Geotronics Consulting Inc
Vineyard Optimisation

Sample Vineyard Bioavailability Report

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1 Introduction

Geotronics Consulting carried out soil sampling within the sample vineyard owned and operated by a vineyard owner which is located near the Okanagan, British Columbia.

The vineyard contains weak and unbalanced growth areas and therefore the purpose of the soil sampling was to determine what nutrients the weaker growth sites were deficient and/or excessive in as well as to create a more balanced environment. The benefits are fourfold:

1. To better understand how the living soil is behaving and the role it is playing in the vineyard's terroir.
2. To assess the bioavailability of nutrients within the vineyard, particularly over problem areas, identifying deficiencies and excesses.
3. To enable the vineyard to be more precise in the use of fertilizer needed for weaker areas, achieve more balance within the vineyard, reduce fertilizer spend, and chart the evolution of the vineyard.
4. To create a healthier, more balanced, living soil which is more expressive of the terroir and more resistant to disease, thus being easier to manage.

Note: Bioavailability survey maps are attached to the *Appendix* of this report.

2 Bioavailability Premise

Geotronics uses a new soil sampling technology that offers very significant advantages over traditional sampling techniques. This technique requires more accurate equipment within the lab that can measure the parts per billion (edging into the parts per trillion) over current standards of parts per million.

Plants secrete a weak acid that breaks down nutrient compounds into ions which are then able to cross the root membrane. Our technology enables the use of a less aggressive reagent applied to the sample, which mimics this process, hence giving a superior reading of bioavailability. In standard soil sampling common, stronger acids are used which are too harsh, resulting in compounds being measured which the plant is unable to uptake. There are other problems as well, but this is the most important as it relates to bioavailability.

In addition, a technical and specifically reproduceable methodology is used in gathering the samples which significantly increases consistency of analysis over traditionally employed techniques.

Lastly, traditional soil sampling does not take enough samples to provide anything approaching an accurate representation of the behavior of the soil. As the soil maps show, there can be massive differences in available nutrients in the soil. We also take "control" samples of undisturbed soil which provides background information against which the vineyard can be compared. By taking more samples that accurately measure bioavailability, one is able to reduce the amount of fertilizer used and accurately target trouble areas (and prevent trouble areas from forming due to over-fertilization). This reduces costs and boosts yields.

Further, it is possible to "fingerprint" high performance and quality areas and to then reproduce these soil conditions in other areas of the vineyard resulting in increased performance and quality across the vineyard. This is an avenue of application we are currently exploring.

3 Interpreting the Data

3.1 Macronutrients

"Macronutrients" are a name for nutrients which plants require in large quantities for growth and development. Typically, macronutrients are applied to the soil either via broadcasting/banding or fertigation.

With nutrients, deficiency is not the only concern. Excess can both reach the level of toxicity within a plant or may impede the uptake of other nutrients. A common relationship is between potassium and magnesium, where a K:Mg ratio greater than 3 can impede magnesium uptake (this ratio is noted on the Sampling Results Table). And the inverse is also possible. Another common relationship is between low potassium and high calcium, which leads to a lower pH grape and thus more acidic wine.

The macronutrients for a vineyard are calcium (Ca), potassium (K), magnesium (Mg), nitrogen (N), phosphorus (P), and sulfur (S).

Nitrogen is the only nutrient that we are not able to analyze using our technology (due to the contents of the extraction). For this reason, we use the common measure of NO3 (nitrate), although we have carried out other forms of analysis of nitrogen.

3.2 Micronutrients

"Micronutrients" (or "trace elements") are named for nutrients in which a small amount (relative to macronutrients) is required for vine health and optimization.

Because these nutrients are required in smaller quantities they are more prone to excess/toxicity. This is particularly true due to human intervention. Of particular note is boron, which has the smallest range between deficiency and excess. And like macronutrients, excess of one nutrient can impede the uptake of another.

Micronutrients are typically applied via foliar sprays.

The micronutrients for a vineyard are boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and Zinc (Zn).

3.3 pH

Soil pH is a required component for understanding nutrient availability and overall vineyard health. pH is a measure of the acidity or alkalinity of a substance using a logarithmic scale ranging from 0 to 14, with 7 being neutral. Anything below 7 is acidic and anything above 7 is basic or alkaline. Soil pH operates within that scale on a range from 3 to 10.

