# High Elevation Viticulture and Winemaking Scientific Literature Search

Compiled by Willow Corson and Jeremiah Timm
Undergraduate Students, California State University, Fresno
Fresno State University

Overview

The Fresno State group focused their viticulture and enology literature search on UV radiation, climate change, cold hardiness and altitude effects. The literature found through their search has been organized into 5 categories:

1) Altitude/Elevation
2) UV Radiation, Sunlight
3) Climate Change, $CO_2$ Levels
4) Cold Hardiness
5) Miscellaneous

Altitude and Effects on Vines and Wine

Dinnella, C., E. Monteleone, N. Condelli and V. Iannelli (2005). Effects of Altitude on Aglianico Grapes Composition at Different Stages of Maturity. International Workshop on Advances in Grapevine and Wine Research, Venosa, Italy, 2005.

Grape phenolic profile strongly influences the characteristics of the resulting wine in terms of sensory properties, such as colour, bitterness and astringency, which are considered important determinants of wine quality. Wines from Aglianico grape show strong colour intensities. Astringent, bitter and sour are the dominant descriptors of sensations perceived when tasting these wines. The ripening stage of grapes is one of the main factors influencing their phenolic composition. Harvesting time is usually determined on the basis of technological indices related to barriers weight, sugar content and acidity. Several investigations demonstrated the lack of constant correlations amongst these technological parameters and grape phenolic composition. On the other hand, the evolution of phenolics during wine aging towards stable coloured pigments as well as less astringent or less bitter compounds strictly depends from grape "phenolic maturity". The main objective of this work was to study the effect of vineyard altimetry on evolution of Aglianico grapes composition in terms both of technological indices and phenolic profile during berries ripening. Grapes from vineyard at three different altitude (L: 200-300, M: 300-350 and H:400-550 mt) were collected at different ripening stages. Phenolic maturity and anthocyanins profile were assayed. Antioxidant activity and reactivity with mucin of grape phenolic extracts were determined. taking into account their relationship with phenol polymerisation degree and potential contribution to wine astringency, respectively. Principal Component Analysis of data indicate that grapes from L and M altitude levels are characterized by better technological indices and higher values of phenols and anthocyanins in respect to grapes from H level. Moreover seeds tannin from L and M levels resulted to be more polymerized and less reactive towards to proteins in respect to samples from H level. A delay in harvesting time of grape from H altitude level could partially overcome the relative weakness of its phenolic profile by increasing both phenol extractability index and anthocyanin concentration.

Dutt, G. R., E.A. Mielke, and W.H. Wolfe (1981). "The Use of Soils for the Delineation of Viticultural Zones in the Four Corners Region." Am. J. Enol. Vitic 32(4): 290-296.

Delineation of viticultural zones has been useful in making varietal recommendations and predicting wine quality. The California base 50 growing-degree-day model fails to predict zones in the Four Corners Region which are comparable to California, either in adaptable varieties, sugar and acid or color of red varieties. A new model has been developed based on modern soil surveys and altitude. The soil parameter most useful in describing viticultural adaptability is the mean annual soil temperature at 50 cm. This parameter subdivides soils into hyperthermic, thermic and messic. Most wine grapes in California are produced on thermic soils, hence, this soil group has been subdivided. Altitude (inter-related to temperature) is the secondary parameter. Zones defined are HT (hypothermic), T1 (low-level thermic), Tm (mid-level thermic), Th (high-level thermic), and M (messic). This system while encompassing the G.D.D. concept, allows for wider climatic conditions to be considered.

Failla, O., L. Mariani, L. Brancadoro, R. Minelli, A. Scienza, G. Murada, and S. Mancini (2004). "Spatial Distribution of Solar Radiation and Its Effects on Vine Phenology and Grape Ripening in an Alpine Environment." Am. J. Enol. Vitic 55(2): 128-138.

Climate, soil, and vineyard performance were characterized in the northern Italian alpine valley of Valtellina to develop an ecophysiological model for zoning viticultural aptitude of the district. Based on a representative sample of 54 small, steep-sloped terraced vineyards planted with the late-ripening red cv. Nebbiolo, the model included three-year (1998 to 2000) data sets for phenology, maturity curves, yield, vigor, and grape assays, with appropriate indices to manage these sets. Soils were characterized by pedological description and climate by annual values of potential photosynthetically active radiation (PPAR) and estimated thermal fields expressed as growing degree days (GDD) using base 10°C. PPAR ranged from 2700 to 3200 MJm-2year-1 and GDD ranged from 1100 to 1800. Vineyards showed a 12-day range in phenological timing, with early sites having the highest technological maturity and medium sites having the highest phenolic maturity. Elevation and PPAR were the main environmental factors affecting vine budbreak and bloom date; veraison was also affected by crop load and its interaction with PPAR availability. Technological maturity was affected by elevation; phenolic maturity by crop load, PPAR, and its interaction with crop load and elevation. The highest phenolic maturity was recorded in low-cropping vineyards at low elevation and PPAR.

Haba, M., A. Mulet, and A. Berna (1997). "Stability in Wine differentiation of Two Close Viticultural Zones." Am. J. Enol. Vitic 48(3): 285-290.

Pattern recognition techniques were applied to the discrimination of wines from two very close viticultural regions. They are two zones in the Utiel-Requena region (Valencia, Spain) of Certified Origin centered in the Utiel and Requena towns, respectively. The differentiation is due to various climatic factors, since soil characteristics are very similar and the cultivars are the same. This climatic differences influence the degree of ripeness attained The differences in altitude of the zones account for their climatic differences. This study focused on data corresponding to rosé wines (Bobal cultivar) from the 1988 vintage. Discriminant analysis showed that four variables (ethanol, anthocyanins, K, and Na) allowed a satisfactory zone classification of these rosé wines (93.5% well classified). The application of the discriminant analysis results to a series of wines of the same year, not considered previously, has also led to successful results (90.6% well classified). In order to evaluate the discriminant power of these variables, the study was broadened to include a

longer period (1987-1994). In each case, the analysis was similar although data used were only those corresponding to the four variables above-mentioned. In all cases, the classification was acceptable (90.7% well classified on average and better than 81% in each individual case), thus showing the stability of the discriminant variables along a period of eight years. The influence of the climate (year) is demonstrated through the variation of the discriminant variables coefficients.
Mateus, N. (2001). "Proanthocyanidin Composition of Red Vitis vinifera Varieties from the Douro Valley during Ripening: Influence of Cultivation Altitude." Am. J. Enol. Vitic 52(2): 115 - 121.

The effect of altitude and its related climatic conditions on the proanthocyanidin composition of Touriga Nacional and Touriga Francesa varieties during berry maturation is reported for the 1997 vintage. At berry maturation, low altitude is shown to be an important factor favoring the biosynthesis of higher concentrations of grape-skin catechin monomers ((+)-catechin, (-)-epicatechin gallate), procyanidin dimers, trimer C1, as well as total extractable proanthocyanidins. At harvest, grape-skin dimer conted was comprised almost entirely of dimer B1, followed by dimers B2 and B3, whereas Ca-C8 linked dimers (B1 to B4) and B2-gallate were the most abundant found in seeds. Dimer B2, which was one of the less important dimers at the early stage of development in seeds, showed a tendency to increase during ripening, while its respective gallate ester (B2-gallate) markedly decreased.

Mateus, N., S. Proenca, P. Ribeiro, J.M. Machado, and V. de Freitas (2001). "Grape Wine Polyphenolic Composition of Red Vitis Vinifera Varieties Concerning Vineyard Altitude." Ciencia y Tecnologia a Alimentaria 3(002): 102 -110.

Myburgh, P. (2005). "Effect of altitude and distance from the Atlantic Ocean on mean February temperatures in the Western Cape Coastal region." Wine Land.

