ORIGINS OF GRAPE AND WINE AROMA. PART 1. CHEMICAL COMPONENTS AND VITICULTURAL IMPACTS

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Wine is an ancient beverage and has been prized throughout time for its unique and pleasing flavor. Wine flavor arises from a mixture of hundreds of chemical compounds interacting with our sense organs, producing a neural response that is processed in the brain and resulting in a psychophysical percept that we readily describe as “wine.” The chemical components of wine are derived from multiple sources; during fermentation grape flavor components are extracted into the wine and new compounds are formed by numerous chemical and biochemical processes. In this review we discuss the various classes of chemical compounds in grapes and wines and the chemical and biochemical processes that influence their formation and concentrations. The overall aim is to highlight the current state of knowledge in the area of grape and wine aroma chemistry.


ORIGINS OF GRAPE AND WINE AROMA. PART 2. CHEMICAL AND SENSORY ANALYSIS

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Part 1 of this review summarized the current state of knowledge with respect to the chemical compounds contributing to grape and wine aroma. Much of our understanding of the chemistry of grape and wine composition comes from advances in analytical and sensory methods for identifying and quantifying the compounds that contribute to flavor. Therefore, Part 2 of this review provides an overview of the chemical and sensory analysis approaches that have been used to deconstruct wine flavor into its component parts with an aim toward relating the chemical composition to the unique sensory properties that are associated with different wine varieties and styles.


N, P, and K SUPPLY TO PINOT NOIR GRAPEVINES: IMPACT ON BERRY PHENolics AND FREE AMINO ACIDS

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The composition of Pinot noir berries on grapevines grown with varying nutrient (nitrogen, phosphorus, and potassium) supply was investigated in a pot-in-pot, sand culture vineyard. Vines were managed to minimize differences in vine water status and shading of fruit so that indirect effects on berry chemistry could be largely eliminated. Vines grown under reduced nitrogen supply had lower levels of amino acids and YANs, but higher levels of some phenolics. Results show that reducing nitrogen supply can improve berry color (anthocyanins), but this positive effect on berry composition did not occur until crop yield and berry YAN were greatly depressed. An increase in berry tannins and phenolic acids under low N supply, however, may be possible before yield is significantly reduced.


USE OF PRODUCTION PRACTICES AND SENSORY ATTRIBUTES TO CHARACTERIZE LOIRE VALLEY RED WINES

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Quality wines are typically the product of soil, climate, and wine production practices. Sensory attributes are increasingly

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used to distinguish among protected designation of origin (PDO) wines. Since 2010, the International Organization of Vine and Wine has taken all such parameters into account in an official definition of terroir. However, links between production practices and sensory attributes in geographically circumscribed PDO areas had not been investigated until now. Production practices and sensory attributes of distinct PDO wines within the same area were assessed. The production practices of producers of 33 commercial PDO wines from the Loire Valley, France, were surveyed, including vineyard training systems, viticulture, harvest timing, winemaking, and aging practices. Descriptive sensory analysis was conducted to characterize the significant sensory attributes of these same wines. PDO wines were separated from one another by classical statistical analyses. About 25% of the analyzed production practices and less than 50% of the analyzed sensory attributes could differentiate PDO wines produced in the same area: percentage of Cabernet franc, time of leaf removal, harvest date, yield, duration of fermentation, duration of aging and use of oak, color intensity, viscosity, cloudiness, blackcurrant, prune, spicy, moldy, animal, bitterness, and astringency. Relationships between some production practices and sensory attributes were identified. Results demonstrate that, under similar climatic conditions and soil characteristics, production practices and sensory attributes can distinguish PDO wines in well-defined geographic areas.


Modeling Dormant Bud Cold Hardiness and Budbreak in Twenty-Three Vitis Genotypes Reveals Variation by Region of Origin

