MAPPING PLANT WATER STATUS TO INDIRECTLY ASSESS VARIABILITY IN GRAPE FLAVONOIDS AND INFORM SELECTIVE HARVEST DECISIONS

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Abstract:

Context and purpose of the study – Plant water stress affects grape (*Vitis vinifera* L.) berry composition and is variable in space due to variations in the physical environment at the growing site. Could we use water status maps as a sensitive tool to discriminate between harvest zones?

Material and methods – The study was carried out on 35experimental units placed on an equidistant grid within a 3.5 ha vineyard located in Sonoma County, Northern California. This drip irrigated vineyard was planted with Cabernet-Sauvignon on 110R, spur pruned and trained in two single high wires in a horizontally split canopy. The site was described through a digital elevation model, terrain analysis, NDVI and electrical resistivity maps. The natural variability of grapevine water stress was monitored by stem water potential (Ψ_{stem}), leaf gas exchange and $\delta^{13}C$ of grape must at harvest. Geospatial analysis and clustering were used to differentiate the vineyard block into two management zones according to variability in water status.

Results – The two management zones were very distinct in water status and presented severe and moderate water stress. The average difference in Ψ_{stem} between the zones was of 0.2 MPa. Differences in stem water potential affected stomatal conductance, net carbon assimilation, and intrinsic water use efficiency that were different in all measurement dates. The two zones were selectively sampled at harvest for measurements of berry chemistry. Berry mass and yield per vine in the two water status zones were not different. A significant difference in total soluble solids (3.56 Brix) and in titratable acidity indicated a direct effect of water stress on ripening acceleration. Berry skin flavonol and anthocyanin composition and concentration were measured by C18 reversed-phased high-performance liquid chromatography (HPLC). Berry anthocyanins showed the highest differences between the two water stress zones. Dihydroxylated anthocyanins were more affected than the trihydroxylated ones, therefore, the ratio of the two forms increased. Flavonols were different in total amounts, but hydroxylation patterns were not affected. Proanthocyanidin isolates were characterized by acid catalysis in the presence of excess phloroglucinol followed by reversed-phase HPLC. Proanthocyanidins showed the least significant difference, although (+)-catechin terminal subunits were important predictors in a partial least square model used to summarize the multivariate relationships, predicting Ψstem or the management zone. The results highlight the importance of vineyard water status information for differential harvesting or direction to vineyard operators to modify irrigation management to equilibrate berry composition at harvest.

Keywords selective harvest; spatial variability; management zones; water stress; anthocyanins; flavonols; proanthocyanidins;

1. Introduction.

Mapping Plant Water Status to Indirectly Assess Variability in Grape Flavonoids and Inform Selective Harvest Decisions

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Abstract

Plant water stress affects grape (*Vitis vinifera* L. cv. Cabernet Sauvignon) berry composition and is variable in space due to variations in the physical environment at the growing site. We monitored the natural variability of grapevine water stress by stem water potential (Ψ_{stem}) and leaf gas exchange in an equi-distant grid in a commercial vineyard. Geospatial analysis and clustering allowed to differentiate the vineyard block into two distinct zones having severe and moderate water stress. Water status variability was related to topography.

The two zones were selectively sampled at harvest for measurements of berry chemistry. Significant differences in TSS (3.56 Brix) and in TA, were observed but not on yield, thus indicating a direct effect of water stress on ripening acceleration. The anthocyanins were most affected by the two water stress zones. The di-hydroxylated anthocyanins were more affected than tri-hydroxylated, therefore the ratio of the two forms increased. Flavonols were different in total amounts, but hydroxylation patterns were not affected. Proanthocyanidins showed the least significant difference, although (+)-catechin terminal subunits was an important predictor in a PLS models used to summarize the multivariate relationships, predicting Ψ_{stem} or the management zone.

The results provide fundamental information on vineyard water status to discriminate harvest or direction to vineyard operators to alter applied water amounts to equilibrate berry composition at harvest.

Scope

The natural variability of plant water status at the vineyard scale can affect grape flavonoid composition, regardless of cultural practices. The aim of this work was to investigate how plant water status and primary metabolism was variable at the field scale, causing intra-vineyard variability in secondary metabolism (qualitative and quantitative composition of grape flavonoids). This work also evaluated using grapevine water status as a proxy for delineating the vineyard to manage harvest selectively, answering the question:

IS WATER STATUS A SENSITIVE TOOL TO DISCRIMINATE BETWEEN HARVEST ZONES?

Methodology

- VINEYARD & EXPERIMENTAL DESIGN
  - Cabernet-Sauvignon/110 R, two single high wires in a horizontally split canopy, at 8 x 11 feet (1.8m x 3.3m)
  - 35 experimental units on an equidistant grid
- DIGITAL ELEVATION MODEL
  - elevation, wetness index
- GRAPEVINE PHYSIOLOGY
  - Solar-noon stem water potential (Ψ_{stem})
  - Leaf gas exchanges (CIRAS 3).
- GRAPE COMPOSITION & YIELD
  - Total soluble solid, titratable acidity and pH
  - Yield components (yield per plant, cluster #, cluster weight, berry mass)
  - Low molecular weight phenolics (anthocyanins and flavonols by HPLC)
  - Proanthocyanidins (phloroglucinolysis)
- GEOSTATISTICAL & MULTIVARIATE ANALYSIS