Mean February temperature is one of the parameters used to select the most suitable locality for a specific wine grape cultivar. However, temperature data is not always available for all localities or vineyards. Decisions often depend on information gathered at the nearest weather station, which does not necessarily represent the situation at the specific locality. Processing existing data showed that the mean February temperature declines at a rate of ca. 0.5°C with a 100 m increase in altitude and increases by ca. 0.6°C per 10 kilometre increase in distance away from the ocean. If the altitude and distance from the Atlantic Ocean for a specific locality is known, it could be used in an elementary model to obtain an indication of the mean February temperature. However, factors such as slope and aspect, as well as the effects of topography on air flow and the occurrence of fog, may cause a varying degree of temperature deviations at specific localities.

Pfeifer, M. T., P. Koepke, and J. Reuder. (2006). "Effects of altitude and aerosol on UV Radiation." Journal of Geophysical Research 111.

Measurements of erythemally weighted UV radiation during about 600 days at different sites in Bolivia and Germany ranging from 550 to 5240 m above sea level have been used to derive the altitude effect AE under cloud-free conditions. In Germany, AE values between 7 and 16%/km have been obtained. In Bolivia, the altitude effect between the lowlands and the Bolivian plateau reached values of 5-10%/km. An altitude effect of 8-23%/km has been measured between the plateau and a high-mountain station. In accordance with previous studies these results indicate that the altitude effect of UV irradiance cannot be described by a single number in %/km, because it strongly depends on the atmospheric and surface parameters. In order to understand the high variability of the AE, the effects due to variations in solar elevation, albedo, and aerosol properties

on UV radiation and the AE have been analyzed. To eliminate the influence of clouds, an algorithm for the selection of cloud-free time intervals has been developed and applied. Furthermore, the measured data have been normalized to a fixed ozone content to avoid masking of the AE by different ozone amount. In addition, the background altitude effect, i.e., the AE resulting only from the reduced barometric pressure and reduced ozone content with increasing altitude, has been modeled. Depending on solar elevation and albedo, it ranges between 3 and 7%/km. Measured higher values of the AE, as well as negative values of the AE, are explained by the specific regional aerosol conditions, with important sources at high altitudes. The aerosol influence on UV is shown in detail for extreme conditions after strong bonfires in connection with a local holiday.

UV Radiation, Sunlight

Allen, D., S Nogues and N Baker (1998). "Review article. Ozone depletion and increased UV-B radiation: is there a real threat to photosynthesis?" Journal of Experimental Botany 49(328): 1775-1788.

This critical review of recent literature questions earlier predictions that photosynthetic productivity of higher plants is vulnerable to increased ultraviolet-B (UV-B) radiation as a result of stratospheric ozone (O3) depletion. Direct UV-B-induced inhibition of photosynthetic competence is observed only at high UV-B irradiances and primarily involves the loss of soluble Calvin cycle enzymes and adaxial stomatal closure in amphistomatous plants. However, even under these extreme UV-B exposures, acclimation (e.g. induction of UV-B absorbing flavonoids) can protect the photosynthetic processes. In plants irradiated with UV-B throughout development a reduction in productivity is usually associated with a reduced ability to intercept light (i.e. smaller leaf area) and not an inhibition of photosynthetic competence. Finally, a review of field experiments utilizing realistic UV-B enhancement is made to evaluate whether the mechanisms involved in UV-B-induced depressions of photosynthesis are likely to impact on the photosynthetic productivity of crops and natural vegetation in the future. Predictions of plant responses to O3 depletion are suspect from square-wave irradiance experiments due to the increased sensitivity of plants to UV-B at relatively low photosynthetically-active photon flux densities (PPFD) and ultraviolet-A (UV-A) irradiances. Realistic modulated UV-B irradiances in the field do not appear to have any significant effects on photosynthetic competence or light-interception. It is concluded that O3 depletion and the concurrent rise in UV-B irradiance is not a direct threat to photosynthetic productivity of crops and natural vegetation.Key words: Biomass, development, ozone depletion, photosynthesis, ultraviolet-B.

Bonomelli, A., L. Mercier, J. Franchel, F. Baillieul, E. Benizri, and Marie-Claude Mauro (2004). "Response of Grapevine Defenses to UV—C Exposure." Am. J. Enol. Vitic 55(1): 51-59.

The defense potential of a tolerant American Vitis rupestris cultivar (Rupestris du Lot) and a susceptible European Vitis vinifera cultivar (Chardonnay) in response to UV-C irradiation was investigated. The expression of eight defense-related genes coding for enzymes of the phenylpropanoid pathway (phenylalanine ammonia lyase and stilbene synthase), the octadecanoid pathway (lipoxygenase), and pathogenesis-related proteins (class I and III chitinases, ß-1,3-glucanase, class 6 pathogenesis-related protein, and class 10 pathogenesis-related protein) was followed by real-time reverse transcription polymerase chain reaction (RT-PCR). Phenolic compound accumulation was monitored by microscopic observation. Accumulation of resveratrol, a major grapevine phytoalexin, was evaluated by HPLC, and chitinase and ß-1,3-glucanase enzyme

activities were measured. Both grapevine species responded to UV-C treatment by enhancement of defense mechanisms. Intensity of some defense responses was correlated with tolerance to diseases, as previously described for stilbene accumulation: the tolerant species responded more intensely to UV-C exposure than the susceptible one. UV-C irradiation is a practical and reproducible method for inducing grapevine defense responses and can be useful in determining the defense potential of grapevine cultivars.

Chalmers, Y. (2005). "Leaf and Fruit Responses of 'Riesling' Grapevines to UV-Radiation in the Field." International Society for Horticultural Science.

The effects of UV-radiation on grapevine leaf and fruit physiology under field conditions were investigated. Selected portions of the light spectrum (within the UV wavelengths) were attenuated with polyester and di- and tri- acetate films. The entire canopy or parts thereof were covered wit these films during berry development. Berry skin pigment composition was determined using a non-destructive spectrophotoetric technique. There was a strong UV-induced shift towards the formation of red and brown pigment components without affecting the sugar levels. Chlorophyll degradation in the leaves and berry skins occurred more rapidly in the high UV-radiation treatments. Exposure to UV-B radiation increased both the concentration of total bound glycosidic secondary metabolites and phenolics. There were some noticeable effects on the aromatic expression in the resulting wines.

Crippen, D. D. J. a. J. C. M. (1986). "The Effects of Sun Exposure on the Compositional Development of Cabernet Sauvignon Berries." Am. J. Enol. Vitic 37(4): 235-242.

The effects of sunlight on Cabernet Sauvignon fruit clusters were studied in a Napa Valley, California, commercial vineyard. Clusters were chosen from sun-exposed locations and from locations shaded by the grapevine canopy. Selected exposed and shaded clusters on one vine were monitored for air temperature and light flux. Berry samples were collected weekly from anthesis and were analyzed for tartrate, malate, glucose, and fructose by HPLC and for potassium by emission spectroscopy. Berry juice was also analyzed for pH, titratable acidity, and soluble solids content. Data were presented both on a concentration basis (mg/g fresh weight) and on a per berry basis (mg/berry). Sun berries were significantly higher in concentrations of tartrate, malate, glucose, and fructose as shown by analysis of variance. No significant differences were found when expressed on a per berry basis, however. Potassium expressed either as concentration or per berry, pH, titratable acidity, and soluble solids showed no significant differences between sun and shade berries. Berries from the canopy shade were significantly heavier than berries exposed to the sun. The observed differences in concentration were attributed to a higher water content in the berries from shaded clusters.

Failla, O., L. Mariani, L. Brancadoro, R. Minelli, A. Scienza, G. Murada, and S. Mancini (2004). "Spatial Distribution of Solar Radiation and Its Effects on Vine Phenology and Grape Ripening in an Alpine Environment." Am. J. Enol. Vitic 55(2): 128-138.

