Role of soil properties in orchard productivity

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Understanding soil attributes plays an essential role in understanding, and potentially improving, our horticultural systems. Supporting growers to be more profitable is an industry goal, with a target of increasing yields to an average of 15t/ha of high quality fruit.

This improvement needs to be environmentally sustainable, as well as economically, and more growers are looking to their soils and asking questions of what they can do to improve economic and environmental outcomes. To achieve these outcomes, many growers are looking more closely at soil biology.

This article looks at what soil attributes contribute to success in the orchard, and will outline a project underway to understand this further.

As well as playing direct roles in supporting orchard production, understanding soil biology can provide clues to other soil properties that influence productivity, such as physical structure and chemical composition. So what do the soils look like on some of our more productive orchards in our different regions, and what properties define a "good" soil in our avocado orchards? We are currently undergoing a project to find out more.

NZ Avocado, in partnership with Plant & Food Research, has been awarded a Rural Professionals Fund to characterise soils in some of our avocado orchards. This project is the first to collect a combination of biological, chemical, and physical soil data and look to correlate them with yield.

While the number of orchards being looked at is reasonably small, outcomes could help establish biological benchmarks, nutritional level targets and open a debate on how to better manage our inputs to achieve improved production and environmental outcomes. It will also improve our knowledge about how soil characteristics interact in avocado orchards.

1. Orchard selection

Orchards from the three main growing regions of the Bay of Plenty, Mid-North and Far North have been selected based on different criteria. In the Bay of Plenty, 17 of the chosen orchards are part of the Avovantage project. There is a robust amount of data already collected from these trees relating to fruit quality, and the orchards represent a range of yields to compare.

An additional two orchards that are part of the New Cultivar Trials were also included to provide information on plantations achieving over 15t/ha. In the Mid and Far North, high yielding orchards that produce above 15t/ha were chosen to give a snapshot of what the soils look like on these successful orchards as well. Ten trees, and associated soil, were assessed in each orchard. Soil, leaf and fruit samples were collected in during autumn for nutrient testing.

2. Information being gathered

The main information that this project aims to correlate includes:

Soil microbiology: Soil samples have been tested using three commercially available soil biology tests. Hot Water Extractable Carbon (HWEC), Advanced Biological Package, and Microbe Wise tests provided by Hill Laboratory, Soil Foodweb New Zealand, and Linneaus Laboratory, respectively.

Nutrients: Soil, leaf and fruit samples underwent nutritional analysis by Hill Laboratories, including basic soil, organic soil profile, Total copper, Mehlich 3 profile, fruit nutrient and leaf nutrient.

Soil physical characteristics: Visual Soil Assessment methodology (Shepherd, 2019) was used to assess physical properties. Assessment includes a range of visual indicators relating to soil structure, soil texture, number of earthworms and potential rooting depth.

Productivity data: Taken from the industry database supplied by registered pack sheds as well as grower personal records.

Land Use Capability classification (LUC): from the New Zealand Land Resources Inventory (NZLRI), LUC assessments rate the ability of each parcel of land to sustain agricultural production, based on an evaluation of factors such as climate, the effects of past land use, and the potential for erosion (Lynn et al., 2009).

Context (inputs): While management practices won't be part of the initial analysis, information relating to chemical application such a foliar or hard fertiliser, spray applications (including copper), and other practices (e.g. compost applications) will be used to critically interpret results from each orchard.

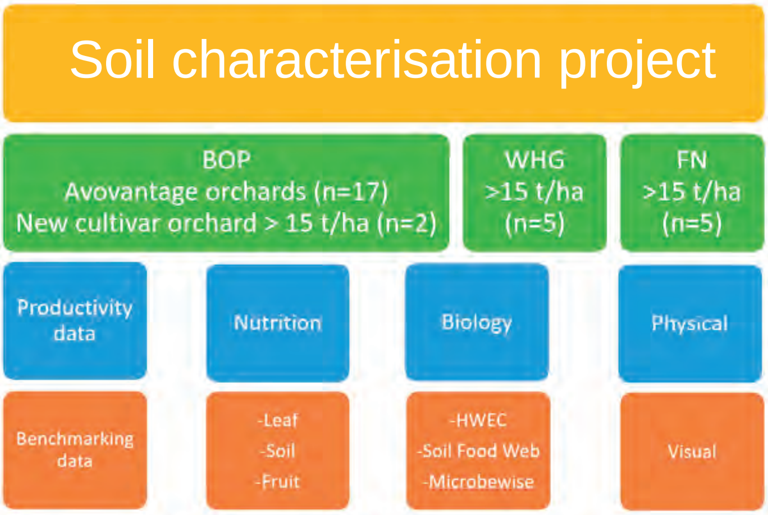

Figure 1. Overview of the soil characterisation project with the different sources of information.

