

High Elevation Viticulture and Winemaking Literature Review

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May 1, 2007

Overview

Different countries and different regions have different ideas of what constitutes high altitude, so that should be considered when reading the following information. Differences could perhaps be extrapolated, though; for example, in some cases the authors make direct comparisons between two altitudes. A great deal of work has been done by the Italians in Trentino-Alto Adige regarding complex slopes and altitude. The Portuguese have done some interesting work regarding wine quality. The former Eastern Bloc countries have done some interesting work in vine physiology. Most of the Italian work is in Italian; most of the Portuguese work is in English; some of the Eastern European work is translated and some is not. Unfortunately, what look like some of the most interesting articles are not in English.

To summarize briefly what these papers have posited as significant:

Altitude has been linked to:

differences in plant physiology/anatomy

- higher foliar N
- higher leaf water content
- lower leaf cell sap concentration
- higher photosynthetic rate
- higher net CO₂ assimilation
- lower stomatal conductance
- lower CO₂ diffusion
- early ripening
- late phenological development
- smaller leaves
- shorter canes
- low yield tied to: smaller berries
 - fewer clusters
 - smaller clusters

differences in berry composition/wine

- higher anthocyanins
- lower proanthocyanidins
- lower monoterpenes and norisoprenoids
- higher "phenolic maturity"
- higher carotenoids
- higher titratable acidity
- higher malic acid
- lower color intensity in wines
- lower/slower sugar accumulation

all linked to differences in

- interception of solar radiation
- diurnal temperature differences
- lower relative humidity
- lower or higher plant available water (dep. on site)

The annotated list is separated into four main topics: vineyard establishment, vineyard management, plant physiology, and grape composition/wine quality. In a few cases, papers were relevant to more than one category, so an unannotated listing can be found in the second relevant category with a note as to where to find the abstract. There are a few papers not directly related to viticulture, but with interesting implications to plant and soil responses to slopes and altitude, so they were included. Also, following the categorized, annotated list is an unannotated alphabetical (by author) bibliography.

Annotated List of Articles:

Vineyard Establishment: site selection, clone selection, trellising, terracing

Balan, V. and I. Neamtu (1997). "Amenajarea antierozionala in platforme late a terenurilor in panta pentru plantatiile viticole.; Antierosional arrangement of sloping lands for vineyards in large platforms." Cercetari Agronomice in Moldova **30**(3): 173-179.

The arrangement of land with a slope of 12-20% in large platforms with rectilinear rows on the contour, delimited by roads and a sewer network to prevent erosion, has the following advantages compared to a terraced vineyard: the high cost of establishing vineyards on slopes is reduced; the factors favourable for landslides are reduced; the micro-earth works on each interval allow the mechanization of maintenance works; and plant growth and the yield obtained are normal. Permanent maintenance of the drainage system and additional measures like alternative weed control on the intervals or on the uncovered crops of row micro-gradients are required. (Language: Romanian)

Costacurta, A., D. Tomasi, et al. (1988). "Measurement of the amount of direct solar energy received by the vineyard as a function of location and structure." Rivista di Viticoltura e di Enologia **41**(12): 491-510.

A model for measuring intercepted radiation is described. It is used to analyse the effects of environmental parameters (latitude, slope and aspect) and vineyard structure (training form, row direction, inter-row distance, etc.) on the quantity of radiation available to the vines at different times in the growth cycle. (Language: Italian)

Dumas, V., E. Lebon, et al. (1997). "Differentiation of local climate in the Alsatian vineyards." Journal International des Sciences de la Vigne et du Vin **31**(1): 1-9.

Climate and soil characteristics are the main factors affecting the qualitative potential of a vineyard. At the level of the 'terroir', it is important to know the variability of the local climate (mesoclimate). Landscape parameters (altitude, slope, etc.) affecting the local climate of vineyards in Alsace, France, were studied at 6 sites, each representative of a terroir type, during 1991, 1992 and 1993. Climatic variables were measured hourly and daily throughout the growing season (April-September). Wind speed was the variable which was most affected by the landscape. The gradient of the landscape, its altitude and its orientation were the main factors differentiating the terroirs. The variability of global solar radiation depended on the slope, the orientation, and the height of and distance to topographic elements. This variability depended on solar angle and was smallest in June. Small differences in average seasonal temperature were observed between sites. More detailed studies considering different daily weather conditions (cloudy versus clear weather) and measures per hour and per day contributed to a better differentiation between sites. In cloudy weather conditions, temperatures depended on altitude only

(thermic gradient -0.6 degrees C/100 m). In clear weather conditions, night temperatures depended on the altitude and the slope of the site; day temperatures were also influenced by the orientation and the gradient of the landscape, and the characteristics of the soil surface. (Language: French)

Egger, E., M. Leprini, et al. (2002). "Observation of late frost damage in grapes." Informatore Agrario **58**(5): 63-66.

The tendency to late frosts and the ensuing damage to 56 vine varieties or clones was studied from 1997 through 2001 in a vineyard at Arezzo, Italy (270 m altitude). Frosts in March had little effect on the plants but April frosts caused significant damage, particularly if March temperatures had been mild. The severity of the damage varied according to the stage of development of the buds or shoots and varietal differences were also apparent. A table classifies the vines according to sensitivity to late frosts: slightly sensitive (12), moderately sensitive (9), sensitive (22, including all but three of the Sangiovese clones) and highly sensitive (13, including the remaining Sangiovese clones). The only defence against late frosts appears to be the choice of tolerant vine varieties. (Language: Italian)

Fonteneau, P. and A. Carbonneau (2005). "Vineyards on very steep slopes: the Harp, a training system with an original plant water regime." Progres Agricole et Viticole **122**(17): 361-369.

Two criteria were chosen in order to study the physiological functioning and the qualitative potentialities of the vineyard training system Harp in Valtellina, North Italy, an alpine vineyard characterized by its very steep slopes. These criteria are the potential exposed leaf area (Carbonneau's formula) and the plant water regime (leaf water potentials). The methodology used to evaluate the two criteria was adapted to the particularities of this mountain vineyard: steep slopes, complex architecture of vegetation. The Harp system results in a high exposed leaf area. Due to its original water regime, which is different between the two divided canopies, the Harp system should permit a particular adaptation of the training system to the terroir in Valtellina. The qualitative interest of the Harp system for the valley has been now noted for most aspects. (Language: French)

Fregoni, M. and D. Triacca (1979). "Examples of soil lay-out for viticulture on steep slopes." Vignevini **6**(5): 27-31.

Three methods of maintaining soil on steep slopes are outlined. Choice of the most suitable depends on angle of slope, soil type and depth of parent rock. In the first method wide terraces are retained by walls and the vine rows run down the slope on what are still fairly steep inclines. In the second wide terraces are held by grassed banks and contain 3-4 vine rows running horizontally along the contour. In the third the arrangement is also horizontal with retaining banks but the terraces are narrower, each with a single vine row. (Language: Italian)

Iacono, F., M. Stefanini, et al. (1993). "Adaptability of Chardonnay clones at different altitudes. II. Organoleptic characteristics of wines." Wein Wissenschaft **48**(3-6).

Thirteen French and Italian clones of the winemaking grape cv. Chardonnay were grown at altitudes of 250 and 700 m. Sensory properties of wines prepared from grapes harvested in 1990 and 1991 were assessed by a trained panel; results were evaluated by the factor analysis procedure (varimax rotation method). The clones differed considerably in wine sensory properties. Altitude of cultivation influenced most sensory properties of the wine; high altitude improved body, and the sour-fruity, sweet pungent and varietal

fruity characteristics of the wines. Year of production also influenced sensory quality of the wines. The relation of sensory properties of the wines to sugar accumulation properties of the grapes during ripening is discussed. [See Stefanini and Iacono abstract below for part I.] (Language: English)

Jones, G. V., N. Snead, et al. (2004). "Geology and wine 8. Modeling viticultural landscapes: A GIS analysis of the terroir potential in the Umpqua Valley of Oregon." Geoscience Canada **31**(4): 167-178.

Terroir is a holistic concept that relates to both environmental and cultural factors that together influence the grape growing to wine production continuum. The physical factors that influence the process include matching a given grape variety to its ideal climate along with optimum site characteristics of elevation, slope, aspect, and soil. While some regions have had hundreds and even thousands of years to define, develop, and understand their best terroir, newer regions typically face a trial and error stage of finding the best variety and terroir match. This research facilitates the process by modeling the climate and landscape in a relatively young grape growing region in Oregon, the Umpqua Valley appellation. The result is an inventory of land suitability that provides both existing and new growers greater insight into the best terroirs of the region. (Language: English)

Laville, P., A. Marre, et al. (1996). "Landslide and erosion modelling with geographical information systems." Seizieme conference du COLUMA Journees internationales sur la lutte contre les mauvaises herbes, Reims, France, 6 8 decembre 1995 Tome 3.

The development is described of a method which evaluates the risk of landslides and other erosion events in Champagne vineyards as a function of natural and soil conditions. A numerical database containing information on elevation and soil has been used in conjunction with data obtained from geographical information system sources to create atlases (1/25,000) for erosion and landslide hazards. Used in conjunction with statistical methods and a knowledge of field conditions, the maps have been shown to be a valid tool in the prediction of soil movements. (Language: French)

Madelin, M. and G. Beltrando (2005). "Spatial interpolation-based mapping of the spring frost hazard in the Champagne vineyards." Meteorological Applications **12**(1): 51-56.

