grapevine of all treatments achieved a higher yield compared to the other seasons. The trend from 2013 is mirrored in here. The control plants reached the highest yield followed by the bunch zone defoliated. Using the Sigwald for defoliation caused yield per single vine of approximately 2.6 kg $vine^{-1}$. Bavaresco and co-workers (2008) couldn´t identify an influence of the leaf removal on yield of treated grapevines but the must sugar content and nitrogen content.
In 2014 the highest incidence and severity during the three investigated seasons were observed, nearly 100 per cent of the leaves were infested closed to harvest independent of the treatment. In 2015 plants defoliated manually early in the season (DpF) showed the highest incidence but at a low level of approximately 10% and mechanical defoliation led to the lowest infested leaves (Fig. 3).
A similar result is given for the infected bunches prior to harvest. The lowest severity could be determined in 2013 with no clear differences between the conducted treatments but a decreased incidence for mechanically defoliated plants (MDC) and the highest for BZD (Fig. 4). In the consecutive years, 2014 and 2015, a relatively high severity and incidence on bunches were determined. The bunches of the control treatment were infected most in 2015 and the usage of the Sigwald for defoliation led to the lowest incidence and severity in this dry year. Because of the three different microclimatic conditions in these three years no biunique result could be achieved.

The non-invasive measurements with the polyphenolmeter (Multiplex, FORCE-A) on leaves decrease in chlorophyll index over time (Fig. 5a) and nitrogen index (Fig. 5b) and increased during the season in the anthocyanin related index Anth_RG. For plants defoliated manually prior flowering up the third bunch (DpF) the highest chlorophyll and nitrogen index were found accompanied with lowest anthocyanin index. After mechanical remove of leaves above the bunch zone the plants respond with a decreased nitrogen index in leaves and an increased anthocyanin index. In berries of red grapevine varieties an increased Anth_RG indicates increased anthocyanin content in berry skin in relation to surface (Tuccio et al. 2011). Increase of anthocyanins in leaves can be an indicator of a stress situation in response to environmental issues (Chalker-Scott 1999, Liakopoulos et al. 2006). The early performance of the DpF and the undefoliated canopy of the control treatment didn´t led to a situation of excessive light whereas the defoliation took part around flowering could influence the incident light and resulted perhaps in a stress situation for plants of MDC, BZD and DmS treatment especially young leaves which are not fully developed are affected. The accumulation of phenolic compounds in leaves is important for the response with pathogens (Dalla Marta et al. 2008 and citations herein). Because of the less dense canopy of the latter treatments the leaves and bunches are less infected with *Plasmopara viticola* and *Botrytis cinerea*.

Anthocyanin index of berry measurements conducted with the Multiplex increased over the ripening season accompanied with decreasing SFR_G (data not shown). Berries of undefoliated grapevines showed the highest NBI_G and the lowest Anth_RG with lowest sugar accumulation and lowest N-OPA in the must.

4 CONCLUSION

In years with extreme wet conditions a difference in yield could be detected with highest single vine yield for control treated plants. No clear trend is given for all three years with regard to infection of leaves with *Plasmopara viticola* or bunches with *Botrytis cinerea* caused by the different weather situation. The nitrogen related measurement in leaves with the polyphenolmeter can be a good indicator for nitrogen content in the must. These technique can be used to characterize the vineyard and enhance the quality of the harvested grapes.

