Influence of soil type and changes in soil solution chemistry on vine growth parameters and grape and wine quality in a central coast California vineyard

Influence du sol et des propriétés chimiques du sol sur la croissance des vignes et la qualité du raisin et du vin dans un vignoble de la côte centrale californienne

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Summary

The objective of this study was to determine the influence of four soils with contrasting chemical and physical properties on vine growth parameters and wine chemistry in a Paso Robles, California Cabernet Sauvignon vineyard. The selected soils covered contiguous vineyard patches planted with the same cultivar, on its own roots. Furthermore, these vineyards contained vines of the same age that have received the same management practices. The soils belonged to the orders Alfisols, Mollisols and Vertisols. Soil heterogeneity in this vineyard was attributed to variability in soil parent material, originating from old Estrella River alluvial deposits, which ranged from cobbly and gravelly to fine-grained alluvium. Soil moisture was recorded throughout the growing season. Plant water potentials at pre-dawn and midday were monitored on vines growing at two sites per soil type. Vine growth parameters were recorded along with leaf and petiole sampling for tissue analysis. Nutrient balance in the soil solution was characterized at the onset, mid-point and harvest time during the growing season and analyzed in relation to growth parameters and fruit yield. Soil solution concentrations of macronutrients, such as K and NH_4/NO_3, were related to differences in soil pH, organic matter, and clay mineralogy. Petioles and blades were sampled at bloom, veraison and harvest to evaluate plant nutrient concentrations and the relationship to nutrient availability in the soil solution. Variability in soil physical and chemical properties determined cation exchange capacity and nutrient availability in the soil solution, and these properties were found to be related to vine vigor and differences in fruit yield and quality between soils.

Keywords: soil chemistry, pedology, vigor, yield

Introduction

The effects of soil physical and chemical properties on the perceived quality of wine have been the subject of many assumptions and much speculation in the popular wine press. The term “terroir” is often used to express this relationship, although it is not always clearly defined, as its meaning can depend on the user and the context. However, few attempts have been made to show how soil properties could affect vine nutrition and fruit composition in a way that would provide evidence for a direct link to wine (Tomasi, 2006, Andres-de-Prado, 2007). Understanding the soil-vine relationship and its impact on grape composition is critical to interpreting wine quality parameters. The goal of the proposed research is to shed new light on the relationship between vineyard soils and the wines produced on them by using a variety of biogeochemical and mineral analyses, coupled with an analysis of vine properties, juice characteristics and wine chemistry.

Much of the previous work devoted to the relationship between wine quality and soils has emphasized the importance of soil physical properties. Most important among these properties are adequate drainage, depth, and a textural composition that ensures a good water holding capacity. Soil depth and water availability can affect vine vigor, hence canopy size, and impact the resulting grapevine microclimate. Soil texture affects moisture content over the duration of the growing season, influencing the time when vegetative growth stops, and vines turn to the ripening stage.

Soil chemical and mineralogical composition controls nutrient availability. This is particularly relevant in soils with an excess or deficiency of particular nutrients. For example, excess nitrogen leads to excessive vine vigor, sometimes inducing a deficiency in other nutrients, and affecting fruit yield and quality. As a result, there is increased interest in the relationship between soil N and vines (Walter et al., 1986, Peuke, 2000, Bell, 2005). Soil potassium, and its relative proportion to other nutrients depending on soil types, is also essential and impacts yields as well as wine quality (Mpelasoka et al., 2003). Other elements, such as Si in the soil solution and xylem sap, are also being investigated for their role in vine growth and health (Blaich, 1997). It could therefore be predicted that nutrient availability affects vegetative growth, canopy architecture, and microclimate in the bunch zone, leading to significant effects on grape quality and ultimately wine.

The objective of this study was to determine the influence of four contrasting soils on vine growth parameters and wine chemistry in a Paso Robles Cabernet Sauvignon Vineyard. The soils covered contiguous vineyard patches planted with the same cultivar, on its own roots. The vineyards contained vines of the same age, planted in 1989-1990, treated with the same management practices, and receiving irrigation water from the same wells. The specific objectives of the study were: (1) Characterize the activity of various macro and micronutrients in the four different soil types and relate them to soil pH, organic matter quality, and clay mineralogy; (2) Understand how differences in soil physical and chemical properties affect grapevine tissue and berry chemistry, growth, fruit yield and quality; and (3) Relate soil-induced differences in grapevine chemistry, growth and fruiting characteristics to wine chemistry and quality.

