What Does it Take to Maintain Healthy Roots?

This fact sheet presents some of the important soil-based factors that provide for, and maintain, healthy roots. Many of these aspects are "common-sense" but which often we forget or reduce our attention. We have developed crop production practices that provide for efficient management of crops but some scientists are now thinking we have, along the way, lessened our attention to certain basic soil and agronomic practices and principles. This fact sheet may serve to remind us of some of these good agricultural practices as they pertain to soil management and healthy root systems. Building soil health is a long-term practice.

Optimal soil moisture, nutrient, and oxygen contents are important for healthy roots. Roots are living parts of plants and require optimal soil conditions to thrive. The factors involved in optimal soil conditions can be grouped into three major categories: **physical**, **chemical**, and **biological**. We will focus on our sandy soils, typically used for crop production in many areas of the USA.

Physical

Soil physical condition affects root growth by impacting root extension. Roots can produce up to 100 psi pressure to force their way through the soil. Some soils are compacted beyond this level. Sandy soils can contain zones that impede root growth. Compacted zones can develop in sandy soils due to traffic and due to lack of organic matter, especially at depths greater than 12 inches. All soils, even sandy soils usually will have some degree of compaction and soil compaction should be considered a permanent challenge to be dealt with. Plants growing in compacted soils will experience the following:

- Have reduced root length due to less oxygen in compacted soil and increased pressure needed to grow into compacted soils
- Have reduced volume of soil to explore for nutrients and water
- Having reduced volume of soil means more fluctuations in water and nutrient availability – the "bank" is smaller and needs to be refilled more frequently
- Have stunted plant size and reduced yied (fruiting capacity)
- Compacted soil is less able to support soil biological activity and favors root disease organisms, partly due to reduced oxygen content

Cover crops are an important factor in soil compaction. The lack of maintaining vigorous cover crops in soils may enhance soil compaction over time because little organic matter is produced. As plant residues decompose, the organic matter can move deeper in the root zone helping reduce compaction.

Correcting compacted soil in a perennial tree crop is not as easy as with an annual crop. Reducing the tendency for soil compaction should begin with the new field establishment by building organic matter, as compost, in the planting site. Perhaps deep tillage to break up compacted soil should be done prior to the planting process. Deep tillage can be used to incorporate organic matter deep in the citrus bed prior to planting. In existing groves, organic matter should be added by application of organic materials or by growing cover crops. We need to find the best cover crops that are easy to grow and maintain and that meet the needs for improving soil organic matter. Cover cropping was a common practice decades ago, but is less common today with the advent of herbicides and the practice of "clean cultivation."

Questions: Can we add organic matter to existing soils and work it into the soil? What are the limitations? Can we inject organic matter or soil organic matter enhancing materials into a grove soil without serious damage to the root system? Can we add materials that will encourage soil organic matter decomposition and cycling?

Some agronomic principles for dealing with soil compaction:

- Consider compaction, especially with row crops, as a continual problem to be dealt with. Soils generally do not “recover” permanently from compaction – it is something we need to deal with on a continual basis.
- Management strategies should not create new compaction zones in new places
- Get in the habit of measuring soil penetration force (penetrometer) and focus on the measurements in the main rooting area. Soil penetrance should be less than 200 psi (about 1.4 megapascals), preferable less than 150 psi.
- Restrict working in the field when soils are wet as this will enhance compaction. Wet soils will compact nearly twice as deep as dry soils and 25% more than soil at normal moisture.
- Use vegetated areas, or mulched areas for driving and restrict traffic over the crop’s root “footprint.” Use set-aside traffic areas.
- Use wide-tired vehicles where possible to spread out the pressure per square inch of soil surface. Use smaller vehicles where possible. A 10-ton machine can compact soil to 1-foot depth and a 15-ton machine can compact soil to a depth of 2 feet.
- Try to increase organic matter in the soil; this will reduce the compaction tendency. Inject organic matter or microbes that can enhance soluble organic matter below the root zone so soil particles can be coated with organic matter. Coated soil particles tend to accumulate in larger aggregates that are less subject to compacting. Build soil organic levels with proper rotations and cover crops.
- Grow cover crops that have deep root systems to penetrate compacted soil. Add organic matter to the soil surface that can decompose adding soluble organic matter deeper in the soil; essentially work to build the soil organic matter content
- Sub-soiling (shank) can work with annual row crops but would be problematic with tree trees. However, there may be possibilities with deep aerators, similar to turfgrass aeration. Deep aeration (physical-punch or pneumatic) may help move organic matter deeper in the soil profile. Work is needed to develop a machine for aeration in cropping soils.