The Champagne vineyards, famous worldwide, are located at the northern limit of viticulture. Consequently, they are very sensitive to spring frosts that can occur after bud burst. These spring frosts occur mainly in radiative atmospheric situations (low speed wind, clear sky) where spatial variations in minimum temperatures are very important. The latter depend on several factors at different scales: from the macroclimatic scale, where the geographical location (latitude/longitude) has a strong influence, to the topoclimatic scale, where environmental and topographical factors play an important role. After a brief recall of the definition of these different factors extracted from a Digital Elevation Model and a land-use database, we propose a spatial interpolation of minimum temperatures in the Champagne vineyards based on multiple regression. From this interpolation, we can map the frost hazard for the whole vineyard from data measured over five spring seasons (1998-2003) and for about 20 weather stations. In this paper, we present this mapping technique and compare it with the data for spring 2003 when particularly strong frosts occurred. (Language: English)

Murisier, F., M. Ferretti, et al. (2003). "New training systems for vineyards on steep slopes in narrow terraces. Experiments on Merlot in Ticino." Bulletin de l' OIV **76**(871/872): 739-750.

Training systems were evaluated in a vineyard (cv. Merlot) on terraces in Gudo, Switzerland. The natural inclination of the ground was 65% and the distance between terraces of vine rows was 3 m. Six training systems were tested with the aim of optimizing the use of space. Double Guyot with simple vertical tying (control) was compared with Guyot or cordon training with double tying, ascending and descending the slope. The level of pruning for the system of double tying was increased from 20 to 60% compared with the control. Between 1995 and 2000, this pruning level resulted in an average yield increase of 30-50%, without a negative effect on grape or wine quality. The maintenance of quality was attributed to the relationship between exposed leaf area per kg of grapes that was similar for all the systems. Cordon training resulted in an increase of pruning and of weight of grapes, but reduced the fertility of buds and the percentages of unburst buds and weak wood. In comparison with the control, the tested training systems required an increase in hours of labour of 30-150 h/ha. This was compensated for by the increase in yield. (Language: French)

Ramos, M. C. and J. Porta (1997). "Analysis of design criteria for vineyard terraces in the Mediterranean area of North East Spain." Soil Technology **10**(2): 155-166.

The most widely used measure for soil conservation in this area is terracing (hillside ditches, locally termed rases). Local technical solutions were studied and different types of terraces are described and analysed in terms of their effectiveness for runoff control. Mean potential soil losses were evaluated according to the USLE and compared with field measurements in experimental plots. The distances between terraces were calculated using the criteria proposed by several authors. Owing to the wide diversity of results, an acceptable value for 'soil loss tolerance' (T-value) has been used in order to establish some criteria to make recommendations, taking the values of soil loss measures in the field as a reference. According to these preliminary results based on measurements taken over a period of two years, recommended distances between terraces in vineyards are a distance of 28 m with a slope of 6%, and 20 m in fields with a slope of 8%. Bennett's criteria for calculation of distances between terraces are preferred, being close to experimental results in the area. (Language: English)

Rapcha, M. P., M. F. Kisil, et al. (2004). "Effect of vineyard location on productivity." Sadovodstvo i Vinogradarstvo **2004**(3): 19-21.

Effect of altitude, elevation, slope and orientation of a vineyard on productivity and grape sugar content was studied in Moldova. Data on effect of location parameters on the variables studied are tabulated. Statistical models describing relationships between the parameters and variables are presented. Variable results were obtained for different grape cultivars and combination of parameters. The authors state that orientation of a vineyard is responsible for 61% of variation in productivity and sugar content. (Language: Russian)

Simon, J. L., F. Murisier, et al. (1983). "Terrace cultivation in Swiss vineyards: effect on environment and production." XVIIIe Congres international de la vigne et du vin de l' OIV.

Terrace cultivation, which is standard practice in the Tessin region, is spreading to other regions. It ensures protection against erosion and may allow the development of slopes which could not have been cultivated otherwise. The type of terrace recommended depends on the slope. Factors such as the yield, mechanization possibilities and the trellising system must be considered. Yields in relation to terrace width are discussed, together with cover crop problems and vole damage. (Language: French)

Simon, J. L. and W. Koblet (1978). "Choice of grapevine cultural systems in relation to climatic restraints (altitude and latitude)." Bulletin de l' OIV **51**(567): 329-334.

A review and discussion, with mention of the geographical situation and climate of Swiss vineyards, characteristics of viticultural production, and cultural systems and their development. (Language: French)

Stefanini, M., F. Iacono, et al. (1993). "Adaptability of Chardonnay clones at different altitudes. I. Evaluation of a mathematical model for the definition of the sugar accumulation rate." Wein Wissenschaft **48**(3-6).

Thirteen clones of Chardonnay winemaking grapes from France and Italy were grown at altitudes of 250 and 700 m. During the grape ripening period, grapes were sampled weekly and sugar concn. and yield were determined. A mathematical model (quadratic model with a plateau) of sugar accumulation in grapes was assessed. Cluster analysis was applied to define groups of clones with similar sugar accumulation rates. 3 groups were differentiated among grapes grown at 250 m altitude; 4 groups were differentiated at 700 m altitude. The mathematical model fitted the experimental data well. The relation of veraison earliness, ripening and sugar accumulation rate is discussed in relation to selection of the optimum clone for restrictive environments. [See Iacono abstract above for part II.] (Language: English)

Stefanini, M., F. Iacono, et al. (1995). "Adaptability of Pinot noir clones to different altitudes." Acta Horticulturae; Apr 1995 (388); 71-76.

The results are presented of studies on the environmental adaptability of Pinot noir grape [*Vitis vinifera*] clones cultivated at different altitudes. The trial was carried out for 3 years on 7-year-old vineyards planted with French and Italian Pinot noir clones grafted on SO4 rootstock. All vineyards were trained with the Guyot system. The vineyards were located in two Trentino areas (north Italy) at two different altitudes (250 and 700 m a.s.l.). Environmental adaptability was evaluated using a model of sugar accumulation rate in berries during ripening, and through quantitative and qualitative data obtained at harvest. There were significant differences in must composition between altitudes and data confirm that Pinot noir has a low adaptability to different cultivation areas. Thus, specific Pinot noir clones must be used, particularly in restrictive environments, in order to obtain a high quality crop. (Language: English)

Stefanini, M., F. Iacono, et al. (1993). "Adaptability of some Sauvignon Blanc clones to altitude evaluated by wine sensory analysis." Vignevini **20**(12).

Adaptability of Sauvignon blanc clones to cultivation at different altitudes was determined during the 1990-1991 period for 5 clones (242, 376, 377, R3, and 297) of Sauvignon blanc vines, using sensory evaluation of the wines produced from these grape varieties. Clones were cultivated at 250 or 700 m and grapes were sampled weekly from fruit set to harvest to monitor sugars accumulation, titratable acidity, pH, malic and tartaric acids, and K. Wines were evaluated by a test panel and statistical analysis. Quadratic equations were used to relate sugars accumulation with effects of clone, yr and environment. R3 had highest sugar concn. at both altitudes; sugar concn. was higher in grapes at 250 m than at 700 m. Accumulation of sugar was slower in clones 242, 376, and 377 than in the other clones. Similarly R3 had highest titratable acidity and lowest pH of all clones, with those grown at 250 m having higher acidity and lower pH than at 700 m. Sensory evaluation indicated that wines from grapes grown at higher altitudes generally had more typical fruity, floral and acid-bitter aroma and flavour than wines from grapes grown at 250 m, but there was variation between clones. (Language: Italian)

Tarara, J. M., J. C. Ferguson, et al. (2005). "Asymmetrical canopy architecture due to prevailing wind direction and row orientation creates an imbalance in irradiance at the fruiting zone of grapevines." *Agricultural and Forest Meteorology* **135**(1/4): 144-155.