Materials and methods

Soil Sampling

Soils were sampled at four vineyard sites designated as Blocks 52, 53, 56 and 57. In each of these four blocks, two soil pits were excavated using a backhoe, for a total of eight pits. Soil horizons were described in the field, and samples were taken from each horizon for chemical and physical analyses. A Trimble GeoXH GPS was used to georeference pit locations and vines, allowing for precise mapping of soil variability.

Soil Physical and Chemical Analyses

Solid-phase soil characterization was performed for replicate samples from each site. Soil texture was analyzed by laser granulometry and by the hydrometer method. Soil pH and electrical conductivity were measured in the laboratory using a 1:1 soil:water paste. Soil samples were processed by passage through a 2-mm sieve to separate coarse fragments from the fine-earth fraction. In addition, soil solutions were collected *in situ* using implanted suction devices located at depths of 30, 60 and 90 cm under drip emitters. Samples were collected at harvest time and at two months post-harvest. Soil chemical analyses were performed in the UC Davis DANR Analytical Laboratory for the following parameters: exchangeable cations (Ca, Mg, K, Na), CEC, pH, EC, total C, carbonate-C, total N, NO_3, NH_4, P, S, Zn, Cu, Mn, Fe, Si, B.

Leaf Petiole and Blade Sampling

Leaf petioles and blades were collected from three sets of ten replicate vines from two sampling sites within each of the four distinct soils, for a total of 240 vines. Sampling was repeated at bloom, veraison, and harvest. Leaves and petioles were separated, dried at 60°C, ground through a 60-mesh in a Wiley mill, and sent to the DANR laboratory for chemical analysis (http://groups.ucanr.org/danranlab/Methods_of_Analyses_2/).

Plant and Soil Water Status

Predawn and mid-day leaf water potentials (Ψ's) were measured manually with a pressure bomb at bloom, veraison and harvest on randomly selected vines within each block. Soil moisture was measured at 30, 60 and 90 cm using Time Domain Reflectometry probes embedded in soil pit walls at one site for each soil type. Canopy temperature sensors were also installed at each site. Temperature and moisture data were recorded at 30-minute intervals.

Vine Growth and Fruit Production

Vine trunk diameters were measured at heights of 25 and 50 cm. Root distributions were determined in the field by hand counting root intercepts using a 10x10 cm counting grid. Vine canopy density was measured using a metering system based on photovoltaic panels. Fruit yield was determined by weighing the harvest and dividing by the number of vines at each site. Berry clusters were counted and weighed manually, and berry diameters were recorded using a caliper. Pruning weights were determined in late December 2007 for all 240 vines; this included three groups of ten vines per sampling site.

Berry and Juice Analyses:

At harvest, juice samples were analyzed for pH, sugar content (°Brix), total acidity, yeast available nitrogen, and free amino nitrogen (NOPA). Sensory analysis panels were created using eight trained volunteers. Berries were sampled from vines in each of the areas surrounding the eight individual soil pits and cryopreserved at -80ºC prior to tasting. Small lot wines were prepared by J. Lohr Vineyards, Paso Robles, using grapes harvested from each of the eight sampling sites.

Results and discussion

Soil Characterization

Vineyard blocks were designated as Blocks 52, 53, 56 and 57. Soils were sampled at two sites within each block. Based upon field observations and on preliminary soil descriptions and physical analyses, the soils present at each site were classified. To the east and south-east, the rolling landscapes of Blocks 56 and 57 were found to contain two related Alfisols. The soils located on the flat terrace remnants in Block 57 had a loamy/sandy loam topsoil and a clayey subsoil with an abrupt textural change. These soils were characterized as fine, smectitic, thermic Typic Palexeralfs similar to the established San Ysidro series. The swales in Block 56 contained shallower, less developed Alfisols. Block 56 soils were characterized as fine-loamy, mixed, superactive, thermic Typic Haploxeralfs similar to the Arbuckle series. Notably, these soils had a strong argillic horizon but coarse fragments were also present.

The soils in Block 53 were classified as Vertisols; fine, smectitic, thermic Haploxererts with characteristics similar to the established Diablo series. This soil, found primarily within swales in the landscape, was characterized by greater than 30% clay content throughout the profile, with a consequent tendency for ‘shrink/swell’ behavior. On the upper part of the topography, the soils in Block 52 were characterized as Mollisols; these were fine-loamy, mixed, superactive, thermic Calcic Haploxerolls similar to the established Nacimiento series. These soils, found primarily on knolls in the landscape, had calcareous seams, laminar lime concretions and an angular blocky structure in the subsoil.