Climate, soil, and vineyard performance were characterized in the northern Italian alpine valley of Valtellina to develop an ecophysiological model for zoning viticultural aptitude of the district. Based on a representative sample of 54 small, steep-sloped terraced vineyards planted with the late-ripening red cv. Nebbiolo, the model included three-year (1998 to 2000) data sets for phenology, maturity curves, yield, vigor, and grape assays, with appropriate indices to manage these sets. Soils were characterized by pedological description and climate by annual values of

potential photosynthetically active radiation (PPAR) and estimated thermal fields expressed as growing degree days (GDD) using base 10°C. PPAR ranged from 2700 to 3200 MJm-2year-1 and GDD ranged from 1100 to 1800. Vineyards showed a 12-day range in phenological timing, with early sites having the highest technological maturity and medium sites having the highest phenolic maturity. Elevation and PPAR were the main environmental factors affecting vine budbreak and bloom date; veraison was also affected by crop load and its interaction with PPAR availability. Technological maturity was affected by elevation; phenolic maturity by crop load, PPAR, and its interaction with crop load and elevation. The highest phenolic maturity was recorded in low-cropping vineyards at low elevation and PPAR.

Jansen, M. A. K., V. Gaba, and B.M. Greenberg (1998). "Higher plants and UV-B radiation: balancing damage, repair and acclimation." Trends in Plant Science 3(4): 131-135.

Although UV-B is a minor component of sunlight, it has a disproportionately damaging effect on higher plants. Ultraviolet-sensitive targets include DNA, proteins and membranes, and these must be protected for normal growth and development. DNA repair and secondary metabolite accumulation during exposure to UV-B have been characterized in considerable detail, but little is known about the recovery of photosynthesis, induction of free-radical scavenging and morphogenic changes. A future challenge is to elucidate how UV-B-exposed plants balance damage, repair, acclimation and adaptation responses in a photobiologically dynamic environment.

Keller, M. a. N. T.-M. (2004). DOES UV RADIATION AFFECT WINEGRAPE COMPOSITION? ISHS Acta Horticulturae 640: XXVI International Horticultural Congress: Viticulture - Living with Limitations.

Ultraviolet (UV) radiation is known to influence plant growth, development, morphology, and physiology, but its effects on the fruit composition of grapevines are unknown. Potted ‘Cabernet Sauvignon’ and ‘Chardonnay’ grapevines were grown in Australia under either ambient or reduced (2% of ambient) UV during two conescutive seasons. UV reduction was achieved using diacetate films suspended above the plants. In addition, two nitrogen treatments were applied at bloom in the first season and two water regimes were imposed from fruit set to leaf fall in the second season. Ambient UV reduced early-season shoot growth but stimulated lateral shoot growth later in the season and enhanced root growth. UV had no clear effect on leaf chlorophyll and gas exchange but reduced leaf water content and increased carotenoid and flavonoid concentrations. Flower calyptra contained high concentrations of flavonols, but this UV protection was temporarily lost during cap fall (anthesis), making the flowers vulnerable to UV. The combination of ambient UV and low nitrogen stress resulted in reduced fruit set. Nevertheless, UV failed to influence yield and fruit sugar content. Ambient UV increased the flavonol content in ripening post-veraison berries, but had no effect on anthocyanins and hydroxy-cinnamic acids. The impact of UV on fruit amino acids varied with individual compounds, but was insignificant for the predominant amino acids proline and arginine. Hence, of the fruit composition parameters examined, only flavonols were notably affected by UV radiation. Compared with ‘Chardonnay’, vegetative growth of ‘Cabernet Sauvignon’ was more tolerant, but reproductive growth was more sensitive to UV. In general, low nitrogen stress enhanced the UV effect, but low water stress reduced it.

Kliewer, M. W. (1977). "Influence of Temperature, Solar Radiation and Nitrogen on Coloration and Composition of Emperor Grapes." Am. J. Enol. Vitic 28: 96-103.

Fruit coloration was investigated in Emperor vines grown in pots in sunlit phytotron, lathhouse, and field conditions under various temperature and light regimes in combination with different levels of nitrogen.
At day/night temperatures of 37/32°C no anthocyanins were formed in fruits under either high light (HL; 66.5% sunlight) or low light (LL; 9.5% sunlight), whereas at field temperatures (FT; mean daily temperature 20.3°C), considerable anthocyanins formed under HL (100% sun) or LL (8.9% sun). At 37/32°C, soluble solids in fruits did not increase above 12.9° Brix, whereas at FT, 21° Brix was obtained under HL. The inhibition of anthocyanin formation and sugar accumulation in berries at 37/32°C and HL could not be reversed by transferring vines to temperature favorable for anthocyanin synthesis (FT), whereas when vines at 37/32°C and LL were transferred to FT at HL there was rapid accumulation of sugars but only slight formation of anthocyanin. Anthocyanin in berries decreased 59% in 20 days when the vines were transferred from FT-HL to 37/32°C-HL. Anthocyanin and soluble solids were significantly greater ($P<0.01$) in fruits ripened under FT-HL than under FT-LL. Anthocyanin and soluble solids were significantly less ($P<0.05$) in berries that received 15% sunlight than 54 or 100% sunlight. Anthocyanin formation did not occur in the complete absence of light, whereas °Brix did not differ significantly between 15%, 3%, and 0% sunlight.
Fruit color and soluble solids were significantly less ($P<0.05$) and arginine and total free amino acids greater with high levels of nitrogen fertilization than with low levels. The reduced fruit coloration at high nitrogen fertility conditions was attributed mainly to reduction in carbohydrate accumulation and an increase in nitrogenous substances stored in fruits.

Kolb, C. A., J. Kopecký, M. Riederer and E E. Pfündel "UV screening by phenolics in berries of grapevine (Vitis vinifera)." Functional Plant Biology 30(12): 1177-1186.

The role of phenolics in UV-screening was investigated in berries of a white grape cultivar (Vitis vinifera L. cv. Bacchus). Fluorescence microscopy revealed accumulation of phenolics in the skin of berries and, by high performance liquid chromatography and mass spectrometry, flavonols and hydroxycinnamic acids were identified as the main groups of UV-absorbing phenolics. Relationships between natural radiation and the synthesis of phenolics were studied in plants that were cultivated in the absence of UV radiation in a greenhouse before outdoor exposure to three different light regimes: the entire solar spectrum, the solar spectrum minus UV-B radiation and only visible radiation. During six days of exposure, flavonol synthesis was significantly stimulated by natural UV, in particular UV-B, but concentrations of hydroxycinnamic acids decreased under all conditions. Direct comparison of fluorimetrically-determined skin absorbance with absorbance of extracted flavonols or hydroxycinnamic acids suggested that acclimation of UV screening depends almost exclusively on flavonol synthesis. While increased flavonol levels resulted in efficient UV-A shielding, UV-B shielding was incomplete, probably due to decreased levels of the UV-B-absorbing hydroxycinnamic acids during exposure.

Kolb, C. A., M.A. Kaser, J. Kopecky, G. Zotz, M. Riederer, and E.E. Pfundel (2001). "Effects of natural intensities of visible and ultraviolet radiation on epidermal ultraviolet screening and photosynthesis in grape leaves." Plant Physiology 127(3): 863-875.

Grape (Vitis vinifera cv Silvaner) vine plants were cultivated under shaded conditions in the absence of ultraviolet (UV) radiation in a greenhouse, and subsequently placed outdoors under three different light regimes for 7 d. Different light regimes were produced by filters transmitting natural radiation, or screening out the UV-B (280-315 nm), or screening out the UV-A (315-400

nm) and the UV-B spectral range. During exposure, synthesis of UV-screening phenolics in leaves was quantified using HPLC: All treatments increased concentrations of hydroxycinnamic acids but the rise was highest, reaching 230% of the initial value, when UV radiation was absent. In contrast, UV-B radiation specifically increased flavonoid concentrations resulting in more than a 10-fold increase. Transmittance in the UV of all extracted phenolics was lower than epidermal UV transmittance determined fluorimetrically, and the two parameters were curvilinearly related. It is suggested that curvilinearity results from different absorption properties of the homogeneously dissolved phenolics in extracts and of the non-homogeneous distribution of phenolics in the epidermis. UV-B-dependent inhibition of maximum photochemical yield of photosystem II (PSII), measured as variable fluorescence of dark-adapted leaves, recovered in parallel to the buildup of epidermal screening for UV-B radiation, suggesting that PSII is protected against UV-B damage by epidermal screening. However, UV-B inhibition of CO(2) assimilation rates was not diminished by efficient UV-B screening. We propose that protection of UV-B inactivation of PSII is observed because preceding damage is efficiently repaired while those factors determining UV-B inhibition of CO(2) assimilation recover more slowly.