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Cold injury is a key environmental challenge in many grape-producing regions, especially those at high latitudes. Although grapevines acclimate to cold temperatures in fall and deacclimate when warm temperatures return in spring, cold hardiness varies with species, cultivar, phenology, ambient weather, day length, and plant organ, which hampers implementation of effective mitigation practices. Using long-term data sets of lethal temperatures and spring phenology for primary buds of Vitis vinifera and Vitis × labruscana, we developed and evaluated a robust, quantitative model that simulates daily changes in primary bud hardiness throughout the winter and during budbreak for 23 diverse cultivars. In addition, the model also predicts time of budbreak for these cultivars. The only input data required to run the model is mean daily temperature, which is easily recorded by affordable weather stations and should make this model easy to use and widely accessible. The model revealed a north/inland-south/coastal gradient for cultivar origin in terms of cold hardness and time of budbreak. Budbreak occurred earlier in harder genotypes, consistent with more rapid deacclimation of genotypes originating from colder climates, paradoxically making these genotypes more vulnerable to spring frost in warmer environments. The model should be useful in climate change modeling to predict cold acclimation and deacclimation responses of different genotypes under variable climate change scenarios. It may also be used as a risk-management tool for site selection in regions with unknown grapegrowing potential and for vineyard management in regions where cold damage is common. Using temperature data from automated weather stations, the model automatically provides local and daily simulated lethal temperatures for the grape cultivars reported in this study. Coupled with a weather forecasting service, the model may be used as an early warning system for impending and potentially damaging cold-temperature events. Supplemented with additional, static information on how to respond to cold damage, this forms a decision support system for risk assessment and damage mitigation in grapes.


A High-Resolution Cumulative Degree Day-Based Model to Simulate Phenological Development of Grapevine

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Common cumulative degree day models used to forecast grape growth stages often are only of local validity, restricted to a limited number of phenological stages, or do not take into consideration that the forcing effect of temperature is limited at higher temperatures. A new model was developed to simulate all 26 phenological stages (according to the BBCH scheme; Biologische Bundesanstalt, Bundesforschungsamt und Chemische Industrie) of Vitis vinifera L. Müller-Thurgau between budburst and harvest. Sixty time series of grape phenology from four European countries were used to set up and validate the model. Three cumulative degree day models starting with budburst: BBCH 09) with one, two, or three optimized temperature threshold values were compared. The incorporation of an upper threshold temperature, above which a further increase of the temperature will not accelerate plant development, and of a heat threshold, above which a further increase of the temperature leads to a development decrease, significantly improved the accuracy of the model compared to previous cumulative degree day approaches. The threshold triplet 5°C, 20°C, and 22°C for lower (base), upper, and heat threshold temperature, respectively, allowed the most precise forecast. In 70.5 or 95.8% of the cases, phenological stages were correctly predicted in 5 or 7 days (assuming daily mean temperatures of 20°C), respectively, around the predicted cumulative degree day. The model can be used for a range of applications in viticultural research and practical viticulture and could further be parameterized for other varieties.

Uniformity of fruit composition and berry size are regarded as key fruit quality parameters for winemaking. However, there is little objective data to confirm the relationship between both variables with fruit quality. In view of the lack of empirical information on the relationship of fruit uniformity and berry size with the production of high quality wine, a study was conducted to evaluate and statistically compare fruit uniformity using crop price as an indirect metric of quality. Three California Cabernet Sauvignon vineyards, each with a high ($9,000–10,000/ton), medium ($4,000–5,000/ton), and low ($500–1,000/ton) crop price, were selected and fruit uniformity at commercial harvest (24 Brix) was measured for two consecutive years. No differences in fruit uniformity, fruit composition (Brix, pH, and anthocyanin concentration), and berry size were detected, despite substantial differences in crop price, vineyard sizes, and management styles. Anthocyanin concentration decreased with berry mass in fruit from the medium and low crop price fruit, whereas no relationship was found in the high crop price fruit. Results indicated that if the high crop price fruit in this study is better for winemaking than the low crop price fruit, it is not due to differences in fruit uniformity or berry size.


Late-Season Foliar Urea Applications Can Increase Berry Yeast-Assimilable Nitrogen in Winegrapes (Vitis vinifera L.)