Textural characteristics of the four soils are summarized in Figure 1. The Alfisols (Blocks 56 and 57) were sandy clay and sandy clay loams. The Vertisol in Block 53 had higher clay content, while the Mollisol in Block 52 was lower in sand and higher in silt than the other vineyard soils.

Soil chemical analyses revealed a high cation exchange capacity (CEC) throughout the clayey textured Vertisol in Block 53 (Figure 2). Soil moisture content generally mirrored CEC, with highest moisture content in areas of high clay, such as the Vertisol in Block 53. In contrast, the two Alfisols in Blocks 56 and 57 had subsoil horizons with high clay content, resulting in a high CEC and relatively high moisture content at a depth of 50-100 cm. Surface horizons in these Alfisols had high exchangeable K^+ (data not shown). The Alfisol in Block 57 had a high sodium absorption ratio, particularly in the subsoil.

The Mollisol in Block 52 showed a very high exchangeable Ca^{2+} content. This soil also had deep cracking, resulting in increased moisture content with depth (Figure 2). Although most soil samples in all profiles had pH values in the neutral range, the Mollisol was slightly alkaline with values ranging from 7.6 to 9.0. Soil electrical conductivity was also highest in Block 52 (data not shown). Extensive characterization of soil solution chemistry and irrigation water chemistry is currently ongoing, and results of these analyses will provide additional information to interpret soil-plant interactions.

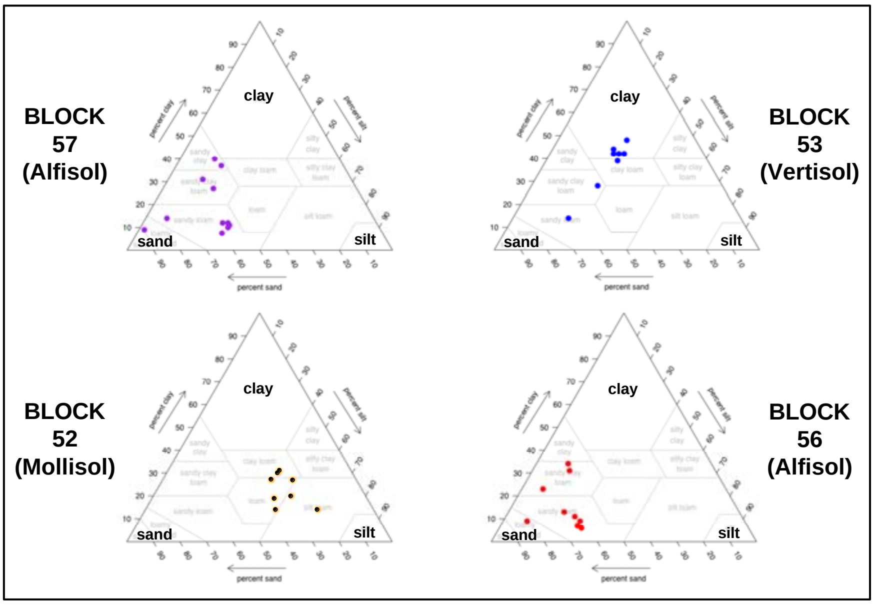

Figure 1 Soil texture analysis for each of the four soil types. The soil textural triangle indicates the percent sand, silt and clay. Each dot represents an individual horizon within the profile.

