

Container Soils - Water Movement and Retention

A Discussion About Container Soils

As container gardeners, our first priority should be to **ensure the soils we use are adequately aerated for the life of the planting**, or in the case of perennial material (trees, shrubs, garden perennials), from repot to repot. Soil aeration/drainage is the most important consideration in any container planting. Soils are the foundation that all container plantings are built on, and aeration is the very cornerstone of that foundation. Since aeration and drainage are inversely linked to soil particle size, it makes good sense to try to find and use soils or primary components with particles larger than peat/compost/coir. Durability and stability of soil components so they contribute to the retention of soil structure for extended periods is also extremely important. Pine and some other types of conifer bark fit the bill nicely, but I'll talk more about various components later.

What I will write also hits pretty hard against the futility in using a drainage layer of coarse materials in attempt to improve drainage. It just doesn't work. All it does is reduce the total volume of soil available for root colonization. A wick can be employed to remove water from the saturated layer of soil at the container bottom, but a drainage layer is not effective. A wick can be made to work in reverse of the self-watering pots widely being discussed on this forum now.

Since there are many questions about soils appropriate for use in containers, I'll post basic mix recipes later, in case any would like to try the soil. It will follow the Water Movement information.

Consider this if you will:

Container soils are all about structure, and particle size plays the primary role in determining whether a soil is suited or unsuited to the application. Soil fills only a few needs in container culture. Among them are: **Anchorage** - a place for roots to extend, securing the plant and preventing it from toppling. **Nutrient Retention** - it must retain a nutrient supply in available form sufficient to sustain plant systems. **Gas Exchange** - it must be amply porous to allow air to move through the root system and gasses that are the by-product of decomposition to escape. **Water** - it must retain water enough in liquid and/or vapor form to sustain plants between waterings. **Air** - it must contain a volume of air sufficient to ensure that root function/metabolism/growth is not impaired. This is extremely important and the primary reason that heavy, water-retentive soils are so limiting in their affect. Most plants can be grown without soil as long as we can provide air, nutrients, and water, (witness hydroponics). Here, I will concentrate primarily on the movement and retention of water in container soil(s).

There are two forces that cause water to move through soil - one is gravity, the other capillary action. Gravity needs little explanation, but for this writing I would like to note: Gravitational flow potential (GFP) is greater for water at the top of the container than it is for water at the bottom. I'll return to that later.

Capillarity is a function of the natural forces of adhesion and cohesion. **Adhesion** is water's tendency to stick to solid objects like soil particles and the sides of the pot. **Cohesion** is the tendency for water to stick to itself. Cohesion is why we often find water in droplet form - because cohesion is at times stronger than adhesion; in other words, water's bond to itself can be stronger than the bond to the object it might be in contact with; cohesion is what makes water form drops. Capillary action is in evidence when we dip a paper towel in water. The water will soak into the towel and rise several inches above the surface of the water. It will not drain back into the source, and it will stop rising when the GFP equals the capillary attraction of the fibers in the paper.

There will be a naturally occurring "**perched water table**" (PWT) in containers when soil particulate size is under about .100 (just under 1/8) inch. **Perched water is water that occupies a layer of soil at the bottom of containers or above coarse drainage layers that tends to remain saturated & will not drain from the portion of the pot it occupies.** It can evaporate or be used by the plant, but physical forces will not allow it to drain. It is there because the capillary pull of the soil at some point will surpass the GFP; therefore, the water does not drain, it is said to be 'perched'. The smaller the size of the particles in a soil, the greater the height of the PWT. Perched water can be tightly held in heavy (comprised of small particles) soils where it perches (think of a bird on a perch) just above the container bottom where it will not drain; or, it can perch in a layer of heavy soil on top of a coarse drainage layer, where it will not drain.

