Aerobic compost and the soil microbiome

Putting oxygen loving microbes to work in your soils

There is unseen complexity hidden in the soils below our feet. For a long time much of agriculture's research has focused on the relationship between plants and their surroundings with very little focus on the beneficial plant-microbe interactions. Plants and microbes have, over long periods of time, evolved intimate relationships that enable them to co-exist. Many experiments have tried to investigate these interactions by simplifying the interactions that occur to an individual plant-microbe relationship, but in reality, these interactions are much more complex and involve a vast array of microbes. We should forget the idea that soil systems can be simply explained and instead consider all the factors that influence these complex ecosystems. The plant, the soil, and the soil microbes all working together to mediate and influence the various exchanges (see Fig. 1) that contribute to plant health and productivity.

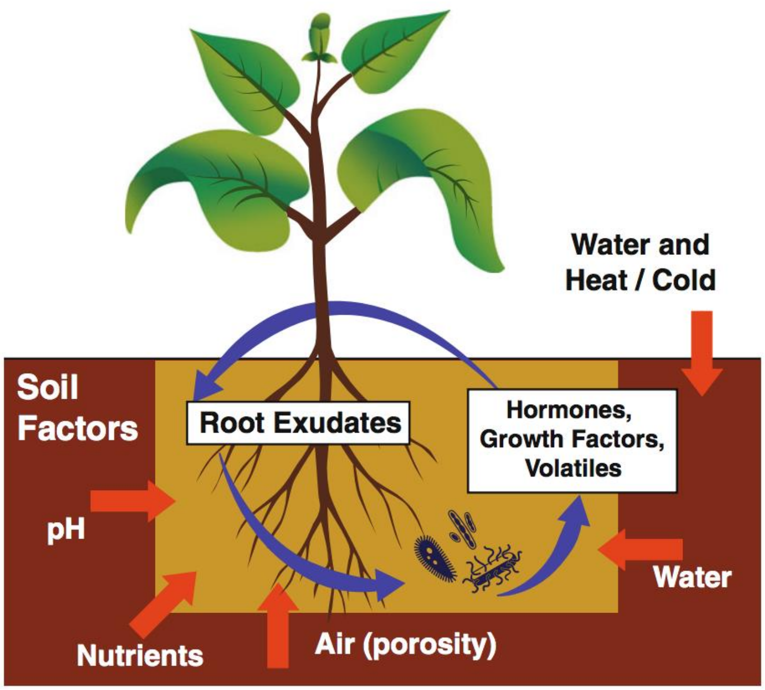

Fig. 1 Schematic illustration of how soil factors influence both plant roots and soil microbes which in turn reshape the soil environment through a dynamic exchange of chemical responses to living and nonliving stimuli.
Adopted from: Chaparro, J.M., Sheflin, A.M., Manter, D.K. and Vivanco, J.M., 2012. Manipulating the soil microbiome to increase soil health and plant fertility. *Biology and Fertility of Soils*, *48*(5), pp.489-499.

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Introduction to the complexities within soils

Understanding the soil complexities requires some basic knowledge of the interactions at play. Before we begin discussing the role of aerobic compost in the soil ecosystem, it is necessary to briefly describe some of the concepts which we will introduced below.

The microbe - small living things

A microbe, or “microscopic organism,” is a living thing that is too small to be seen with the naked eye. The term is very general and is used to describe many different types of life forms, with dramatically different sizes and characteristics. Bacteria, archaea, fungi, protists, viruses, microscopic animals, and some algae are all examples of microbes.

The soil rhizosphere - around the roots

The interaction between plants and their surroundings is a dynamic process in which plants monitor their environment and react to changes. The root system, which was traditionally thought to only provide anchorage and uptake of nutrients and water, is a key element to a plant interacting with its surroundings. This region, where plant roots interact, is collectively termed the rhizosphere. The rhizosphere is continuously influenced by plant roots through the excretion of exudates, mucilages, and dead cells. Plant roots can influence the surrounding soil microbes and the rhizosphere microbes can influence the plant.

The plant microbiome - the plant and associates

Plants are teeming with microbial organisms which can be found colonizing both their internal tissues and the soil surrounding them. Combined with the vast diversity of microorganisms in the soil rhizosphere, these plant–soil-associated microbes comprise the plant microbiome. The microbiome is intricately involved in plant health and serves as a reservoir of additional genes that plants can access when needed. Thus, the rhizospheric microbiome acts as a highly evolved external ‘organ’ for plants which may be either beneficial or detrimental. This can be further identified as the soil food web.