Much effort is invested in trellising and training grapevines to maximize radiation interception by the canopy and to manage the radiation environment of the fruit clusters. Slope permitting, conventional wisdom among winegrape growers prompts many to adhere to north-south row orientations to balance between the two sides of the canopy both photosynthetic efficiency and the exposure of fruiting zones to solar radiation. In windy sites, thigmomorphogenesis in annually renewed shoots can reshape a bilaterally balanced canopy. We measured irradiance at the fruiting zone and shoot geometry in two contiguous vineyards differing only in row orientation. The prevailing west-southwest winds were roughly parallel to the rows of one vineyard and at an oblique angle to the rows of the second vineyard. Mean wind velocity in the prevailing direction was 3.3 m s⁻¹ during the growing season. Shoots were grouped into four classes based on row orientation and shoot azimuth from the cordon. Windward shoots were significantly shorter (26-29%) than all other classes of shoots because of fewer nodes per shoot. Mean internode length per shoot (~5 cm) did not vary between shoot classes and was not related to row orientation. Regardless of row orientation or initial shoot azimuth, shoot tips tended to be displaced eastward (leeward). In rows oriented roughly parallel to the prevailing wind, shoots exhibited distinct down-row streamlining and vines had a bilaterally uniform canopy about the cordon. In rows at an oblique angle to the prevailing wind the vines did not form a uniform canopy about the cordon. Both row orientations resulted in similar differences between sides of the canopy in total irradiance at the fruiting zone (+5.4 MJ m⁻² d⁻¹ on the west side of rows oriented at an oblique angle to the wind; +6.0 MJ m⁻² d⁻¹ on the south side of rows oriented parallel to the wind); however, the timing of peak intensity on the side receiving higher irradiance differed by row orientation (11.9 LST at south-facing fruit; 13.7 LST at west-facing fruit). Wind-induced canopy asymmetry could result in unequal berry ripening in areas of high irradiance where peak insolation of the berries coincides with the highest temperatures of the day. Results indicate that in consistently windy locations, growers should establish row orientation based both on sun-earth geometry for maximizing radiation interception by the canopy, and on the consequences of radiation distribution at the fruiting zone due to wind-induced canopy asymmetry. In established vineyards, growers could compensate for non-uniform canopy architecture to some extent with modifications to the trellis system and standard training practices. (Language: English)

Management: cultivation, irrigation, frost protection, canopy management, soil management

Barthes, B. and E. Roose (2002). "Aggregate stability as an indicator of soil susceptibility to runoff and erosion; validation at several levels." *Catena* **47**(2): 133-149.

The evaluation of soil susceptibility to runoff and water erosion in the field is often expensive or time-consuming. Several authors have reported that susceptibility is linked to aggregate stability, whose determination is far easier. However, this susceptibility has generally been deduced from rainfall simulation experiments on sieved soil samples, whose behaviour is not always representative of field-scale phenomena. Our aim was to extend the validity of relationships between soil aggregation and erosion through

comparisons of topsoil aggregate stability and field-assessed susceptibility to runoff and erosion. Susceptibility to runoff and erosion was determined at several levels: first, on a southern French Regosol, through measurements of runoff and soil loss from 1-m² microplots under simulated rainfall; second, from 100- to 800-m² runoff plots on a Nitisol [Nitisols] in Benin, a Ferralsol in Cameroon and a Regosol in Mexico (with additional data on Syria from the literature); and finally, soil susceptibility to erosion was determined through semi-quantitative assessment of the frequency of erosion features on vineyard hillsides in southern France. Aggregate stability was determined by immersion in water and wet-sieving of 2-mm sieved, air-dried 0- to 10-cm soil samples, which actually tests aggregate resistance to slaking. Under simulated rainfall, runoff depth and soil loss after 30 minutes were negatively correlated with topsoil content in stable macroaggregates (>0.2 mm). On runoff plots, 3-year runoff rate and soil loss were negatively correlated with topsoil aggregate stability, especially stable macroaggregate content; these correlations were improved when slope gradient and climate aggressiveness were considered in addition to aggregate stability. On vineyard hillsides, the frequency index of erosion features was negatively correlated with topsoil content in stable macroaggregates, especially in the absence of conservation practices. These results confirm that aggregate stability is a relevant indicator of soil susceptibility to runoff and erosion, especially in Mediterranean and tropical areas where intense rainfall is frequent. They also confirm that simple laboratory determination can provide data closely correlated with those resulting from field investigations. (Language: English)

Battany, M. C. and M. E. Grismer (2000). "Rainfall runoff and erosion in Napa valley vineyards: effects of slope, cover and surface roughness." Hydrological Processes **14**(7): 1289-1304.

The effects of slope, cover and surface roughness on rainfall runoff, infiltration and erosion were determined at two sites on a hillside vineyard in Napa County, California, USA using a portable rainfall simulator. Rainfall simulation experiments were carried out at two sites, with five replications of three slope treatments (5%, 10% and 15%) in a randomized block design at each site (0.64 m² plots). Prior to initiation of the rainfall simulations, detailed assessments, not considered in previous vineyard studies, of soil slope, cover and surface roughness were conducted. Significant correlations (at the 95% confidence level) between the physical characteristics of slope, cover and surface roughness, with total infiltration, runoff, sediment discharge and average sediment concentration were obtained. The extent of soil cracking, a physical characteristic not directly measured, affected analysis of the rainfall-runoff-erosion process. Average cumulative runoff and cumulative sediment discharge from site A was 87% and 242% greater, respectively, than at site B. This difference was linked to the greater cover, extent of soil cracking and bulk density at site B than at site A. The extent of soil cover was the dominant factor limiting soil loss when soil cracking was not present. Field slopes within the range of 4-16%, although a statistically significant factor affecting soil losses, had only a minor impact on the amount of soil loss. The Horton infiltration equation fit field data better than the modified Philip's equation. Owing to the variability in the 'treatment' parameters affecting the rainfall-runoff-erosion process, use of ANOVA methods were inappropriate; multiple-factor regression analysis was more useful for identifying significant parameters. Overall similar values were obtained for soil erosion parameters as those from vineyard erosion studies in Europe. (Language: English)

Belvini, P., L. Dalla-Costa, et al. (1983). "Effects of some genetic, environmental and growing factors on importance of frost damages on vines." Vignevini ; Mar 1983; 10(3): 33-40 **10**(3): 33-40.

In studies at two localities in 1980-1981 during which temperatures down to -10 deg C were recorded, Prosecco was the most badly damaged, Riesling Italico [Italian Riesling], Cabernet Sauvignon and Chardonnay had moderate damage, Pinot Grigio [Grey Pinot] and Merlot had only slight damage, and Verduzzo Trevigiano [Treviso Verduzzo] was not damaged. Vigour was negatively correlated with frost damage. (Language: Italian)

Centeri, C. and R. Pataki (2005). "Soil erodibility measurements on slopes of the Tihany Peninsula, Hungary." Advances in Geocology(36): 149-154.

Soil loss prediction is a very important consideration in the Tihany Peninsula in Hungary. Rainfall simulation studies were conducted using the Universal Soil Loss Equation (USLE) to determine the K factors (i.e., soil loss, rainfall erosion index, soil erodibility factor, slope length, slope gradient factor, cropping cover management factor and agricultural practices factor) for shallow soils (Vertisols) where vineyards are widespread. The soil samples were also analysed for CaCO₃, organic matter content, cation exchange capacity, particle size distribution and infiltration rate. Tabulated data are given of K factor calculations based on soil loss data from rainfall simulation and with USLE equations. (Language: English)

Corino, L., E. Gambino, et al. (1996). "Soil management in Piedmont viticulture." Obstbau Weinbau **33**(7/8): 207-208.

A study was made of yields of grape cv. Barbara on R4 rootstock and soil erosion in an Italian vineyard on a 20% slope with the rows running up the slope, on plots with (1) mechanical soil cultivation, (2) green-plant cover. Vine growth, grape yields and Botrytis infection were greater in (1) but soil erosion was severe, whereas in (2) soil erosion was insignificant. (Language: German)

Dizengof, L. F. (1969). "Green manuring in hilly vineyards." Sadovodstvo(10): 28-9.

In a vineyard on a 15 degrees slope clean cultivation was compared with green manuring either in alternate interrows or in every interrow. The cover crops, a mixture of legumes, oats and barley, were sown in the autumn and ploughed-in in May. Vegetative growth, up to the time of bearing, was increased by 14.7% by green manuring in alternate interrows and by 37.3% by green manuring in every interrow; average yield increases over 5 years were 22.1% and 43.3% respectively. Soil erosion was reduced. (Language: Russian)

Ferrero, A., B. Usowicz, et al. (2005). "Effects of tractor traffic on spatial variability of soil strength and water content in grass covered and cultivated sloping vineyard." Soil and Tillage Research **84**(2): 127-138.

Frequent machinery traffic on sloping vineyard influences spatial distribution of soil physical properties. Our objective was to assess the effects of crawler tractor traffic across the slope (20%) on spatial distribution of soil strength and water content of silt loam soil under controlled grass cover and conventionally cultivated vineyard. The experiment was situated on hillside vineyard (NW, Italy) arranged with rows crosswise the slope. The grass covered treatment included periodical mowing and chopping of herbs and the cultivated treatment - autumn ploughing (18 cm) and spring and summer rotary-hoeing in the vineyard inter-rows (2.7 m). A crawler tractor (2.82 Mg) was used at the same locations across the slope for all tillage and chemical operations. The measurements of soil bulk density, penetration resistance and volumetric water content were done in autumn (after vintage) within the sloping inter-row. The results were analyzed using classic statistics and geostatistics with and without trend. The highest

variability was obtained for penetration resistance (CV 56.6%) and the lowest for bulk density (9.6%). In most cases, the semivariograms of the soil parameters were well described by spherical models. The semivariance parameters of all properties measured were influenced by trend. Three-dimensional (3D) maps well identified areas with the highest soil strength in lower crawler ruts being positioned in the upper side of vine row and successively lower strength in upper ruts situated on other side of the same row and inter-rut area. Higher strength in lower than upper ruts was induced by tractor's tilt and resulting higher ground contact pressure. Soil water content in both treatments was the lowest below the upper rut and increased in inter-rut and lower rut areas. The differences in the soil properties between the places within the inter-row were more pronounced in grass covered than in cultivated soil. (Language: English)

Fic, V. and Z. Klobaska (1984). "Effect of the slope of the land on the setting of the inclination of the nozzles when spraying in vineyards." Zemledelska Technika **30**(5): 287-292.

