Properties of Greenhouse Substrates

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Everyone seems to be searching for the ideal greenhouse substrate. The criteria are simple: make a mix with good aeration, that doesn't dry out too quickly, can be used in all cell sizes, contains all the nutrients necessary, and stores indefinitely. All that is needed is a substrate that is not affected by other forces in the greenhouse; a mix that does not change with cultural practices.

Obviously, trying to make the mix totally responsible for air, water and nutrition will be unsuccessful. A better strategy is to integrate the mix into a production system that addresses substrate aeration and water retention as well as plant nutrition.

Aeration and Water Retention

Balancing the air and water contents has been one of the biggest problems facing greenhouse growers, especially plug and bedding plant growers. Just after seeding, plugs are too wet, and many drown. But later in production, plugs dry out too quickly, as plants mature and increase in size. To compensate for changing plant demands, growers must change their watering practices as the plugs mature.

People tend to think of the mix as the overriding factor that determines air and water content in the root zone. Therefore most mixes made over the last 20 years have been characterized according to their air and water values, as if these were fixed properties of the mix. They are not. There are four major factors which affect the air and water status in containers. These factors are like the four corners of a plug or tray cell; each is necessary in supporting the air and water content in that cell (Figure 1). The four corners are: ❶ the substrate (components and ratios); ❷ the container (height and shape); ❸ substrate handling procedures; and ❹ watering practices. Each of these four factors have a profound effect on air and water content.

The Substrate. Indeed, the substrate can greatly influence the air and water content in the root zone. Most mixes used in greenhouses contain 30 to 60% peat moss or 30 to 60% of a peat moss plus composted pine bark combination. These two mix components can vary in quality,

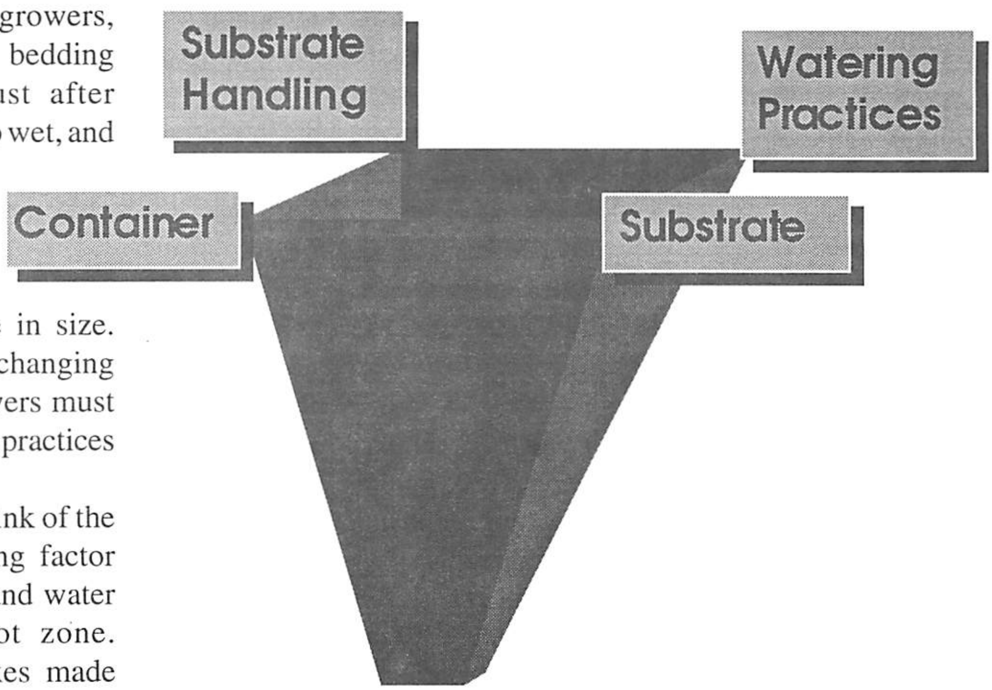


Figure 1. The four major factors which affect the air and water status in containers.

and growers mixing their own substrate should select peatmoss and pine bark based on the following.

Generally, sphagnum peat is preferred because it has an advantageous fiber structure over hypnum or reed-sedge peats, which allows for good aeration and drainage. A word of caution--simply using a sphagnum peat does not assure you of uniformity. If the peat has been milled too much, fibers can be crushed and the quality will be reduced. Mix ingredient quality control is essential for repeatable, consistent production results.

If the mix does contain pine bark, the bark should be composted and not "green." Bark that is aged and not composted will result in nutritional imbalances due to microbes decomposing the bark. The microbes will out compete the plants for available nutrients.

