MODULE 13

Soil Health - what is it, how do we assess it and how do we improve it?

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Introduction
There is increasing recognition of soil as an important non-renewable asset that needs to be managed well and looked after. The Australian government is required to produce State of the Environment reports every five years, which includes information on how our soils are managed. This module defines what is meant by “soil health” from a viticultural production and general agricultural perspective. It highlights the benefits of soil health as a management tool during periods of drought and reduced water availability and provides the latest thinking about how growers can assess soil health from a qualitative and quantitative point-of-view.

For more information and training contact your local Innovators Network member or go to http://waterandvine.gwrdc.com.au.

1 What is soil health?
Soil health is defined as ‘the capacity of soil to function as a vital living system to sustain biological productivity, maintain environmental quality, and promote plant (and animal) health’. To summarise, soil health is a measure of sustainability of farming practices on soil. It is a relative judgement made according to our expectations with respect to fitness for use. It is dynamic and can be influenced and changed depending on management practices. There are three main properties of soil: physical, chemical and biological (Figure 1).

Figure 1: Physical, chemical and biological properties of soil. The healthiness of a soil is influenced by all three properties (Figure 2).

2 The role of soil in viticulture
Grapevines are perennial crops, with a vineyard expected to have a commercial lifespan of at least 30 years. The soil provides the habitat for the grapevine root system and contributes to vine longevity, sustained yield and wine quality.

3 Physical properties of soil
Soil is a three-phase system with approximately 50% solid matter, the rest being air and water. The physical structure of soil is an arrangement of solids and spaces, with water and air filling the spaces.

Soil particles are arranged and bound together to form aggregates (Figure 3). The spaces between particles and aggregates are called micro- and macro-pores respectively. Macropores are the spaces that allow water to drain, and micropores are the spaces that trap and hold soil moisture. Soil porosity is measured indirectly by bulk density ie low bulk density indicates a high number of pores.

A well-structured soil has stable aggregates that are not easily dispersed in water, and enough pores to promote aeration, water infiltration and allow roots to easily penetrate through the soil.

Figure 3: Micropores – the spaces within a soil aggregate – and macropores – the spaces between soil aggregates

Grapevine roots have been recorded up to six metres deep searching for moisture if vines are grown on deep gravely soils. As a general rule, roots reach more than 60 cm on irrigated vines and up to 2 metres on non-irrigated vines. Therefore, an ideal soil allows roots to grow and function unrestricted by compaction layers. Compaction layers can occur naturally, or from the use of heavy machinery particularly when the soil is wet.

The soil structure determines the water and nutrient reservoir available for vine growth. An ideal soil will retain water in the rootzone, and have good aeration following irrigation and rain (minimum 15 – 25% air in soil pores).

4 Chemical properties of soil
The ideal soil provides grapevines with an adequate supply of macro- and micro-nutrients, with an absence of toxicity or deficiencies. A limitation of nutrients reduces plant growth and vigour, but an oversupply of nutrients can be toxic to plant growth and pollute waterways through leaching.

Many of the nutrients are in the soil as positively-charged cations. Clay particles and soil organic matter are negatively-charged. The cation exchange capacity (CEC) of soil describes the ability of the soil to retain these cations on the negatively-charged soil particles in the vicinity of the rootzone, ensuring they are available for plant use.

Nutrient form and availability are highly dependent on soil pH. The ideal vineyard soil is pH 5.5 – 8, but many of our Australian vineyard soils have a natural pH > 8, particularly in the subsoil. Soil chemical analyses are useful for determining the reasons for current vine nutrition and probable trends for future years, as well as monitoring appropriate remediation strategies for problem soils. To monitor vine nutrition, petiole and leaf blade analyses are the most suitable tests.

Nutrients are continually cycling through the soil-plant system, and soil organic matter is an important source.
5 Soil biology
Soils support a diverse range of organisms, including fungi, bacteria, nematodes, worms and insects. A single gram of soil may contain more than 2,500,000,000 micro-organisms. The benefits of soil organisms are considerable. They decompose plant residues, contributing biomass to soil organic matter, forming humus and producing carbon dioxide which dissolves in water to form weak carbonic acid, breaking down insoluble mineral compounds in rock. They convert nutrients from organic to mineral forms, rendering them available for uptake by roots. They stabilise soil structure, providing the ‘glue’ that holds soil aggregates together, thus improving water holding capacity. And they can reduce disease problems by out-competing soil-borne pathogens.

Grapevine roots form a special relationship with some species of fungi. This symbiotic relationship is called a mycorrhizal association (Figure 4). The fungus colonises the grapevine root and uses it as a ‘home base’ from which it gains sugars and carbohydrates from the vine. From this ‘home base’, the fungus grows a threadlike network of hyphae into the soil, accessing spaces too small for the root hairs. In this way, the grapevine gains access to phosphorus, zinc and water reserves that it cannot get at by itself.

Figure 4: Mycorrhizal association between a root hair and a fungus.