Kolb, C. A. a. E. E. P. (2005). "Origins of non-linear and dissimilar relationships between epiderman UV absorbance and UV absorbance of extracted phenoloics in leaves of grapevine and barley." Plant, Cell and Evironment 28(5): 580 - 590.

A recent review of climate patterns in Sourthern Germany has suggested significant increases in Ultraviolet (UV) radiation due to decreases in cloud coverage and in cloud frequency which compound the effects of stratospheric ozone depletion. Whether such UV radiation increases result in UV damage of higher plant leaves depends partly on the capacity of UV-absorbing hydroxycinnamic acids and flavonoids located in the plant epidermis to screen out UV radiaiton. Epiderman UV screening is most often assessed from UV absorbance of whole-leaf extracts but in the present work, this method is critically examined. In grapevine (Vitis vinifera L.), hydroxycinnamic acid as well as mono-hydroxylated and orthodihydroxylated flavonoid concentrations increased in parallel with flurometrically detected adaxial epidermal UV absorbance but only the latter class of flavonoid was associated with epidermal UV absorbance in barley (Hordeum vulgare L). For both species, curvilinear relationships between epidermal and total phenolic UV absorbance were established: initial slopes of the curves differed markedly between species. Modelling suggested that curvilinearity arises from UV-transparent epidermal areas located between vacuoles which are particularly UV-absorbind due to high levels of phenolics. The species-dependent differences were related to allocation of high amounts of phenolics in the mesophyll and abazial epidermis in barley but not in grapevine. Both factors, optical heterogeneity and variable distribution of phenolics, severely restrict the use of phenolic absorbance to estimate true epidermal screening.

Lafontaine, M., H.R. Schultz, C. Lopes, B. Bálo, and G. Varadi (2005). Leaf and fruit Responses of ´Riesling´ Grapevines to UV-Radiation in the Field. International Society for Horticultural Science.

Grapevine plants (Vitis vinifera L. cv. Silvaner) were cultivated under shaded conditions in the absence of UV radiation in a greenhouse, and subsequently placed outdoors under filters transmitting natural radiation, or screening out the UV-B (280 to 315 nm), or screening out the UV-A (315 to 400 nm) and the UV-B spectral range. All conditions decreased maximum chlorophyll fluorescence (FM) and increased minimum chlorophyll fluorescence (F0) from dark-adapted leaves; however, with increasing UV, FM quenching was stimulated but increases in F0 were

reduced. The FV/FM ratio (where FV=FM−F0) was clearly reduced by visible radiation (VIS): UV-B caused a moderate extra-reduction in FV/FM. Exposure of leaves (V. vinifera L. cv. Bacchus) to UV or VIS lamps quenched the FM to similar extents; further, UV-B doses comparable to the field, quenched F0. A model was developed to describe how natural radiation intensities affect PS II and thereby change leaf fluorescence. Fitting theory to experiment was successful when the same FM yield for UV- and VIS-inactivated PS II was assumed, and for lower F0 yields of UV- than for VIS-inactivated PS II. It is deduced, that natural UV can produce inactivated PS II exhibiting relatively high FV/FM. The presence of UV-inactivated PS II is difficult to detect by measuring FV/FM in leaves. Hence, relative concentrations of intact PS II during outdoor exposure were derived from FM. These concentrations, but not FV/FM, correlated reasonably well with CO2 gas exchange measurements. Consequently, PS II inhibition by natural UV could be a main factor for UV inhibition of photosynthesis. Abbreviations: F0 and FM - minimum and maximum chlorophyll fluorescence from dark-adapted leaves; PS I and PS II - Photosystem I and II; TUV−A and TUV−B - epidermal transmittance for UV-A and UV-B radiation; VIS - visible radiation; UV-A and UV-B - radiation in the range of 315 to 400 nm and 280 to 315 nm; V, VA and VAB - outside exposure to VIS, VIS+UV-B and VIS+UV-A+UV-B.

Lenk, S., L. Chaerle, E. E. Pfündel, G. Langsdorf, D. Hagenbeek, H.K. Lichtenthaler, D. Van Der Straeten and C.Buschmann (2007). "Multispectral fluorescence and reflectance imaging at the leaf level and its possible applications." Journal of Experimental Botany 58(4): 807-814.

Images taken at different spectral bands are increasingly used for characterizing plants and their health status. In contrast to conventional point measurements, imaging detects the distribution and quantity of signals and thus improves the interpretation of fluorescence and reflectance signatures. In multispectral fluorescence and reflectance set-ups, images are separately acquired for the fluorescence in the blue, green, red, and far red, as well as for the reflectance in the green and in the near infrared regions. In addition, ‘reference’ colour images are taken with an RGB (red, green, blue) camera. Examples of imaging for the detection of photosynthetic activity, UV screening caused by UV-absorbing substances, fruit quality, leaf tissue structure, and disease symptoms are introduced. Subsequently, the different instrumentations used for multispectral fluorescence and reflectance imaging of leaves and fruits are discussed. Various types of irradiation and excitation light sources, detectors, and components for image acquisition and image processing are outlined. The acquired images (or image sequences) can be analysed either directly for each spectral range (wherein they were captured) or after calculating ratios of the different spectral bands. This analysis can be carried out for different regions of interest selected manually or (semi)-automatically. Fluorescence and reflectance imaging in different spectral bands represents a promising tool for non-destructive plant monitoring and a ‘road’ to a broad range of identification tasks.

Núñez-Olivera, E. J. M.-A., Rafael Tomás, Saúl Otero, and María Arróniz-Crespo (2006). "Physiological Effects of Solar Ultraviolet-B Exclusion on Two Cultivars of Vitis vinifera L. from La Rioja, Spain." Am. J. Enol. Vitic 57: 441-448.

The response of two cultivars of Vitis vinifera (Tempranillo and Viura) typical of La Rioja to current levels of ultraviolet-B (UV-B) radiation was evaluated. Plants were exposed to near ambient radiation (PAR + UV-A + UV-B) or near ambient radiation 95% depleted in UV-B. At the end of the 16-day exposure, diurnal variations in photosynthetic pigment composition, soil-plant-analysis-development (SPAD) values, variables of chlorophyll fluorescence, methanol-extractable UV-absorbing compounds (MEUVAC), and sclerophylly were analyzed. The responses of the two

grapevine cultivars to the reduction of solar UV-B were somewhat different. The only significant response of Viura was a decrease in MEUVAC. This response was also found in Tempranillo, together with a reduced action of the xanthophyll cycle and an increase in the concentrations of chlorophyll and carotenoids and in SPAD values. Thus, solar UV-B seems to cause slight damage in Tempranillo grapevines. This damage as compared to the almost unaltered Viura grapevines could be related to the lower capacity of Tempranillo to produce MEUVAC under solar UV-B. Given that the exclusion of solar UV-B causes only modest physiological effects, at least in the short term, both cultivars seem to be adapted to the high solar radiation typical of the Mediterranean climate, and their photosynthetic performance (derived from chlorophyll fluorescence variables) does not appear to be at risk from current levels of UV-B.

Pfündel, E. E. (2003). "Action of UV and visible radiation on chlorophyll fluorescence from dark-adapted grape leaves (Vitis vinifera L.)." Photosynthesis Research 75(1): 29-39.