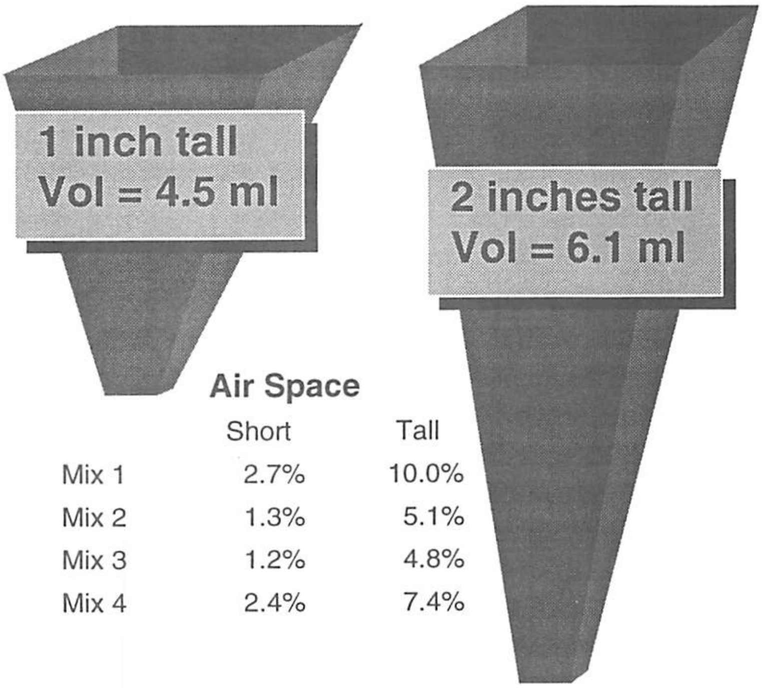
Aggregates are generally added to peat moss / pine bark mixtures to provide more rapid drainage and increase aeration. Most commonly, vermiculite, perlite and polystyrene beads are added; calcined clays are also used. Vermiculite is the aggregate used most often and in the largest ratio, from 20 to 60% by volume. The size of the vermiculite is very important. The size of vermiculite commonly used in general potting mixes and bedding plant flat mixes is #2 (horticultural grade). This does provide large pores (macropores that will provide air space in the substrate), and is recommended for large-celled flat production and large containers. However, plug mixes generally contain grade #3 (which is finer) to allow the mix to flow more evenly into the trays at filling. Ironically, grade #3 is one of the poorest aggregates for adding air space. It holds less water and much less air than #2. It is also more susceptible to compaction and structural collapse.

What does all of this mean? First, peat plays a much more dominant role in plug and bedding plant flat production than in larger containers (bark is rarely used in plug substrates), and the quality of the peat used is very important. Second, the aggregates used may or may not help improve drainage and add air space, depending on size and shape of particles. Third, smaller particle sizes do not necessarily improve air and water content and can in fact hurt. When selecting a substrate, examine the contents and particle sizes prior to deciding on what is best for the crop (plugs, bedding plant flats, or larger containers) that are being grown.

The Container. The second "corner" of cell air and water content is container height and shape. For large containers and large cell flats, container effects are not as much of a concern, but the effects of containers are greatly accentuated in plug production.

The main reason why it can be harder to grow a good plug than a good pot mum is the plug cell itself. Plug cells have only two basic problems - they are too short and too small. They are so short that at best they drain very little and at worst (like in the 648 waffles) they do not drain at all. For example, a 1 peat: 1 vermiculite mix has an air space of 2.8% by volume in the 288 cell and only 0.5% in the 648 tray. This same mix has an air space value of 13% in a 4 inch pot (3 1/4" tall) and 20% in a 6 inch pot (4 1/2" tall).

The importance of height is illustrated well by Figure 2. A normal 273 plug is approximately 1 inch tall. We "manufactured" a tall 273 cell with the same length and width at the top opening, but made it 2 inches tall with the same general taper. The effect on drainage was dramatic. The four mixes in Figure 2 are commercial plug mixes run through our lab for diagnostic purposes and are simply listed as Mix 1, 2, 3, and 4. Notice the difference in air content between the short and tall plugs. Air content went from a range of 1% to 3% in the short plugs to 5% to 10% in the talls. If we could get 10% air space in all of our plugs we could cut our plug production problems in half. Taller cells equals more air space. Obviously, it is possible to grow good plugs in short plug cells. But the smaller the cells, the greater the chance of the plants being over-watered and under-watered.



Air Space

	Short	Tall
Mix 1	2.7%	10.0%
Mix 2	1.3%	5.1%
Mix 3	1.2%	4.8%
Mix 4	2.4%	7.4%

Figure 2. Effect of cell height on air space (reported as percent by volume) in the substrate.

