SOIL QUALITY AND STRESSED VINES, ARE WE COVERING UP PROBLEMS?

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INTRODUCTION

When decisions regarding purchase and planting of grapevines are being made, one inevitably runs into issues relating to the soil's suitability for grapegrowing, the concept of terroir and of stressing vines to increase grape quality.
Decisions to buy land for grapegrowing are not always taking enough account of soil conditions. In some cases prospective growers may realise that their soils have limited fertility or other restrictions, but they may support the approach that putting stress on the vines ultimately will produce better wines.

There is no doubt that fertile soils with high levels of nitrogen can make the vine excessively vigorous and can directly and indirectly affect grape quality in a negative way.
However there are clearly some forms of stress that are not good for either the vines or the grapes. Stressing vines by waterlogging the soil is an obvious example. Nutritional deficiencies like boron deficiency generally do not help quality either (boron is important for flowering and fruitset and may also play a role in frost sensitivity). Restricted rootgrowth as a result of compaction is another, very dubious, contributor to vine health and grape quality.

There is no doubt that low soil fertility and compaction can increase stress on the vine. At best it may only reduce the nutritional support base for the crop. At worst, it will increase the incidence of berry splitting (calcium deficiency), affect flowering and fruitset, increases the incidence of root diseases, may reduce nutrient and water uptake, and may more than likely reduce the long-term sustainability of the successful grapegrowing on that site.

ARE WE UNDERESTIMATING THE POTENTIAL PROBLEMS?

The word *soil* means different thing to different people. One would assume that, to people in the grape and wine industry, the word soil would mean more than the "the surface we walk on".
However in many cases only lip service is paid to proper soil management in the vineyard. There are those, even in the grape industry, for whom soil is not much more than something that "can get your tractors stuck when wet".

On the other hand we have the "terroir" representatives, who attribute some of the most important grape and wine quality parameters to the soil in which the vines are growing (excluding terroir-aspects like microclimate etc. from this discussion at this point).
Most people involved in the industry would probably support the notion that there is a relationship between soil and grape quality. In many cases one might consider this relation mostly based on soil type and the inherent soil parameters associated with soil types. Little regard is given to the **actual** soil parameters of the vineyard soils. Soil type defines, or relates to, certain soil parameters of which texture is probably one of the more important. Within one soil type however, one can find a wide range and variation of other soil quality parameters which are mostly determined by soil management. (Organic matter content, soil biological activity, soil structure (aggregates), water infiltration etc.).

Poor management of soils belonging to soil types that are considered well suited for grapegrowing can mean the loss or partial loss of some of the parameters that make that soil a good vineyard soil.
In other cases a soil type may be considered less suitable for grapegrowing for instance because of its propensity to get compacted easily as a result of machinery use. Sometimes, good soil management that takes into account these soil type related inherent weaknesses, can overcome these shortcomings or prevent them from developing. There are vineyards where very good quality wine is produced from grapes that are produced on some of the generally considered less than desirable soil types.

It is beyond the scope of this article to discuss the concept of terroir in great depth, or to present a complete list of all important soil parameters that relate to grape quality. There are a number of publications that address some of these issues in more detail.

However some basic issues are discussed here, because they are often overlooked in many vineyards, or at least do not get the attention they deserve.
With the recent boom in vine plantings and the buying of land in grapegrowing areas, suitability of individual sites and soils for grapegrowing is sometimes partially or completely overlooked. If one chooses to grow grapes on a difficult site or less suitable soil, that is anyone's prerogative and there may be good reasons for such a decision (for instance financial reasons).
Assuming that one bought a good grapegrowing block simply because it is in a grape growing area, without checking its suitability for grapegrowing first, could be an expensive mistake. Detailed soil testing and investigation of the top and subsoil can save a lot of money.
This also applies to existing vineyards, where it will become more and more important to monitor long-term effects of soil management. Soil quality monitoring is a tool to prevent or remedy problems, to reduce the presence of, or susceptibility to pathogens, and as a tool to improve certain grape quality parameters.

SUBSOIL PROBLEMS; EASY TO COVER UP?

