Understanding Water Movement in Soils

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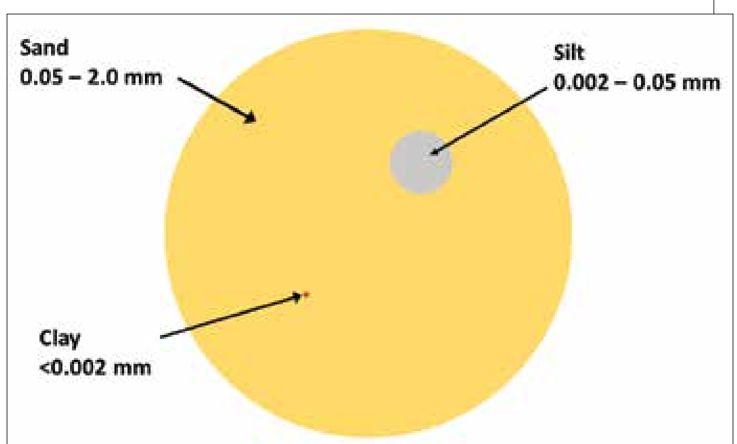
On January 25, 2023, the California Avocado Commission held a field day at Pine Tree Ranch. When we planned this field day, California was being inundated by atmospheric rivers so we planned for an indoor field day. Dr. Ben Faber, UC Farm Advisor, and I planned a few topics to kick off the discussion, but the attendees were armed with excellent questions and the discussion travelled far beyond our original planned topics. A question that came during the discussion of mulch had to do with the grower's observation that mulch seems to trap water and keep it from reaching the soil beneath. Interesting.

A few weeks later in the Winter 2023 edition of the UC Cooperative Extension's Topics in Subtropics Newsletter, Dr. Faber wrote an article about observations he has made of mistakes growers make when planting avocado trees. Included on his list of mistakes is incorporating amendments such as potting soil, manure or compost in the planting hole. Interesting.

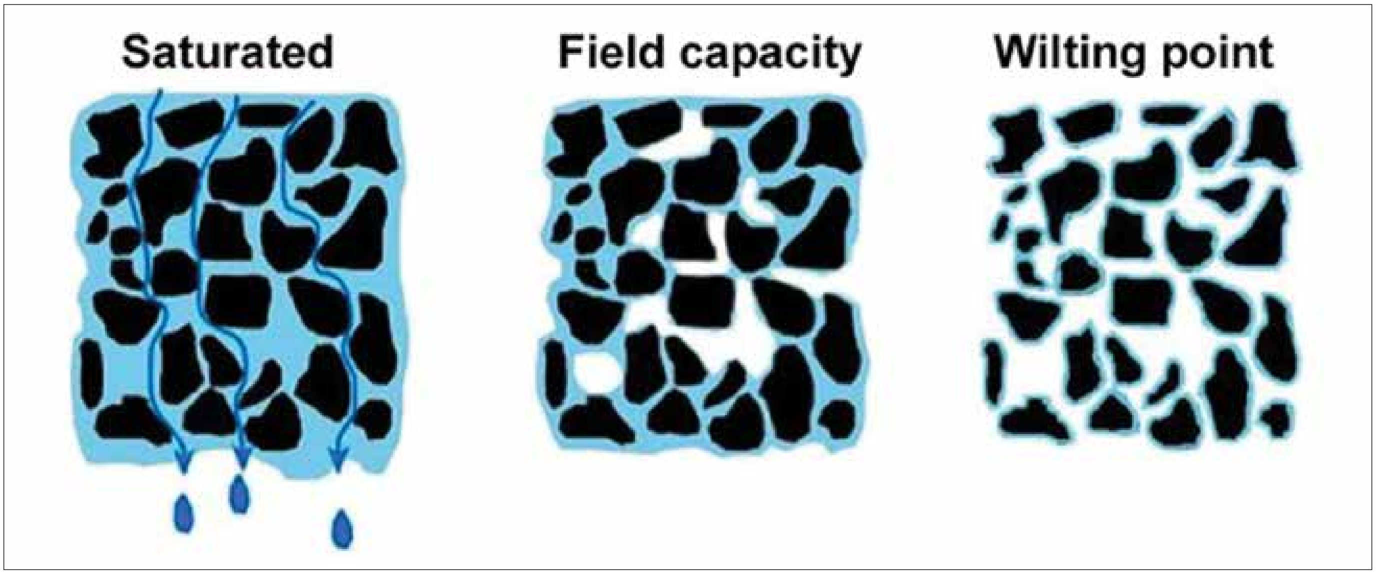
These two seemingly disparate topics got me thinking and were the genesis for this article. What do these topics have in common? They both relate to the physics of water movement in soil, or any media for that matter.