3. Why should we be interested in soil biology, physical and chemical composition?

3.1 Soil biology

Historically, in avocado orchards, the main focus is on the chemical aspect of the soil and what fertiliser should be applied. Nutrient amounts and ratios are associated with both tree yields and fruit quality. However, soil physical and biological characteristics also contribute to nutrient availability and tree performance.

Avocado trees have shallow roots that predominate in the first 30cm of the topsoil. The zone where the tree roots and microorganism interact is called the rhizosphere, and several symbiotic relationships happen between tree roots and microorganisms.

Some of the most relevant roles of soil biology for avocado production are:

3.1.1 Nutrient harvesting: Mycorrhizae are among the most successful associations between fungi and plant roots, and virtually all the angiosperm species, including the avocado tree, have this relationship. The fungus colonises the below-ground tree structures and creates a network of fungal mycelia in the root cortex. The mycelium extends outside the roots, into the soil, and increases the plant's ability to absorb nutrients (Sullia, 1991). The relationship works by the tree supplying sugars to the mycorrhizae fungi in exchange for phosphorus and other nutrients the mycorrhizae helps collect.

3.1.2 Nutrient cycling/solubilisation: The first step in nutrient cycling is typically done by saprophytic fungi that can catabolise some sources of carbon that are difficult to break down, such as lignin and cellulose. These fungi make bioproducts (e.g. organic acid) available for other microorganisms (Ingham, 2021). Another important group is the Actinomyces. These hyphal bacteria can metabolise difficult to break down compounds such as chitin, cellulose and hemicellulose (Pepper, Gentry, and Gerba, 2015). Phosphate solubilisation is thermodynamically unfavourable. In nature, microorganisms such as Pseudomonas (Kumar et al., 2017) and fungi help solubilise it and make it available to plants.

One essential part of nutrient cycling is the nitrogen cycle. In brief, the nitrogen cycle is dominated by redox reactions where certain species of bacteria can help transform nitrogen into different forms. Some of these forms can be used by plants, where as others are more likely to be lost from the soil and become unavailable to the plant. Certain species of bacteria are involved in the fixation of nitrogen (N_2) gas from the air into ammonia that can be used by plants. Nitrifying bacteria convert ammonia (NH_3) to nitrate (NO_3^-), which can be used by plants as well, but is more easily leached from the soil than ammonia. Denitrifying bacteria convert nitrate to gaseous forms of nitrogen like nitrous oxide (N_2O) and N_2 that will remove nitrogen from the soil. Denitrifying bacteria are more likely to convert nitrogen to gaseous form under waterlogged or compact soil environments where oxygen is less available. Pseudomonas (Kumar et al., 2017) and protozoans also generate ammonia as part of their metabolism that adds to the nitrogen cycle.

3.1.3 Disease suppression: This function is covered by microorganisms with predatory behaviours such as protozoa. Some of these small eukaryotes can propel themselves and hunt pathogens. One example of this is the ciliates which feed, preferably on anaerobic bacteria. Pseudomonas also play an essential role in their ability to produce antibiotics and cell wall-degrading enzymes that target pathogenic microorganisms (Kumar et al., 2017). Studies also show that Pseudomonas have some insecticidal activity by causing lethal infection in insect larvae (Flury et al., 2016; Vesga et al., 2020).

3.1.4 Tree health: Tree health can be supported by making more nutrients available to the plant, by suppressing pathogens and by producing phytohormones. The latter is where Pseudomonas, that colonise roots, and Actinomyces, that can form hyphae, stand out because they make phytohormones that stimulate the plant immune system (Kumar et al., 2017; Pepper, Ian L. and Gerba, Charles P., 2015). The benefit of mycorrhizae in tree health has been well known for decades, mainly because it helps the tree to absorb nutrients that would obtain directly from soil (Menge et al., 1978). They can also help with drought tolerance through accessing soil moisture in more soil volume.