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When grapevines have ready access to high quantities of nitrogen, they can grow too large, are susceptible to disease, and produce grapes with undesirable properties. To avoid these negative consequences, vineyard managers in the Okanagan Valley of British Columbia, Canada, tend to apply only low rates of nitrogen fertilizer, even though the soils are typically poor in nutrients. As a result, grape juices from this region frequently do not have enough nitrogen to support the growth of yeasts used in winemaking. Urea is a nitrogen-containing chemical that easily dissolves in water and is often used as a nitrogen fertilizer. This experiment tested whether urea could be sprayed on grapevine foliage close to the time when grapes start to change color (veraison) to increase the nitrogen content of grape juice and avoid the undesirable effects sometimes associated with high soil nitro-

Effect of Water Stress on the Reproductive Performance of Shiraz (Vitis vinifera L.) Grafted to Rootstocks

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An experiment was conducted in the Barossa Valley, South Australia, to examine the effect of rootstocks on reproductive performance of Shiraz (Vitis vinifera L.) under water stress. Vines were grown on own roots or grafted to 110R, 1103P, 99R, Ramsey, Schwarzmann, or 140Ru. Vines either were unirrigated or irrigation was applied at 56 to 128 mm/ha across three seasons. Water stress (Ψp < 0.8 MPa) was apparent in the unirrigated vines from veraison onward. The absence of irrigation strongly influenced vine growth and performance. Pruning weight, cane weight, and cane number were all reduced as a consequence of zero irrigation. Yields were reduced in unirrigated treatments due to a reduction in cluster number, cluster weight, and berry weight rather than fruit set or berry number. Unirrigated Ramsey was the only rootstock able to maintain yield comparable with irrigated rootstocks. Unirrigated own roots performed well in the first season but not in the second and third seasons when water stress had a negative effect on yield. Millerdandage, coulure, and seedless berry numbers were the main reproductive parameters found to have a negative impact on yield, and both own-rooted and grafted vines were as susceptible to these parameters. Season had a greater influence than either rootstock type or irrigation. These findings have significant implications for regions facing future drought and declining water supplies.

**Comparison of Two PCR-Based Genetic Fingerprinting Methods for Assessment of Genetic Diversity in Saccharomyces Strains**

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The genetic heterogeneity of wine strains of *Saccharomyces* has been well documented and winemakers take advantage of these genetic differences to manipulate wine flavor and aroma. There are several different molecular tools that are used to assess genome relatedness among strains and several studies have been published that group strains by similarity in sequence. These methods use the nuclear or chromosomal DNA to assign strain similarity scores. Cytoplasmic or mitochondrial DNA can also be used as an index of strain similarity. The DNA of the mitochondrion is inherited in a distinctly different pattern from that of the chromosomal DNA. The goal of this paper was to compare strain groupings of a diverse set of wine strains of *Saccharomyces* using both genomic and mitochondrial genome assessment methods. Individually, both methods grouped strains into related clusters, but the groupings did not match, meaning that strains that were grouped together by their genomic DNA content were not placed in the same groups by comparison of their mitochondrial DNA, thus confirming the independence of the evolution of these two genomes. The combination of the two methods resulted in the separation of all strains evaluated, with the exception of those known to be of the same parentage. Thus, either method will provide an assessment of similarity but not yield the same relationships among individual strains.


**Wavelength Selection with a View to a Simplified Handheld Optical System to Estimate Grape Ripeness**

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Simple devices in the enological sector are important to wine-grape growers in monitoring the ripening of grapes and planning harvest time. Currently available vis/NIR spectroscopy devices are, however, expensive and not suitable for small-scale wineries. The aim of this work was to identify the three most significant wavelengths able to discriminate in the field those grapes ready to be harvested using a simplified, handheld, and low-cost optical device. Nondestructive analyses were carried out on a total of 68 samples, and a total of 1360 spectral measurements were done using a portable, commercial vis/NIR spectrophotometer. Chemometric analyses were performed in order to extract the maximum useful information from spectral data and to select the most significant wavelengths. Correlations between the spectral data matrix and technological (total soluble solids) and phenolic (polyphenols) parameters were carried out using partial least square (PLS) regression. Standardized regression coefficients of the PLS model were used to select the relevant variables, representing the most useful information of the full spectral region. To support the variable selection, a qualitative evaluation of the average spectra and loading plot, derived from principal component analysis, was considered. The three selected wavelengths were 670 nm, corresponding to the chlorophyll absorption peak, 730 nm, equal to the maximum reflectance peak, and 780 nm, representing the third overtone of OH bond stretching. Principal component analysis and multiple linear regression were applied on the three selected wavelengths in order to verify their effectiveness. Simple equations for total soluble solids and polyphenols prediction were calculated. The results demonstrated the feasibility of a simplified, low-cost, handheld device for ripeness assessment in the field.