Soils are rarely uniform, rather they consist of particles of varying sizes typically classified as sand, silt and clay. Sand particles are the coarsest and range in size from 0.05 mm to 2 mm. Silt particles range in size from 0.002 mm to 0.05 mm and clay particles are <0.002 mm. Particles larger than sand are classified as gravel, which is itself categorized based on size. A soil classified as loam has a majority of particles in the sand classification and lesser amounts of silt and clay. This gives the soil good water holding capacity due to the small particles and good drainage due to the sand.



A graphical representation of the relative sizes of sand, silt and clay particles.

But what happens in those cases when a uniform layer does



An illustration of the three phases of soil moisture — saturated, field capacity and the permanent wilting point. At saturation, all of the soil pores are filled with water, the capillary forces holding water in the soil are weak and the large pores will empty by gravity. At field capacity, the large pores have drained and filled with air, the capillary forces are strong enough to hold water against gravity and no more drainage will occur by gravity. At the permanent wilting point, the capillary forces holding water are very strong and neither gravity nor plant roots can overcome these forces to extract more water.

exist in a soil, such as a clay layer or a gravel layer? Those layers disrupt the movement of water, which can sometimes be bad and sometimes be good.

First, how does water move through soil? The basic downward movement is governed by gravity, a force we're all familiar with so I will not describe it here. That said, we all know that water doesn't just move straight down in a soil, it also moves laterally. That lateral movement is caused by capillary action.

Capillary action is the process by which water moves in all directions, even against gravity, in a soil through the fine (capillary) pores of the soil. This happens because of surface tension forces between the water and the soil particles. The strength of the surface tension forces holding water in a soil is inversely related to the pore sizes in the soil. That is, water in larger pores such as in sand, is held more weakly than water in finer pores such as in clay. When all of the pores in a soil are full of water, the soil is saturated and water will drain from the soil by gravity until the gravitational forces equal the surface tension forces, at which point the soil will be at field capacity.

That last sentence is very important. Read it again and make sure it makes sense to you. That bit about gravity pulling water from a saturated soil is critical to understanding why mulch seems to trap water and why it's a bad idea to add amendments to the planting hole. When there are very distinct layers of different textures in a soil the rules of water movement described above only apply to the movement within a layer of a given texture, not the movement between layers.

Let's think about the example of a decomposed granite soil with a layer of coarse woody mulch on top of it. How will the water move through the mulch layer and into the soil beneath? Under microsprinkler irrigation or a "normal" rain event where the rate of water application is relatively low — in the range of 0.25 inch per hour — the capillary action within the mulch layer will hold the water against gravity until the mulch layer becomes saturated. Once the mulch layer is saturated, the water will flow through the mulch layer and begin to moisten the soil beneath. Thus, a mulch layer can appear to trap water. To ensure a tree is properly watered, it's important that enough volume of water is applied to fully saturate the mulch layer and moisten the soil beneath it to a sufficient depth to irrigate the trees. As concerns mulch, these same principles also work in reverse – helping to trap moisture in the soil and reduce its loss to evaporation since the water cannot readily move from the soil surface to the mulch layer to the atmosphere.

Now let's consider the issue of planting a new tree. No nursery uses native soil to fill the containers they grow their young avocado trees in. However, some do incorporate some native soil in their container mix to try to produce trees that will be adapted to the native soil conditions found in California avocado groves. That said, there is still a difference in soil texture between the root ball of the young tree and the surrounding native soil. Thus, when that tree is first planted, the root ball must become saturated before the irrigation water will move into the native soil. This is why many growers start their trees on drippers to ensure the root ball receives enough water.

When amendments are added to the soil used to refill the planting hole, a situation of three different soil textures is created — the soil from the nursery, the amended soil and the native soil. In effect, by adding amendments you are creating a secondary container around the young tree. When a tree in this scenario is irrigated, the root ball must become saturated before water will move out into the amended soil, and the amended soil must become saturated before water will move out into the native soil. If insufficient water is applied to wet the unamended native soil, the tree may grow well initially but when its roots reach the edge of the amended soil they will not grow out into the dry native soil. Furthermore, there is a strong likelihood of drowning the young tree because the amended soil can become nearly saturated but not enough so that the water moves out into the native soil. This creates a hypoxic — low oxygen — environment and the roots will die.

The amended soil also can become problematic when we look at water movement from the native soil into the amended soil. The soil was probably amended to create a coarser texture soil with the belief that it would drain better. But if the amended soil dries out it is unable to draw moisture from the surrounding native soil due to the textural differences. In this case the native soil may have sufficient water to support the tree, but the water is inaccessible to the tree because it is planted in the amended soil and there is no way for that water to move from the native soil into the amended soil.

The concepts discussed here can be difficult to visualize, but thanks to the Internet you don't have to try to visualize them. In 1959, Dr. Walter Gardner, a professor at Washington State University, created what was for its time a remarkable movie demonstrating how water moves through soil layers of different textures. This movie is available on YouTube at the following URL: https://www.youtube.com/watch?v=iugY5jNGNx0. Alternatively, searching for "water movement in soils" in the YouTube search field should bring up the movie for you.