Grapevine plants (Vitis vinifera L. cv. Silvaner) were cultivated under shaded conditions in the absence of UV radiation in a greenhouse, and subsequently placed outdoors under filters transmitting natural radiation, or screening out the UV-B (280 to 315 nm), or screening out the UV-A (315 to 400 nm) and the UV-B spectral range. All conditions decreased maximum chlorophyll fluorescence (FM) and increased minimum chlorophyll fluorescence (F0) from dark-adapted leaves; however, with increasing UV, FM quenching was stimulated but increases in F0 were reduced. The FV/FM ratio (where FV=FM-F0) was clearly reduced by visible radiation (VIS): UV-B caused a moderate extra-reduction in FV/FM. Exposure of leaves (V. vinifera L. cv. Bacchus) to UV or VIS lamps quenched the FM to similar extents; further, UV-B doses comparable to the field, quenched F0. A model was developed to describe how natural radiation intensities affect PS II and thereby change leaf fluorescence. Fitting theory to experiment was successful when the same FM yield for UV- and VIS-inactivated PS II was assumed, and for lower F0 yields of UV- than for VIS-inactivated PS II. It is deduced, that natural UV can produce inactivated PS II exhibiting relatively high FV/FM. The presence of UV-inactivated PS II is difficult to detect by measuring FV/FM in leaves. Hence, relative concentrations of intact PS II during outdoor exposure were derived from FM. These concentrations, but not FV/FM, correlated reasonably well with CO2 gas exchange measurements. Consequently, PS II inhibition by natural UV could be a main factor for UV inhibition of photosynthesis.

Price, S. F., P.J. Breen, M. Valladao, and B.T. Watson (1995). "Cluster Sun Exposure and Quercetin in Pinot noir Grapes and Wine." Am. J. Enol. Vitic 46(2): 187-194.

Anthocyanin and flavonol content of disks of sun-exposed Pinot noir (Vitis vinifera L.) berry skin were compared to disks from shaded berries from the same clusters. Anthocyanin content was not affected by sun exposure, but quercetin glycoside concentration of sun-exposed disks was 1.46 µg mm-2 for the sun-exposed disks compared to 0.14 µg mm-2 for the shaded. Wines were made from Pinot noir clusters from a single vineyard block from three different sun exposure levels: shaded, moderately exposed and highly exposed. The concentration of quercetin glycosides in wine was 4.5, 14.8, and 33.7 mg L-1 in the shaded, moderate and highly exposed treatments, respectively. The level of quercetin aglycone also increased with sun exposure. Cluster sun exposure appears to be the primary factor determining quercetin levels in grapes and wine. Wines from highly and moderately exposed cluster positions had higher total anthocyanin levels than those from shaded clusters, but wines from highly exposed clusters had 40% greater polymeric anthocyanins than the other two treatments. Caftaric acid, catechin, and epicatechin concentrations

in wine were inversely related to cluster sun exposure. The low levels of caftaric acid in wines from sun-exposed clusters appeared to be related to hydrolysis of the tartaric ester, with wines from highly sun-exposed clusters having 50% more caffeic acid than moderate and 130% more than shaded clusters. Caffeic acid was not present in fruit samples. It is possible that the increase in polymeric anthocyanins in wines from sun-exposed clusters is directly related to quercetin levels. High wine quercetin levels may increase the rate of polymerization with potential stability and quality implications.

Spayd, S. E., J.M. Tarara, D.L. Mee, and J.C. Ferguson (2002). "Separation of Sunlight and Temperature Effects on the Composition of Vitis vinifera cv. Merlot Berries." Am. J. Enol. Vitic 32(4): 171-181.

Anthocyanin and phenolic profiles of berry skins from Vitis vinifera cv. Merlot in the Yakima Valley of Washington were influenced by sun exposure and temperature in 1999 and 2000. Growing degree days (base 10°C) accumulated between veraison and harvest were lower in 2000 than in 1999. Total skin monomeric anthocyanin (TSMA) concentrations were higher in 2000 than in 1999 in any given treatment. Berry temperature was increased as much as 13°C above ambient and shaded cluster temperatures when clusters were exposed to sunlight, regardless of aspect for north-south oriented rows. However, maximum fruit temperatures were higher for clusters on the west side of the canopy because ambient temperatures were higher after 1200 hr. Temperatures of west-exposed clusters at times exceeded 40°C. East-exposed clusters had higher TSMA concentrations than west-exposed or shaded clusters. To separate light and temperature effects, west-exposed clusters were cooled to the temperature of shaded clusters and shaded clusters were heated to the temperature of west-exposed clusters. Exposure to sunlight increased TSMA concentrations regardless of temperature in both years. In 1999 and 2000, cooling sun-exposed clusters increased TSMA concentrations. Heating shaded clusters decreased TSMA concentrations in 1999, but had no effect during the cooler ripening period of 2000. Ultraviolet (UV) light barriers did not influence either cluster temperature or TSMA concentrations. Decreased TSMA concentrations in berry skins from west-exposed clusters were due to temperature and not to UV radiation. Exposure to solar radiation increased concentrations of the 3-glycosides of quercetin, kaempferol, and myricetin. In 2000, sun-exposed clusters, regardless of aspect, had almost 10 times greater concentrations of total flavonols than shaded clusters. UV-light barriers significantly reduced individual and total flavonol concentrations, while temperature had little to no effect on their concentrations.

Steel, C. C. a. M. K. (2000). "Environmental Effect on Lipids: Atmosphere and Temperature." Biochemical Society Transactions 28: 883-885.

The carotenoid content was examined in leaf and berry tissues of grapevines (cv. Cabernet Sauvignon) grown either under ambient conditions or under polyester film to reduce UV light by 98%. Total carotenoids in leaves were less in vines grown under the UV screen. Levels of □-carotene decreased with berry development around veraison. This effect was more pronounced in vines grown under reduced UV light. The lutein content of berries appeared to remain relatively constant with berry development, but levels were decreased under the UV screen. These observations are important for the wine industry because of the biosynthetic link between carotenoids and wine flavour and aroma compounds.

Zorer, R., T. Cobelli, D. Tomasi, L. Zulini, and M. Bertamini (2005). Effect of Temperature and Light Availability on Ripening of Vitis Vinifera L. CV. Pinot Noir. International Workshop on Advances in Grapevine and Wine Research, Venosa, Italy.

Air temperature is widely used to build ripening models but it is also well known that the sunlight exposure of grape clusters is important to berry composition and metabolism. Berry temperatures usually match the diurnal solar radiation curve but can be increased as much as 13 °C above ambient and shaded cluster temperatures when clusters are exposed to sunlight, regardless of aspect for north-south oriented rows. Differences in temperature between ambient air and exposed fruit increase as solar radiation increase and wind speed decrease. In the present work the ripening process in Vitis vinifera L. cv. Pinot noir was investigated by periodical sampling of 20 single clusters and °Brix, pH and total acidity determination. In parallel the light microclimate of clusters was characterized by means of hemispherical pictures taken at the cluster position in order to calculate the direct, diffuse and total radiation cumulated from veraison to the sampling date. Main microclimatic parameters (air and soil temperature, air humidity, solar global and diffuse radiation, insolation, precipitation) were acquired by an automatic meteorological station. The data have been used to apply different ripening models and the role of the single meteorological parameters in the ripening process has been investigated. The use of different combinations of base temperatures limits in degree-day calculations provided big improvement over the degree-day summation system based on the l0 °C threshold temperature value (Winkler ripening index; R2 = 0.901; p = 0.012). The most accurate fitting of the °Brix data was obtained at a optimum temperature of 18.7 °C (R2 = 0.998; p < 0.001). Among the main micrometeorological cumulated parameters the correlation with the ripening status (°Brix) was very high and significant for the mean daily soil (-10 cm) temperature (R2 = 0.889; p = 0.018), air temperature (R2 = 0.902; p = 0.014), daily insolation (R2 = 0.933; p = 0.007), diffuse (R2 = 0.911; p = 0.012), total (R2 = 0.942; p = 0.005) and direct radiation (R2 = 0.964; p = 0.002). The possibility to implement local ripening data to GIS-based models is finally discussed.