Soil pH has a significant impact on nutrient availability (see: *6.3 Availability of Nutrients at Different pH Levels*). Roughly, below 5.5 or above 7.0 certain nutrients become less available to the vine. This is particularly true of micronutrients. In addition, the soil biome can be negatively affected by high acidity or alkalinity. Lastly, there is some research that suggest grapes within the range of 5.5-7.0 retain more acidity, and thus complexity, as they ripen.

In general, the Naramata area has very alkaline soil. Many vineyards have a pH above 8.0 requiring more intervention to both lower pH and adjust nutrient availability.

Lastly, it is a common practice to take only one or two samples across a vineyard, or to blend samples. We think it is critical to take pH with every sample, and in line with our general practice, across the vineyard to get a representative picture of the local vineyard environment. This is in large part because nutrient availability is so directly affected by pH. A real-life example is vineyards where one area may have alkaline soil of 8.5 and another area acidic soil of 5.5. It would be harmful (and wasteful) to treat these areas the same.

3.4 Silicon

Silicon is a new avenue in vineyard management that comes from other agricultural practices. While silicon is not an essential nutrient for plant development (plants will grow normally without it), there is significant evidence that silicon can increase both stem strength and grape skin thickness.

There are two advantages to this. First, it increases disease resistance of vines, particularly to fungal diseases. Second, by increasing skin thickness it can increase the feasibility of automated gathering. For example, this has been of particular benefit to the blueberry industry. There is even some indication that silicon supplementation can increase brix and bunch sizes.

Given the newness of this approach we do not have recommended levels of silicon bioavailability, although the Symbol Plots do give relative values of silicon within the Okanagan. If you are interested in this area, please contact us.

3.5 Geology

Geology can provide important foundational information for a vineyard. As part of our service, we test for calcium, cerium, and nickel which can give indications of underlying lithology. There are a number of contexts where this may be important. One example is in understanding the behavior of different sections of the vineyard. Further, we know that vineyards with a single geological provenance are more susceptible to nutrient deficiency. Lastly, known geology, such as calcareous rock, can boost the value or cachet of a vineyard.

Currently, we are exploring adding additional soil tests which may be able to give very precise mapping of underlying geology.

4 Interpreting the Maps

4.1 Map Types

4.1.1 Aerial Photo Map

- This map provides an aerial view of the vineyard along with its rows and sample sites. In addition, we have included a contextual overview of the relevant findings over the problem areas within the vineyard.
- These maps are useful for providing a high-level overview of the weaker areas within the vineyard.

4.1.2 Contour Plan Maps

- Taken from each element analysed as well as pH, these maps use an algorithm to generate contoured values over the entire vineyard.
- These maps are not predictive but are useful for visualizing differences in values between sample sites. Values/colors assigned to non-sampled areas are not a useful indication of likely values.
- The one benefit of the contour plan maps is that if enough samples have been taken, they can be used during fertilization to determine where, when, and how much fertilizer should be used. A simple application is to dump more/less fertilizer in the appropriate areas as identified by the plan maps.

4.1.3 Symbol Plot Plan Maps

- These show the values for each sample site with relatively-sized symbol plots.
- These are the primary maps we use for interpretation (along with the Sampling Results Table).
- The key difference between the Symbol Plot Maps and the Sampling Results Table is that the color and size of the symbol plots are based on averages within Okanagan soils. The respective size and color may not be indicative of overall deficiency/excess although it does give an indication of values relative to other Okanagan vineyards.

4.1.4 Sampling Results Table

- A color-coded table which provides an effective overview of all information from the vineyard.
- Unlike the Symbol Plot Maps, the color coding in the Sampling Results Table is based on worldwide averages of samples taken from European and Western Australian agricultural properties (including a lot of vineyards).

4.2 Where Should You Start?

The way we'd recommend viewing and interpreting the maps is by first viewing the Symbol Plot Plan Maps. This will give you an idea of the relative value of nutrients against other Okanagan wineries and will show immediate excesses and deficiencies. From there, take a look at the Aerial Photo Map and Sampling Results Table. The Aerial Photo Map will give you an overview of major problem areas we've identified within the vineyard, while the Sampling Results Table will show excesses and deficiencies.

The Contour Plan Maps give a useful visualisation of the relative bioavailable values within the vineyard. It is important to note that as an algorithm generates the values in between samples, these maps shouldn't be viewed as predictive in areas where few or no samples are taken. As well, these are a useful tool for getting a snapshot of the vineyard but are not the primary interpretative mechanism (the Symbol Plots and Sampling Results Table are used for that).