**Evaluation of Sensory Thresholds and Perception of Sodium Chloride in Grape Juice and Wine**

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Poor water quality and lack of rainfall can lead to higher salt levels in vineyard soil and the production of wine with salt (sodium chloride, NaCl) concentrations that may affect wine quality or exceed regulatory limits. The first part of this study aimed to determine how sensitive people are to NaCl levels in white and red grape juice and wine so that better harvest and winemaking decisions could be made regarding salt-affected fruit. The detectable NaCl levels were often within legal limits; thus, a large number of wine consumers may detect salt in wines at concentrations below the legal NaCl limits. The detection and recognition thresholds of NaCl in grape juice and wine increased with panelist age. The second part of the study investigated how NaCl affects wine aroma, taste, flavor, and mouthfeel. Four Chardonnay wines made from fruit perceived to possess varying degrees of saltiness were tasted using a trained panel of nine people and chemically analyzed. The results were compared to those of Chardonnay wine samples that had NaCl added. Wines made from fruit grown on salt-affected vines and wines with NaCl added tasted similar. Wines with higher NaCl levels tasted less fruity, saltier, and felt more slippery in the mouth. The presence of NaCl in Chardonnay wine had a negative impact on wine taste and flavor, even at levels below the legal limits.

Characterization and Classification of Turkish Wines Based on Elemental Composition

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This study presents an elemental characterization of Turkish wines from native and nonnative grapes to show their differences and similarities. Commercial wines from four vintages (2006–2009) were analyzed by inductively coupled plasma with atomic emission spectrometry and mass spectrometry (ICP-AES and ICP-MS), followed by multivariate statistics to study vintage, varietal, and regional differences. According to the partial least square-discriminant analysis, wines from western regions could be discriminated with their higher Pb content. The red wines of two native grapes, Boğazkere and Öküzgözü, were separated from the remaining varieties based on their high Ca and low B and Cu levels. Öküzgözü wines were different than Syrah and Cabernet Sauvignon wines. Similarly, native Emir wines showed differences from Muscat wines. The effective variables for discrimination analysis were natural minerals (Sr, Li, Al, Ba, and B) and minerals originating from agricultural activities, processing, or pollution (Ca, Cu, Mg, Co, Pb, and Ni). Characteristics of Turkish wines from native and nonnative grape varieties such as Cabernet Sauvignon, Merlot, Syrah, and Chardonnay are defined in terms of their mineral content for the first time.


Transfer of Cesium and Potassium from Grapes to Wine

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The accident at the Fukushima Daiichi Nuclear Power Plant following the Great East Japan Earthquake and tsunami in March 2011 caused a large release of radionuclides, of which contamination to food has been a matter of great concern. Thus, the food-processing transfer parameters of radioactive and stable cesium and potassium were determined from grapes to wine. The concentration of cesium in the pomace was higher than that in juice, as was the case of potassium. During white and blush wine fermentation, cesium concentration did not change significantly, while potassium concentration decreased. These results suggest that the absorbance of cesium by yeast is much lower than that of potassium in the winemaking environment. The food-processing retention factor ($F_r$, content in wine/content in grape) of radioactive cesium and stable cesium for red wine was higher than that for white wine, reflecting the yields of wine and the extraction of cesium during maceration.


Characterization and Identification of Minority Red Grape Varieties Recovered in Rioja, Spain

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Rioja, in the northern center of the Iberian Peninsula, is one of the most important grapegrowing regions in Spain. A research project began in 1988 to recover and preserve the minority varieties of this region in response to genetic erosion caused by vineyard restructuring. Grapevine biodiversity accumulated during the past centuries was being lost and an important source of genetic material was in danger of extinction. Over 700 vineyards throughout the Rioja appellation were sampled and selected wines were preserved within a germplasm bank. Morphological description and genetic characterization through DNA analysis were performed for each of the 45 red accessions recovered. In total, 26 different varieties were found by the ampelographic and genetic analysis and 24 of them were identified. The remaining two varieties did not match with any other genetic profile of the Spanish or European microsatellite database. The origin of the identified varieties is very diverse, indicating the importance of grape variety exchange that occurred during the last centuries. Minority varieties could play an important role in the future, considering their capacity to adapt to new climatic conditions and their specific wine profiles, which could fulfill new market demands.


