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Ohio State University Extension Fact Sheet

Horticulture and Crop Science

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Physical Characteristics of Growing Mixes

HYG-1251-97

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"Whoever holds the end of the hose in your greenhouse will determine whether or not you make a profit." This saying is probably as old as container-crop production itself and is as true today as ever. Early container growers realized quickly that their watering practices significantly affected crop quality. Yet, it took years of scientific observation and research to determine the relationship between water retention, air porosity, and growing media characteristics.

Functions of Growing Medium

Growing mixes used to produce greenhouse floricultural crops provide four functions (order does not indicate importance):

1) allow gas exchange (oxygen, carbon dioxide)
2) hold water that is available to the plants
3) create a reservoir of mineral nutrients
4) provide plant support

The growing mix takes care of only the fourth function. The grower is "co-responsible," along with the growing mix, for the other three functions. This means that crop management or cultural practices, along with the growing medium, determine how much water, oxygen, and nutrients the mix will hold. Although the composition of a growing mix greatly influences how much air, water, and nutrients a container can hold, no "ideal" mix will take care of every root's every need. The composition of the mix also influences irrigation, fertilization, and pest management practices. Some mixes are better than others, and the grower is responsible for using the most appropriate growing medium available for operations.

Physical and Chemical Characteristics

Soil scientists separate soil characteristics into two groups: chemical and physical. Chemical characteristics include pH, cation exchange capacity, electrical conductivity, and fertility. This article will discuss only the physical characteristics of soil. Physical characteristics include bulk volume, bulk density, texture (particle size), and structure (organization of the particles). Texture and structure affect air porosity and water retention.

Texture and Structure

Two important soil characteristics are texture and structure. Texture refers to the size and distribution of particles in a soil or mix (Fig. 1). Structure refers to the particles' combination into larger aggregates (Fig. 2). Texture affects water retention and, consequently, air porosity. Soils with smaller particles (fine texture) have smaller pores. Smaller pores present higher resistance to water flow, which in turn increases water-holding capacity.

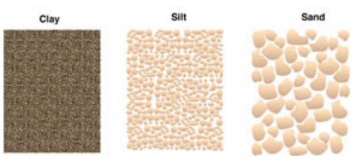

Figure 1. Soil texture. The size of the particles and their distribution determine texture. Clay is comprised of smaller particles, while sand is comprised of larger particles.

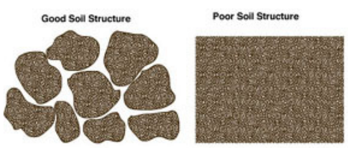

Figure 2. Soil structure. When particles are unorganized, soil structure is poor (right). When particles are organized into larger particles, such as clay particles "glued" by decomposed organic matter or humus, soil structure improves, increasing air porosity (left).

Mixing components of varying particle size dramatically affects air porosity. For example, smaller particles located in the spaces left by larger particles reduce pore diameter (Fig. 3). Mineral soils tend to have smaller particles. When mixed with organic components, which usually are comprised of larger particles, soil lodges between the larger particles, reducing air porosity and increasing water retention.

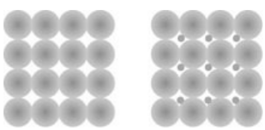

Figure 3. When various-sized particles are mixed, smaller particles lodge in the spaces left by larger particles, reducing pore size.

Aeration and Water Retention

One of the challenges floriculture growers face is balancing aeration and water retention, especially when growing crops in small containers. Increasing aeration decreases water retention and vice versa. Some growers believe that this challenge can be met by finding the ideal, all-purpose growing mix. **However, the ideal, all-purpose growing mix does not exist because other variables also affect air and water status in containers.** These variables are:

1) growing mix components
2) container size and shape
3) growing mix handling procedures
4) watering routines

1) Growing Mix Components

Ingredient type and proportion affect air and water content of a mix. A variety of ingredients--such as field soil, peat moss, bark, vermiculite, perlite, polystyrene foam, and coconut coir-- comprise most modern soil mixes. However, not all ingredients within a category are "born equal." For example, not all peat mosses are the same. Old peat moss has different properties (and visual characteristics) than young peat moss (Table 1). Old peat moss has smaller particles than younger peats. How peat is harvested also affects particle size. Similarly, vermiculite is available in different particle sizes. Each size has different uses in floriculture. Size 2, which is horticultural grade, provides good air porosity and water retention. Size 3, which has smaller particles than size 2, holds less water and air and is more prone to collapse.

If the soil pores are large, they will fill mainly with air, which limits water retention. On the contrary, if pores are too small, they will retain too much water, which limits air porosity (oxygen). Unfortunately, increasing water retention reduces air porosity and vice versa. Finding a particle size distribution that provides an adequate balance of air and water is crucial.

2) Container Size and Shape

With large containers (standard 6-inch diameter or larger), height and shape are less of a problem. However, with small containers, such as plug cells, height and shape are critical. The height of a plug cell affects air porosity. Taller cells have a larger percentage of air space, even with the same mix (Fig. 4, top).

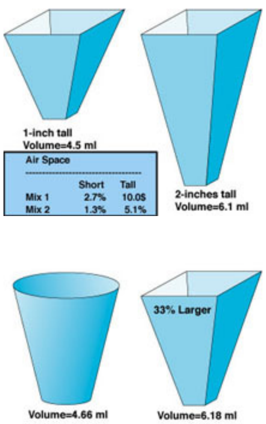

Figure 4. Effect of cell depth on air porosity (top) and cell section shape (bottom) on cell volume. (After Fonteno et al., 1995. North Carolina Flower Growers' Bulletin)

The shape of the container affects volume. For example, two seemingly similar plug cells hold significantly different volumes (Fig. 4, bottom). Even though each cell has the same top dimensions (diameter equal to square's side) and same height, the square cell holds 33 percent more by volume than the circular cell.