It will also be beneficial to identify soil deficiencies with corresponding visible nutrient deficiencies within the vineyard (see sections *9.1 Effects of Micronutrient Imbalances* and *9.2 Effects of Macronutrient Imbalances*).

5 Analysis

This section is best referenced with the attached survey maps (see *Appendix*).

"World Average" refers to values from a 2,000+ agricultural/vineyard soil sampling survey in Australia and Europe (see Comparison to Australia & Europe).

5.1 General Comments

- Entire vineyard is low in boron (below detection limit). This is probably due to the underlying bedrock, though it could also be due to the higher pH lowering the bioavailability of boron.

- The entire vineyard is lower in sulphur, and copper. For copper, the World Average higher average may be due to most vineyards using a mildew spray which contains copper. This therefore suggests that a mildew spray is not used on the Vista Ridge vineyard. However, another possible cause is the higher pH which limits the bioavailability of copper.

- Most of vineyard is very low in molybdenum and iron and low in manganese. The comparison is with the World Average table of which most of the vineyards have lateritic soil resulting in their higher iron and manganese. Therefore, the World Average table may be unusually high in these two elements.

- The magnesium, in general for this vineyard, is in the medium range.

- Entire vineyard is higher than World Average in calcium and potassium. This suggests that the vineyard does not need liming

- The low cerium values, except for two very high ones, and the high nickel values suggest the underlying bedrock may not be the intrusive granodiorite that is widespread in the area but rather a more basic rock type, possibly one of the metamorphic rock-types that are known to occur in the area. Knowing the type of rock that is underlying a vineyard is important in understanding its terroir. For example, it is probably the reason for the low boron.

5.2 Sample Sites of Weak Growth Areas

These are sample sites #'s 03 and 06, which occur within northwest section of the vineyard.

The weaker growth areas display a definite characteristic in lack of nutrients:

- Lower boron than other samples, including control. Boron deficiency will typically represent as very short internodes, mottle chlorosis, poor fruit set, shoot tip death and impaired cane ripening.
- 06 is very low in potassium. It is also quite high in magnesium, which can further impact potassium uptake. Potassium deficiency will usually show in early-to-mid summer as yellowing (white varietals) or reddening (red varietals) of older leaf margins with leaf margins eventually becoming necrotic. Berry set can also be poor.
- Potential manganese toxicity as values are 2x as high as world averages. It is important to note that 04, a healthy area, also has very high manganese. Toxicity will typically represent as black spots on leaf blades, shoots and stems as well as deficiency symptoms similar to other nutrients.
- We have seen some correlation between high molybdenum and poor growth. The weaker areas are higher in molybdenum, but it is unlikely this is the culprit. If it were, we would expect leaf malformation and scorching and signs similar to salt damage.

6 Recommendations

It is very important that dialogue continue to maximize the impact of these results. This report is one part of the process towards identifying and correcting problem areas within the vineyard as well as overall vineyard health.

After you've received this report and had a chance to review it, we will have a follow up conversation covering what's been attempted, immediate recommendations, and how we can further assist in the success of your vineyard. For example, it will be useful to connect soil deficiencies with observable plant deficiencies.

Initial recommendations:

1. The first step will be to further lower the soil pH. This usually takes time, but we'd expect that lower pH would increase overall nutrient bioavailability.
2. Boron supplementation in the weaker areas of the vineyard.
3. Overall the vineyard is high in potassium *except* for 06. Targeted potassium supplementation in this area would be beneficial.

4 04 and 06 are low in potassium, exacerbated by the magnesium imbalance. Reducing magnesium supplementation or increasing potassium supplementation should remedy this issue.

7 Methodology & Survey Procedure

For each vineyard soil samples were taken from each of the weaker growth areas as well as the stronger growth areas. This was done in order to correlate the results of data between that of poor and good so that possible deficiencies and excesses could be identified. A “control” sample was also taken outside of the planted area. This provides background information on the behavior of the local soil prior to viticultural intervention.

The sampling was done according to our technical method with each sample being taken at a specific depth. For the vineyard, a total of 15 samples were taken, with 6 in stronger growth areas, 7 in weaker growth areas, and 2 control samples outside of the vineyard. The strong and weak growth areas were identified by the owner.

The samples were analyzed for 15 elements as well as for pH. Twelve of these elements are considered important nutrients for vineyard performance. These may be grouped into two categories, macro and micronutrients.