Indirect Estimation of Leaf Area Index in VSP-Trained Grapevines Using Plant Area Index

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Leaf area is one of the most important parameters of plant growth and vigor. Therefore, rapid, nondestructive, and accurate measurement of leaf area is of central importance in agronomic, physiological, and ecological studies, as well as in commercial agriculture. In viticulture, leaf area is a crucial indicator of water use, whole-plant assimilation, light interception, and impact on bunch exposure. Indirect, nondestructive techniques of leaf area index (LAI) estimation, which are based on the relation between radiation interception and canopy structure such as measurements of canopy gap fractions, provide a powerful tool for leaf area determination. Many studies show the difficulties of implementation of gap fraction analysis in row crops and trellised vineyards in particular due to the heterogeneous distribution of foliage in rows. The aim of this study was to compare directly measured LAI and estimated plant area index (PAI) for VSP-trained grapevines and to design a protocol which accurately and rapidly estimates LAI in a VSP-trained vineyard (Vitis
Determination of Evapotranspiration and Crop Coefficients for a Chardonnay Vineyard Located in a Cool Climate

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A study was conducted in a Chardonnay vineyard located in the Carneros district of Napa Valley to derive vineyard evapotranspiration (ET) and seasonal crop coefficients (Kc) values. The vineyard was planted on 2.13 m rows, using a vertical shoot-positioned trellis. Vineyard ETc was measured using the soil water balance method. Soil water content (SWC) was measured in one-fourth of an individual vine's soil profile (six access tubes per site) to a depth of 2.75 m. Vineyard ETc the first year of the study was approximately 400 mm. Thereafter, calculated vineyard ETc (the product of reference ET [ET0] and the Kc) ranged from 346 to 503 mm per season. Midday leaf water potential (Ψl) was used to validate estimated ETc (to determine that vines were not stressed for water) and the derived Kc values. Midday Ψl, A and gs were linearly related with applied water amounts and SWC across irrigation treatments and years. The results from this study are the first in which vineyard ETc has been measured on vines grown at a cool vineyard site in California. Estimates of ETc from this study would be valid for a vineyard with a row spacing of 2.13 m and a canopy vertically positioned using a maximum Kc of 0.74.


Physical and Physiological Heterogeneity within the Grape Bunch: Impact on Mechanical Properties during Maturation

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Mechanical properties are emerging as complementary criteria to evaluate grape berry quality for winemaking. As texture is evaluated on a berry per berry basis from randomly picked samples among grapes in the vineyard, it is important to assess the impact of the within-grape heterogeneity on mechanical properties. Thus, the texture of Cabernet franc berries sampled from whole grape bunches was assayed throughout ripening by a double compression test. This study clearly supports the high value of texture as a quality criterion for grape maturity in revealing several correlations between berry mechanical features and key physical and physiological characteristics for grape quality assessment. This work mapped the mechanical, physical, and physiological heterogeneity within a grape bunch during maturation and proposed sampling strategies to improve the use of this test in the vineyard.


Spatial and Temporal Study of Climatic Variability on Grape Production in Southwestern Michigan

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Daily climatic data were obtained from several sources to calculate growing degree days (GDD) for multiple sites in southwest Michigan, which contains the Lake Michigan Shore American Viticultural Area. The data were examined for spatial and temporal (1950 to 2011) patterns and trends over the region in order to better quantify the role of Michigan climate on juice grape production. The occurrence and severity of frost and freezing temperatures were also considered in this study, as subfreezing temperatures in late spring and early fall can have severe impacts on the region’s juice grape production and fruit quality at harvest. Michigan’s cool-cold climate has warmed in recent decades, particularly since 1980, with an average increase over the region of more than 3.7 GDD (base 10°C) per year. Southwestern Michigan was also found to have higher seasonal temperature variability when compared with Napa Valley (California). Since 1980, the season-to-season variability in Michigan has increased at a more rapid pace. The impacts of the increasing GDD have been positive for fruit quality, with a strong positive correlation between seasonal GDD and fruit maturation, indexed as total soluble solids (Brix). The growing season has also increased by 28 days in length since 1971. However, despite warmer temperatures, the number of days of potential frost and their seasonal variability in southwestern Michigan have remain unchanged, which continues to pose a risk for grapegrowers in the region. While it has become warmer in Michigan, and the spring warm-up is typically arriving earlier in the year, the number of days with damaging frost still has a profound impact on overall climate-related risk for grape production.