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Figure

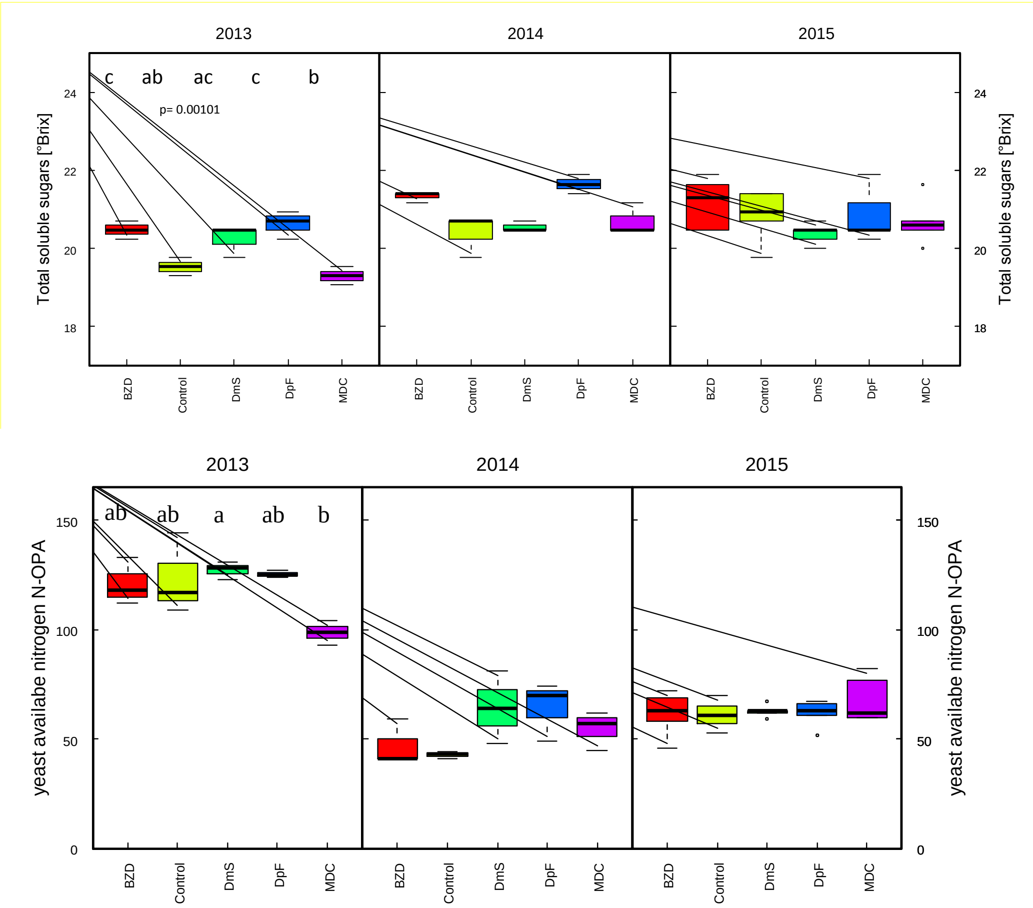

Figure 1 : Ripening parameter Total soluble sugar [TSS, °Brix] and yeast available nitrogen [N-OPA] of the three investigated seasons for all the different defoliation practices at harvest

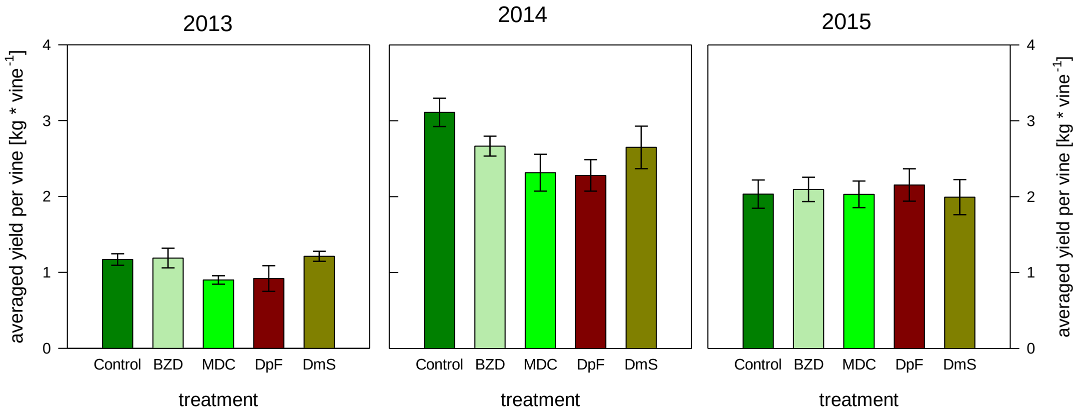

Figure 2 : Yield per single grapevine of three seasons (n=18-24 ±SE)

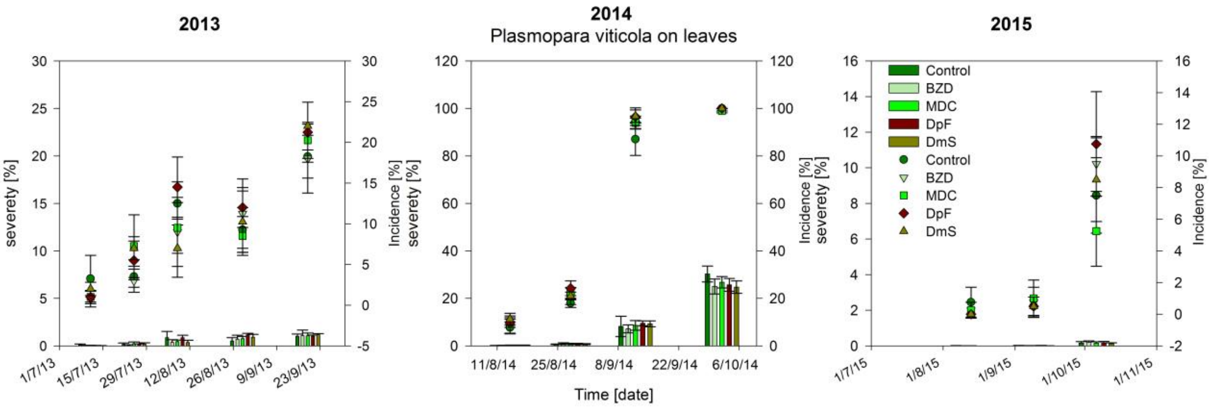

Figure 3 : Disease assessment of downy mildew (*Plasmopara viticola*) on leaves at three seasons close to harvest; the bars indicate the severity of the leaves and the scatter plots display the incidence given in percentage [%] over three seasons (2013-2015)