Using a specific sprayer applying a 0.5% concentration of a spray between the rows of a vineyard on slopes of 0, 7 and 12 degrees, deposit measurements were made on the uphill and downhill side. The spray was collected in 4 replications on 500 x 500 mm panels, placed in the leaf area, i.e. 0.6-1.5 m above ground. The clusters of droplets were analysed and recorded in 5 categories according to their density. The nozzles were set to form an angle of 90 degrees to the vertical axis of the vines on level land. (Language: Czech)

Gracio, A. M. T. M. (1975). "The management of vineyards on steep slopes. A critical analysis of various solutions." Bulletin de l' OIV **48**(530): 297-310.

A review and discussion, with mention of vineyard establishment down and across the slope, terraces, subsoiling, stone removal, levelling, basic fertilization, planting and training systems, and management. (Language: Italian)

Hafner, P. (1997). "Possibilities of mechanization in South Tyrol vine growing." Obstbau Weinbau **34**(2): 35-37.

The aims of mechanization systems (cost savings and labour savings), for transport, plant protection, soil cultivation, leaf and tendril removal using tractors or track and hand-controlled equipment are discussed. Factors affecting the possibilities of mechanization, such as vineyard layout, slope, terracing, access and trellises are outlined. (Language: German)

Hoppmann, D. (1978). "Study of vineyard sites in Rheingau and Baden." Weinberg und Keller **25**(2): 66-92.

A new model for the calculation of heat exchange in relation to must weight and quality (deg Oe) was based on a critical examination of 11 years' climatic data. It was used in a study of 3 vine cvs (Riesling, Muller-Thurgau and Rulander) on 215 plots in 4 vine-growing districts. The heat gain in relation to vine phenological phases proved most important at pre-blossom and fruit ripening. Temperature was important in relation to evapotranspiration and rainfall, and evaporation used 40% of the solar radiation. The altitude, orientation of the slope and its angle affected heat gain. Soil type and its heat and water retaining capacity and conductivity influenced heat radiation. Wind, cold air flow and frost incidence greatly affected yield and must quality. (Language: German)

Lipiec, J., B. Usowicz, et al. (2006). "Management effects of sloping vineyard on thermal properties of soil." Advances in Geocology(39): 71-78.

Thermal properties of soil play important role in heat and moisture flow. They are strongly affected by soil management. We assessed the effect of slope and crawler tractor traffic across the vineyard slope on spatial distribution of heat capacity, thermal conductivity and diffusivity of a silt-loam soil of a hillside vineyard (18% slope) in N.W. Italy, with permanent grass cover (GC) and conventional tillage (CT) of the inter-rows. The experiment was performed on hillside viticulture (N-W Italy) with average slope of 18% and south/south-west aspect. The climate is characterized by rainfall averaging 840 mm and cold and snow winter and dry summer with rainstorms. The vineyard, with rows following the contour lines, lies on silt loam soil. Two treatments that is permanent grass cover and cultivation treatment were applied in the vineyard inter-row of 2.7 m width. In both treatments the crawler tractor (Fiat 55 CV) of 2.82 Mg weight and 1.31 m width was used for tillage and chemical operations along the inter-rows across the slope at the same locations. The width and length in contact with the ground of each track were 0.3 m and 1.4 m, respectively. The statistical-physical model was used to determine the thermal conductivity of soil. Heat capacity was calculated based on the equation of de Vries. All thermal properties were determined at three water statuses. Mean values of all thermal properties in GC and CT were similar at comparable inter-row areas and water statuses except of inter-rut area under GC where they were smaller. Thermal conductivity and heat capacity increased with increasing water content and bulk density while thermal diffusivity was the greatest at approximately field capacity and decreased at saturated state. Spatial distribution of the soil thermal conductivity and heat capacity along the slope was similar to that of bulk density at all water statuses. Increase in soil water content at given bulk density can result in greater, smaller or the same thermal diffusivity depending on the occurrence of the characteristic maximum of thermal diffusivity. (Language: English)

Lisa, L., G. Gay, et al. (1999). "Terrain management for hillside vineyards." Informatore Agrario **55**(11): 79-83.

Developments in the design of vineyard terraces with the aim of facilitating mechanical operations are described. Improvements to earlier designs are suggested. Data are tabulated on operational costs for a vineyard on a 25-35% slope with vines trained using 4 systems. Labour requirements and costs were lowest in vines trained to a central curtain, followed by espalier and double-curtain trained vines (which had similar requirements) and vines trained to an open-lyre which had substantially higher requirements. (Language: Italian)

Madelin, M. and G. Beltrando (2005). "Spatial interpolation-based mapping of the spring frost hazard in the Champagne vineyards." Meteorological Applications **12**(1): 51-56.

See establishment section, above, for abstract.

Mescalchin, E. and M. Varner (1997). "Control of grapevine downy mildew in Trentino." Informatore Fitopatologico **47**(11): 18-23.

The control strategies used in Trentino against *Plasmopara viticola* on grape over the last 10 years are summarized. The slope, position and exposure of land in Trentino is very variable, and microclimatic conditions can vary greatly even in one vineyard. It therefore becomes particularly difficult to regulate control measures. Over the last 10 years, there has been a move away from curative treatments using cymoxanil, which was found to be insufficiently active, to preventive treatments using copper-based products. However, the return to the use of copper-based products brings concerns about the long-term risk of accumulation of copper residues in the soil and grape. Experiments in 1996 indicated that

residues in grape depended more on the dosage of summer treatments than on the number of treatments made over a season at reduced rates. It is therefore recommended that reduced doses of copper products are used in the final treatments from 20-25 July onwards. It is concluded that control measures should also take into account the microclimatic conditions of the area being treated to avoid generalizations. (Language: Italian)

Oliveira, M. T. (2001). "Modeling water content of a vineyard soil in the Douro Region, Portugal." Plant and Soil **233**(2): 213-221.

The soil moisture of a vineyard soil under two different plantation systems, bench terrace and straight down the slope (German system), was measured weekly from 1991 to 1997 in the Demarcated Region of Douro - the Port wine producing region in Portugal. The soils of the region are extremely stony, located on steep slopes along narrow valleys. These conditions complicate the study of soil water relations with deterministic functions. We fitted a large data set to stochastic models to: determine which stochastic model best forecasts soil moisture in various planting systems; objectively evaluate variation of soil moisture in each planting system based on chosen models; and find an objective factor on which to base management decisions. Soil moisture variation was best represented by a time frequency model (Fourier series). Soil under straight down the slope plantation had significantly higher water reserves for most of the year than bench terrace plantation but the difference was not high enough to drive a significant shift on production and fundamentally affect the choice of which system to choose for new plantations. The model-generated data suggested a superficial and subsuperficial downflow of water from upper slopes in the straight plantation relative to bench terraces. However, the model failed to shed additional information on the mechanisms related to soil water balance. Data generated by the time frequency model might prove useful for other management decisions such as schedule and intensity of topping and pesticide application. (Language: English)

Orlandini, S., G. Zipoli, et al. (1991). "Micrometeorology of vineyards and phytopathological models." Bulletin OEPP **21**(3): 431-439.

In intensive viticulture, the distribution of principal meteorological elements depends principally on aspect, slope and altitude. Microclimate modelling in vineyards was investigated by connecting local atmospheric conditions with macroscale meteorological conditions as reported by the standard meteorological networks. To study the effect of topography on crop microclimate, vineyard temp. was measured with an infrared thermometer, and phenological, allometrical and yield measurements were made in vineyards located close to the Chianti Classico hills, Italy. The climatic and pathological data was used to verify mathematical models simulating microclimatic conditions and to protect grapes from downy mildew (*Plasmopara viticola*). The models allow a reduction in the number of treatments against the disease, lightening at the same time the damage to the ecosystem and the cost for the farmer. This paper was presented at the joint WMO/EPPO/NAPPO symposium on practical applications of agrometeorology in plant protection, held at Florence, Italy 4-7 Dec., 1990. (Language: English)

Petrovic, N. and N. Todorovic (1993). "Air temperature in the vineyard situated on the slope." Review of Research Work at the Faculty of Agriculture, Belgrade **38**(1): 93-98.

Air temperature data between July and Oct. were recorded over 2 years at the base and near the top of the slope, with a difference in altitude of 20 m, in a cordon vineyard of cv. Burgundy Black. The vines were oriented E.-W. on a S.-facing slope, 230-250 m a.s.l.,

near Varvarin. Temperatures were measured (1) in the middle of a row, (2) along the row on the N. side, and (3) along the row on the S. side; and also at 3 heights (0.05, 1.00 and 2.00 m above the soil surface). The vine height ranged from 1.70 to 1.80 m. At both the base and top of the slope, the air was warmest (with max. day temperatures and temperature amplitudes) along the S. side of the rows. At the height of densest growth (1.00 m above the soil surface) it was shown that along the N. side of the rows the day temperature was up to 1.0 degrees C higher and the night temperature up to 2.8 degrees lower at the base than at the top of the slope. The mean max. day temperatures were 0.4 degrees higher and the mean min. day temperatures were 1.1 degrees lower at the base than at the top of the slope. (Language: English)

Richter, G. (1989). "Erosion control in vineyards of the Mosel Region, FRG." Soil erosion protection measures in Europe, Proceedings of the European Community Workshop, Freising, Germany.