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A study was conducted to investigate the interaction of N fertilization rates and different irrigation amounts on N fertilizer recovery efficiency ($R_{EN}$) of Cabernet Sauvignon in a commercial vineyard near Oakville, California. The fertilizer treatments consisted of a control (no fertilizer) and two $^{15}$N labeled ammonium nitrate fertilizer applications (6.5 and 13.0 g N/vine). The N fertilizer was applied two weeks before anthesis. The irrigation treatments were various fractions (0.25, 0.5, and 1.0) of estimated vineyard water use ($ET_{c}$), with the applied water amount for the 1.0 irrigation treatment from 7 Apr to 9 Sept equivalent to 312 mm. Midday leaf water potential ($\Psi_{l}$) was measured throughout the season to monitor vine water status. The labeled N fertilizer was detected in the petioles and leaf blades two weeks after application. Irrigation and fertilization treatments significantly affected midday $\Psi_{l}$. There were significant differences in above-ground vine biomass among the treatments. In general, those supplied with more water and/or N fertilizer had greater biomass compared with nonfertilized vines under deficit irrigation. Vine uptake of the $^{15}$N labeled fertilizer increased with increasing fertilization rates and irrigation amounts. The $R_{EN}$ was significantly different between the two $^{15}$N fertilizer treatments (29% for 6.5 g N/vine and 24% for 13.0 g N/vine). $R_{EN}$ at harvest for the 0.25, 0.5, and 1.0 $ET_{c}$ irrigation treatments was ~24, 28, and 27%, respectively, although not significantly different. The data indicate that fertilizer amount had a significant effect on $R_{EN}$ under the conditions of this study and that irrigation rates at full $ET_{c}$ tended to increase $R_{EN}$ in this vineyard when compared with deficit irrigation.


Water Productivity, Yield, and Berry Composition in Sustained versus Regulated Deficit Irrigation of Merlot GRAPEVINES

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Many wine-production regions in the world experience seasonal drought, and irrigation is commonly used to stabilize yield and maintain or improve grape quality. In production regions where the amount of available water in the soil is insufficient to meet the water demand of the vine, irrigation is often used to intentionally induce a water stress in the grapevine. The practice of supplying less water than required by the vine is referred to as deficit irrigation. The ultimate goal of deficit irrigation in winegrape is to optimize berry composition for wine production without compromising yield and to increase water productivity. Water productivity is the amount of yield or net income of product produced per unit of water consumed. The objectives of this study were to measure how different deficit irrigation practices influenced the yield, berry composition, and water productivity of the wine grape cultivar Merlot when grown under arid conditions. Three severities of a sustained water deficit and an irrigation treatment that induced greater water stress before than after berries developed color were evaluated over three growing seasons under arid conditions. Yield, berry size, and pruning weight decreased; and water productivity sequentially increased as the amount of irrigation decreased from the standard amount to 35% of the standard amount. The increase in water productivity as irrigation amount decreased was due to a greater decrease in pruning weight relative to yield. The irrigation amount that produced the greatest quantity of fruit with desirable berry composition was the 70% of standard treatment. The irrigation treatment that induced greater water stress before rather than after the berries developed color used 15% less irrigation water and produced fruit of similar composition as the 70% of standard treatment, but it had similar water productivity as the 70% of standard treatment because of reduced berry size and lower yield.


Selection of a Mechanical Property for Flesh Firmness of Table Grapes in Accordance with an OIV Ampelographic Descriptor

