Alfred Cass in Virginia

By his own admission soil scientists working with vineyards are a rarity. Among the few who can be found in a vineyard, Alfred Cass is certainly one of the most skilled, with forty years of experience studying soils. He comes from South Africa but honed his skills in the U.S. working with Daniel Roberts and Integrated Winegrowing to develop some great vineyard properties in California, mostly in the north coast region. He has been the East a few times, most notably to work on the RdV project in northern Virginia. This time, the Virginia Vineyards Association and Dr. Tony Wolf at Virginia Tech brought Alf in as their main speaker for the 2010 summer vineyard technical meeting held at Linden Vineyards in Linden, VA. Alf has a system that he has developed for soil evaluation that analyzes specific soil characteristics. Since fine wine is largely about water availability (or lack of it), his Total Available Water (TAW) ranking is the key to assigning the correct rootstock and determining how to properly prepare the soil prior to planting. He is most interested in how soil affects wine quality and tries to map the journey a wine travels from soil to bottle. He gave an excellent overview of his methods, which I tried to capture in my notes. Here goes….

There are two analytical tools to address before discussing soils. Normalized Difference Vegetative Index (NDVI) can scan from either above or the side of a vine's canopy and is a good way of measuring vine vigor and color-coding variations into a spatial image of the vineyard. Also, an amalgam of infra-red images can yield similar data that show variability in vigor among vines. These are basic tools in modern precision viticulture. It is a fact of life that soils are variable, like a sandwich in three dimensions – across a field and by depth up and down. Imagery of volcanic ash ridges or sedimentary soils, or the effects of massive rains that cause erosion can help in managing a vineyard. The affect on fruit quality can be dramatic. A chart showing brix (y) against TAW (x-inches of water in the effective root zone) showed a strong correlation. TAW can also be called the least limiting available water. Soil water content varies; it is high after a rain and drops as the soil dries out. The soil bucket itself remains static under different conditions and can only be changed by physical manipulation, usually compaction or ripping. The effective rooting zone has 85% of the shallow, dense and finer roots, while deep roots are marginally effective in driving the vine. This doesn't mean that all shallow soils produce good fruit. Deep soils generally produce poorer quality fruit, and over-irrigating deep soils causes excess vigor. Soil water properties can be modified, especially before planting, to alter the direct and indirect effects of soil on wine quality.

Alf referred to a diagram in *Sunlight into Wine* (R. Smart, 1985) that focuses more on canopy effects on quality and very little on the impact of soil. Half of the vineyard lies below the surface and is often neglected and relegated to a lesser role. This is not a surprise since Smart adjusted canopy choice and management to relative vine vigor (soil effect). Alf proposes to take a more holistic view of the vineyard and to separate soil and viticulture.

His conceptual soil model is based in a holistic ecosystem where everything is interdependent including the physical, chemical, biological and nutritional components of soil. His model includes:

- Physical soil: aeration and drainage, available water, root function
- Chemical soil: nutrients, chemical balance, base status
- Biological soil: microbial populations, organic carbon, mycorrhiza

All of the cogs of the machine must be working together. For example, soil biology is necessary to keep soil physics working. The biological component of soil is the least understood. We know most about and are most comfortable with the soil chemistry because it is based in numbers and we have experience interpreting data and amending soils.

Site characteristics include topography, aspect, slope, root pathogens and irrigation water quality. Soil management implies changing conditions in the ecosystem within the constraints of macro and meso climate conditions. The grower's focus should be on comprehensive soil health (physical, biological, chemical).

Within each soil component, Alf asks "What should we measure?" followed by "What do we want?" For example, in soil biology we can measure root pathogens, mycorrhiza and organic carbon. What we want is compost to stimulate biological activity, biological compounds to correct soil biology problems, and methods to deal with spatial variability. Growers should ask themselves what the effects of compost are? Applying compost certainly has an impact on low organic matter soils, especially soils that were damaged by site preparation activities.

Chemical factors include Ca:Mg imbalance, salinity, sodicity, chloride, alkanlinity/acidity, aluminum, boron and heavy metals. For these to make sense you need critical minimal and ideal and uniform values to know what high/low and average values are and then a smart viticulture soil scientist to interpret the numbers. .

To get an accurate read of the property many cores or holes are necessary to account for variability. Soil chemistry factors include saturation extract, extractable ions and organic matter. Most growers are familiar with soil pH and have a sense of the range in which vines function. If pH is less than 4.5, the chemistry of soil is dominated by soluble aluminum that can impede root function, and it is possible to see the damage to cell walls of roots. A chart shown with extractable Al (y) vs. pH (x) illustrates how Al goes up dramatically with descending pH below

5.5. This is a matter of real concern. Acid soils can be ameliorated with lime – calsic lime for high magnesium soils or dolomitic for low mag soils. Rates should be just enough to elevate pH to 5.5 to 6. Gypsum will move in the profile 100x better than lime and will not change pH but will neutralize aluminum. Use 2-5 t/a in annual or biannual apps at 1 t/a depending on soil conditions. As pH increases to 8.5 and above, the toxic effects of sodium carbonate may create nutrient deficiencies.

