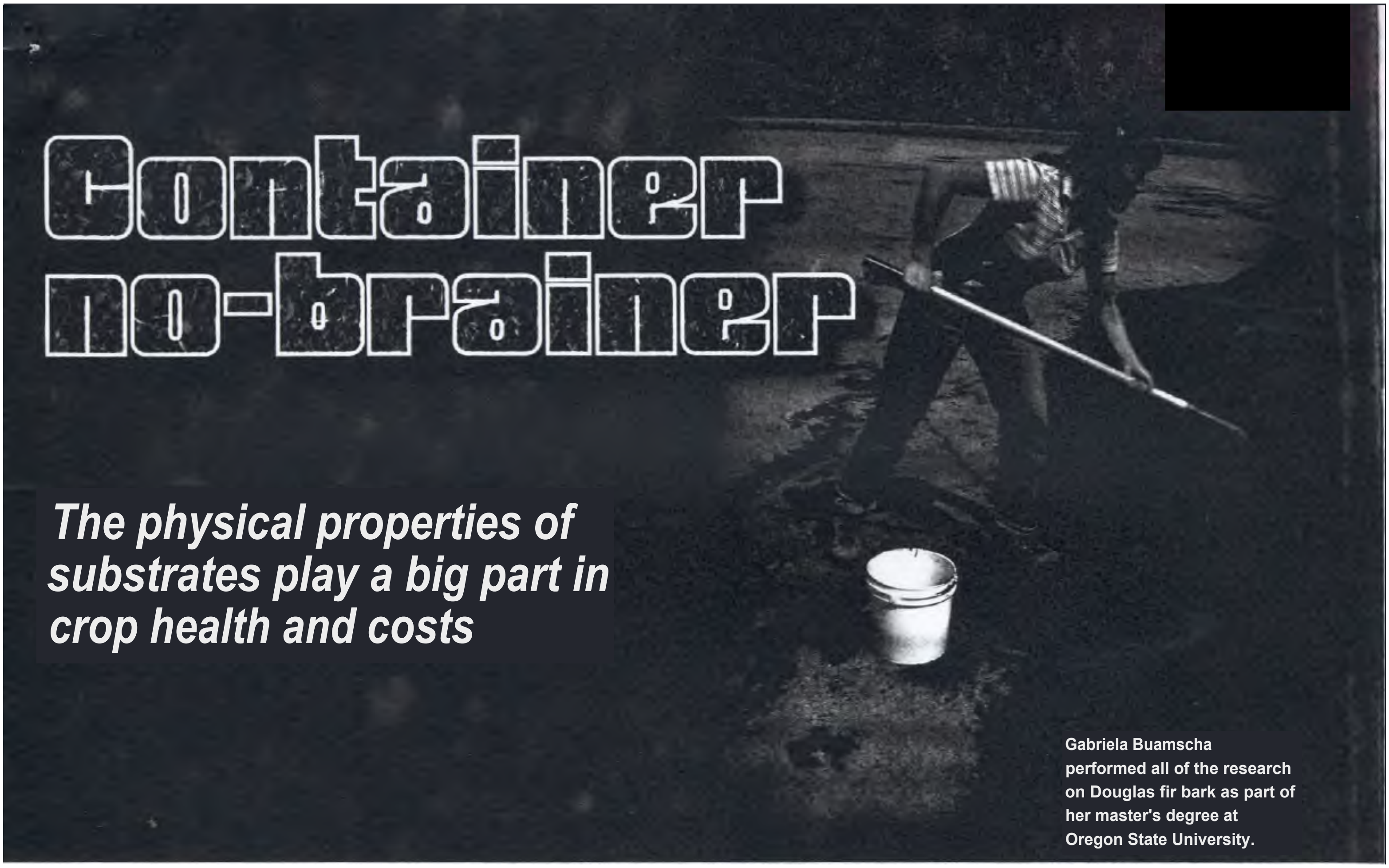
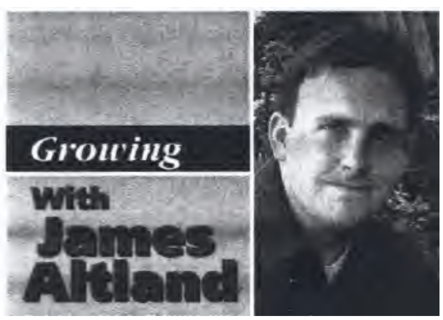
Container no-brainer

The physical properties of substrates play a big part in crop health and costs



Gabriela Buamscha performed all of the research on Douglas fir bark as part of her master's degree at Oregon State University.