6 Soil organic matter
Soil organic matter is a small but crucial proportion of the solids, comprising of decomposed and partly decomposed remains of living material including by-products such as root exudates, etc. The final breakdown product is known as humus, which has five times the water holding capacity and cation exchange capacity of clay particles.

Most organic matter is found in the surface layer of soil. The rate of organic matter decomposition is influenced by temperature, moisture, oxygen, and nutrient content of organic materials. An ideal vineyard soil contains 2-4% organic matter.

Soil organic matter is the key to soil health. It provides the carbon food source for soil microbes and improves aggregate stability, water infiltration and water holding capacity, cation exchange capacity, nutrient availability and has a buffering effect on soil pH.

Soil health management centres on increasing the organic matter content of the soil.

7 Management to improve soil health in vineyards
Vineyard practices such as the use of composts, mulches and cover crops are all ideal ways to improve the health of the soil. Not only do they add organic matter, they suppress weeds, prevent erosion and moisture loss, and provide a habitat for beneficial insects.

The addition of slowly degrading stabilised composts such as biochar, composted grape marc or green organics improves the long-term water holding capacity of soil.

Permanent sward cover crops may compete with grapevines for water during summer. This can be minimised by mowing the cover crop during spring and leaving it on the surface as mulch.

Residues from cover crops can increase or decrease nitrogen availability to grapevines depending on the crop. Winter leguminous crops increase nitrogen. Permanent sward cover crops generally lower nitrogen levels.

Mulches are well-known for reducing evaporation from soil, suppressing weeds and improving water infiltration. They reduce surface soil temperature and dryness, hence increasing the activity of shallow feeder roots. They have also been shown to increase mycorrhizal associations and decrease overwintering inoculum of pathogens such as Botrytis.

How do other agricultural inputs impact on soil health? Mineral fertilisers appear to have little direct effect, but indirectly may increase soil microbes by increasing plant growth. Nitrogen fertilisers, however, can increase soil acidification, which negatively affects soil organisms. Among the pesticides, few effects of herbicides have been documented, but negative effects of insecticides and fungicides are common. Copper fungicides in particular are known to be highly toxic to soil organisms.

8 Measuring and monitoring soil health
Many tests are available to measure particular aspects of the soil, such as pH, nutrients, organic matter content, aggregate stability and bulk density. Some of these can be carried out on-site, while others require samples to be sent for analysis to a commercial laboratory.

While it is possible to measure soil organisms, it is not an exact science to prescribe remedies to promote beneficial organisms to enhance soil health. This is further complicated as we do not know all of the organisms associated with soil health. For bacteria alone it is estimated that we have only identified around 1% of the total bacteria in soil. There are many research programs around the world trying to establish practices that can be used to promote a sustainable microbial community in soil, and identify which key organisms are involved in soil health.
9 Examples of successful soil health programs

The Lodi Rules for Sustainable Winegrowing: California’s first sustainable winegrowing standards, peer-reviewed by scientists, academics and environmentalists, and implemented on a region-wide basis. Participating growers use the Rules detailed in the Lodi Winegrower’s Workbook to make measurable improvements in the environmental health of their vineyards (including soil health) and the surrounding communities and ecosystem. They are then certified as producing sustainably-grown winegrapes.

http://www.lodiwine.com/

The Cornell Soil Health program, based at Cornell State University, USA, utilises a researchable database of regional soil health data, based on a suite of 12 biological, chemical and physical parameters, to benchmark results and produce a ‘soil health test report card’ for farms. This program is well-established for fruit and vegetable farms, and is currently expanding to include viticulture.

http://www.hort.cornell.edu/soilhealth/

In Australia, the ‘Healthy soil for sustainable farms’ program funded by Land Water Australia and Grains Research & Development Corporation works with farmers, community groups and researchers to unite and grow soil health information. Through a national approach, linking industries and regions, it assists the adoption of a coordinated, concerted and cost-effective approach to improved soil health across Australia. This program has mainly focussed on dryland cropping regions, but has made forays into other industries such as vegetables. In the near future, it is anticipated that the website will contain a ‘toolkit’ of simple tests that growers can use to assess the health of their soils.


10 Soil health management plan for viticulture

A suggested program is:

- Know your soil (soil map)
- Soil analysis every few years for pH, EC (salinity), chlorides, CEC
- Conduct annual plant nutrient petiole analyses
- Conduct annual soil analyses for the first three years, then every third year
- Organic matter management. Where possible utilise:
  - Inter-row cover crops
  - Undervine mulches
  - Compost
- Avoid soil compaction
  - Modify equipment (lightest possible, wider tyres, low tyre pressures)
  - Maintain permanent cover crops
  - Never use heavy machinery in vineyard when soil is saturated
  - Utilise undervine mulches to minimise compaction under drip irrigation
- Minimise soil erosion
  - Consider no tillage systems
  - Establish permanent cover crops in vineyard, on farm roads, along irrigation channels
- Surface mulch to conserve soil moisture

11 Useful references


Contact Details

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