Soil physical health factors include healthy root function and growth of roots through soils. Roots are incredibly strong. A measure of the ability of roots to penetrate the soil is soil density or strength. A penetrometer is a steel probe used by engineers and soil scientists to measure the potential for root growth. At 2 to 2.5 MPa a soil is at field capacity. (1 MPa = 145 psi). Look for penetration less than 2 MPa. Penetration is a function of water content. Do not measure soil penetration during summer when soils are too dry. Soil bulk density will influence soil biological health. Look for a shallow curve for good soil structure.

Aeration and drainage are important to root health and vines will die or lose function in saturated soils. Air filled porosity should be greater than 10% of pore volume which is sufficient oxygen for root respiration.

The least limiting available water model uses field capacity and permanent wilting point to indicate relative soil water content. At a rating of 1.0 entire soil profile is filled whereas 0 is empty. Available water is the difference between FC and PWP. Drying curve and strength curve, as water goes away it gets harder for roots to remove it from soil and the soil can hold water prisoner. Porous, friable, soft and well-drained are all characteristics of healthy, balanced soils. Non-porous, compact, hard and poorly drained soils have the least limiting available water. Shallow rocky soils are more likely to produce high quality fruit. You should not passively accept poor conditions.

Physical health factors include depth of soil layers, effective rooting depth, texture structure shape, hardness and size, visible pore space, percent rock content color and mottling, and layer interface. All of these interact to influence root function, available water, aeration and drainage.

Total available water is a critical indicator. How to classify soil moisture and using what to use for criteria? The system Alf uses assumes high density, low vigor vines, and winter rains of > 400mm/yr (soil profile will be full of water at bud break). TAW in the effective rooting zone is measured in inches of water and classes 1 to 7. If TAW is too high it will be difficult to grow high quality fruit. But matching rootstocks to TAW can help control vigor will increase the likeihood of better quality fruit. If a soil is deep and rich, use a devigorating rootstock like Riparia Gloire. Hi Mg soils need 420A which picks up K much better to balance Mg. Using TAW and other soil attributes can determine correct rootstock assignment. The spot in this scenario is a class 3 soil that has a TAW of 2.5 to 3.5 for optimal fruit quality using 101-14, 3309, 1616C or 420A.

TAW can be manipulated by improving aggregate structure and increasing effective root depth. Deep tillage and knowing TAW can change the nature of the soil. The winged tyne can be a tool to improve soil structure and achieve a more uniform TAW across the landscape. This special plow helps to engineer the root zone to suit our choice of rootstock. Instead of a shank that cuts a narrow slit in the soil, the winged tyne rips in a V-shape on the vine row. The depth is two feet and the ends of triangle are about 4'apart. Double the depth of rip. For a proper treatment the soil must be hard to rip depth. If it is too soft the ripping will not have the desired effect. Timing and condition are critical - ripping too wet or too dry could turn the soil from granular to powder (cement).

When are the best time and conditions to rip? Check the soil plasticity to the depth of the rip and try to rip at the lower plastic limit of the soil. Soil is a mechanical thing, when dry it is powdery and cement-like. A wet soil is squishy and plastic. When it goes from gritty to plastic it is right to rip. Dig a hole to rip depth, mold soil into a ball, manipulate it and take a pinch. If you can roll it over and over again to 3mm without breaking, it is too wet. ¼" is the right moisture level. Soils pass through this point quickly so be ready to work at the correct moment.

Deep ripping can go as deep as 4' but most soils will benefit from ripping at 18" to 2'. To achieve an effective rip it is necessary to have adequate tractor power to move uniformly up, down and across a field. Ripping can raise TAW, e.g. from natural root depth to 24" to 48" - which moves TAW too high - so great care must be taken in this process. Rock content will limit TAW increase since rocks do not store water. Rocks also provide macro pores for roots. Rocky soils are very desirable for wine production.

Pit data collected at Linden revealed Seyval growing in a wet area. Edneytown series and Middleburg series boundaries are not well-defined. Identify five layers of soil and apply scores for good or bad. Some factors indicate that the soil is not good for vine roots. The key is to get numerous profiles, since accuracy is increased with each additional sample. It may be an advantage to have a layer that vine roots will not penetrate; then the grower can manipulate soils to correct condition. TAW only works within the boundaries of the effective rooting zone or depth.