The macronutrients are calcium, potassium, magnesium, nitrogen, phosphorus and sulfur. The micronutrients are boron, copper, iron, manganese, molybdenum and zinc. Silicon, which affects the thickness of grape skin, was also analysed. Lastly, cerium and nickel were interpreted as these elements provide indications of underlying geology.

The data for each of these elements, as well as the pH, were then processed into contour plan maps as well as into symbol plan maps.

8 Comparison to Australia & Europe

Over two thousand agricultural samples (including vineyards) in Australia and Europe have been analyzed. These have been used as a baseline to establish a comparison of expected values for the vineyard. The table of values, based on research of these results, are included below.

Nutrient	“Low” Range	“Normal” Range	“High” Range
Ca	<200 ppm	200-400 ppm	>400 ppm
Cu	<2000 ppb	2000-4000 ppb	>4000 ppb
Fe	<20 ppm	20-40 ppm	>40 ppm
K	<20 ppm	20-40 ppm	>40 ppm
Mg	<40 ppm	40-80 ppm	>80 ppm
Mn	<4000 ppb	4000-8000 ppb	>8000 ppb
Mo	<20 ppb	20-40 ppb	>40 ppb
P	<2 ppm	2-4 ppm	>4 ppm
S	<10 ppm	10-20 ppm	>20 ppm
Zn	<1000 ppb	1000-2000 ppb	>2000 ppb

9 Reference Tables

9.1 EFFECTS OF MICRONUTRIENT IMBALANCES+

Nutrient	Effects of Deficiency[1]	Effects of Excess[2]
Iron	Usually occurs early in the season, interveinal, creamy chlorosis on apical leaves; stunted shoots; reduced yield	Reduced yield, usually associated with low pH creating excess available iron
Manganese	Chlorosis bands on basal leaves and death, decreased cold hardiness, no new lateral roots, inhibited nitrate metabolism	Tissue injury, black spots on leaf blades and shoots and stems, deficiency symptoms of other nutrients
Copper	Short intermodes, pale color, distorted young leaves, tip death	Reduced vigor, inhibited root growth or root damage
Zinc	Usually appear in early summer, distorted, mottled apical leaves; stunted shoots; poor fruit set & shoot berries, younger shoots will show deficiency before older ones	Inhibited root growth, young leaf chlorosis
Molybdenum	poor fruit set, deformed young leaves, veinal chlorosis on old leaves	Leaf malformation, leaf scorch and abscission (similar to salt damage)
Boron	Very short intermodes, mottled and patched chlorosis, poor or no fruit set, oblate and shot berries, shoot tip death, stubby roots, impaired cane ripening, inhibited nitrate metabolism	Toxicity: dark brown speckles or necrosis on edges of older leaves, cupped and wrinkled younger leaves

[1] Christensen, et al. (1978), Grant (1998), Marschner (1986), Mullins, et al. (1992), Robinson (1992), Tisdale, et al. (1985).

[2] Barber (1984), Christensen, et al. (1978), Marschner (1986), Robinson (1992), Tisdale, et al. (1985).

9.2 EFFECTS OF MACRONUTRIENT IMBALANCES

Nutrient	Effects of Deficiency[3]	Effects of Excess[4]
Calcium	Uncommon in alkaline soil, usually effects new growth first, necrotic leaf margins, then bunch stem necrosis	Can impede uptake of magnesium and potassium, decreases availability of nitrogen, phosphorus, iron and zinc, increased salinity
Potassium	Usually appears early- to mid-summer, starts at yellowing (white varietals) or bronze-reddening (red varietals) of older leaf margins, as it worsens leaf margins become necrotic and curl upwards and inter-vein alchlorosis develops, berry set can be poor	Will raise pH in wine and lower acidity, may induce magnesium deficiency
Magnesium	Usually occur mid- to late-season, bright yellow (white varietals) or red (red varietals) wedge-shaped areas extend inwards between the veins in older leaves, when severe necrosis extends inward form the leaf margins, fruit cluster stem necrosis and berry withering, can be induced by high pH soil	Reduced vine growth and crop load, potassium deficiency, slow water infiltration and poor soil structure
Nitrogen	Overall reduction in growth, leaves becomes uniformly light-green or yellow, reddening of petiole, berries may be small, necrosis of older leaves, early flowering with marginal N deficiency and late flowering with severe	Wilting, leaf desiccation, too much vigor, root tip burn, variable pigmentation of red varieties, vines with dark green color and long internodes, reduced uptake of K, Ca, Mg
Phosphorus	Usually manifests late in the growing season, vines may have stunted shoots and poor fruitfulness, appearance of red dots on basal leaves in the mid or terminal lobes, these red dots later line up at right angles to secondary veins and form dark red bars	Can induce potassium and micronutrient deficiency
Sulfur	Reddening of young leaves, red dots near the edges of adult leaves, may coalesce into red bars at right angles to the vein leaves, growth lignification is impaired, small and loose clusters	Very rare, can compete with nitrogen uptake