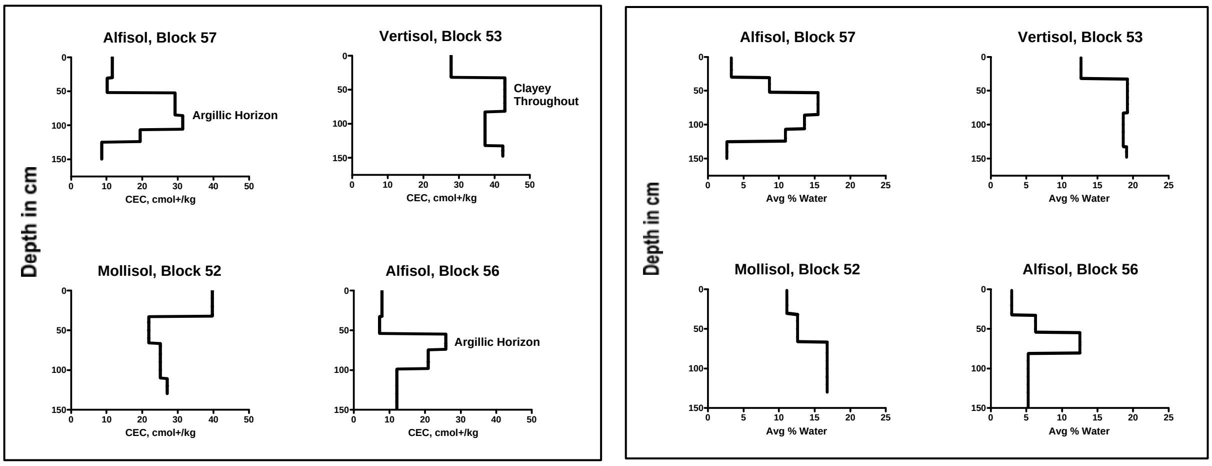

Figure 2 Soil Cation Exchange Capacity (left) and Water Content (right). Argillic horizons, with high CEC and water content, are identified in the two Alfisols. Note the high moisture content at all depths in the Vertisol, and the increasing moisture content with depth, likely due to the presence of deep cracks, in the Mollisol.

Plant and Fruit Analyses

Root counts varied considerably with soil type, and correlated well with soil physical characteristics and water content (data not shown). In the Alfisol (Block 56), root counts were highest at shallow depths, likely due to the presence of a dense clay layer in the subsoil that restricted root growth. In contrast, root counts in the Vertisol (Block 53) were relatively consistent throughout the profile, reflecting a more uniform texture and water content. Root counts in the Mollisol (Block 52) were highest at depth, likely reflecting the hard, calcareous surface horizons and the presence of deep cracks allowing the passage of water to subsurface horizons.

Median vine trunk diameters were in the range of 22-25 cm for four of the eight sampled sites (two sites per Block), as shown in Figure 3 (left panel). However, significantly greater diameters were recorded for vines grown on the Vertisol in Block 53 and at one of the two sampling sites in Block 57. Significantly lower diameters ($P<0.05$) were recorded for vines in Block 52-3.

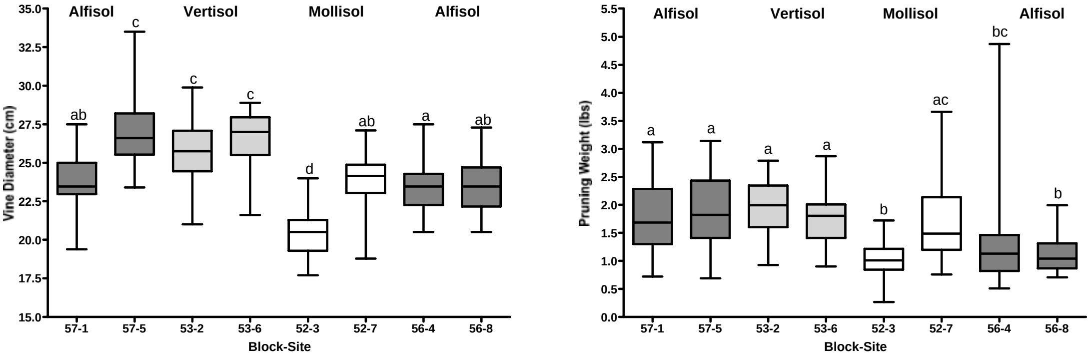

Figure 3 Vine Diameter (left) and Pruning Weight (right). Box plots show median and interquartile ranges for 30 vines per site. Boxes indicate 25th and 75th percentiles; whiskers indicate 10th and 90th percentiles. The letter codes indicate statistically significant differences between groups.

Pruning weights showed a pattern very similar to that of vine diameters (Figure 3, right). Briefly, the highest median pruning weights were observed in Block 57 (Alfisol) and Block 53 (Vertisol), and the lowest were found in Block 52-3 (Mollisol). Pruning weights in Block 52-3 and in Block 56 were significantly lower than in Blocks 57 and 53.

Fruit yield was reported as number of fruit clusters per vine, and as total fruit weight per vine. Average yield values were determined for all sampling sites, and the percent deviation for each site from the overall mean is given in Figure 4. The most notable deviations occurred in Block 57, where fruit yield per vine was more than 30% above the overall mean, and at Block 52-3, where yield was more than 30% below the overall mean. Median cluster weights were generally in the range of 70-90 g; notably, the highest median cluster weight was found in Block 57-5 and the lowest in Block 52-3; the difference between these two was statistically significant ($P < 0.05$). There were no statistically significant differences in median berry weight or density between sites (data not shown).