The quality (chemical, physical, structural and biological quality) of subsoils is of significant importance, and is often overlooked when assessing or monitoring vineyard soils. It is a prime example of a neglected part of soil management. Generally subsoil quality is not measured (soil tests etc.) and (almost by implication) not actively managed.
The more frequent use of machinery (cultivation, spraying, pruning, harvesting) and the increased weight of some of that machinery, notably the mechanical harvesters, mean that there is increased scope for compaction problems developing. In addition, because of the requirement to utilise these more expensive machines to the maximum, vineyard operations are sometimes carried out at times when more damage is done to the soils than is necessary. A harvester working to a tight schedule can cause significantly more damage on a wet soil than on a soil that had an opportunity to dry out again after rain. Subsoil compaction can easily develop under those conditions, and is not easily recognized as it falls in he "out of sight out of mind" department.

So what are the effects of for instance compaction, and what can we do about compaction problems?

COMPACTION EFFECTS

Sometimes the soil is regarded as a living organism. Technically of course this is not the case, but from a biological point of view, the soil can be considered to have a lung function, as well as a digestive function. Free exchange (respiration) of oxygen and carbon dioxide is required to support rootgrowth and to support soil biological activity. It also allows for the dissipation of other gasses that might otherwise harm the vines (for instance a build up of ethylene produced by the plant, or produced by breakdown of organic material under anaerobic conditions). Soil microorganisms fulfill the digestive function of breaking down organic 'waste' (leaves/prunings etc) and recycling the nutrients from that "waste". They rely on good soil respiration.

Compaction will have the following effects:

- Some compounds/gasses can build up to toxic levels in the soil.
- Drainage problems are likely to develop. This can starve roots of oxygen and introduce pathogenic problems.
- Roots will have more difficulty penetrating the soil. This will reduce their potential to source water and nutrients to support the vine and the crop it is producing.
- Reduced rootgrowth will also directly affect the availability of some nutrients and the way nutrients are taken up by the plant. For instance it can affect nitrogen mineralisation, affect phosphorus, sulphate and in some cases potassium availability to the plant. Reduced growth of root tips means the vines are in all likelihood taking up less calcium.
- Soil biological biomass and activity will be affected. This in turn has an impact on soil nutrient availability. It reduces the soil's own suppressive potential to control pathogens. Reduced soil biological activity will lead to long-term degradation of soil structure. To maintain good open soil structure it is important to maintain good levels of organic matter in the soil, and to maintain soil bacterial and fungal activity. The bacteria and fungi play an essential role in maintaining soil structure as both produce glue-like substances that help form soil aggregates. The fungal hyphae are important for the formation of macro aggregates. Without soil biological activity, these aggregates will fall apart, the soil will return to a state resembling dust which is very prone to soil erosion. It can also impede the infiltration of water and exchange of gasses, especially when crusts are formed.

- Soils where respiration is impeded may turn anaerobic. This will affect activity of many beneficial aerobic soil organisms and will result in generally less desirable anaerobic organisms replacing them. Ethylene build up in anaerobic soils will impact on vine performance. Ethylene affects growth of vegetative tissues (roots, stems, petioles) as well as flower senescence, leaf and petiole abscission and berry ripening. Under stress conditions the plant it self will produce 'stress ethylene". This can induce early senescence and can also affect berries.
  In healthy, well aerated soils that support beneficial microorganisms, excessive stress is not only reduced, the production of stress ethylene is also actively suppressed. The presence of a common soil bacteria Pseudomonas putida affects the synthesis of ethylene through the production of ACC deaminase. ACC deaminase is an enzyme, which affects ACC (1-aminocyclopropane-1-carboxylic acid) levels, a precursor of ethylene.

- Certain types of stress on vines result in a reduced ability to defend themselves against pathogenic attack. Some stresses weaken the vines own immune system. It has been suggested that some of these stresses may also affect the incidence and/or severity of YVD (Young Vine Decline or Phaeomoniella chlamydospora), an issue we are currently looking into.

WHAT CAN WE DO?