This phenomenon of changing percent air space based on container height is sometimes called a "perched water table" effect. After watering a container, there will always be a portion of the substrate at the bottom of the container that does not drain, and pores remain saturated with water. This saturation zone is a larger percent of the total volume in shorter containers. A good demonstration sometimes used to visualize the effect of container height is a sponge (Figure 3). Imagine that the sponge is the substrate in a container. The example sponge in Figure 3 is 2" × 4.25" × 8.5". This is a total volume of 72.25 cubic inches or 1,184 ml. When fully saturated (squeezing out all the air then soaking in water), the sponge holds 950 ml; the total porosity is 80%. Holding the sponge so it has a 2 inch height resulted in about 50 ml water being drained. The sponge had 4.2% air space when two inches tall. Turning the sponge on its side to create a height of 4.25 inches drained another 125 ml; total air space of 14.8%. Holding the sponge so the height is 8.5 inches drained another 375 ml and resulted in a total air space of 46.5%! Notice the difference in the total volume drained from the sponge, depending on the height. This effect holds true for different height containers filled with the same substrate as well. The height of the container will dictate the total air space of the substrate after drainage of excess water.

Another issue is container shape. Good plugs can be grown in both round or square plug cells. "Round" cells are actually portions of a cone, while "square" cells are sections of pyramids (Figure 4). Of the two designs, the square cells are preferred because they have a larger volume. In Figure 4 we see a round and a square 288 cell. If you calculate the volumes of each you find that the round cells has a volume of 4.66 ml, while the square cell has a volume of 6.18 ml. Although these numbers are small, the square cell is 33% larger than the round one. This extra volume translates to more water being available to the plant and less chance of drying out. This extra volume does not necessarily increase air space percentage. However, as long as the height remains the same, there is no decrease in drainage, so air space is not adversely affected. There is no advantage to growing in round cells. Even if you can get a better price on round trays, the decrease in container and substrate volume is not worth it.

Substrate Handling. The "third corner" for air and water in bedding plant cells is substrate handling. How a mix is handled can greatly affect the air and water content of the mix. All efforts to select the best material, conscientiously blend them and carefully package them and ship them can be undone on the other end by someone who handles the mix improperly.

What should growers be cognizant of? One factor is *compaction*. Containers, cell paks and plug trays should be lightly filled and the excess brushed away. This can be accomplished by