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Flesh firmness is a sensory characteristic proposed by the International Organization of Vine and Wine as an ampelographic descriptor for grape varieties and Vitis species (Code-N° OIV 235 Berry: firmness of flesh). This descriptor plays an important role in assessing consumer acceptance of table grapes and in determining their breeding programs. To accurately define the flesh firmness of table grapes, an instrumental texture parameter that makes it possible to classify the five reference table-grape cultivars into the three groups (soft, slightly firm, and very firm) established by the OIV according to this descriptor was selected. The berries were sampled at harvest from the middle section of each bunch and were densimetrically sorted to obtain a variety of homogeneous ripeness grades. The mechanical properties of the berry flesh were determined for the peeled grapes using two different types of tests: texture profile analysis (TPA) and a cutting or shear test. The results showed that the berry TPA parameters, such as the hardness and the gumminess, normalized by the berry diameter, can be considered to be good instrumental indicators of flesh firmness because the variations among cultivars were evident, independently of berry size and maturity grade. The inter-quartile ranges of berry hardness normalized by berry diameters for each flesh-firmness group (soft, slightly firm, and very firm) were 0.074 to 0.117, 0.121 to 0.158, and 0.205 to 0.391 N/mm, respectively. Normalized instead for the berry gumminess, the ranges were 0.023 to 0.038, 0.054 to 0.072, and 0.085 to
Irrigated areas, however, are usually adapted to drought conditions, and soil organisms in these systems are typically adapted to severe water stress. What happens when this water stress is removed? Arbuscular mycorrhizal (AM) fungi are soil-dwelling fungi that form an association with plants, including grapevines. These fungi form an essential mutualism with their plant hosts, providing improved nutrient uptake, water-use efficiency, and pathogen protection in return for host-derived carbon. While irrigation is helping the vines persist in dry climates, is it hindering the microbes that associate with them? We tested two common forms of drip irrigation in the drought-stressed Okanagan wine-growing region: daily and every third day. We found that the AM fungal community did not change in response to irrigation frequency but had significantly more absorptive structures when irrigated every third day. This could indicate a long-term functional change in the symbiosis, but more research is needed to fully understand the role of viticultural practices on the AM symbiosis.


Arbuscular Mycorrhizal Fungal Communities Associated with Vitis vinifera Vines under Different Frequencies of Irrigation

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Viticultural practises can have effects beyond what they intend. Vineyard irrigation is common in many parts of the world and allows winegrapes to be grown in a wider variety of climates.

Effect of Combined Use of Benzothiadiazole and Methyl Jasmonate on Volatile Compounds of Monastrell Wine

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As part of the fight against pathogens and the search for alternatives to pesticides in crop protection, the use of different elicitors (compounds that do not display any antimicrobial activity but trigger plant defense mechanisms) has gained interest, especially because of the other effect observed when applying elicitors to plants: the increase in phenolic and volatile compound content. We are interested in the effect of two different elicitors, benzothiadiazole (BTH) and methyl jasmonate (MeJA), on grape and wine phenolic content and sensory perception. Previous studies on the application of both compounds to preharvest grapes have shown increased levels of phenolic and volatile compounds in the treated grapes and their corresponding wines. Given this positive effect of BTH and MeJA treatments, the objective of this study was to determine whether the combined application of these two elicitors to grape clusters at the beginning of ripening also led to wines with higher volatile compound concentration and improved sensory characteristics. Results indicate that the combined application of BTH and MeJA to the grapes led to wines with a similar composition in higher alcohols and esters as wines made with untreated grapes. Treated grapes led to wines with a significantly higher concentration of terpenes, with some of the terpenes only detected in wines from treated grapes. A descriptive sensory analysis indicated that these differences in volatile composition could be detected in wines, with wines made from treated grapes having significantly greater fruity notes, aroma, and mouthfeel quality.


Use of Normalized Difference Vegetation Index Images to Optimize Vineyard Sampling Protocols

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Vineyard monitoring and imaging technologies such as normalized difference vegetation index (NDVI) promise to improve the precision and efficiency of vineyard practices, but their potential is currently limited due to a paucity of well-defined, implementable models that can maximize the value of the collected information in a vineyard setting. We have previously demonstrated that applying traditional statistical models to a vineyard in which variables are sampled at a high spatial resolution, thereby revealing field variability, can be inefficient (i.e., an excessive amount of samples being collected and analyzed). The objective of this paper was to develop a model to guide vineyard sampling based on vineyard variability revealed in NDVI images with the goal of reducing the required sample collection while maintaining or increasing the statistical power of traditional sampling strategies. A previously developed sampling optimization model, which was based on manually collected canopy data, was adapted to analyze aerial NDVI images for the purposes of quantifying vineyard spatial structure and computing optimal vineyard sampling protocols. Aerial NDVI imagery from two Washington State Columbia Valley Riesling vineyards, captured at a resolution of 0.25 square meters per pixel, was analyzed. A heuristic optimization algorithm was used to determine the most efficient sampling protocols needed to accurately capture canopy variability as expressed by the NDVI images. Using NDVI image data as the sole criterion spread of plant varieties and secondarily, recognizing and protecting neglected and threatened cultivars. Forty-five grape varieties traditionally cultivated in Apulia (southeastern Italy), including little known, neglected, and threatened cultivars, were characterized in terms of their genetic profiles and the morphology of their vines. The objective was to investigate local grape diversity, enhance economic exploitation, explore the historical significance of the varieties, and conserve endangered germplasm. Twelve of the cultivars examined were found to be synonyms (same genotype but different names) or somatic mutants (variants of the same type, differing in berry color, berry shape, and/or size). In order to clarify the movement of grapes in ancient times, a search was carried out for other possible synonyms, comparing the genotypes found for Apulia with the published genetic profiles of grapes from other regions, especially those cultivated in the central and eastern Mediterranean; these areas are known to have been related to Apulia by the settlement of colonies and ancient trade routes. Approximately half of the Apulian cultivars investigated were found to have a foreign counterpart along the Adriatic Sea (Croatia), in Greece, or in other southern Italian regions. The new synonyms found with cultivars traditional to other areas shed light on the migration of cultivars following the settlement of colonies and the historical establishment of Mediterranean trade routes.