Imagine that we have five cylinders of varying heights, shapes, and diameters, each with drain holes. If we fill them all with the same soil mix, then saturate the soil, the PWT will be exactly the same height in each container. This saturated area of the container is where roots initially seldom penetrate & where root problems frequently begin due to a lack of aeration and the production of noxious gasses. Water and nutrient uptake are also compromised by lack of air in the root zone. Keeping in mind the fact that the PWT height is dependent on soil particle size and has nothing to do with height or shape of the container, we can draw the conclusion that: If using a soil that supports perched water, tall growing containers will always have a higher percentage of unsaturated soil than squat containers when using the same soil mix. The reason: The level of the PWT will be the same in each container, with the taller container providing more usable, air holding soil above the PWT. From this, we could make a good case that taller containers are easier to grow in.

A given volume of large soil particles has less overall surface area when compared to the same volume of small particles and therefore less overall adhesive attraction to water. So, in soils with large particles, GFP more readily overcomes capillary attraction. They simply drain better and hold more air. We all know this, but the reason, often unclear, is that the height of the PWT is lower in coarse soils than in fine soils. The key to good drainage is size and uniformity of soil particles. **Mixing large particles with small is often very ineffective because the smaller particles fit between the large, increasing surface area which increases the capillary attraction and thus the water holding potential.** An illustrative question: How much perlite do we need to add to pudding to make it drain well?

I already stated I hold as true that the grower's soil choice when establishing a planting for the long term is the most important decision he/she will make. There is no question that the roots are the heart of the plant, and plant vitality is inextricably linked in a hard lock-up with root vitality. In order to get the best from your plants, you absolutely must have happy roots.

If you start with a water-retentive medium, you cannot improve its aeration or drainage characteristics by adding larger particulates. Sand, perlite, Turface, calcined DE none of them will work. To visualize why sand and perlite can't change drainage/aeration, think of how well a pot full of BBs would drain (perlite), then think of how poorly a pot full of pudding would drain (bagged soil). Even mixing the pudding and perlite/BBs together 1:1 in a third pot yields a mix that retains the drainage characteristics and PWT height of the pudding. It's only after the perlite become the largest fraction of the mix (60-75%) that drainage & PWT height begins to improve. At that point, you're growing in perlite amended with a little potting soil.

You cannot add coarse material to fine material and improve drainage or the ht of the PWT. Use the same example as above & replace the pudding with play sand or peat moss or a peat-based potting soil - same results. The benefit in adding perlite to heavy soils doesn't come from the fact that they drain better. The fine peat or pudding particles simply 'fill in' around the perlite, so drainage & the ht of the PWT remains the same. All perlite does in heavy soils is occupy space that would otherwise be full of water. Perlite simply reduces the amount of water a soil is capable of holding because it is not internally porous. IOW - all it does is take up space. That can be a considerable benefit, but it makes more sense to approach the problem from an angle that also allows us to increase the aeration AND durability of the soil. That is where Pine bark comes in, and I will get to that soon.

If you want to profit from a soil that offers superior drainage and aeration, you need to start with an ingredient as the basis for your soils that already HAVE those properties, by ensuring that the soil is primarily comprised of particles much larger than those in peat/compost/coir.sand/topsoil, which is why the recipes I suggest as starting points all direct readers to START with the foremost fraction of the soil being large particles, to ensure excellent aeration. From there, if you choose, you can add an appropriate volume of finer particles to increase water retention. You do not have that option with a soil that is already extremely water-retentive right out of the bag.

I fully understand that many are happy with the results they get when using commercially prepared soils, and I'm not trying to get anyone to change anything. My intent is to make sure that those who are having trouble with issues related to soil, understand why the issues occur, that there are options, and what they are.

We have seen that adding a coarse drainage layer at the container bottom does not improve drainage. It does though, reduce the volume of soil required to fill a container, making the container lighter. When we employ a drainage layer in an attempt to improve drainage, what we are actually doing is moving the level of the PWT higher in the pot. This simply reduces the volume of soil available for roots to colonize. Containers with uniform soil particle size from top of container to bottom will yield better and more uniform drainage and have a lower PWT than containers using the same soil with added drainage layers.

The coarser the drainage layer, the more detrimental to drainage it is because water is more (for lack of a better scientific word) reluctant to make the downward transition because the capillary pull of the soil above the drainage layer is stronger than the GFP. The reason for this is there is far more surface area on soil particles for water to be attracted to in the soil above the drainage layer than there is in the drainage layer, so the water perches. I know this goes against what most have thought to be true, but the principle is scientifically sound, and experiments have shown it as so. Many nurserymen employ the pot-in-pot or the pot-in-trench method of growing to capitalize on the science.