Climate Change, $CO_2$ Levels

Bindi M., L. F., and F. Miglietta (2001). "Free Air CO2 Enrichment (FACE) of grapevine (Vitis vinifera L.): II. Growth and quality of grape and wine in response to elevated CO2 concentrations." European Journal of Agronomy 14(2): 145-155.

A FACE (Free Air CO2 Enrichment) experiment was carried out on Grapevine (Vitis vinifera L.) in 1996 and 1997 in an existing vineyard in Italy. Four FACE arrays were used to fumigate adults plants, while two arrays were used as control. Three CO2 exposure levels were used in these arrays (ambient, 550 and 700 mol mol-1). Dynamics of vegetative and reproductive biomass and grape quality compounds (sugar and acid concentrations) were monitored during the two growing seasons. Chemical analyses of the main wine quality compounds were made after fermentations. Elevated atmospheric CO2 levels had a significant effect on biomass components (total and fruit dry weight) with increases that ranged from 40 to 45% in the 550 mol mol-1 treatment and from 45 to 50% in 700 mol mol-1 treatment. Acid and sugar contents were also stimulated by rising CO2 levels up to a maximum increase in the middle of the ripening season (8-14%); however, as the grapes reached the maturity stage the CO2 effect on both quality parameters almost completely disappeared. Wine quality was not significantly affected by elevated CO2. Furthermore, no significant differences were detectable among the plants grown in the two enriched treatments (550 and 700 mol mol-1), and the effects of elevated CO2 concentration were similar in

the two growing seasons. The absence of any further stimulation of the highest CO2 treatment (700 mol mol-1) on grapevine growth and yield quality (i.e. grapes and wine) may be explained as a result of transport and/or sink limitations. We can conclude that the expected rise in CO2 concentrations may strongly stimulate grapevine production without causing negative repercussions on quality of grapes and wine.

Eysberg, C. D. (1987). "Viticulture in California: Cool airconditioned valleys as the equivalent of warm sheltered “côtes”." Geo Journal 15(4): 367-373.

This essay focuses on the distinctive geographic setting of viticulture in California. It assesses the significance of the prevailing environmental conditions for wine growing in California and offers an explanation of the spatial pattern of Californian wine climate regions. Wine varieties in California, as almost everywhere in the world, are of European origin (Vitis vinifera). The ultimate result of a bio-geographic diffusion process of Vitis vinifera was the development of superior wine varieties in a climate that is marginal for wine growing in Western Europe (Cf-Köppen). Nestled in a cooler and more precarious macro-climatological environment, the relatively warm micro climates of the slopes (cotes) allow wine growing. The noble varieties peculiar to the slopes have been successfully transplanted in California's coastal valleys, this not-withstanding the California environment, which is diametrically opposed to that in Western Europe. In a hot macro environment (Cs-Köppen), high-quality wine growing is only possible due to the cool airconditioned micro climate in the valleys.

Jones, G., M. White, O. Cooper, and K. Storchmann (2005). "Climate Change and Global Wine Quality." Climatic Change 73(3): 319-343.

From 1950 to 1999 the majority of the world's highest quality wine-producing regions experienced growing season warming trends. Vintage quality ratings during this same time period increased significantly while year-to-year variation declined. While improved winemaking knowledge and husbandry practices contributed to the better vintages it was shown that climate had, and will likely always have, a significant role in quality variations. This study revealed that the impacts of climate change are not likely to be uniform across all varieties and regions. Currently, many European regions appear to be at or near their optimum growing season temperatures, while the relationships are less defined in the New World viticulture regions. For future climates, model output for global wine producing regions predicts an average warming of 2 ∘C in the next 50 yr. For regions producing high-quality grapes at the margins of their climatic limits, these results suggest that future climate change will exceed a climatic threshold such that the ripening of balanced fruit required for existing varieties and wine styles will become progressively more difficult. In other regions, historical and predicted climate changes could push some regions into more optimal climatic regimes for the production of current varietals. In addition, the warmer conditions could lead to more poleward locations potentially becoming more conducive to grape growing and wine production.

Neilsen, D., S. Smith, W. Koch, G. Frank, J. Hall, and P. Parchomchuk (2001). "Impact of climate change on crop water demand and crop suitability in the Okanaga Valley, B.C." Technical Bulletin.

Schultz, H. R. (2004). "How may climate change affect viticulture in Europe?" Ace Revista de Enologia, from http://www.acenologia.com/ciencia59_04eng.htm.

Global climate change has been a public discussion topic for several years. It is difficult to predict changes in climate and sea level due to the enhancement of the so-called greenhouse effect (including temperature rise, CO2 increase, and nitrogen deposition) but atmospheric CO2 concentration is measurably increasing and is expected to double current levels during the next century with marked effects on current agroclimatic conditions. Man has effectively accelerated global respiration about 10 million! times by the combustion of several billion years worth of accumulated photosynthate and other organic carbon in the course of a few hundred years. Aside global warming, shifts in rates and distribution of precipitation and increases in surface level ultraviolet (UV)-B radiation due to a depletion of the stratospheric ozone layer are among the likely alterations. Since actions and interactions of climatic factors and man-induced changes in for instance vegetation structure are very complex and oceans can act as large buffers on more radical short-term (years) changes, there is great uncertainty about what to expect over the next century. In contrast to research on natural terrestrial ecosystems and some agricultural crops, possible effects of a change in climate on grapevines have largely been ignored.

Stock, M., F.W. Gerstengarbe, T. Kartschall, and P.C. Werner "Reliability of Climate Change Impact Assesments for Viticulture." International Society for Horticultural Science.

Current Assessments of climate change effects on viticulture are primarily based on global climate models. With respect to temperature and temperature-based indices, this may produce reasonable first approximations. Recent studies indicate that several viticultural regions may become more successful, and others less so, as high-quality wine production area. However, it is not only average temperature but also a variety of other climate parameters and their variability that the allocation of chances an drisks in impact assessments depends on. in this respect, global model resolutions are of limited value. However, current methods of regionalizaiton by statistical down scaling or embedded regional climate models also show deficiencies and uncertainties. This paper presents a new method for the evaluation of regional climate scenarios using the statistical regional model STAR. This model offers improved applicability and reliability concerning viticultural aspects and primarily aims at evaluating measures of adaptation rather than predictions. The results demonstrate the extent and effects of climate change on the viticulutural areas in Europe. Possible impact on grapevine phenology and wine quality for the Rheingau and pest risks for Sardinia is given as an example.

Cold Hardiness

Basinger, A. R., and E.W. Hellman (2007). "Evaluation of Regulated Deficit Irrigation on Grape in Texas and Implications for Acclimation and Cold Hardiness." International Journal of Fruit Science 6(2): 3-22.

Deficit irrigation is used increasingly as a vigor management tool and to conserve water in grape vineyards. Several strategies including regulated deficit irrigation (RDI) have emerged, but none has been evaluated in Texas. Deficit irrigation has also been observed to influence vine acclimation and presumably vine cold hardiness. Experiments were established in a commercial 'Cabernet Sauvignon' (Vitis vinifera) vineyard in west Texas to evaluate RDI under local conditions and to study the potential for deficit irrigation to induce earlier shoot acclimation and influence cold hardiness. RDI significantly reduced pruning weights by as much as 46% and increased applied water-use efficiency up to 72%, but had little or no effect on yield components or fruit composition, indicating that these strategies could be useful in west Texas. Deficit irrigation was

consistently associated with earlier and more rapid development of periderm on shoots, but had no effect on bud cold hardiness.