Land treatment in vineyards may help reduce loss of soil, nutrients and runoff water. Since 1974, plot measurements of runoff and soil loss have been carried out in a vineyard of 0.15 ha at Mertesdorf, Germany. The 12 plots have lengths of 8 m, 16 m and 48 m, and slope is 20-25 degrees. The soil is a regosol, deep ploughed, with a profile depth of about 1 m developed on Devonian shales. New vineyards show high runoff rates and soil loss during the first three years after planting. This is a consequence of deep ploughing, which reduces the structural stability of the topsoil. Break-up of the soil increases infiltration capacity for about three years on soils with a high percentage of rock debris. The best preparation of the soil is normal ploughing before planting. Straw-mulching reduces the soil loss to a greater extent than grass-mulching, but it also has some disadvantages. Compost from urban waste is the best way to reduce runoff and soil loss, but it may be contaminated by heavy metals. (Language: English)

Wang, Y., R. Amundson, et al. (2000). "Seasonal and altitudinal variation in decomposition of soil organic matter inferred from radiocarbon measurements of soil CO₂ flux." Global biogeochemical cycles **14**(1): 199-211.

In this project, a technique was developed for sampling soil-respired CO₂ for isotopic measurements and a model that relates the radiocarbon (¹⁴C) content of soil respired CO₂ to the rate of C cycling in soils. We measured soil CO₂ flux, carbon isotopic content (both ¹³C and ¹⁴C) of soil-respired CO₂, soil temperature, and soil moisture on a monthly basis along an elevation transect in the Sierra Nevada Mountains (California, USA) in an attempt to determine the relationship between the rate of soil C cycling and soil environmental conditions. Both soil CO₂ flux and its ¹⁴C content displayed significant variations (spatially and temporally), which reflect natural variations in the rate of SOM decomposition and in the relative amount of SOM-derived CO₂ versus root-respired CO₂ caused by seasonal changes in soil temperature, moisture, and plant activity. The relative contribution of SOM decomposition to total soil CO₂ production changed throughout the year from ~20-50% at the peak of the growing season to close to 100% in the non-growing season. The apparent decay rate of SOM determined from the ¹⁴C content of soil-respired CO₂ varied from ~0.2 yr⁻¹ in the spring to ~0.01 yr⁻¹ in the fall at the lowest-elevation site and from 0.1 yr⁻¹ in the summer to ~0.01 yr⁻¹ in the late fall at the highest-elevation site. It appears that the apparent decay rate of SOM increased with increasing temperature when soil moisture was adequate but decreased with increasing temperature when soil moisture became limited. The apparent decay rate of SOM also varied with soil moisture. Higher soil moisture content accelerated decomposition of SOM until it reached an optimal level of ~14-25 wt. % water content

and then inhibited decomposition when more pores in soils became saturated with water and perhaps oxygen availability (for microbes) became limited. Although the rate of SOM decomposition varied throughout the year in response to fluctuations in soil temperature and moisture, the maximum apparent decay rate was higher at the low-elevation site (i.e., maximum apparent decay rate=0.22 yr⁻¹) than at the high-elevation sites (i.e., maximum apparent decay rate=0.10 yr⁻¹). Litter decomposition simulated by measuring changes in mass of litter in litter bags placed in the field also showed a similar decomposition pattern with decreasing decomposition rate with elevation. Multivariable regression analyses including various terms of soil temperature, moisture, and site variability suggest that soil moisture was a major factor, but not the only factor, controlling the rate of SOM decomposition and soil CO₂ flux in the Sierra Nevada soils. Both decay rate and total soil CO₂ flux are related significantly to soil moisture, temperature, and site effects. (Language: English)

Grapevine Physiology: phenology, yield components, development, water relations

Bertamini, M., G. Ponchia, et al. (1996). "Environmental effects on yield, growth and grape composition of Sauvignon Blanc in alpine viticulture of Trentino (N.E. Italy)." Proceedings of the Fourth International Symposium on Cool Climate Viticulture and Enology: I-16-I-22.

The experiments were conducted in 7 environments representative of the different conditions in Trentino, Italy, and 7 clones (INRA 108, 316, 161; ENTAV 2452, 376, 377; and VCR3) of Sauvignon Blanc were investigated. ENTAV 377 and VCR3 were grafted on to SO4 rootstock, and the other clones were grafted on to 3309C, 41B and SO4 rootstocks, resulting in 17 clone/rootstock combinations in each vineyard. Plants were spaced 2.8 x 0.8 m apart, were trained on one-armed trellises and were pruned to 2 canes with 8 buds each. Increasing altitude significantly reduced cluster weights, shoot fertility, soluble solids and yields, and increased titratable acidity and malic acid concentrations. At an altitude of 400-600 m, in sites with clay-loam soils on plateaus, cluster weights were reduced compared with clay-loam sites with high slope and southerly exposure. The suitable conditions for Sauvignon Blanc production in Trentino are discussed. (Language: English)

Calame, F., M. Rochaix, et al. (1977). "Phenological observations and bioclimatic measurements at several Valais viticultural sites at different altitudes in order to demarcate the viticultural area." Bulletin de l' OIV **50**(559): 601-616.

The climate, vine phenological stages and must quality of a hillside vineyard, at between 500 and 900 m altitude, were studied in the Conthey region of Valais between 1973 and 1976. The average maximum temperatures were found to fall by 1 deg C/100 m but the average minimum temperatures were 0.7 deg higher half-way up the vineyard than in the valley. Delays of 7-15 days were observed between vine phenological stages at the foot and at the top of the slope. This delay in growth, more marked for cv. Pinot than for Chasselas, was reflected in lower must Oechsle values and a greater total acidity with rising altitude. (Language: French)

Failla, O., L. Mariani, et al. (2004). "Spatial distribution of solar radiation and its effects on vine phenology and grape ripening in an alpine environment." American Journal of Enology and Viticulture; 2004; **55**(2): **55**(2).

Climate, soil, and vineyard performance were characterized in the northern Italian alpine valley of Valtellina, Italy 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 3-year (1998 to 2000) data sets for phenology, maturity curves, yield, vigour, 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 degrees 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. (Language: English)

Flexas, J., M. Badger, et al. (1999). "Analysis of the relative increase in photosynthetic O₂ uptake when photosynthesis in grapevine leaves is inhibited following low night temperatures and/or water stress." Plant Physiology; Oct 1999; 121(2): 675-684 **121(2): 675-684.**

We found similarities between the effects of low night temperatures (5 degrees C-10 degrees C) and slowly imposed water stress on photosynthesis in grapevine (*Vitis vinifera* L.) leaves. Exposure of plants growing outdoors to successive chilling nights caused light- and CO₂-saturated photosynthetic O₂ evolution to decline to zero within 5 d. Plants recovered after four warm nights. These photosynthetic responses were confirmed in potted plants, even when roots were heated. The inhibitory effects of chilling were greater after a period of illumination, probably because transpiration induced higher water deficit. Stomatal closure only accounted for part of the inhibition of photosynthesis. Fluorescence measurements showed no evidence of photoinhibition, but nonphotochemical quenching increased in stressed plants. The most characteristic response to both stresses was an increase in the ratio of electron transport to net O₂ evolution, even at high external CO₂ concentrations. Oxygen isotope exchange revealed that this imbalance was due to increased O₂ uptake, which probably has two components: photorespiration and the Mehler reaction. Chilling- and drought-induced water stress enhanced both O₂ uptake processes, and both processes maintained relatively high rates of electron flow as CO₂ exchange approached zero in stressed leaves. Presumably, high electron transport associated with O₂ uptake processes also maintained a high delta pH, thus affording photoprotection. (Language: English)

Fogliani, G., A. Tammaccaro, et al. (1978). "Experimental research on frost damage to grapevines. Studies in Abruzzo vineyards." Atti Accademia Italiana della Vite e del Vino, Siena(publ 1979): 201-217.

Grapevines, mostly the cv. Montepulciano, growing on 3 farms in the province of Aquila were examined in 1977 after damage had been caused by mid-April night frosts and daytime high temperatures. Symptoms and effects of the damage are described and illustrated. The number of damaged buds depended on their position, vineyard altitude and aspect, and vine training form. The number of latent buds induced to form replacement shoots depended on cv., vine age, microclimate and training, and the fruit yield from these buds was much influenced by pruning. The sugar content of fruit from latent buds was normal but acidity was high because of the later start. (Language: Italian)

Hemborg, A. M. and P. S. Karlsson (1998). "Altitudinal variation in size effects on plant reproductive effort and somatic costs of reproduction." Ecoscience ; 1998; 5(4): 517-525 5(4): 517-525.