Soils need to be investigated thoroughly before new land is bought or planted. This includes testing (pH, major as well as some of the minor elements, bulk density and pH, salinity, and

of course organic matter levels) of both the topsoil layer and subsoil layers. Visual inspection to identify soil structure, the different soil strata, signs of hardpans, compaction layers or waterlogging etc. will be part of the investigation.
For this purpose it is usually required to dig a pit, sometimes banks in road or drain cuttings can provide information. Some problems can be resolved by preparing the soil or through the application of fertiliser, lime or gypsum. Some problems may be very hard to resolve satisfactorily, which may lead to a decision not to go ahead with purchase or planting.

Even in existing vineyards there is a place for regular comprehensive audits of the soil (fertility testing as well as assessment of soil physical and structural parameters). This will provide information which can be used to monitor the effectiveness of soil management systems and can be an indicator of the level of sustainability of soil management systems. Comprehensive soil audits will require the assistance of (external) experts or professionals in most cases.

Use machinery judiciously and make sure all machines are equipped with suitable tires and tire pressure to minimise the impact on the soil. Try to avoid going into the vineyard when soils are wet. The damage that can be done to soil structure often takes a long time to repair.

Maintain a covercrop where possible and do not use herbicides more than required (frequency of use and width of herbicide strip). Minimise excessive cultivation as much as possible.

To promote a better soil structure, aeration and/or deep chiseling to break up subsoils can be good management tools. However there is a cost if such measures are required on a regular basis. Regular soil cultivation will increase the rate of mineralisation of organic matter and long-term lead to a lowering of soil organic matter levels.

Promote conditions that support soil biological activity if there is reason to believe activity is low. Biological activity can be improved by removing obvious impediments to the development of biological activity. Certain management practices discourage activity (excessive use of fungicides and herbicides affects soil microbial biomass, as does cultivation and some fertiliser practices).
If soil organic matter levels are low, organic material can be brought in (compost) or produced by covercrops. It is important to check the quality of the compost (not only the presence of undesirable components but also whether it has been composted well, presence of seeds than can cause problems, and of course Carbon: Nitrogen ratio and NPK content).
When growing covercrops with the aim of improving soil organic matter levels, consideration needs to be given to the effects covercrops can have on vine vigour (nutrient and water competition) and frost sensitivity. Vineyard managers should be encouraged to seek advice, not only on some of the more technical issues, but also on whether or how changes in (soil) management may impact on disease control, vine nutrition, yield and grape quality.

TRIALS

We are currently involved with two trials to study the effects of soil parameters on vine performance. One involves 5 different vineyards which experience some problems with YVD (Young Vine Decline) in newly planted vines (Chardonnay clone 5 on 3309 rootstock). This trial is funded by Bio-Start Ltd to investigate whether reducing stress by improving soil conditions can affect the incidence/severity of YVD in young vines. Stress factors have been identified in these vineyards relating to fertility and subsoil problems including compaction. Treatments include the judicious use of fertiliser, compost and bio-stimulants. It is hoped that the promotion of biological activity in the soil will help improve soil structure and nutrient availability. Promoting PGB (Plant growth promoting) bacteria and beneficial (mycorrhizal) fungi play a role in improving soil structure and also affect plant growth directly.
This is a three-year trial, now in its first season. It appears that some of the treatments so far may have shown some visual responses. However it is too early to draw pertinent

conclusions at this stage. Ongoing assessments of the presence and severity of YVD will take place.

The second trial is a small pilot trial, using our own small research vineyard. In this vineyard block there is a small patch with poor subsoil. This is used in some of our trial work as a means of increasing stress on vines to see how/whether that affects disease resistance. Merlot BDX 481 on 3309 rootstock was planted on 20/1/2000 on both the good and bad subsoil areas. The visual differences between the two areas are very significant. Vines on the poor subsoil failed to thrive, most are barely surviving, some vines have died. Vigour is very low (internodal distance are approx. 1/3 of those on the better soils), leaves are small and appear N deficient. (Petiole and Blade samples however showed adequate N levels)

Fig 1. Poor performing Merlot on poor subsoil (Height of these vines is approx 600mm)

Fig 2 - Some of the better performing Merlot on the better subsoil.
Some of the poorer Merlot can just be seen in the last 2 bays of this row.

The difference in subsoil colour is also visible comparing the soil at the bottom of the photo with the soil visible down the row.