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Genetic Characterization of Grape Cultivars from Apulia (Southern Italy) and Synonymies in Other Mediterranean Regions

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The historical propagation of grapevines is of interest in that it can cast light on trade routes in the ancient world; the study of the DNA of these plants is an indirect means of investigating the

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for measuring vineyard variability, optimized sampling protocols derived from the images reduced sample size requirements up to 69% and reduced distance traveled between sampling locations by over 90% when compared to random sampling.


**Periodic Aeration of Red Wine Compared to Microoxygenation at Production Scale**

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Microoxygenation (MOX) is a widely popular winemaking process used to introduce oxygen into wines in a controlled manner in order to mimic some of the results observed during barrel aging. In this trial, the idea that periodic wine aerations could produce similar effects to those of conventional MOX was tested. The results of the trial showed that for most of the variables analyzed, the periodic aeration treatment produced effects that were equivalent to conventional MOX (e.g., a reduction in the concentration of free anthocyanins and an enhancement in polymeric pigments). These results suggest that well-managed, discontinued aeration treatments should be further studied, as they could possibly be used as an alternative to MOX.


**Modified Method for Producing Grapevine Plants in Controlled Environments**

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The rapid production of small fruiting grapevines under controlled environmental conditions is an invaluable tool for viticulture research, particularly studies involving flowering, fruit set, and berry development. The objective of this study was to determine an optimal growth strategy to produce experimental grapevine plants with adequate and consistent reproductive performance and to fully describe the approach to allow other researchers to produce consistent material from controlled environments year-round. Three different nutrient regimes were used to grow Shiraz (*Vitis vinifera* L.) plants from one-year-old cuttings in perlite-vermiculite and under controlled environmental conditions. Percentage fruit set, Coulure index, and Millardage index were determined. The growth strategy produced a fruit set percentage greater than 50% (in Shiraz) and optimum leaf elemental concentrations. Our modifications to the Mullins and Rajasekaran (1981) method, including automated irrigation, improves assessment and manipulation of grapevine reproductive performance and vine physiology in controlled conditions. It also highlights the importance of knowing how the growth medium contributes to the nutrient status and hence growth of experimental grapevine plants.


**An Improved Multichamber Gas Exchange System for Determining Whole-Canopy Water-Use Efficiency in Grapevine**

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Carrying out physiological studies on the response of whole canopies to any given biotic or abiotic stress factor is troublesome due to the complexity of the experimental unit, which is composed of thousands of leaves varying in age, position, light exposure, and health. The issue can be solved using an apparatus that encloses the entire canopy and monitors its gas exchange continuously for 24 hours. This system, coupled with an innovative device which allows concurrent recording of plant weight and hence accurate transpiration assessment, was successfully and uninterruptedly used for 49 consecutive days on potted, either well-watered or water-stressed, Sangiovese grapevines. Among the volumes of data the system can deliver, it was of particular significance that under severe stress canopy water-use efficiency, given as the ratio of photosynthesis to transpiration, markedly decreased as compared to irrigated pots. Data sets taken in this study, in addition to proving that the system is easy to set up, reliable, and in need of minimum physical attendance, warn about different conclusions that can be driven by the adaptive response of grapevine genotypes to water stress depending on the methodology used to assess gas exchange and water-use efficiency.