Effects of plant size and altitude on reproductive effort (RE) and somatic costs of reproduction were examined for *Ranunculus acris* L. and *Trollius europaeus* L. (Ranunculaceae) in subarctic Swedish Lapland. We estimated investment and cost during one reproductive season in terms of biomass (indexed B), nitrogen (N), and phosphorus (P). Above the tree line, plants of both species had smaller size, and thus, smaller resource pools than at lower altitudes. For *Ranunculus*, reproductive effort did not depend on plant size. In terms of biomass, RE increased, while REB decreased, with altitude. For *Trollius* at lower altitudes, REB and REP varied inversely with size and altitude. However, above the tree line, REB and REP showed no relationship with size. In terms of nitrogen, RE decreased with size for all populations. Somatic costs of reproduction generally did not vary with plant size and/or altitude in a similar manner as RE. Only in terms of P for *Ranunculus*, somatic costs varied proportionally with reproductive effort. For plants of all sizes, somatic costs were often lower as compared to RE. Different effects of size and altitude on RE may result from varied environmental and morphological constraints along the altitudinal gradient. However, patterns of variation in RE were not reflected in the variation in somatic costs. We found an overall lack of conformity between reproductive effort and somatic costs of reproduction. (Language: English)

Kaziev, R. A. and S. A. Kurbanov (1985). "Physiological-biological characteristics of grapes raised in southern Dagestan as function of altitude." Soviet agricultural sciences 1985(12): 17-19. The effect of microphytocoimatic conditions on grape productivity was studied at various altitudes above sea level in the southern Dagestan ASSR in 1982-1984. The data obtained agree with the data from the literature on a close correlation between transpiration, soil moisture content and other ecological factors. The greatest yield was observed in a vineyard at 50 m above the sea level where plant photosynthesis was enhanced. The piedmont zone of the southern Dagestan ASSR is promising for the development of unirrigated viticulture. (Language: English)

Korner, C., P. Bannister, et al. (1986). "Altitudinal variation in stomatal conductance, nitrogen content and leaf anatomy in different plant life forms in New Zealand." Oecologia ; 1986; 69(4): 577-588 69(4): 577-588.

Max. leaf diffusive conductance (g), leaf N content (LN), stomatal density (n) and distribution, and area (A), thickness (d) and specific area (SLA) of leaves were studied in 3 different plant life forms over their full altitudinal range in the Southern Alps: trees, represented by *Nothofagus menziesii* and *Griselinia littoralis* (up to 1200 m); ericaceous dwarf shrubs (up to 1700 m); and herbaceous Ranunculaceae (up to 2500 m). In all 3 life forms g, LN and n increased with alt., while SLA and A decreased. Recent investigations have found similar trends in other mountains in the temperate zone, but the changes are larger in New Zealand than elsewhere. Herbs show the greatest differences, followed by shrubs and then trees. It is concluded that g is dependent on light availability rather than water supply, whereas SLA and related structural features appear to be controlled by temp., as they show similar altitudinal changes under different light and moisture gradients. The higher leaf N content found at high alt. in all 3 life forms suggests that metabolic activity of mature leaves is not restricted by low N supply at high alt. (Language: English)

Moutinho-Pereira, J. M., N. Magalhaes, et al. (2001). "Physiological and agronomic behaviour of cv. Touriga Nacional in a "slope vineyard" at the Demarcated Douro Region." Ciencia e Tecnica Vitivinicola **16**(2): 49-63.

The aim of this study was to compare the vegetative and viticultural behaviour of grapevines planted on the upper and lower edges of a sloped vineyard. The grapevines transplanted in the lower portion of the plot had better soil water content than those in the upper portion during the summer season, which enhanced leaf photosynthesis and minimized foliar senescence during ripening. The grapevines in the upper portion of the plot had high maturation index, whereas production and Ravaz index was low. (Language: Portuguese)

Murada, G., S. Mancini, et al. (2004). "Performance and response of Nebbiolo in Valtellina." Informatore Agrario **60**(1): 45-49.

The results of a survey of the vine Nebbiolo in Valtellina, an Alpine valley in north Lombardy running east-west, are summarised. Bud fertility was generally low and a variation of some 12 days was observed in the time of flowering. Ripening varied considerable between early and late sites, the latter being harvested before the berries were fully mature. The variations were correlated with the altitude and potential photosynthetically active radiation (PPAR) and on this basis a subdivision into 3 altitude zones was tested: <400 m, 400-500 m and >500 m. Details are shown in tables and two insets outline the climate and zonation and the topology and soils of the vineyard zones. (Language: Italian)

Nevryanskaya, A. D., G. V. Shishkanu, et al. (1988). "The effect of growing conditions and mineral nutrition on the photosynthetic productivity of grapevines on a slope." Vliyanie Udobrenii na Obmen Veshchestv i Produktivnost' Rastenii.

Dry mass accumulation in different plant parts, vineyard productivity and DM increment per vine were greater in the middle part of the slope than in the upper part. Photosynthetic productivity and specific surface density of the leaves were affected only slightly by growing conditions on the slope. Yield was higher in the middle part and quality was better in the upper part. Basal mineral fertilizers increased DM accumulation and yields in all parts of the slope, and the possibility of regulating vine productivity by differential fertilizer application is mentioned. (Language: Russian)

Pandeliev, S., D. Braikov, et al. (1983). "Initiation time and differentiation degree of inflorescences in buds of variety Bolgar depending on the altitude of its location on the northern slope of the Rhodope Mountains." Nauchni trudove Vissh selskostopanski institut "Vasil Kolarov" **28**(2): 11-24.

No abstract available. (Language: Bulgarian)

Ponchia, G., M. Bertamini, et al. (2002). "Environmental effects on the growth, yield, grape composition and wine quality of Chardonnay in Trentino area." Italus Hortus **9**(2): 3-8.

The performance of grape cv. Chardonnay was studied in 14 vineyards of varying altitude (between 300 and 730 m) in Trentino, Italy. Plant growth significantly varied among the vineyards. Highly significant variation was also observed for the number of shoots, weight of pruned wood per vine, number and weight of clusters, and yield per vine. Except for one vineyard, grape production and pruning wood ratio showed low variability. With the increase in altitude, the soluble solids content of the must was greatly reduced, but the titratable acidity, pH and organoleptic characteristics of the wine

were not significantly affected. Generally, Chardonnay appeared to be adapted to various environmental conditions. (Language: Italian)

Ramos, M. C. (2006). "Soil water content and yield variability in vineyards of Mediterranean northeastern Spain affected by mechanization and climate variability." Hydrological Processes **20**(11): 2271-2283.

The objective of this paper was to analyse the combined influence of the Mediterranean climate variability (particularly the irregular rainfall distribution throughout the year) and the land transformations carried out in vineyards of northeastern Spain on soil water content evolution and its influence on grape production. The study was carried out in a commercial vineyard located in the Anoia-Alt Penedes region (Barcelona province, northeastern Spain), which was prepared for mechanization with important land transformations. Two plots were selected for the study: one with low degree of transformation of the soil profile, representing a non-disturbed situation, and the second one in which more than 3 m were cut in the upper part of the plot and filled in the lower part, representing the disturbed situation. Soil water content was evaluated at three positions along the slope in each plot and at three depths (0-20, 20-40, 40-60 cm) during the period 1999-2001, years with different rainfall characteristics, including extreme events and long dry periods. Rainfall was recorded in the experimental field using a pluviometer linked to a data-logger. Runoff rates and yield were evaluated at the same positions. For the same annual rainfall, the season of the year in which rainfall is recorded and its intensity are critical for water availability for crops. Soil water content varies within the plot and is related to the soil characteristics existing at the different positions of the landscape. The differences in soil depth created by soil movements in the field mechanization give rise to significant yield reductions (up to 50%) between deeper and shallow areas. In addition, for the same annual rainfall, water availability for crops depends on its distribution over the year, particularly in soils with low water-storage capacity. The yield was strongly affected in years with dry or very dry winters. (Language: English)

Rapcha, M. P., M. F. Kisil, et al. (2004). "Effect of vineyard location on productivity." Sadovodstvo i Vinogradarstvo **2004**(3): 19-21.

See establishment section, above, for abstract.

Schubert, A., C. Lovisolo, et al. (2004). "Territorial and bioclimatic description of the area of the Moscato docg in Piedmont." Informatore-Agrario **60**(46): 63-68.

Based on data (1997-2001) from 16 automatic weather stations in the area producing Moscato d'Asti docg wine and on phenological data from 30 Moscato Bianco vineyards in the same area, and combining these with geo-morphological data, such as site altitude and orientation, a series of digital maps on a scale of 1:25 000 were produced. These showed temperature range, date of sprouting, flowering and fruit set, as well as the alcohol potential and total acidity of the must. Linear correlations were analysed showing significant relationships between these variables. Geo-morphological and bio-climatic variability were shown to have a greater effect than geology and soil factors on grape quality. The maps provide a valuable indication of the optimal time for grape harvest at the different sites. They are useful tools for planning vineyard management. (Language: Italian)

Shi, Z., S. Liu, et al. (2006). "Altitudinal variation in photosynthetic capacity, diffusional conductance and (Se superscript 13(BC of butterfly bush (*Buddleja davidii*) plants growing at

high elevations." *Physiologia plantarum*; 2006 Dec; 128(4): 722-731 **128(4): 722-731.**