Soils and the impacts of agriculture

Soils are among the most biologically diverse habitats on Earth. It has been estimated that 1 g of soil contains up to 1 billion bacteria cells comprising tens of thousands of taxa, up to 200 meters of fungal hyphae, and a wide range of nematodes, earthworms, and arthropods. Land-use intensity is constantly increasing on a global scale, with adverse effects on soil ecosystems. One quarter of soils worldwide face degradation and an increasing number of studies have shown that intensive land use threatens **soil biodiversity** (the variety of living organisms inhabiting soil), with some groups of soil microbes severely affected in very intensive systems. Simultaneously, land-use intensification and associated reductions in soil biodiversity contribute to several environmental problems, such as the eutrophication of surface water, reduced aboveground biodiversity, and global warming, which can negatively affect human well-being. To combat the negative consequences of human land use, **ecological intensification** (the attempt to integrate ecosystem services provided by biodiversity into crop production systems) has been proposed as an approach to integrate ecological processes into land-management strategies to enhance **ecosystem service** (benefit that humans derive from ecosystems) delivery and reduce anthropogenic inputs.

Aerobic composting

Finally, we will discuss the reasons we suggest making aerobic compost for inclusion into the soils. The term aerobic implies that the process occurs under the presence of oxygen (O_2). It has been previously mentioned that the soil is comprised of a diverse mix of life which and, under aerobic conditions, utilize O_2 through respiration and release carbon dioxide (CO_2) plus heat. Generally, aerobic microbes are considered our friends as they thrive in O_2 rich soils which are necessary for healthy root development. Aerobic compost is simply the management of temperature, moisture and built up gasses like CO_2 through turning. If the compost was left to its own processes, the soil microbes would rapidly deplete the available O_2 creating anaerobic conditions. Anaerobic is the opposite of aerobic, and implies the absence of oxygen. Anaerobic soils are often characterized by foul smells produced such as the intense smell of rotten eggs which is due to the release of sulphur dioxide during anaerobic respiration. Anaerobic microbes can be likened to the “bad-neighbours” of decomposition and many of the disease causing microbes thrive under low oxygen conditions. An example would be *Phytophthora* which is particularly virulent in areas of high soil moisture where there is little available oxygen.

Composting the Ritlee way

The Ritlee Compost Turner is able to significantly reduce labour required and makes commercial compost production possible. With the Ritlee Compost Turner is is possible to turn large volumes of compost which have a maturation time of 7 - 12 weeks. The Ritlee Compost Turner thoroughly turns and mixes row at a speed which is most friendly to resident microbes, reducing high temperatures, expelling built-up CO_2, breaking up anaerobic clusters, mixes in moisture, reintroduces O_2, and fluffs compost to allow easier flow of fresh air through row.

A good compost requires:

1. Aeration, Aeration, Aeration! Aerobic microbes require O_2 to function and produce CO_2 as buy product. Aerobic microbial activity slows down as the oxygen is depleted and can result in loss of microbial diversity.
2. Moisture management - the microscopic nature of microbes means that they rely on residual moisture for both mobility and the transport of nutrients. As a rule, a handful of compost should hold its form when squeezed and released without dripping. If the compost is too dry it will be necessary to introduce more water to allow the microbes to properly function.

3. Temperature control - high temperatures are a sign of metabolic activity within the compost and is an important part of the process. Compost piles should reach temperatures of 65 ℃ which is able to efficiently kill weed seeds and most plant pathogens. When temperatures exceed 70 ℃ there are detrimental effects on the community of microbes at work and the compost should be turned before this is allowed to happen.
4. Microbial functional diversity - due to the complex interactions at play within the composting process it is crucial to manage microbial functional diversity. This can be done by the correct selection of starting materials which are considered food sources for the microbes. Functional diversity implies that instead of focusing on the specific species of microbe, it is important to have certain functions occurring. Microbes need carbon, nitrogen, and a range of micronutrients to operate efficiently and it may be useful to introduce some site specific species. Before creating the compost you can collect leaf matter from an area of old forest of bush on your site which will introduce a unique set of endogenous microbes to your compost.
5. Clay - small amounts of clay should be added to the process to improve the cation-exchange capacity (CEC) of the compost. CEC is a measure of the soil's ability to hold positively charged ions (e.g. K^+, NH_4^+, Ca_2+). It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilisers and other ameliorants.
6. Nitrogen - nitrogen (N) is important for the growth of microbes. Under aerobic conditions there is generally little combustion of N for metabolic energy however, it is important to supply sufficient nitrogen for the compost process to run to completion. The ratio of N to carbon will depend on your specific starting materials and should be carefully considered. Dr Google is full of suggestions should you be looking for some clarity.
7. Pile dynamics - there are different zones that form within the compost pile and should be considered. The innermost zone is going to be partially anaerobic moving to higher O_2 concentrations towards the pile edges. When testing temperature and moisture it is necessary to be aware of these zones and manage appropriately.
8. Finishing - when the composting process is in the final stages of maturation the temperature will remain at ambient and after handling the compost a fine coffee coloured residue should be noticed on your hand. This residue is generally associated with the humate component of the compost.
    a. Humate or humic acid a dark-brown or black organic substance made up of decayed plant, tree or animal matter full of microbial and fungal life. Humate provides nutrients for plants and increases the ability of soil to retain water.

