What Is Your Substrate Trying to Tell You

Part IV

Robert R. Tripepi
Associate Professor
Plant Science Division, University of Idaho
Moscow, ID 83844-2339

This article is the fourth in a five-part series of articles on properties of potting mixes that are important for optimum plant growth. The goal of these articles is to provide you with some guidelines for chemical and physical characteristics of potting mixes. The words potting mix, container growth medium, and substrate are used interchangeably throughout these articles.

In the first two articles, we reviewed chemical properties of soilless potting mixes, those being pH, electrical conductivity (EC), cation exchange capacity (CEC), and carbon to nitrogen (C:N) ratio. In the third article, three methods used to measure pH and EC were described, since plant growth can be altered by controlling pH and EC of potting mixes. In this article, I will discuss ways to adjust pH and EC as well as describe several important physical characteristics potting media.

pH Basics for Substrates

After a potting medium is moistened, the pH may take from 1 to 7 days to equilibrate due to substrate components, type of limestone and preplant fertilizers added, and the quality of the irrigation water used. Before planting a crop in a mix, fill several pots with only the substrate, water them with the tap water you use on the crop, and then set them aside for a few days, either in a greenhouse or container yard. Be sure to keep the medium most during this equilibration period. Measure the pH and EC after several days, anytime from 2 to 5 days after the initial watering. At the end of the equilibration period, both pH and EC should be within the target range for the crop being grown. If these chemical properties are out of acceptable ranges, then action will be needed to adjust them.

Adjusting EC and pH

Adjusting the EC is straight forward. To lower EC, use enough good quality tap water to leach salts out of the substrate. To raise EC, add fertilizers to the substrate before planting or plan to use some type of supplemental fertilization once the crop is growing. Be sure to follow label directions when using fertilizer.

pH is harder to adjust because changes in H^+ concentration depend on chemical reactions in the substrate and the buffering capacity of components in the potting mix. Raising pH can be done with limestone or with dolomite if magnesium is desired. The pH can be lowered with agricultural sulfur. Keep in mind that raising or lower the pH of the substrate before planting can sometimes be difficult and another test with an equilibrium period should be completed to determine if the corrective action yielded the desired effect. Particle size will affect the speed of pH change; small particles of limestone or sulfur usually dissolve more quickly and so can affect pH earlier than large particles.

Strategies to Control pH

As the crop grows, pH of the substrate should be checked once a month. What should be done, however, if the pH is out of the target range established for the crop or how can the pH be prevented from becoming out of range? First, keep in mind that preplant amendments, water alkalinity, and fertilizers used will affect pH. These factors must be accounted for when trying to control substrate pH.

If medium pH must be lowered, some corrective steps include (a) acidify the water to a pH of 5.8, using phosphoric, nitric or sulfuric acid; (b) spread agricultural sulfur on the surface of the medium (the quantity needed will depend on the results from a test of the medium's buffering capacity); (c) reduce or discontinue use of nitrate forms of N, but do so ONLY IF YOUR CROP CAN TOLERATE AMMONIUM FORMS OF N; and (d) drench the substrate with aluminum sulfate or iron sulfate solution to rapidly lower the pH, if an immediate response is needed. A rate such as 3 grams per liter (0.5 ounces per gal) might be a good starting point.

When attempting to lower the pH of the potting mix by using one of the methods mentioned above, several important factors should be kept in mind. First, mixing concentrated acid with water can be dangerous and requires extreme care plus the proper equipment. For this reason, you should consult with companies that specialize in modifying water quality before attempting to acidify irrigation water. Second, the form of N used affects potting mix pH, since plant roots cause the substrate to become more basic if they take up nitrate. They can also cause the mix to become more acidic when they absorb ammonium. Before eliminating nitrate from fertilizers applied to your crop, be sure your crop can tolerate ammonium as the N source. For instance, the form of N in fertilizers used on poinsettias should contain 50% or less ammonium, which also includes urea since it breaks down to form ammonium. If poinsettias receive too much ammonium, their new growth will become distorted, which is a toxicity reaction.

If medium pH must be raised, some corrective steps include (a) discontinue acidifying irrigation water if it is treated with acid; (b) use nitrate forms of N, such as calcium nitrate, to fertilize plants; (c) spread limestone or calcium hydroxide on the medium surface (the quantity needed will depend on the results from a test of the medium's buffering capacity); and (d) drench the potting mix with a potassium bicarbonate solution either as a one-time treatment (supposedly a rate of 5 to 10 grams per liter [0.6 to 1.3 ounces per gallon] should be sufficient) to raise pH quickly, or inject a lower rate of this compound into your irrigation water during crop production.

PHYSICAL PROPERTIES OF SUBSTRATES

The last substrate properties that try to tell growers something about how plants might grow in them are physical properties. A number of physical properties can be measured for media, but I will discuss only bulk density, air capacity, water-holding capacity, and total porosity. Of particular interest to growers are air and water-holding capacities because these two properties affect plant growth and cultural practices, such as irrigation frequency.

Bulk Density

Bulk density is the dry mass per unit volume of moist medium. In other words, it is the dry weight of the substrate that occupies a certain volume when the medium is moist. In practical situations, bulk density is important since wet, dense potting mixes are heavier that wet light mixes. Bulk density is also important if you need to convert CEC from a weight (per 100 grams) to a volume (per liter) basis (see the January/February 1998 Taproot for a discussion on CEC). Keep in mind that bulk density and total pore space are inversely related, meaning the higher the total pore space the lower the bulk density.