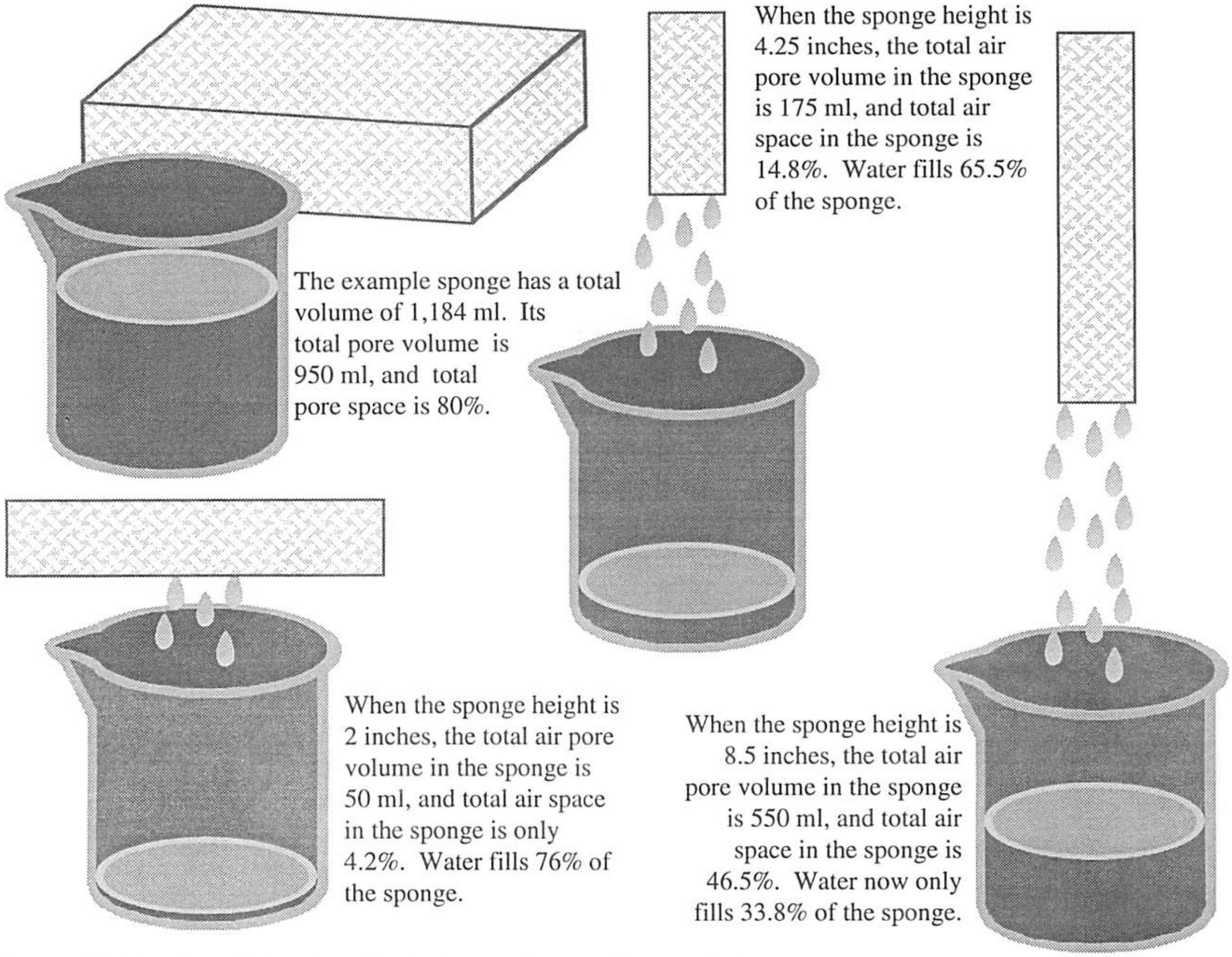


Figure 3. Container height drastically affects air space in a substrate.

hand or machine flat fillers and pot fillers. The substrate should not be packed down, and pots and trays should not be stacked directly over one another. Air space can be cut in half or even completely eliminated by compaction.

The second consideration is the *moisture content* of the mix prior to container filling. When water is added to dry components, such as peat, they hydrate and swell. This swelling helps to create more aeration by reducing the tendency of the particles to nest within one another. This effect is not so dramatic on larger containers, but can be the difference between success and failure of a plug crop. Most plug mixes tend to be inadequately moistened prior to flat filling. Water should be added to the mix before it is placed into the cells.

How much water should be added to the mix? For peat-based substrates used in large containers and bedding plant cell pak production, approximately 100% by weight is sufficient. Plug mixes should have approximately 200% by weight water added to them prior to filling the plug tray. The rule of thumb is, the smaller the cell, the more water to add prior to planting. This level of moisture will seem much wetter than "normal," but will actually improve aeration. A word of caution for plugs, do not soak down the mix after seeding. Light misting for germinating the seed is fine but the mix does not need more moisture after filling.

Pre-filling pots, cell paks or plug trays and letting them dry out can be detrimental if they are handled much before they are remoistened.

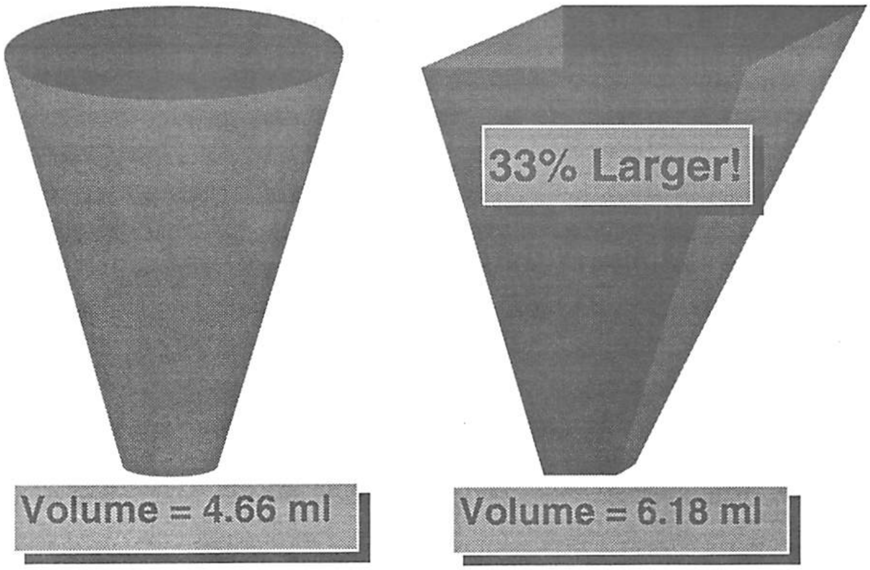


Figure 4. Container shape can affect cell volume, as demonstrated by these two 288 cells.