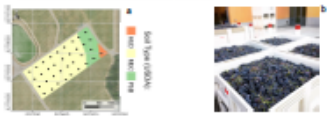

Figure 1a. Location of the experimental units, and soil map according to the USDA soil survey (black dots (35) represents middle points of experimental units composed of 5 grapevines /plots at the field site according to the USDA soil survey, MbC: fine-loamy, mixed, semiactive, thermic Ultic Palexeralfs; HdD: Fine, mixed, superactive, thermic Typic Haploxerults; PsD: Fine-loamy, mixed, superactive, thermic Aquic Ultic Haploxeralfs. (coordinates EPSG: 32610). b). Harvest was done from the experimental units in three-time replicates

Results

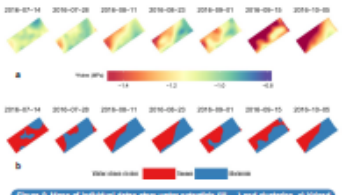

Figure 2. Maps of individual dates stem water potentials (Ψ_{stem}) and clustering. a) Kriged maps of plant water status as stem water potential. To more negative values (red) correspond increased water stress. b) K-means clustering of the stem water potential kriged maps in two zones

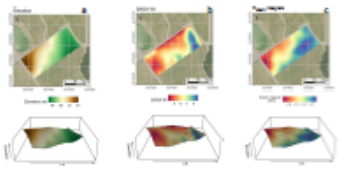

Figure 3. Maps of elevation, SAGA wetness index, and Ψ_{stem} integrals (summarizing plant water stress throughout the whole season). a) Elevation, meters above sea level, of the vineyard site b) SAGA GIS Wetness Index c) Ψ_{stem} integrals, in 2D (top) and 3D (bottom). . Elevation is doubled in 3D maps, to enhance topographic variation within the field. Coordinates are EPSG:32610.

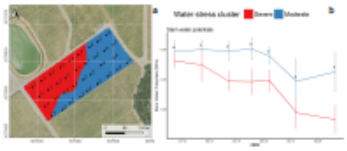

Figure 4. a) K-means clustering of the field in two management zones for differential harvest according to water status throughout the season, as evaluated by Ψ_{stem} integrals. Data pods labeled with 1 (n: 18) were considered part of the severe water stress cluster, red zone, while data pods labeled with 2 (n: 17) were considered part of the moderate water stress cluster, blue zone. Coordinates are EPSG:32610. b) Trend of the stem water potential within the 2 clusters

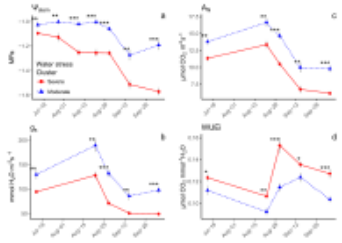

Figure 5. Trends of water status and gas exchanges between the two management zones. a) Evolution of stem water potential, Ψ_{stem}. b) stomatal conductance, g_s. c) net Carbon assimilation, A_N. d) intrinsic water use efficiency, WUE_i. Error bars are standard error of the mean, stars indicate significant difference.

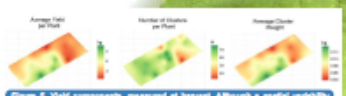

Figure 5. Yield components, measured at harvest. Although a spatial variability exists, it does not follow the water status pattern, and differences are not significant between the two harvest zones.

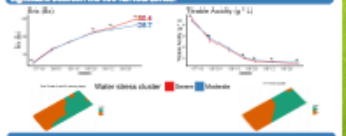

Figure 6. Trends of TSS (Brix) and TA during the season, and k-means clustering at the field scale. The spatial structure corresponds to the plant water status.

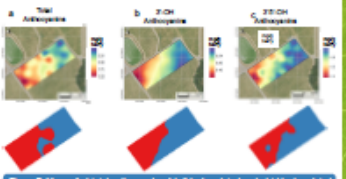

Figure 7. Maps of a) total anthocyanins, b) di-hydroxylated and c) tri-hydroxylated anthocyanins at harvest

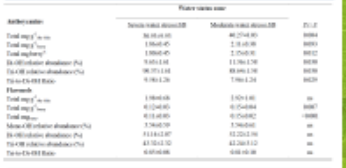

Table 1. Anthocyanin concentration and ratio of di-and tri-hydroxylated, and their relative molar abundance of Cabernet Sauvignon/110R in a commercial vineyard as separated by water status zoning at harvest.

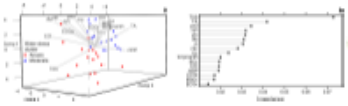

Figure 8. Results of the PLS analysis classifying water stress from grape composition with 90% accuracy. a) triplot b) variable importance of predictors in the full model.

Conclusions

Selective harvest is an off-the-shelf state-of-the-art method that can also be performed mechanically with commercial harvesters. This approach was shown to be commercially viable, and can be implemented to separate the harvest in one pass, or in two passes, at different time points. Differentiating into harvestable zones according to grapevine water status has shown to be effective, and can be implemented in simpler ways (chemistry, sensing, modelling, etc.). Other strategies with the aim of reducing the variability in the water status could also be implemented, such as differential irrigation or selective cover crop removal. Their effect on grape composition deserves to be investigated in future works.

DOWNLOAD THE FULL ARTICLE HERE!

Brillante et al., 2017. Assessing spatial variability of grape skin flavonoids at the vineyard scale based on plant water status mapping. *Journal of Agricultural and Food Chemistry* https://doi.org/10.1021/acs.jafc.7b01749