Fennell, A. (2004). "Freezing Tolerance and Injury in Grapevines." Journal of Crop Improvement 10(1-2): 201-235.

Grapes, due to their wide distribution, are one of the temperate fruit crops most frequently damaged by freezing temperatures. Freezing injury can result in decreases in yield and substantial economic losses to grape growers, subsequently impacting fruit wholesalers, wineries, distributors, and related industries. Freeze damage is not limited to the northern or southern limits of the production range. Freezing injury can occur in spring, fall, or winter in many of the grape growing regions. An understanding of the mechanisms involved in freezing tolerance, acclimation, and deacclimation in grapevines is needed to match cultivars appropriately with growing sites, improve cultural practices that minimize freezing injury, and aid in breeding and selecting cultivars with improved freezing tolerance. The ability to avoid or tolerate freezing temperatures includes a complex set of traits that is influenced by the inherent genetic characteristics of the grapevine and its interaction with the environment. In the present review, the mechanisms of freezing tolerance in grapevines are summarized and discussed in relation to the influence of genotype, phenological development, and environmental factors.

Hamman, R. A. J., I.-E. Dami, T.M. Walsh, and C. Stushnoff (1996). "Seasonal Carbohydrate Changes and Cold Hardiness of Chardonnay and Riesling Grapevines." Am. J. Enol. Vitic 47(1): 31-36.

Cold hardiness and endogenous levels of soluble sugars were monitored during the dormant season for Chardonnay and Riesling (Vitis vinifera L.) dormant buds and stem cortical tissues. Endogenous levels of glucose, fructose, raffinose, and stachyose were strongly associated with cold hardening, increasing from the onset of cold acclimation in August to maximum cold hardiness in December and January. During dehardening in March and April, endogenous levels of these sugars dropped as temperature increased. A high ratio of glucose and fructose to sucrose coincided with maximum cold hardiness, and a low ratio was associated with the dehardened condition in fall and spring. Sucrose levels, however, were not associated with cold hardiness in either cultivar. Neither cold hardiness nor soluble sugars of grape tissues were influenced by a late harvest compared to harvest at normal fruit maturity.

Mills, L. J., J.C. Ferguson and M. Keller (2006). "Cold-Hardiness Evaluation of Grapevine Buds and Cane Tissues." Am. J. Enol. Vitic 57(2): 194-200.

A system for differential thermal analysis (DTA) was constructed to assess cold hardiness of grapevine buds and cane tissues. This updated system incorporated a sample chamber of our own design with a commercially available programmable freezer and data acquisition system (DAS). Thermoelectric modules (TEM) were used to sense exotherms that are produced when water or tissues freeze. The TEM signals recorded by the DAS at 15 sec intervals were downloaded directly to an Excel spreadsheet. The DTA system was designed to test up to 35 samples of five buds or three canes per TEM simultaneously. Bud and cane low temperature exotherms (LTE) recorded by this system correlated very closely with those of a standard system, and the extent of cane phloem and xylem injury, based on tissue browning, corresponded well with expected injury based on LTE analysis. The LTEs of moist buds were 3°C to 4°C higher and those of moist canes 2°C higher than LTEs of corresponding dry tissues, indicating that surface moisture increases the susceptibility to

cold injury. Cold hardiness of eight grape cultivars increased from late fall through mid-January, after which buds and canes began to deacclimate. Riesling was the hardiest of all cultivars tested. Chardonnay reached similar levels in midwinter, but was considerably less hardy in late fall and late winter. Pinot gris and Viognier were the least hardy among the white winegrape cultivars. Among red winegrape cultivars, Cabernet Sauvignon was generally the hardiest and Merlot the least hardy, with Malbec and Syrah being intermediate.

Smallwood, M. a. D. J. B. (2002). "Coping with the Cold: The Molecular and Structural Biology of Cold Stress Survivors." Philosophical Transactions: Biological Sciences 357(1423): 831-847.

Miscellaneous

Bernston, G. M. (1994). "Modeling Root Architecture: Are There Tradeoffs between Efficiency and Potentialof Resource Acquisition." New Phytologist 127(3): 483 - 493.

Carrion, J. S., M. Munuera, M. Dupre, A. Andrade (2001). "Abrupt Vegetation Changes in the Segura Mountains of Southern Spain throughout the Holocene." The Journal of Ecology 89(5): 783 - 797.

Chuine, I. a. P. C. (1999). "Climatic determinants of budburst seasonality in four temperate-zone tree species." New Phytologist 143(2): 339 - 349.

Several physiological processes controlling tree phenology remain poorly understood and in particular bud dormancy. Many studies have emphasised the action of chilling temperatures in breaking dormancy. However, the effect of the preceding summer temperature has rarely been investigated although there is some evidence that they may be involved in the settlement and intensity of dormancy as well as cold acclimation. In this paper, thermal time to budburst in relation to the duration of chilling outdoors, preceding summer temperatures and forcing temperatures was studied by outdoors experiments in seedlings of Platanus acerifolia, Vitis vinifera, Quercus pubescens and Castanea sativa. Results showed that temperatures of the predceding summer had no significant effect on the timing of budburst, P. acerifolia and Q. pubescens showed a very weak response to the duration of chilling, and the phenological characteristics of each species were found to be adapted to the climate conditions of its own geographical area. The phenological model used in this study explained 82-100% of the variance of the data without taking into account summer temperatures. Thus, although summer temperatures may be well involved in the intensity of dormancy and cold hardiness, they do not significantly affect budburst and therefore may not need to be considered in phenological models for predicting budburst.

Corino, L., L. Sansone, and S. Dellepiane A Survey of Recent Vineyard Stresses and Suggestions for Better Performance. International Society for Horticultural Science, ISHS Aca Horticulturae 640: XXVI International Horticultural Congress: Viticulture Living with Limitations.

In Italian vineyards and elsewhere a common concern is early vine senescence. During the past several decades, viticultural techniques have changed greatly, especially those related to improved vigor and production. From 1985 present research was carried out to understand the impact of vine stress especially that which affects vineyard longevity. Trials were carried out manily in Piedmont, Liguria and Lombardy as well as several surveys in other regions. The main

observations were: climatic conditions, soil characteristics, grower proficiency and vineyard history (yield, pruning technique, soil management). Two problems have been considered, Esca disease and FD disease. It was proved that under stressful conditions, Esca disease is more virulent. Moreover, wounds on the trunk are deleterious and unsatisfactory soil structure is increasing the problem. FD seem to be closely related to plant stress caused mostly by over cropping, poor soil management, deleterious wounds on the trunk and lack of vine-site relationship within which older traditional cultivars proving to be more tolerant. As some modern cultural techniques are rather aggressive on plant and soil management, plants are increasing in vascular disorders that are greatly affecting plant longevity. In order to reduce the above-mentioned problems, improving the professionalism in vineyard management is suggested. The future of profitable viticulture should pay more attention to environmental concerns and to the production of regionally typical wines.

Cowham, S. a. A. H. (2001). "French Pinot Noir Clones - an Australian perspective." The Australian Grapegrower and Winemaker April 2001: 93 - 97.

Downey, M. O., N.K. Dokoozlian and M. P. Krstic (2006). "Cultural Practice and Environmental Impacts on the Flavonoid Composition of Grapes and Wine: A Review of Recent Research." Am. J. Enol. Vitic 57(3): 257-268.

Flavonoids are a large and diverse group of compounds that, by their presence or absence, contribute greatly to wine quality. While the flavonoid content and composition of a wine reflects the vinification process to some extent, the primary determinant is the composition of the grapes at harvest. Thus, considerable research has been directed toward understanding the nature of flavonoids in grapevines, the factors that influence their biosynthesis, and how this knowledge might be used to manage and manipulate the flavonoid composition of berries at harvest. This review examines the flavonoids as a class of compounds, the role these compounds play in the plant, their contributions to wine quality, and recent research on the impacts of environmental factors and cultural practices on the flavonoid content and composition of grape berries.