Spreading the compost

- Just before rain or planned irrigation is the most ideal way to introduce the life within the compost into the soil. Many of these soil microbes are photosensitive and exposure to prolonged periods of sunlight can be detrimental. The compost is not simply a fertilizer, but rather a community of oxygen loving microbes that will begin reproducing within the soil after the are applied and water is a very efficient way to get them in.

- Field spreading can be done with a lime spreader.
- Orchard or vine spreading by bucket or directional calibratable dropper with-out any wastage

Benefits of compost on your farm

- Moisture holding capacity increases (1% organic matter in soil increases water holding capacity by up to 170,000 litres per Ha) (80 to 90% of its composted weight).
- Leaching of nutrients is minimized as they are intertwined in the soil food web becoming available to the plants when required.
- Nutrients are in continuous cycle by the microbes in the soil and the enhanced cation-exchange capacity censures that they are held in the soil safe from being leached by rain or irrigation.
- Disease suppressing microbes such as, **Actinomycetes** thrive under aerobic conditions.
- The inclusion of aerobic microbes into soils aids in reducing soil compaction as soil structure improves. This process happens when there is sufficient area for interaction in the soil in the form of roots.
- Plant diseases decrease as many diseases are associated with anaerobic conditions.
- Humus is a colloidal substance, and increases the soil's attraction exchange capacity, hence its ability to store nutrients by binding.
- The biochemical structure of humus enables it to moderate or buffer excessive acid or alkaline soil conditions.
- Soil pH becomes more neutral with the continued application of good aerobic compost which has a pH of ∓7 (neutral).

One example out of many

There are so many individual interactions at play that it would require an entire book to begin to address them all. Instead, I will provide one specific example of how fungi, a type of microbe, can benefit the soils.

- Fungi produce a microscopic web of fungal hyphae in the rhizosphere. The fungi that form a symbiotic relationship with plant roots are called mycorrhiza.
- Mycorrhizal fungi play an important role in the soil biology and are able to significantly enhance the available surface area of absorption for the plant roots.
- Mycorrhizal fungi are also able to ‘fetch’ nutrients from areas not accessible to the root systems and can transfer these to the roots making them available to the plants.
- There are also protective functions associated with the mycorrhizal fungi as some species are carnivorous feeding on root nematodes. In the process of digestion of the nematode at the root-fungal boundary, certain nutrients are released which are taken up by the plant.
- *Trichoderma* is a naturally occurring soil dwelling genus of fungi it forms a physical bond with the root system of the plants, establishing itself in the rhizosphere and thereby preventing other pathogens from colonizing the soil. The bond and continual growth of the *Trichoderma harzianum* throughout the root system forms a physical barrier to plant pathogens like for example, phytophthora.

Composting advice from Ritlee

When asked how to get the composting process working in the rows, we always suggest that the row is reinforced (activated) with local resident microbes and fungi. These are easily obtained from your farm by adding a mix with a mix of clay and reeds from your river and river banks, some soil from an undisturbed "healthy" area of your farm, and a truckload of either kraal or chicken manure as a source of nitrogen. The mix should be added at about 6 - 10 % of the total volume which will allow for successful colonization of your endogenous, site specific, microbes. We know there are a vast range of microbial mixes on the market, but when the suppliers cannot tell you the species of microbes or fungi in the mix then we get worried. Some microbes are able to dominate the process and reduce the diversity. This is not our aim, we look to improve the soil diversity through aerobic selection of microbes that include a site specific mix. If you require an inoculant for the compost, please send me an email describing the mix, how it is turned and managed and I will source a product for you marc@ritlee.co.za

Using the compost turner

- Start your first turn with turner set at its highest position then set down to lower and then turn again and keep it here for all future turns.
- Please keep temperatures under control.
- Allow the pile to reach a maximum of 70 ℃ before turning.
- Water should be applied to the row in the turning process.

Depending on your mix, you will find that the row must be turned some 3 to 6 times in the first 2 weeks, some 2 to 4 times during the next 2 weeks and 1 to 3 times the third 2-week cycle. Temperature will dictate when you must turn. Once you have made your first row successfully and you are happy with this compost set aside 20% to re-inoculate the new row you have been preparing. This will allow you to build up site specific microbes that are found on your farm. Let's pay more attention the microbiology under the soil and focus on creating healthy soils which in turn provide healthy productive crops.

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