In this study, we have examined several physiological, biochemical and morphological features of *Buddleja davidii* plants growing at 1300 m above sea level (a.s.l.) and 3400 m a.s.l., respectively, to identify coordinated changes in leaf properties in response to reduced CO₂ partial pressure (P_a). Our results confirmed previous findings that foliar (Se superscript 13(BC), photosynthetic capacity and foliar N concentration on a leaf area basis increased, whereas stomatal conductance (g_s) decreased with elevation. The net CO₂ assimilation rate (A_{max}), maximum rate of electron transport (J_{max}) and respiration increased significantly with elevation, although no differences were found in carboxylation efficiency of Rubisco (V_{cmax}). Consequently, also the J_{max} to V_{cmax} ratio was significantly increased by elevation, indicating that the functional balance between Ribulose-1,5-biphosphate (RuBP) consumption and RuBP regeneration changes as elevation increases. Our results also indicated a homeostatic response of CO₂ transfer conductance inside the leaf (mesophyll conductance, g_m) to increasing elevation. In fact, with elevation, g_m also increased compensating for the strong decrease in g_s and, thus, in the P_i (intercellular partial pressure of CO₂) to P_a ratio, leading to similar chloroplast partial pressure of CO₂ (P_c) to P_a ratio at different elevations. Because there were no differences in V_{cmax}, also A measured at similar PPFD and leaf temperature did not differ statistically with elevation. As a consequence, a clear relationship was found between A and g_m, and between A and the sum of g_s and g_m. These data suggest that the higher dry mass (Se superscript 13(BC) of leaves at the higher elevation, indicative of lower long-term P_c/P_a ratio, cannot be attributed to changes either in diffusional resistances or in carboxylation efficiency. We speculate that because temperature significantly decreases as the elevation increases, it dramatically affects CO₂ diffusion and hence P_c/P_a and, consequently, is the primary factor influencing Se superscript 13(BC) discrimination at high elevation. (Language: English)

Stoychev, S. (2001). "Soil conditions, moisture stocks and grape-vine yields in the region of Perushtitsa." *Pochvoznanie, Agrokhimiya i Ekologiya* **36(4/6): 71-73.**

The different soil varieties distribution in the land, belonging to the town of Perushtitsa, Plovdiv county, is considered. It is established that the soils differ between themselves in their structure, composition and properties, they are suitable for grape-vines cultivating and are typical of the Pazardjik - Plovdiv region of Southern Bulgaria. Under the conditions of the region hilly relief, with rising of the level difference of the Northwestern slope the quantity of the fallen precipitation rises too. On the shorter and lower Northeastern slope, leeward towards the basic moisture transportation, the precipitation amount diminishes with the height. The stocks of available moisture of the soil during the period from "sap-movement beginning" till "mass blooming" are optimum and the grape-vine vegetation runs faster in the middle part of the slope. During the period "mass blooming"-"mass physiological maturity" the moisture stocks are insufficient everywhere and this period runs faster in the valley. The peculiarities of the microclimatic conditions of the hilly relief are shown best upon the grape size and upon the mean weight of the clusters. In the valley these indicators are biggest, up the slope they diminish. Up the slope the sugar content in the grape-juice rises, but the acids in it are changed in the opposite direction. (Language: Bulgarian)

Tarara, J. M., J. C. Ferguson, et al. (2005). "Asymmetrical canopy architecture due to prevailing wind direction and row orientation creates an imbalance in irradiance at the fruiting zone of grapevines." *Agricultural and Forest Meteorology* **135(1/4): 144-155.**

See establishment section, above, for abstract.

Tomasi, D., A. Calo, et al. (2000). "Effects of the Microclimate on the Vegetative and Aromatic Response in Sauvignon Blanc." Rivista Viticoltura e di Enologia **53**(2/3): 27-44.

Microclimate changes in a vineyard (Sauvignon b. clone R3) in the Berici hills, Italy, were studied during 1992-93 and 1995-97. A soil depression caused the development of different climate conditions between the lower and upper zone of the vineyard. Plant development and fruit ripening were studied in response to these microclimate differences. The upper zone had a higher average temperature than the lower zone, but the lower zone had a greater range of temperatures, and had the lowest temperature at night and the warmest temperature in the day. Plant development and fruit ripening were delayed at lower temperatures. Grape quality and wine quality were better from the lower zone of the vineyard. Differences in the chemical composition of fruits (sugars and secondary metabolites including terpenoids) were observed in fruits obtained from the lower and upper zones of the vineyard. Fruits obtained from the lower zone were judged to be 'more typical'. (Language: English)

Variceva, V. M. and V. T. Uzun (1960). "The influence of soil erosion in vineyards on the yield and quality of the grapes." Vinodelie i Vinogradarstvo **20**(7): 15-19.

In a sloping vineyard strips of grass were sown up and down and across the slope, dividing the area into rectangular blocks. Erosion was greatest at the top of each block; some deposition occurred at the bottom of the blocks. When vines were planted on the slope fewer losses occurred in the bottom sections of the blocks, where it was also found that yields were highest. Sugar content of the grapes was lowest in the lower sections of the blocks and was highest in the centre of the blocks. (Language: Russian)

Veres, A. and A. Valachovic (1978). "Phenological observations and bioclimatic statistics on certain vinegrowing areas of Czechoslovakia at different altitudes, with a view to the demarcation of vineyards." Bulletin de l'O I V **51**(564).

12 vine-growing areas of Czechoslovakia were compared in respect of latitude, climate, altitude (120-300 m), the local interaction of the last two, aspect, and especially frost risk. Italian Riesling vines grown in these areas in 1968-1970 were studied for dates of flowering, setting, and ripening, the length of the growing period, the yield and wt. of grapes, and their acidity (range 15.8 (Skalice-Zahoria)-8.4 g/l. (Tokay)) and must sugar content (range 15.4-... (Language: French)

Grape Composition/Wine Quality: flavor, aroma, and color compounds; sugar development

Bavaresco, L. (2003). "Role of viticultural factors on stilbene concentrations of grapes and wine." Drugs under Experimental and Clinical Research **29**(5-6): 181-187.

Stilbenes are phenolics that can be found in different grapevine organs, such as berries, leaves, canes and roots. Stilbenes act as antifungal compounds since they are synthesized by the plant in response to pathogen attack. Other abiotic elicitors, such as ultraviolet rays and heavy metals, can trigger stilbene production. Many stilbenic compounds have been detected in grapes and wine (resveratrol, piceid, viniferins, astringin, etc.). The latest stilbene to be analyzed is piceatannol (or astringinin). Stilbene synthesis in grapes depends on different viticultural factors such as the grape variety, the environment and

cultural practices. Concerning grape variety, red berry-grapes have higher stilbene levels than white berry-grapes. With regard to climate, preliminary results suggest a positive correlation between vineyard elevation and stilbene grape concentrations. Quality-oriented cultural practices produce grapes with high levels of stilbenes. Berries of *Vitis vinifera* L. cv. Barbera were infected, at veraison and during ripening, by a conidial suspension of *A. japonicus*, *A. ochraceus*, *A. fumigatus* and two isolates of *A. carbonarius* to control ochratoxin A production and stilbene induced synthesis. The experimental design provided also for intact and punctured berries and incubation temperature of 25 degrees C and 30 degrees C. All the tested fungi, except *A. fumigatus*, significantly increased trans-resveratrol synthesis over the control, while trans-piceid was not affected; only *A. ochraceus* significantly elicited the berries to synthesize piceatannol. The two isolates of *A. carbonarius* produced higher amounts of ochratoxin A than did the other fungi. A positive correlation between ochratoxin A and trans-resveratrol synthesis occurred. trans-Resveratrol and piceatannol showed fungicidal activity against *A. carbonarius*, being able to completely inhibit fungal growth at a concentration of 300 micro g/g and 20 micro g/g, respectively. (Language: English)

Bertamini, M., G. Ponchia, et al. (1996). "Environmental effects on yield, growth and grape composition of Sauvignon Blanc in alpine viticulture of Trentino (N.E. Italy)." Proceedings of the Fourth International Symposium on Cool Climate Viticulture and Enology: I-16-I-22.

See physiology section, above, for abstract.

Boselli, M. (1996). "Suitability of grapes from the Ariano Irpino area for sparkling wine production." Vignevini **23**(1/2).

The viticultural features (soil, altitude, temp., grafting stock) of the Ariano Irpino area (Avellino province, Italy) of relevance for production of grapes for sparkling wine manufacture are discussed. Cv. considered suitable for expanding this sector of the wine market are Greco di Tufo, Fiano di Avellino and Coda di Volpe. Changes in the titratable acidity, pH, and tartaric and malic acid contents of Chardonnay musts are reported, to illustrate the influence of different vine grafting stocks on grape and must composition. (Language: Italian)

Calame, F., M. Rochaix, et al. (1977). "Phenological observations and bioclimatic measurements at several Valais viticultural sites at different altitudes in order to demarcate the viticultural area." Bulletin de l' OIV **50**(559): 601-616.

See physiology section, above, for abstract.

Failla, O., L. Mariani, et al. (2004). "Spatial distribution of solar radiation and its effects on vine phenology and grape ripening in an alpine environment." American journal of enology and viticulture; 2004; **55**(2): **55**(2).

See physiology section, above, for abstract.

Iacono, F., F. Romano, et al. (1990). "Sensory approach to characterization of Trentino base wines for sparkling winemaking." Vignevini **17**(10).