Chemical

Plant roots grow best in a moderate pH range, between 5.5 and 6.5. Under acidic soil conditions, certain micronutrient and heavy metal toxicities may result if those elements are present in the soil. As we farm land for long periods of time, we should be aware of soil pH and chemistry in, and below, the root zone. Too often we are concerned primarily for the chemistry of the upper 6 inches of soil. As irrigation became common-place for crop production, soil pH has been impacted due to the liming equivalents we add with the irrigation water. Rising pH in the soil affects nutrient availability because the availability of certain nutrients can be reduced under high pH (water pH >7.0). Routine soil pH testing should be practiced not only in the upper soil layer but also deeper in the root zone where most of the active roots are present. Certain non-mobile nutrients (P and micronutrients) may be adequate in the surface soil (and this may be a suitable measurement for row crops or trees, but what about nutrient levels deeper in the root zone of older trees or with deep rooted crops?

Biological

Plants are living, functioning organisms by themselves, but they also form relationships with other living organisms in the root zone. Scientists are learning more about the symbiotic relationships plants have with micro-organisms such as fungi (mycorrhizae), bacteria, and other microbes. Certain microbes (bacteria) release plant growth promoting substances. Some of these microbes manufacture biofilms that coat plant roots and enhance nutrient and water availability, or fight off disease organisms. Others recycle soil organic matter and root cells as they are discarded as the root system develops. Roots produce exudate (secretions and diffusates) containing carbon that can be used by the microbes near the root. Many functions of these products are coming to light (nutrient uptake, disease suppression, releasing enzymes, changing rhizosphere pH, nutrition for microbes, and many others). There is considerable interest in understanding how these relationships can be encouraged for improving plant growth and crop performance. For example, scientists have found that certain microbes and plants can "talk" to each other through chemical signals and this communication can help the plant growth. Further, microbe biofilms can act in unison through a process called "quorum sensing." We need to understand how to harness these important abilities of the soil ecology.

We have come to rely on certain manufactured additives (pesticides, herbicides, etc.) to improve crop performance. These inputs have been important for improving crop performance but we are losing many of these tools. They will need to be replaced by other and perhaps more sustainable practices. We will need to rely on our increased knowledge and understanding of soil biology and ecology to enhance crop performance. One teaspoon of healthy soil can contain more micro-organisms than the number of all the people on earth. For example, can we add organic matter to the root zone to enhance soil biological processes? Can we add certain microbes to the soil to build up populations of microbes that perform the work described above? Can we add energy sources, such as soluble carbon to the soil that will enhance the growth and development of the beneficial organisms? These questions are particularly important for sandy soils that are inherently low in soil organic matter.

An Integrated Approach to Crop Management

Scientists have been working on developing increased integrated approaches to crop management. More details about how soil and crops interact are being incorporated in crop management practices. Some of these practices are common knowledge and some are now being brought into crop management practices more actively today. Some of these principles are being incorporated in the Advanced Production Systems for crops being researched at Universities. We may need to think more critically about the three important components (physical, chemical, and biological) that impact healthy soil and provide the conditions for healthy roots. What can we (should we) be doing to rethink how we manage our soils to incorporate all three components and raise each to a greater level of consideration as we deal with the challenges of sustainable production today?

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