Air Capacity - also called Air-Filled Porosity

Air capacity is the proportion or percentage of a substrate's pore space that contains air after the medium has been saturated with water and allowed to drain. Air capacity is often used as an indicator of aeration of a substrate. A general range for air capacity is from 5 to 25%, with a consensus that 10 to 20% air capacity is desirable.

Water-holding capacity - also called Container Capacity

Water-holding capacity is the proportion or percentage of a substrate's pore space that is filled with water after the medium has been saturated and allowed to drain. Keep in mind that some of the water held will be unavailable to plants when the dryness of the substrate reaches the permanent wilting point. A general range for water-holding capacity is between 20 and 60%. Specifying a narrower range depends on the plant species being grown. The lower the water-holding capacity of the substrate, the less water will be available for plants, meaning low numbers indicate more frequent irrigation will be needed.

Container depth and water retention are strongly related and can affect the water-holding capacity of the potting mix. The taller the pot, the higher the column of medium, usually resulting in proportionally more medium in the pot that is well drained compared to short or squat pots. For this reason, measure air and water-holding capacities in the pot size that you are growing the crop in. This suggestion is easy for pots 1 gallon or smaller in size but can be difficult for larger pots. In my work, I have found that a 1-gallon pot will provide a decent approximation for air and water-holding capacities of a substrate in a 5-gallon squat container.

Total Pore Space - also called Total Porosity

Total porosity is the total volume of the medium unoccupied by mineral or organic materials. This value is usually obtained by adding air capacity and water-holding capacity. In general, a substrate with a total porosity between 50 and 85% is considered satisfactory. Knowing the proportion of the pores filled with air or water, however, is more useful than knowing only the total porosity.

Measuring Physical Properties of Potting Mixes

Measuring the four physical properties of potting mixes that were mentioned above will require only a few pieces of equipment such as a balance, a container with a drainage hole(s), a watertight pan to collect water from the container, and a graduated cylinder. Trying to complete these measurement may seem a bit awkward at first, but with a little practice you can become proficient at it.

Bulk density is measured by placing slightly moistened medium in a container of known volume and filling the container to the top or volume mark line. The container, which should be shatterproof, is then dropped onto a hard surface from a height of three inches for a total of four times. Potting mix is added to bring the volume up to the top of the container or the volume mark line. After the container is refilled, all the potting mix is removed from the container and put in a clean, dry tray. The tray should be placed in a drying oven set between 160 to 200ºF to dry out the mix completely. Drying the potting mix in your kitchen oven would work but should probably be avoided, since certain volatile compounds released from the drying medium may leave an unpleasant odor in your oven, kitchen and the rest of the house. After the potting mix is dried, use a balance to measure the weight of the medium. Finally, divide the weight of the dry mix by the volume of the container to calculate weight per unit volume.

Several methods can be used to measure air porosity, water-holding capacity, and total porosity. The technique described here can be done relatively quickly and needs a minimum of equipment. This technique was adapted from The Container Tree Nursery Manual, Volume 2, Containers and Growing Media, 1990, by T.D. Landis, R.W. Tinus, S.E. McDonald, and J.P. Barnett. First, use a container that you grow your plants in and measure its volume. You may want to measure the volume at the final height of the potting mix in the pot. You will need to seal the drainage hole(s), which can be difficult. Electrical tape, artist's tape or florist's clay can be used to seal the hole(s). After the pot is sealed, use a graduated cylinder to measure the amount of water in the pot and record it as container volume.

The second step is to empty the water and dry the container, then fill it with slightly moistened potting mix to the same height that you used to measure the volume. Be sure to use slightly moistened medium since dry medium will be try to repel water rather than absorb it. You should then drop the container from a height of a few inches several times to mimic the potting procedure. Add more potting mix to bring it up to volume if necessary. Next, slowly add water to the growing medium to saturate the pore space in the mix. Be sure to measure the volume of water that you add to the medium! I recommend slowly adding the water at one side of the container. The object is to avoid trapping air in the medium because trapped air will cause measurement errors. Continue adding water until the potting mix is completely saturated and the surface glistens. When you see the surface glistening, you know that all the pore space in the mix is filled with water. Depending on the size of the pot, adding water could take from a few minutes to several hours. Record the total volume of water added as total pore volume.

Next, place the container over a watertight pan, remove the seal(s) from the container's drainage hole(s) and collect water that drains from the medium. Allow all the water to drain freely from the pot, which may take several hours depending on container size. Measure this volume of water in the graduated cylinder and record it as aeration pore volume.

Once these three measurements are made, you can calculate the following physical properties:

Total porosity (%) = (total pore volume ÷ container volume) x 100%

Air capacity (%) = (aeration pore volume ÷ container volume) x 100%

Water-holding capacity (%) = total porosity - air capacity

In the next (and final) article of the series, I will present some examples of chemical and physical properties of potting mixes made with paper sludge. The last article will provide examples of how changes in potting mix components alter properties of potting mixes and influence plant growth. If you have questions about information contained in this article, contact your local county extension educator or contact me (by phone: 208.885.6635 or by e-mail: btripepi@uidaho.edu).