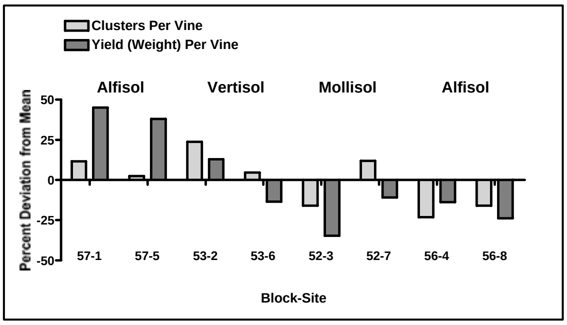

Figure 4 Fruit yield in berry clusters per vine and total yield (weight) per vine. Data for each soil type are graphed showing the percent deviation from the average values for all eight sampling sites.

Taken together, multiple measurements of fruit yield and pruning weight revealed consistently low vine vigor in Block 52-3, and consistently high vigor in Blocks 57 and 53 as compared to the other sites. Results for Block 56 indicated intermediate vine diameter, below average pruning weights and below average fruit yield. Leaf and petiole chemical analyses are ongoing and should shed further light on differences in plant vigor between sites, and the relationship of these differences to soil properties.

Berry, Juice and Wine Analysis

At harvest, juice samples were analyzed for sugar content (°Brix), total acidity, yeast available nitrogen, and free amino nitrogen (NOPA). Results for sugar content and total acidity are shown in Figure 5. Sugar content was highest in juice prepared from grapes grown in Blocks 56 and 57, the two Alfisols. Total acidity was accordingly lowest in juice prepared from these grapes. Juice from Block 52-3 was highest in total acidity.

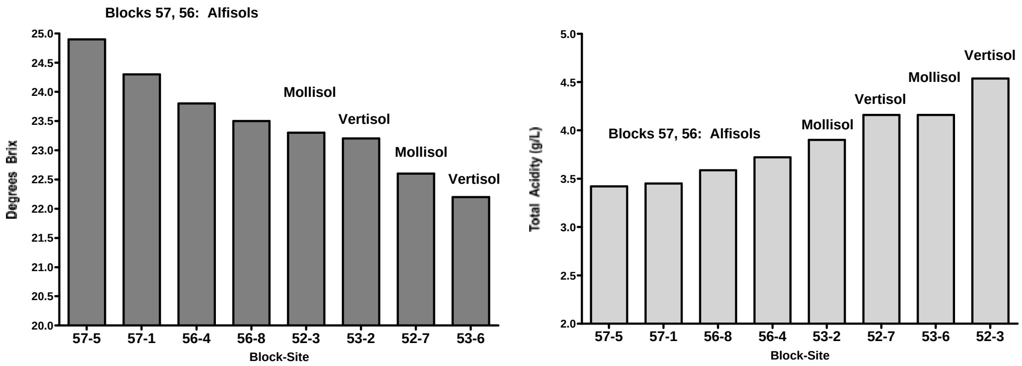

Figure 5 Sugar content (left) and total acidity (right) of grape juice from each site.

Conclusion

In summary, the Alfisol (Palexeralf) in Block 57-5 and the Mollisol in Block 52-3 gave contrasting results in terms of vine, fruit and juice characteristics. Vines grown in the Palexeralf had the following characteristics: average to high vine diameters; the highest fruit yield per vine in terms of weight and cluster number of any vines studied; the highest cluster weight of any vines studied. Finally, juice from these vines had the highest °Brix and lowest total acidity of any in the study. In contrast, vines grown in the Mollisol had the lowest vine diameters of any in the study; they also had the highest root density at depth, the lowest fruit yield per vine (in weight), and the lowest berry cluster weights of any in the study. Juice from these vines had the highest total acidity and among the lowest °Brix of any in the study.

Vines grown on the two other soils, the Vertisol in Block 53 and the Haploxeralf in Block 56, showed intermediate characteristics. Vines grown in Block 53 had above average vine diameters, an even root distribution throughout the profile, and average fruit yield. Juice from these grapes had low °Brix and the second highest total acidity of any in the study. Vines grown in Block 56 had average vine diameters, high root density near the soil surface, below average fruit yield per vine, and average berry cluster weights. Juice from this site had the second highest °Brix and the second lowest total acidity.

Thus, in this study comparing Cabernet Sauvignon grapes from a single clone, on its own roots, grown in four distinct soil types within a single vineyard, vines grown on contrasting soil types had different growth characteristics, which were reflected by differences in fruit yield and juice characteristics. The extent to which these differences will result in differences in wine chemistry and/or sensory characteristics remains to be determined and will be an important emphasis of our future studies.

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