If you discover you need to increase drainage, you can simply insert an absorbent wick into a drainage hole & allow it to extend from the saturated soil in the container to a few inches below the bottom of the pot, or allow it to contact soil below the container where the earth acts as a giant wick and will absorb all or most of the perched water in the container, in most cases. Eliminating the PWT has much the same effect as providing your plants much more soil to grow in, as well as allowing more, much needed air in the root zone.

In simple terms: Plants that expire because of drainage problems either die of thirst because the roots have rotted and can no longer take up water, or they suffer/die because there is insufficient air at the root zone to insure normal root function, so water/nutrient uptake and root metabolism become seriously impaired.

To confirm the existence of the PWT and how effective a wick is at removing it, try this experiment: Fill a soft drink cup nearly full of garden soil. Add enough water to fill to the top, being sure all soil is saturated. Punch a drain hole in the bottom of the cup and allow the water to drain. When drainage has stopped, insert a wick into the drain hole . Take note of how much additional water drains. Even touching the soil with a toothpick through the drain hole will cause substantial additional water to drain. The water that drains is water that occupied the PWT. A greatly simplified explanation of what occurs is: The wick or toothpick "fools" the water into thinking the pot is deeper than it is, so water begins to move downward seeking the "new" bottom of the pot, pulling the rest of the water in the PWT along with it. If there is interest, there are other simple and interesting experiments you can perform to confirm the existence of a PWT in container soils. I can expand later in the thread.

I always remain cognizant of these physical principles whenever I build a soil. I have not used a commercially prepared soil in many years, preferring to build a soil or amend one of my 2 basic mixes to suit individual plantings. I keep many ingredients at the ready for building soils, but the basic building process usually starts with conifer bark and perlite. Sphagnum peat plays a secondary role in my container soils because it breaks down too quickly to suit me, and when it does, it impedes drainage and reduces aeration. Size matters. Partially

composted conifer bark fines (pine is easiest to find and least expensive) works best in the following recipes, followed by uncomposted bark in the <3/8" range.

Bark fines of pine, fir or hemlock, are excellent as the primary component of your soils. The lignin contained in bark keeps it rigid and the rigidity provides air-holding pockets in the root zone far longer than peat or compost mixes that too quickly break down to a soup-like consistency. Conifer bark also contains suberin, a lipid sometimes referred to as nature's preservative. Suberin, more scarce as a presence in sapwood products and hardwood bark, dramatically slows the decomposition of conifer bark-based soils. It contains highly varied hydrocarbon chains and the microorganisms that turn peat to soup have great difficulty cleaving these chains - it retains its structure.

Note that there is no sand or compost in the soils I use. Sand, as most of you think of it, can improve drainage in some cases, but it reduces aeration by filling valuable macro-pores in soils. Unless sand particle size is fairly uniform and/or larger than about BB size, I leave it out of soils. Compost is too fine and unstable for me to consider using in soils in any significant volume as well. The small amount of micro-nutrients it supplies can easily be delivered by one or more of a number of chemical or organic sources that do not detract from drainage/aeration.

My Basic Soils

5 parts pine bark fines (partially composted fines are best)
1 part sphagnum peat (not reed or sedge peat please)
1-2 parts perlite
garden lime (or gypsum in some cases)
controlled release fertilizer (if preferred)

Big batch:

2-3 cu ft pine bark fines
5 gallons peat
5 gallons perlite
2 cups dolomitic (garden) lime (or gypsum in some cases)
2 cups CRF (if preferred)

Small batch:

3 gallons pine bark
1/2 gallon peat
1/2 gallon perlite
4 tbsp lime (or gypsum in some cases)
1/4 cup CRF (if preferred)

I have seen advice that some highly organic (practically speaking - almost all container soils are highly organic) container soils are productive for up to 5 years or more. I disagree and will explain why if there is interest. Even if you were to substitute fir bark for pine bark in this recipe (and this recipe will long outlast any peat based soil) you should only expect a maximum of two to three years life before a repot is in order. Usually perennials, including trees (they're perennials too) should be repotted more frequently to insure they can grow at as close to their genetic potential within the limits of other cultural factors as possible. If a soil is desired that will retain structure for long periods, we need to look more to inorganic components. Some examples are crushed granite, fine stone, VERY coarse sand (see above - usually no smaller than BB size in containers, please), Haydite, lava rock (pumice), Turface, calcined DE, and others.