3) Growing Mix Handling Procedures

The way a grower handles a growing mix before it is deposited inside the container can profoundly affect air porosity. Organic compounds, such as peat, and vermiculite absorb water and expand, much like a sponge. When particles expand inside the container, they do so at the expense of the pores, which get squeezed out. Adding water to mixes before placing them inside containers helps maintain an acceptable level of air porosity.

After filling containers with a moist growing medium, avoid compacting the mix inside the containers by not applying any pressure while filling the pot. Do not stack filled pots unless the pots on the top are resting on the rims of the pots below.

4) Watering Routines

Of course, how often you irrigate and how much water you apply per irrigation event determines the amount of water and air present in the growing medium. You can have the "best" mix on the market and still subject roots to low levels of oxygen because of poor watering techniques. To achieve a balance between aeration and water retention, reduce the volume of water applied and increase the frequency of irrigation. This becomes more important with smaller containers; the smaller the container, the more susceptible a mix is to overwatering.

Table 1. Peat moss classification based on degree of decomposition, using a scale from H1 to H10

Class	Degree of Decomposition
Light peat	H1-H3
Dark peat	H4-H6
Black peat	H7-H10

Watering Containers

A few seconds after you start watering a container, all pores are filled with water, displacing the air from the pores. Drainage occurs through the holes at the bottom of the container (Fig. 5.1). After you stop watering, drainage continues and the wet profile slowly moves downward while air moves inside the pores at the top. After drainage has stopped (Fig. 5.2-5.5), the lower part of the mix remains saturated with water. The depth (or height) of this saturation layer is not determined by the number and size of the drainage holes. Saturation is determined by the pore sizes of the mix, which is determined by particle size or texture. A pot filled with a coarse mix (with large pores) will have a smaller saturation zone (Fig. 5.5) than a pot filled with a fine (smaller pores) mix (Fig. 5.6). This is strictly a physical phenomenon called capillarity.

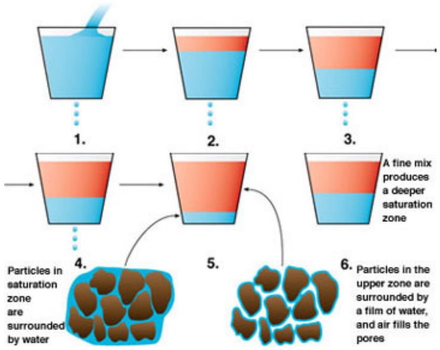

Figure 5. The watering of containers. 1) Saturation of the medium due to watering. 2-4) Drainage occurs; water moves out of the containers through the bottom holes allowing air to move in at the top. 5) After drainage has stopped, the lower portion of the mix is still saturated while in the upper portion of the mix the particles are surrounded by water but pores have air. 6) If the same pot is filled with a finer mix, the saturation layer would be larger (higher).

In a saturation zone, all pores are filled with water and no air, while the mix above has pores containing both air and water. Unless roots remove the water from the saturation zone, water remains at the bottom of the pot for a long time, because evaporation through the top of the mix is a very slow process.

Lack of oxygen puts root systems of some plants under severe stress, making them more susceptible to diseases. Furthermore, pathogens such as Pythium and Phytophtora require a water-saturated environment to infect roots. For growers, minimizing the size and duration of the saturation layer should be a high priority.

The idea still persists that drainage from containers can be improved by adding a layer of coarse material, such as gravel, to the bottom of the container. In reality, this makes matters worse because the saturation layer is simply moved up, reducing the unsaturated portion of the container (Fig. 6).

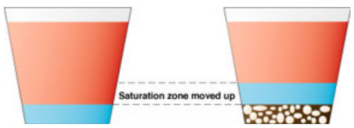

Figure 6. Adding gravel to the bottom of a container decreases air porosity of the mix (right). The saturation zone moves up, reducing the volume of the unsaturated portion at the top of the mix. Particles in saturation zone are surrounded by water. Particles in the upper zone are surrounded by a film of water, and air fills the pores. A fine mix produces a deeper saturation zoneSaturation zone moved up. Saturation zone is 1/10 the height of a 6-inch container. Saturation zone is 1/2 the height of a plug cell

Suppose we fill different-sized containers (from 6 inches to plug cells) with the same hypothetical growing mix and irrigate all of them. After drainage, all pots will have a saturation zone (Fig. 7). The saturation zone is practically of the same height in all containers because it is a function of the size of the pores in the growing mix. Note that the saturation zone is one tenth of the height of a 6-inch container, while it is half of the height of a plug cell.

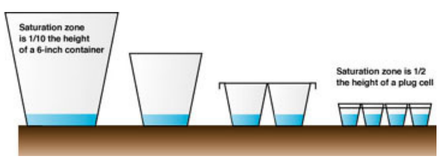

Figure 7. Saturation zone in relation to the height of four types of container (from left to right, a 6-inch pot, 4-inch pot, a six pack, and plug cells). All containers were filled with the same hypothetical growing mix, irrigated to saturation, and left to drain.

Summary

In this brief fact sheet, I have tried to provide an understanding of the impact that rooting media physical characteristics have on the root environment and, therefore, on the vigor of the entire plant. Growers should keep in mind these two essential points: there is no ideal growing mix for every growing situation, and whoever holds the end of the water hose in a greenhouse significantly impacts the bottom line.

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