Ebadi, A., S. Asbahi Cis, Z. Zamani, M. Reza Naghavi (2005). Influence of Three Training Systems on Fruit Yield and Quality of Five Grapevine Cultivars. International Workshop on Advances in Grapevine and Wine Research, Venosa, Italy.

Due to the vegetative and reproductive characteristics of grape, it is grown and trained on supporting systems for commercial production. The aim of training systems in grapevine growing is to maximize yield and fruit quality, facilitate garden operations and improve plant protection. A research was conducted in Horticultural Department Research Centre, Faculty of Agriculture, University of Tehran during period of 1998-2002, to investigate the effects of three training systems on yield, fruit quality and some vegetative characters of five grapevine cultivars. The systems used in this study were Vertical Shoot Positioning (VSP), Y and Sloping-T and the cultivars were Flame Seedless, Daste Chin, Bidane Sefid, Bidane Ghermez and Shahroodi. Length of bunch and sugar content of berries were affected by training systems, but yield per vine and other measured characters were not affected. Sugar content of berries at Y and Sloping-T training systems was higher than VSP system, although there was no significant difference between them. Bunch length of bunch in Sloping-T system was higher than other systems. There were also significant differences among the cultivars that were attributed to their genetic characters. Wind blowing resulted to some problems in Sloping-T system such as breaking of shoots in early spring

and rotating of vine canopy and the need to frequently tying cordons to cordon wire in this system. Since Y system had some better advantages including easier pruning and harvesting operations due to better access to canes and bunches, therefore it is suggested as the best of three systems for these five cultivars.

Evans, J., E.A.R. Tattersall, W. Johnson and G.R.Cramer (1996). "Toward Wine Grape (Vitis vinifera) Vineyard Establishment in Northern Nevada." 1 - 5.

Fiola, J. A., R.D. Meyers, B. Beale, H. Reed and G.R. Welsh, Jr. (2006). "Winegrape Cultivar, Clone and Training System Evaluations."

Gillerman, V. S. D. W., K. Shellie, and R. Bitner (2006). "Geology and Wine 11: Terroir of the Western Snake River Plain, Idaho, USA." Geoscience Canada 33(1): 37 - 43.

Heazlewood, J. (2005). "Stabilizing the yields of Pinot Noir grape vines in Tasmania."

Howell, G. S. (2001). "Sustainable Grape Productivity and the Growth-Yield Relationship: A Review." Am. J. Enol. Vitic 52(3): 165-169.

Research reports and experiemental efforts during the last century are presented with the goal to encourage discussion of balancing grapevine fruit yeild and vine growth and leaf area. Fruit and subsequent processed quality are equally relevant economic issues as we strive to create conditions for both sustainable grapevine productivity and vine capacity for tolerating abiotic and biotic stress episodes. It is proposed that methods to achieve vine balance will vary with regard to macroclimate and cultivar, but will be most critical for those macroclimates commonly called cool-climate regions. Regardless, vine balance is most readily understood when based on the principles of vine carbon balance as mediated through well-understood factors such as leaf area/gm fresh weight of fruit at harvest and allmetric practices as the Ravaz Index and the Growth-Yield Relationship.

Newman, J. L. (1986). "Vines, Wines and Regional Identity in the Finger Lake Region." Geographical Reviews 76(3): 301 - 316.

Oliveir, C., A. Barbosa, A.C. Silva Ferreira, J. Guerra and P. Guedes DE Pinho (2006). "Carotenoid Profile in Grapes Related to Aromatic Compounds in Wines from Douro Region." Journal of Food Science 71(1): 1365 - 2621.

The aim of this work was to characterize 8 representative grape varieties of the Douro Region using the carotenoid profile as it related to aromatic compounds in the respective wines. Some other analyses, such as the determination of sugar, probable alcohol, pH, and total acidity, were also performed in an attempt to understand in which way the evaluated characteristics influenced by grape variety could contribute to the wine aroma. For the 3 years of the study, grape varieties with high concentrations of carotenoids (Touriga Femea, Tinta Amarela dn Tinta Barroca) have lower values of free norisoprenoids, even with exceptions (Touriga Femea). Conversly, grape varieties with lower concentrations of carotenoids (Touriga Nacional, Sousao and Tinto Cao) appear to have higher contents of free norisoprenoid, namely b-ione for Touriga Nacional and vitispirane and 1,1,6-trimethyl-1,2-dihydronaphthalene (TDN) Sousao and Tinto Cao. Touriga Nacional, followed by Tourig Femea, was the wine variety with the highest values of total free

terpenols (linalol, a-terpinol, nerol and geraniol), the presence of which is reponsible for the floral aroma.

Ortega-Regules, A. R.-C., Inmaculada; López-Roca, Jose M; Ros-García, Jose M; Gómez-Plaza, Encarna (2006). "Anthocyanin fingerprint of grapes: environmental and genetic variations." Journal of the Science of Food and Agriculture
86(10): 1460-1467.

The anthocyanin content and fingerprint of four different Vitis vinifera L. varieties (Cabernet Sauvignon, Merlot, Syrah and Monastrell), the last grown in two different locations, were studied during three growing seasons to determine how seasonal conditions and location affect the content of berry anthocyanins and their relative percentages. Important differences in the content of anthocyanins were detected among varieties—Monastrell grapes from one of the locations presenting the highest anthocyanin content—when expressed as μg g−1 of skin. However, due to the large berry size of Monastrell grapes, when the results were expressed as mg kg−1 of berry, Cabernet Sauvignon and Syrah grapes presented the highest concentration. Significant differences were found as regards growing season, the concentration of anthocyanins being lowest in 2003, the warmest year. As regards the relative percentage of the different anthocyanins, substantial differences were found between varieties, but again, the results were also influenced by the year under study. When the percentages of anthocyanins were used as variables in a discriminant analysis, a 100% correct classification of the four different varieties was obtained. Moreover, to check the suitability of this tool for classifying varieties, data referring to the anthocyanin percentages of the four varieties grown in very different agroecological conditions and at different ripening stages were tested with the model we have built, 89% of correct classification being achieved.

Pastor del Rio, J. L. a. J. A. K. (2006). "Development of Proanthocyanidins in Vitis vinifera L. cv. Pinot noir Grapes and Extraction into Wine." Am. J. Enol. Vitic 57(2): 125-132.

The effect of grape maturity on proanthocyanidin concentration, composition and transfer into wine was studied. Vitis vinifera L. cv. Pinot noir grapes (Pommard clone) were monitored for three consecutive vintages (2001 to 2003). Proanthocyanidin content was monitored by reversed-phase HPLC after acid-catalyzed cleavage in the presence of excess phloroglucinol (phloroglucinolysis). After three growing seasons, results indicated that an increase in heat summation between fruit set and veraison was associated with an increase in proanthocyanidin content in grapes and wine. Maturity did not have a consistent effect on the total proanthocyanidin content in wine, but the proportion of seed-derived proanthocyanidins extracted consistently increased with maturity.

Pirie, A. a. M. G. M. (1978). "Interrelationships of Sugars, Anthocyanins, Total Phenols and Dry Weight in the Skin of Grape Berries During Ripening." Am. J. Enol. Vitic 28: 204-209.

The relationship between levels of anthocyanins, total phenols and sugars in the skin of ripening grapes (Vitis vinifera cvs. Shiraz and Cabernet Sauvignon) was studied in the fruit during the period from véraison to maturity. In grapes with a wide range of anthocyanin contents per unit area of skin there was a good correlation between sugar content of the skin and levels of phenolic substances. The closest correlations, e.g. sugar vs. anthocyanin ($r = 0.96$) and sugar vs. total phenols ($r = 0.95$), were found in the first five weeks after véraison. There was a poor correlation between berry Brix levels and levels of polyphenolic substances in the skin at all stages of ripening

(r = 0.44-0.45). The role of sugars in the regulation of phenolic biosynthesis in ripening grapes is discussed.