Fertility of the topsoil was very similar for the two areas.
The only difference between the good performing and poor performing areas appear to relate to subsoil structure and subsoil fertility.
The "poor" patch of soil is prone to waterlogging, however there were no serious heavy rainfall events in the last 12 months or so. It is doubtful whether the poor performance of these vines can be attributed to waterlogging during this period.

The poor subsoil is almost impenetrable and very compacted. Virtually no roots could be found penetrating this subsoil. This means that during dry periods the vines are prone to drought if the topsoil is allowed to dry out.
Perhaps not surprisingly, the poor soil vines also appeared to be more prone to downy and powdery mildew, or possibly they were less well equipped to overcome the effects of powdery/downy mildew.
The poor area had a much higher bulk density or soil volume weight (1.1 gr./ml compared with 0.7 gr./ml for the "good" subsoil). This is indicative of a more compacted poor subsoil.

Table 1- Comparing subsoil parameters

	Good Sub Soil	Bad Sub Soil
pH	5.7	4.8
Organic Matter	3.2	1.3
Bulk density (ug/ml)	0.7	1.1
Total P (ppm)	400	58
Total S (ppm)	750	175
NH4-N (ppm)	6.13	4.89
NO3-N (ppm)	81.3	34.1

The poor subsoil also had a lower pH (pH 4.8 compared with pH 5.7 for the good subsoil) and low levels of organic matter (1.3% organic matter compared with 3.2% organic matter in the good subsoil).
Fertility was extremely low in the poor subsoil; this soil only contained 58 ppm P (Total P) which is amongst the lowest we have ever seen in New Zealand soils.

Interestingly enough, the difference between leaf and petiole samples taken from both the good and the poor soils showed surprisingly little differences. If there was a difference, in most cases it was the "poor sample" that tended to have the (slightly better) results.

The most deficient element was magnesium (blade as well as petiole), in line with the soil test results. Magnesium levels in the poor sample (blade and petiole) were better than in the good sample. This is probably related to the much lower growth rate, which allowed some magnesium accumulation and reduced need for translocation of magnesium from the older basal leaves to support shoot growth (which was almost absent).

Nitrogen levels were very similar between the good and the bad samples.

More work is required to positively identify the most important parameters that explain the difference in performance vine growth between these two specific areas. All of the earlier mentioned effects related to compaction/hard pans may have played a role here. Educated guesses however would implicate (on this site):

* Low sub soil pH in the poor sample leads to aluminium and possibly manganese and copper toxicity. Aluminium toxicity is not easily recognized, leaf and petiole testing for aluminum is not standard practice and in any case would be poor indicators of aluminium toxicity. Data from a Bordeaux study on the affects of Aluminium ions on growth of Cabernet Sauvignon (V. vinifera) grapevines. showed that only 10 ppm Al (mg/l) in solution reduced vine growth almost in half. Aluminium ions are not absorbed by the roots, and do not enter the vine. Aluminum ions directly inhibit root growth. Toxicity cannot be detected from petiole mineral element analysis; vine roots must be inspected. This study (*Delmas, Pont-de-la-Maye, 1984,* [1]*)* showed that at 200 ppm Al, cane growth almost ceased.

- The subsoil was severely compacted; this impacts on the roots ability to penetrate beyond the topsoil layer. This has obvious implication for the vine ability to take up water in droughts.

- Although no heavy rain events were encountered this season, heavy rain would quickly lead to waterlogging of the poor soil because of the poor drainage characteristics of the subsoil.

- The effects of the poor subsoil parameters are likely to have affected soil biota, possibly resulted in elevated ethylene levels (some of the symptoms could be explained by ‘stress ethylene” effects).

These results clearly underline the importance proper investigation of soil biological, physical and chemical parameters before planting new vineyards.
If a large scale vineyard was planted on soils like these, a significant number of vines may have died in the first 2 years, while surviving vines are doing little more than just that; surviving.

Comprehensive soil audits would have quickly identified these problems pre-planting. This could have impacted on the decision to plant, or, alternatively, remedial work may have improved some of the poor subsoil parameters enough to make grapegrowing a viable option on such a soil.
In existing vineyards, such audits can still play an important role in identifying problems, monitoring soil management, or improving vine performance and grape quality. Active soil management must include careful monitoring of the soil.

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