For long term (especially woody) plantings and houseplants, I use a superb soil that is extremely durable and structurally sound. The basic mix is equal parts of pine bark, Turface, and crushed granite.

1 part uncomposted screened pine or fir bark (1/8-1/4")
1 part screened Turface
1 part crushed Gran-I-Grit (grower size) or #2 cherrystone
1 Tbsp gypsum per gallon of soil
CRF (if desired)

I use 1/8 -1/4 tsp Epsom salts (MgSO₄) per gallon of fertilizer solution when I fertilize if the fertilizer does not contain Mg (check your fertilizer - if it is soluble, it is probable it does not contain Ca or Mg. If I am using my currently favored fertilizer (I use it on everything), Dyna-Gro's Foliage-Pro in the 9-3-6 formulation, and I don't use gypsum or Epsom salts in the fertilizer solution.

About the Author

Hello! Im guessing you have seen something Ive written on one of the forums and came to see if you could learn a little about me. Thank you for that interest. Ill start by saying that a fair number of years ago (20+), I became enamored of bonsai trees and quite suddenly decided I would become a bonsai practitioner; then failed miserably at it, having to accept the reality in the fact I didnt have the skill set required to keep diminutive plants alive in the small volumes of soil they are grown in. I quickly determined that to minimize my frustrations and maximize my satisfaction, Id need to do some extensive homework. **I began to study the more technical aspects of plant physiology, container culture, and soil science.** After about 4 years of fairly diligent study, I set about acquiring a few new trees & companion plants to replace the dead ones, and to my surprise, I was able to keep them flourishing. **Incidental to my bonsai related studies I found a growing interest in understanding the broader culture of container gardening, with emphasis on soils and nutrition (fertilization).** I still continue to attempt to satisfy a considerable appetite for the knowledge I gather from many texts and the net, and to carefully observe and note the cause/effect relationships that affect my own plants. To further my knowledge of plant systems and their individual cultural requirements, I regularly take advantage of local symposia, and travel often to conventions and other plant related events. **I'm also called on regularly by local clubs and organizations, frequently Master Gardener groups, to speak about plants, pruning, propagation, soils, container gardening, or other related subjects.** I maintain several of my own gardens, many raised beds, some 250+ containerized woody plants/bonsai, and dozens of companion plants in containers. I also build about 30 large display containers for the gardens each year, including both floral and foliage compositions, pictures of which litter the forums here at GW. **I never buy soils,** choosing instead to build all my soils from easily obtainable components, always kept on hand. Im active in 5 garden/plant related clubs, and **have completed Master Gardener training.** I have a large indoor growing area (64 sq ft) with controlled humidity, temperature, and supplemental lighting where I maintain many tropical bonsai, assorted houseplants & succulents. If youd like to search these forums for any comments I may have offered about a particular subject, simply enter the search word tapla, followed by the subject of your search. e.g.: tapla container soil, or tapla fertilizer. The satisfaction I enjoy in exchange for my participation on the forums comes in large part from the thought that what I offer on the forums might possibly be helping another gardener. I probably neglect a few things, (including perhaps, my own plants at times) just so I can hang here with the plant people I enjoy so much. The fact that Im learning new things every time I log in, and each time I open a book or search the net to confirm the accuracy of my comments is a big plus for me, too. I hope to see you on the forums; or, feel free to contact me off-forum by e-mail. Dont be bashful - I average several plant related questions or comments in my mail every day, so your questions wont pose an imposition. Thanks for taking the time to read about "where Im coming from". _____ Best growing to you! _____ Al