Continuous flow mixers can also cause problems when portions of the mix sit on the conveyor belts overnight. Slight separation of the mix can occur on the belt which can result in a "different mix" in several containers.

Watering Practices. The fourth "corner" for air and water in cells is watering practices. How you water a mix can influence air and water content in the root zone more than the mix itself, especially for plugs. Because plugs do not drain well they are easily over-watered. There is an old saying in the greenhouse business, "the person at the end of the hose controls your profits." This is certainly true for plug production. Knowing when to water is perhaps the most important skill for a bedding plant grower. It is also the biggest headache.

Watering is the product of frequency of irrigation × volume of water applied. For best aeration and water availability, as cell size decreases, decrease water volume and increase irrigation frequency. Also, the smaller the cell size, the smaller the droplet size should be to avoid "blasting out" the cells and plants.

By understanding the four corners outlined in Figure 1, you can begin to use them as management options. They should be considered together, as a package when trying to optimize the air and water conditions in bedding plant cells. Each of the factors are interrelated, and none can be modified without affecting the rest.

Nutrition

The chemistry of nutrition in greenhouse crops can be very complex and varies from crop to crop and even from season to season. However, the basics are generally the same.

Incorporated fertilizers. A minimum base charge is placed in the mix (Table 1) and additional nutrition is applied as liquid feed. This gives the grower added flexibility in speeding up or holding back plants.

The incorporated charge should supply ample calcium (Ca) and magnesium (Mg) for short term crops such as bedding plants from the dolomitic lime added for pH control . It will also supply sufficient micronutrients for short term crops as long as the substrate pH is managed correctly. For more long-term crops such as pot mums and poinsettias, additional Ca, Mg and micronutrients may be needed during the cropping cycle.

Phosphorus additions are also made during greenhouse production, even though phosphorus is included in most substrates during blending. Sulfur is also included in most substrates. The addition of nitrogen and potassium charges is optional. If liquid feed can be started soon after planting then they are not necessary additions to the mix. However, fast growing crops such as chrysanthemums and poinsettias may benefit from a preplant charge of both N and K.

Substrate pH. The pH of the substrate, as estimated by measuring the pH of a substrate extract, is very important to plant nutrition. The pH directly affects the availability of many plant nutrients, especially micronutrients.

Table 1. Nutrient sources commonly added into greenhouse substrates during formulation.

	Rate per cubic yard	
Nutrient source	Soil-based substrates	Soilless substrates
To provide calcium and magnesium		
Dolomitic limestone	0 to 10 lb	10 to 15 lb
To provide phosphorus and sulfur		
Superphosphate (0-20-0)	3.0 lb	4.5 lb
OR		
Treble superphosphate (0-45-0)	1.5 lb	2.25 lb
+ gypsum (calcium sulfate)	1.5 lb	1.5 lb
To provide micronutrients: iron, manganese, zinc, copper, boron, and molybdenum		
F-555HF	3 oz	3 oz
OR		
F-111HF	1 lb	1 lb
OR		
Esmigram®	5 lb	5 lb
OR		
Micromax®	1 to 1.5 lb	1 to 1.5 lb
To provide nitrogen and potassium (optional)		
Calcium nitrate	1 lb	1 lb
Potassium nitrate	1 lb	1 lb

Too low of a pH can result in increased micronutrient availability that can lead to phytotoxic responses in some plant species. For example, a low pH in conjunction with excessive levels of iron and manganese can result in iron and / or manganese toxicity in geraniums and marigolds.

At the other end of the spectrum, pH above 6.2 can lead to micronutrient deficiency problems such as iron deficiency chlorosis in petunias and azaleas; and boron deficiency in salvia, petunias, and pansies. Both excessively low and high pH's should be avoided in greenhouse production.

Most greenhouse crops grow best at pH 5.4 to 6.0, but some crops such as azaleas prefer a more acidic substrate (4.5 to 5.8) while others such as Easter lilies are grown at a higher pH (6.5 to 6.8). Although most mix pH recommendations call for a range of 5.4 to 6.0, it may take from 24 hours to 7 days for the pH to adjust up to this level after the mix has been moistened. This will depend on the ratio of components, particle size and grade of lime used, the salts used to make the base charge, and the pH and alkalinity of your irrigation water. Prior to using a mix, fill a few pots with it, water them in with distilled water, and set them in the greenhouse for a few days, keeping them moist. After this "equilibration period", measure the pH of the substrate; it should be within the range given above for best results. Monitoring and controlling substrate pH is essential in a greenhouse fertility program.