Ripping to 18" produces dramatic changes in TAW, shifts from category 1 to 3. A 24" rip creates a dramatic change, penetrating into hard soils, and changing red dots to green and yellow dots on soil maps. If a soil is ripped to 36" too many green dots appear and vigor us too high. 24" is often the sweet spot for ripping depth. Get a uniform area of color and assign proper rootstock based on TAW.
Try to minimize ripping. Rip on the vine row. Do not rip row middles.

To decrease TAW, rip more shallow, but it is important to rip. Not ripping at all is usually bad for the vines.

When ripping a planted vineyard rip with 2 tynes on the tractor wheels. It is very difficult to get a big enough tractor and to get the shank deep enough.

The distribution of rain is more important to than the total amount. It is important in arid regions to recharge the soil in spring. The problem in our region is the uncontrolled addition of water.

Is TAW stable over time? Soils will move back to pre-rip condition. Growers are looking for finer and denser root systems for their vines. Ripping creates preferential flow paths for water and roots.

The soil evaluation form that Alf uses in vineyards includes these categories:

- Depth from surface (surface = 0)
- Moisture content
- Main soil color (moist)
  - Prefix
  - Secondary
  - Primary
- Rock
  - Percent proportion
  - Condition
- Sand grade
- Texture
- Soil structure units
  - Shape
  - Size (inches)
  - Hardness
  - Plasticity
- Visible pores
- Mottles
- Root density
- Acid reaction
- Internal drainage
- Chemistry sample number

Within most of these categories there are rankings. For example, moisture content is ranked from 1 to 6 (dry to water table). Color from 1 to 11 (1=black > green > red, yellow and 11=orange)

<u>In the field (rough notes)</u>

Pit #1 – upper location, mid slope, Pigeonroost soil.

Maximum allowable pit depth is 5' for safety reasons. If the pit collapses and you are buried, you can survive for about 20 minutes. Even a collapsed 3' pit can immobilize a person. Be careful. Once filled in, soil pits can alter the performance of nearby vines for quite a long period. Growers should be aware of this.

When, where and how to dig soil pits: Pit analysis is best done in the fall or spring when soil condition is optimal. The purpose of a pit is to determine where the vine roots are and where they will be later. We are not interested in the soil as a natural entity, we want to understand how it affects vine growth. We need to understand soils over the vineyard landscape, not just in one place, and this means looking at it in numerous spots. Soil examination is the last step in evaluating a site. Dig pits in healthy areas and problem areas, either prior to planting or determined by vine performance. Get as close to the roots as you can. A soil pit will stimulate vine vigor, possibly for a long time after it is filled in. The pits will help to detect variability in soils across a landscape and the number of pits is dictated by the extent of variability. More variable = more pits. For example, dig first pit, move 200' in a direction, dig second pit – if it is the same as first keep moving away, if it is different, move ½ distance back towards first pit and keep this process until soil pattern is determined. On a flat plain pits may be 1000' apart, on hillsides 20' due to greater variability. Give good exposure to the pit walls, the vine side should be in the sun but look at all 3 walls. Observe factors to measure soil quality – quantify and characterize the soil according to a system that can be compared to other soils in and out of the vineyard. You'll need water, hammer, tape measure, soil color guide, clipboard, nails, flagging tape and sharpie (to ID pit) and measuring tape. Oh yes, and a backhoe. Do not examine glazed sides, instead, chip away at sides to reveal the true nature of the soil structure and to expose roots. Use nails to mark changes in soil profile (horizons). The first nail is at the base of the Effective Rooting Depth (ERD). This is the area that contains 85% or more of the fine root system and indicates where a change in soil strength occurs. Get a big chunk of soil from the bottom of the pit for soil pore examination.

Color: Vines do not care about soil color but it is an indicator of some key soil properties. Roots do not like pale colored soils. Bright colors are preferred (red, whitish, etc). Pale browns and greens are indicators of reduced, anoxic soils with low soil air availability. This condition is not good for root growth. The soil color manual is good for beginners but eventually it's easy to tell which are good and bad colors. Mottling is a sign of wet soils.

Rock: it's important to quantify rock content. This is a separate category from soil texture – silt/loam/clay. Particles > 2mm qualify as rock pieces but there is lots of variation in this category. Use the hammer to tap the side of the pit and feel and hear the rock. Try to determine rock content to +/- 10% in each layer. Look for exclusionary rock layers. Rocks that are bigger than a person's head will cause problems with ripping. Small rocks are okay. Ripping can fracture granite.

Texture: you'll need to get your hands dirty to determine soil texture. This is a bit of an art along with science to determine the plasticity of soil. Take a handful of soil and add water but not too much. Alf could tell right away that it is a clay/loam. Roll soil and push out between thumb and forefinger until it breaks off. The length of the broken part will help to determine the plasticity. You can hear the grit in the sand. Categorize each layer as sand-loam-clay or combinations. Water storage ability is a function of texture. Sands usually go deeper, clay holds the most water. Rock is not part of soil texture.