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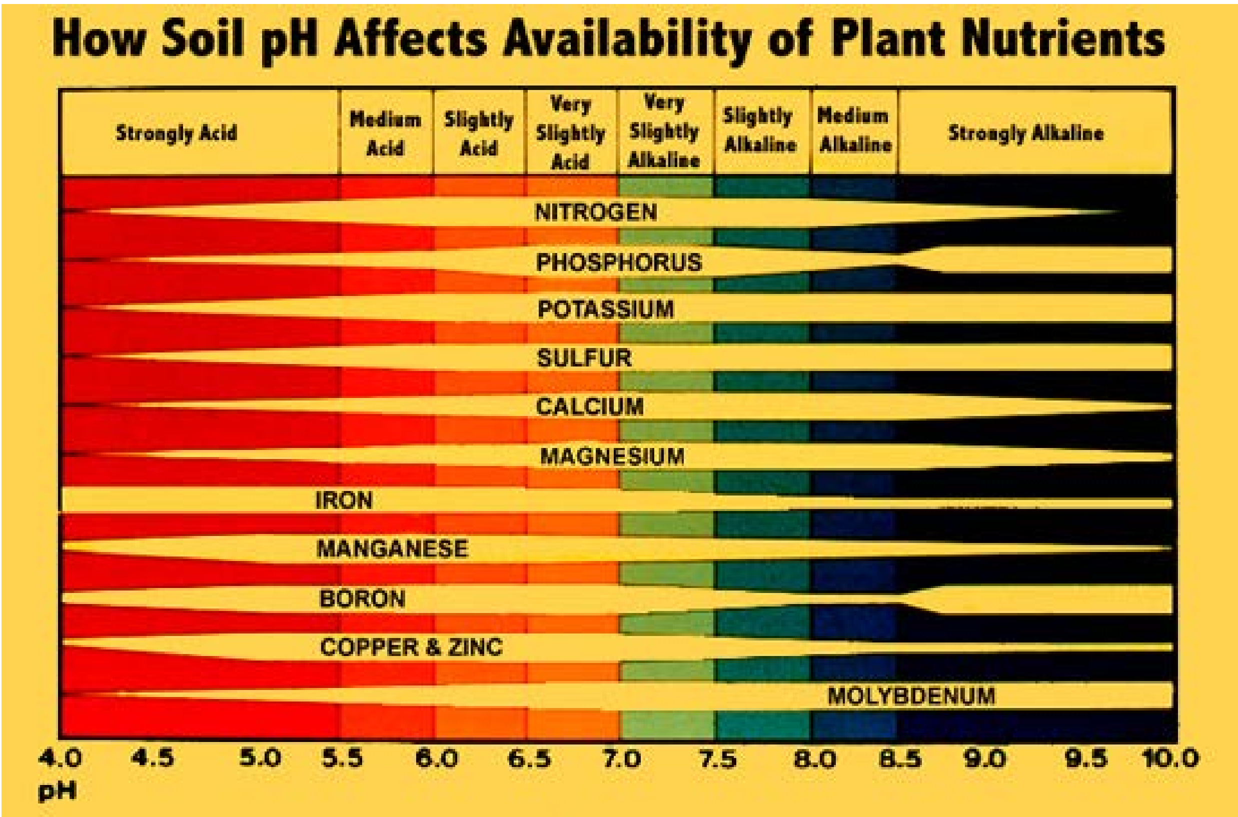
[3] Christensen, et al. (1978), Grant (1998), Marschner (1986), Mullins, et al. (1992), Robinson (1992), Tisdale, et al. (1985).

[4] Barber (1984), Christensen, et al. (1978), Marschner (1986), Robinson (1992), Tisdale, et al. (1985).

9.3 AVAILABILITY OF NUTRIENTS AT DIFFERENT SOIL pH LEVELS[5]



[5] Chien, M. Grapevine Nutrition.

10 Appendix