3.1.5 Drought tolerance/Soil structure: It is well known from other crops that certain microorganisms can increase drought tolerance; this is the case of Actinomyces (Grover et al., 2016; Pepper, Ian L. and Gerba, Charles P., 2015) and Mycorrhiza fungi (Li et al., 2019). Along the way, these microorganisms colonise the soil by expanding their hyphae; they open the soil structure and effectively increase the soil volume that the roots can extract water and nutrient from.

3.2 Soil physical properties

The physical structure of soil influences water dynamics, water holding capacity, root penetration and aeration. Soil physics plays a remarkable role in soil quality for avocado trees.

3.2.1 Soil texture: Soil texture is determined by the proportion of different particles sizes in the soil. These particles are sand (>0.06 mm), silt (0.06-0.002 mm) and clay (<0.002 mm). Different proportions of these particles influence fundamental soil properties such as water-holding capacity, aeration, soil structure drainage, and nutrient retention.

3.2.2 Soil structure: Soil structure relates to the compaction of the soil, aggregates and clods of soil and the proportion of macro and micropores. A good soil structure is dominated by friable and fine aggregates with sub-rounded shape and no significant clodding. These soils have excellent water mobility, aeration, gas exchange capacity, soil temperature management and potential for root development. A poor soil structure increases susceptibility to drought, ponding and will have a higher risk of erosion. It also decreases the supply of oxygen to the root, and therefore, can limit the availability of some nutrients such as N, P, Ca, Mg, Z, and B (Shepherd, 2019).

3.2.3 Potential rooting depth: This is the depth that roots can potentially explore before a physical barrier such as a hardpan prevents further root expansion. This indicator influences some important elements in tree health, such as water holding capacity, availability of nutrients, and resilience against drought. On top of that, an excellent potential rooting depth (>0.8 m in irrigated and > 2.0 m in non-irrigated orchards) can reduce environmental impacts by decreasing leaching, expand the rhizosphere and increase carbon sequestration (move carbon down). Therefore, although avocado trees have a shallow root, no limitation in potential rooting depth can drive several benefits.

3.2.4 Earthworm number: Sometimes earthworms can be overlooked, but they can drive several benefits to tree health by making essential nutrients available (N, P, K and Mg). Earthworms also improve soil structure improving porosity, aeration and water mobility. Soils with significant numbers of worms can have up to threefold more microorganisms and up to 6-7 times more Actinomyces than low worm soils (Shepherd, 2019). Earthworms play an essential role in transforming organic matter into humus by bonding carbon to clay particles. Overuse of acidifying salt-based fertiliser and ammonia-based products reduces the number of earthworms. Different earthworms work at different depths, and a good community has a mixture of species (see table below).

Earthworm specie	Zone
Lumbricus rubellus	Superficial litter
Aporectodea caliginosa	Topsoil dwelling
Aporectodea longa	Deep burrowing
Octolasion cyaneum	Indicate adverse conditions the soil

Table 1. Common earthworms species can be found on soil and the zone where they inhabit (Shepherd, 2019).

3.3 Soil chemistry (nutrients)

Soil chemical composition is something many growers are more familiar with, with most carrying out regular soil nutrient testing to inform fertiliser planning. During any crop production, a portion of nutrients is removed with the crop that is harvested. Additional nutrients can be lost through leaching and volatilisation. These nutrients that are removed or lost need to be replaced to ensure crop production remains sustainable. Nutrient amounts and nutrient ratios are essential for tree health and yield. Since trees take macronutrients and micronutrients from soil, it is crucial to monitor nutrient levels to understand which nutrients need to be replaced.

4. Summary

Available literature shows us how biological, physical, and chemical soil attributes are important for good tree health and yield.

The soil characterisation project is expected to be completed by the end of winter and should provide insight into what the soils look like on some of our most productive orchards. Information gathered will also support the Avovantage project, working to understand factors influencing fruit quality. We also expect to get some key questions from the project and some avenues to explore about how influencing soil characteristics might support growers to improve orchard productivity, quality and grower profitability in a sustainable way.

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