Structure: determine whether soil is round and touching like golf balls in a box, or more cubical with abutting ends and sides or of a more horizontal design. A soil can be massive with no real structure at all. These are the least preferred for vineyards. The vines don't care about structure but they need to have a place to move roots through and structure will influence this ability.

Whether granular or blocky, generally the smaller the particles the easier it is for roots to find a path. The size of the unit is important, e.g. large-blocky (2-4”) is not easy for roots to push through. Tillage such as ripping can break up large blocky soil pieces. Shape and hardness can be categorized into friable, firm, hard and rigid. Rigid soils are so hard they cannot be ripped. Firm and hard soils need to be ripped for better suitability. A friable soil will break easily between thumb and forefinger, while firm takes more effort. Hard is 4-8 MPa.

Pore size: look for little holes that are visible to the naked eye or with a hand-lens. Visible pores determine the quality of drainage. Visible pores are preferred to 3’ or more.

Soil strength: can be measured with a penetrometer. This is a probe that measure resistance. You can do it with a simple method using a 3/16” steel rod, about a foot long with blunt ends. Hold it with your palm against the side of the pit and push. If it goes in easily the soil is < 2 MPa, if it hurt,s soil resistance is > 2 MPa. If it goes through your hand then it is 4-8. For Alf, soil strength trumps rootstock in importance for vine growth and fruit quality.

Roots: 85% should be in the effective rooting zone. Fine and dense roots are the best. All 3 sides of the pit should be examined for the presence of roots. In this pit roots are quite shallow, vines have modest vigor, 6 years old and hedged 2x so far in a dry season. Roots do not care about the presence of other roots. They do not compete with each other if there are no limiting soil factors (water, nutrients). Roots will stay shallow where living is easy. They tend not to go deep as is often thought. As vines age roots will tend to move downward. Alf has found that root pruning will not encourage roots to go deep but instead it causes more roots in shallower zones of softer soils and exacerbates vine vigor.

Adjusting pH: lime must be mixed in order to have impact. It will not readily leach into the soil. Gypsum is much more soluble but will not change pH. P is insoluble but K and N are more soluble. It’s always better to work amendments into the soil as much as possible.

Pit #2 is a weak soil with lots of roots below. Cabernet Sauvignon on Riparia planted in 2008. Vines are small and showing signs of Mg with possible mild P deficiencies on Edneytown soils. P is 9 ppm. P at 2-3 ppm will show signs of deficiency. Mg deficiency is related to low soil pH of 4.5 even though TAW is in midrange of 4.5. Use dolomitic lime (not calcitic) to improve magnesium uptake. Get the lime down 6-12” into soil. pH 4.5 puts roots at risk of aluminum toxicity; check the roots for damage. Platey structure is possible for roots to penetrate. Good profile and vines are doing well. Jim is trying to restrict vine size. This is not a field to deep rip; just a shallow rip is okay. RG may be to restrictive, 101-14 may be a more suitable rootstock. 3309 and 101-14 are both drought susceptible. Rocks on the surface are very deceptive because there are no rocks below. They were probably moved in later or picked up and placed on the vine row. Soils in VA generally have high potassium and low phosphorus. Hi K can cause problems with wine pH. There is not a good method to predict how soil K level will translate into wine pH. Mg is not blocking K entry into roots – it's not a chemical barrier but rather physical: Mg is affecting soil structure, making uptake more difficult. Vine tissue tests are the only way to accurately measure vine nutrition status. Trace elements are especially difficult to track in the vine using soil tests. Bruce says wine growers are now using YAN in must to determine nutrient status in the vineyard according to grape origin. Compare bloom petiole to YANs at harvest.

Pit #3 is near the own-rooted Seyval. There are windows with no roots present. The root system is weak but this may be more a function of variety than soil. Seyval vines are in very good balance. Fruit is ripe and will be harvested in 2 days.

Pit #4 is a Middleburg soil that is wet and typical of flooded land, with mottling and indicating a reductive process of Fe+++ reducing to Fe++. Gray color indicates that moisture is always present. Alternate reduction and oxidation causes mottling. Vines do not like wet feet and this will affect growth and health of the plants. Drain tile would help but what is the cost/benefit for the area in question?

Pit #5 is on top of the hill was granite and loaded with large rocks and looks to be the best vineyard soil. Rock reaches down 4+ feet. Reddish-brown soils look like rock mixed with clay.

Greenstone can make good wine if the drainage characteristics are good. It doesn't have nearly the rock as granite. The greenstone soils reminded me of the soils at Allegro in York County - very well drained clay loams that can make high quality wines with the right care and use. Correct rootstock assignment is critical for red wine production and that is a lot of what this process is about.

In the end, having someone like Alfred Cass evaluate your vineyard soils, before or after you have planted, will yield great insights into the fundamental nature and functioning of your vineyard.

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