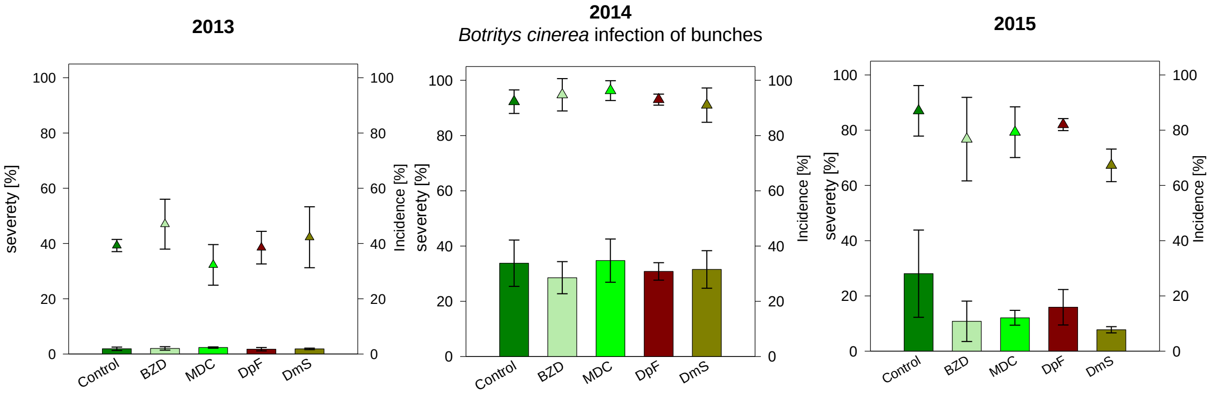

Figure 4 : Disease assessment of grey mold *(Botrytis cincerea)* on bunches at three seasons close to harvest; The bars indicate the severity of the leaves and the scatter plots display the incidence given in percentage [%] over three seasons (2013-2015)

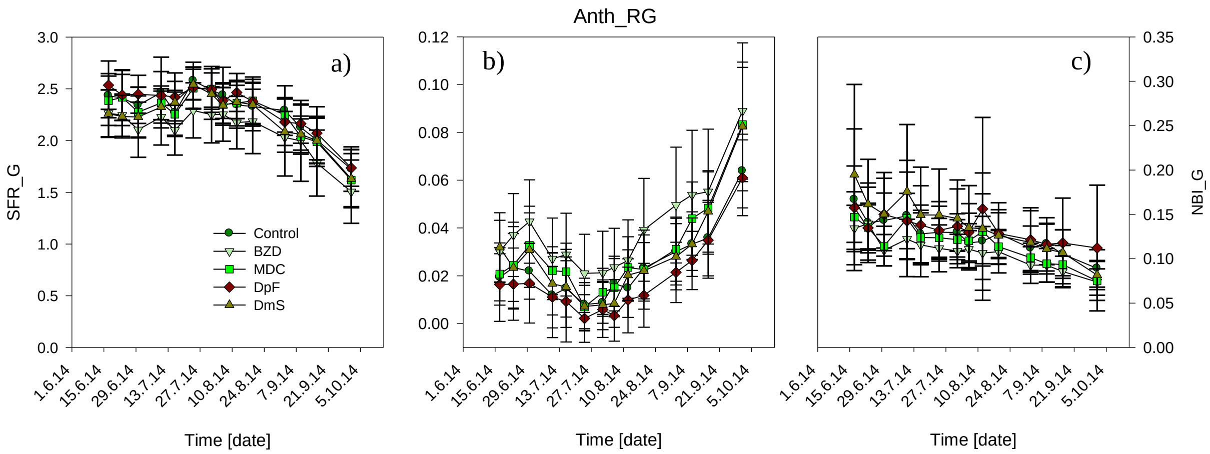

Figure 5 : Leaves measured non-invasively with the polyphenolmeter Multiplex (FORCE-A) over the whole season 2014 ; a) A time course of the chlorophyll related index (SFR_G) ; b) Measurements of the anthocyanin related index Anth_RG in a time course ; c) The nitrogen related index NBI_G were measured weekly in 2014 (n=6, ±SD)