Tests were carried out on base wines for sparkling winemaking, made from Chardonnay cv. grapes grown in 27 vineyards throughout the whole of the Trentino region of Italy, to determine whether the wines could be characterized solely on the basis of sensory and agronomic characteristics. A team of 20 trained taste panellists used a parametric system, developed by the authors' institutes, involving 9 specified flavour notes which corresponded to known wine constituents, e.g. 'banana-pineapple' = esters, 'flowery' =

linalool. The system also took into account agronomic factors, specifically vineyard location and altitude and grape ripening characteristics. Results (given in tables and graphs) showed that the system successfully demonstrated the existence of a link between the wines' sensory profile and the agronomic factors, and could provide a useful tool for wine characterization. (Language: Italian)

Katona, J. (1977). "Relationship between environment and biochemical characteristics of grapes in some wines." Bulletin de l'O I V **50**(557/558).

With the long-term aims of improving the quality of wines, and calculating what additional watering or fertilization is necessary for the cultivar, the optimum biological environment and ecological conditions for the growth of vines have been studied in Hungary, notably at the Pecs experimental station. Climate, type of soil and its chemical composition, relief of the country, altitude and aspect of the vineyards, intensity of the light and amount of sunshine were taken into account. 2000 samples of Hungarian wines were analysed for 7 successive yr, and results compared with relevant meteorological data. Relationships between the number of h sunshine and the sugar content of the must and between the temp. factor and the alcohol content were established. (Language: French)

Mateus, N., J. M. Machado, et al. (2002). "Development changes of anthocyanins in *Vitis vinifera* grapes grown in the Douro Valley and concentration in respective wines." Journal of the Science of Food and Agriculture **82**(14): 1689-1695.

Touriga Nacional and Touriga Francesa red *Vitis vinifera* cultivars were sampled from two vineyard sites at different altitudes during three consecutive vintage years (1997, 1998, and 1999) in the Douro Valley, Portugal. The total anthocyanidin monoglucosides (AMGs) detected by HPLC/DAD and the red colour of grape skin extracts were monitored during the last month of maturation. Microvinifications were performed with the grapes studied and the resulting Port wines were analysed. Malvidin 3-glucoside and its acylated esters were the major AMGs irrespective of cultivar at harvest date. Vineyard altitude, together with other variables, was an important factor contributing to the amount of anthocyanin compounds found in grapes of Touriga Nacional and Touriga Francesa. Overall, the climatic conditions (relative humidity, air temperature, precipitation, total radiation, and photosynthetically active radiation) observed at higher vineyard sites appeared to be advantageous, resulting in larger amounts of AMGs in grapes. The same outcome was obtained in the resulting wines, which showed higher levels of AMGs when made from grapes grown at higher altitude, especially for Touriga Francesa. (Language: English)

Mateus, N., S. Marques, et al. (2001). "Proanthocyanidin composition of red *Vitis vinifera* varieties from the douro valley during ripening: influence of cultivation altitude." American journal of enology and viticulture; 2001; **52**(2): 115-121.

The effect of altitude and its related climatic conditions on the proanthocyanidin composition of Touriga Nacional and Touriga Francesa cultivars during berry maturation is reported for the 1997 vintage. At berry maturation, low altitude is shown to be an important factor favouring the biosynthesis of higher concentrations of grape-skin catechin monomers ((+)-catechin, (-)-epicatechin, (-)-epicatechin gallate), procyanidin dimers, trimer C1, as well as total extractable proanthocyanidins. The grapes (skin and seeds) of Touriga Nacional were found to be richer in low molecular weight flavan-3-ol compounds, while Touriga Francesa contained higher concentrations of total extractable proanthocyanidins. At harvest, grape-skin dimer content was comprised almost entirely

of dimer B1, followed by dimers B2 and B3, whereas C4-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. (Language: English)

Mateus, N., S. Proenca, et al. (2001). "Grape and wine polyphenolic composition of red *Vitis vinifera* varieties concerning vineyard altitude." *Ciencia y Tecnologia Alimentaria* **3**(2): 102-110. Effects of altitude of the vineyard (and its associated climatic parameters) on polyphenols concn. of red winemaking grapes of the cv. Touriga Nacional and Touriga Francesa, and the resulting Port wines, were evaluated. Trials were conducted at 2 altitudes (100-150 or 250-350 m) in a vineyard in the Douro region of Portugal in 1997. Concn. of catechin monomers ((+)-catechin, (-)-epicatechin and (-)-epicatechin-O-gallate), procyanidin oligomers (B1-B8, B2-3"-O-gallate and trimer C1) and total extractable proanthocyanidins were determined at harvest in grape skins and seeds, and anthocyanin concn. were determined in the grape skin. Sensory properties and composition of Port wines made from these grapes were also determined. Anthocyanin concn. were greater in skins of grapes grown at higher altitude, whereas procyanidin components in skin and seeds were higher at lower altitudes. Anthocyanin levels were higher, but colour intensity lower, in wines made from grapes grown at the higher altitude. Implications for wine quality are discussed; it is suggested that, overall, wine quality was higher for grapes grown at the lower altitude. This was especially true for sensory properties of wines made from Touriga Nacional grapes. (Language: Spanish)

Miguel-Tabares, J. A., B. Martin-Luis, et al. (2002). "Effect of altitude on the wine-making potential of Listan negro and Ruby Cabernet cultivars in the South of Tenerife island." *Journal International Des Sciences De La Vigne Et Du Vin* **36**(4): 185-194.

In the south of the island of Tenerife (Valle de Guimar), a study was made of the composition of the grape and fundamentally in colour potential during the ripening of the red varieties Listan negro and Ruby Cabernet in two vineyards located at different heights above sea level. The conventional ripening parameters and total and extractable anthocyanin content have been determined in order to estimate all the main characteristic phenolic. Significant differences were detected between the varieties, along with a clear influence of vineyard altitude on accumulation of colour and phenolic substances in the grapes. (Language: English)

Naito, R., N. Ueda, et al. (1965). "The influence of the altitude of the vineyard on the quality of grapes." *Shimane-Naka-Daigaku-Kenkyu-Hokoku/Bull-Shimane-agric-Coll* **14**: 14-17.

When grown at a high altitude, Delaware and DK151 reached maturity 12 days later than when grown at a lower altitude; similarly, Super Hamburg and Muscat were 4-5 days later. The strains of Delaware and DK151, which are red grapes, contained a higher anthocyanin content when grown at the higher altitude; no such difference was observed in the other two varieties, which are black grapes. (Language: Japanese)

Oliveira, C., A. C. Ferreira, et al. (2004). "Effect of some viticultural parameters on the grape carotenoid profile." *Journal of agricultural and food chemistry*; 2004 June **30**; **52**(13): 4178-4184

The effect of some viticultural parameters on the grape carotenoid profile was investigated. Grape cultivar, ripeness stage, sunlight and shade exposure, altitude, and vegetative height were studied. Differences between cultivars were observed in eight

different black grape varieties: Touriga Brasileira (TBR), Tinta Barroca (TB), Tinta Amarela (TA), Souzao (S), Touriga Franca (TF), Touriga Nacional (TN), Tinta Roriz (TR), and Tinto Cao (TC), from the Douro region. TA and TBR clearly produced higher concentrations of carotenoids. Results showed that carotenoid content decreased during ripening. Decreases of lutein were observed until 66%, whereas b-carotene slowly decreased, having a constant level until the harvest date. Carotenoid contents were consistently higher in grapes exposed to shade than in those exposed to direct sunlight in both studied white grape varieties, Maria Gomes (MG) and Loureiro (L). In the Douro Valley, high-elevation terraces, which presented a lower temperature and higher humidity during the maturation period, appeared to produce grapes with higher carotenoid values. Grapes grown with higher vegetative height seem to have higher carotenoid levels; furthermore, grapes grown with lower vegetative height had higher weight and sugar concentrations. (Language: English)

Ponchia, G., M. Bertamini, et al. (2002). "Environmental effects on the growth, yield, grape composition and wine quality of Chardonnay in Trentino area." Italus Hortus **9**(2): 3-8.

See physiology section, above, for abstract.

Schubert, A., C. Lovisolo, et al. (2004). "Territorial and bioclimatic description of the area of the Moscato docg in Piedmont." Informatore-Agrario **60**(46): 63-68.

See physiology section, above, for abstract.

Stoychev, S. (2001). "Soil conditions, moisture stocks and grape-vine yields in the region of Perushtitsa." Pochvoznanie, Agrokimiya i Ekologiya **36**(4/6): 71-73.

See physiology section, above, for abstract.

Tomasi, D., A. Calo, et al. (2000). "Effects of the Microclimate on the Vegetative and Aromatic Response in Sauvignon Blanc." Rivista Viticoltura e di Enologia **53**(2/3): 27-44.

See physiology section, above, for abstract.

Vercesi, A. (1991). "Pinot noir thinning trials in Oltrepo Pavese, N. Italy." Vignevini **18**(7/8).

During 1989-1990, Pinot noir cv. grapes were thinned manually at 0, 30 and 50% of the clusters during veraison in 2 different vineyards (altitude, 200 and 450 m above sea level), and effects on grape production characteristics (yield, wt.) and must composition (sugar). (Language: Italian)

Veres, A. and A. Valachovic (1978). "Phenological observations and bioclimatic statistics on certain vinegrowing areas of Czechoslovakia at different altitudes, with a view to the demarcation of vineyards." Bulletin de l'O I V **51**(564).

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