Physical properties of substrates used in nursery containers have important implications for irrigation management, fertility management, weed control and freight costs. This article will discuss the important physical properties of Douglas fir hark, based primarily on new research conducted over the past two years at Oregon State University. Most of this work was generously funded by the Oregon Association of Nurseries, through the Oregon Department of Agriculture.

Basic information on substrate physical properties was presented in a previous *Digger* article (September 2003). This article will further discuss the importance and interpretation of several physical properties. We also provide reference information for the physical properties of fine (<3/8 inch) and medium (<7/8 inch) grade Douglas fir bark.

Water vs. air in substrates

Water and air relations in a substrate are inherently linked, so it makes sense to discuss them together. Fill a container with any substrate and there will he solid particles, with small spaces between the particles called pores. The percent of container volume composed of pore space is referred to as *total porosity (TP).* Pores in a media must be filled with either air or water. The fraction filled with air is called ***air space*** (AS) and the fraction filled with water is called *water-holding capacity* (WHC).

Container media should contain 50 percent to 85 percent TP. Total porosity of container media is important, but more crucial is the portion that is AS versus WHC. Some plants prefer wet soils, while others prefer dry soils. On average, 10 percent to 30 percent of the container volume should be composed of air space, and 45 percent to 65 percent should be water.

Table 1 shows the AS, WHC and TP of fresh and aged Douglas fir bark. Note that AS and WHC always sum to equal TP. Total porosity for fresh and aged bark are similar; however, AS is slightly higher and WHC is slightly lower in fresh bark compared with aged hark. Differences were minor and not likely to affect irrigation requirements of the crop. Research at North Carolina State University indicated that differences in plant growth among crops grown in fresh or aged *pine* bark were due to the fact that fresh bark held less water. However, differences in AS and WHC in North Carolina pine bark were much greater than differences in Douglas fir bark observed in our research.

Native Douglas fir bark has high AS, low WHC, and adequate TP, compared with guidelines developed for pine bark in the southeastern U.S. (Table 1). Some nursery managers believe Pacific Northwest substrates, particularly those used in Oregon,

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Table 1.
Water-holding capacity, air space and total porosity of fresh and aged Douglas fir bark from two different grades.

Grade	Type	WHC (%)	AS (%)	TP (%)
Medium	Aged	40	43	83
	Fresh	32	49	81
Fine	Aged	48	36	84
	Fresh	42	39	81
Recommended[z]		45 to 65	10 to 30	50 to 85

[z] Values recommended based largely on work done in the southeastern U.S. on pine bark substrates.

must have more AS and less WHC than what is recommended in the Southeast. This stems from the thought that Pacific Northwest substrates need to compensate for the higher precipitation rates during the dormant winter season typical of this area. Lack of drainage during the winter, when plants are transpiring little or no water through foliage, coupled with high precipitation rates, has caused root rot problems with some species.

Water and air distribution

Water is not distributed evenly throughout the container. Adhesion, cohesion and capillary action attract water to particles and resist gravity. The ability of media to hold water through adhesion and cohesion is referred to as *matric potential.* Matric potential is the same throughout the container. Gravity pulls water down through the container and out of the drainage holes. While gravity is constant throughout the container, *gravitational potential* is greater at the top of the container and lower at the bottom. Because of this gradual decrease in gravitational potential toward the container bottom, matric potential is higher at the container bottom and media particles are able to hold more water. This causes a *perched water table,* or layer of saturation, at the container bottom.

Figure 1 shows the relationship between WHC and AS at each level of a 6-inch-tall container filled with either medium or fine-grade Douglas fir bark. Most researchers agree that that ideal AS for vigorous growth in container substrates is 10 percent to 30 percent. Medium-grade Douglas fir bark has over 51 percent AS in the surface's top inch. The AS:WHC gradient has important consequences on new plantings, especially plantings of small hare-root plants. Consider the water needs of a recently planted bare-root shrub. At planting, how deep in the container will its roots reside? Will there be sufficient WHC at that depth in the container to support root growth? This is why recently potted liners should be irrigated more frequently but with less water volume.

Bulk density

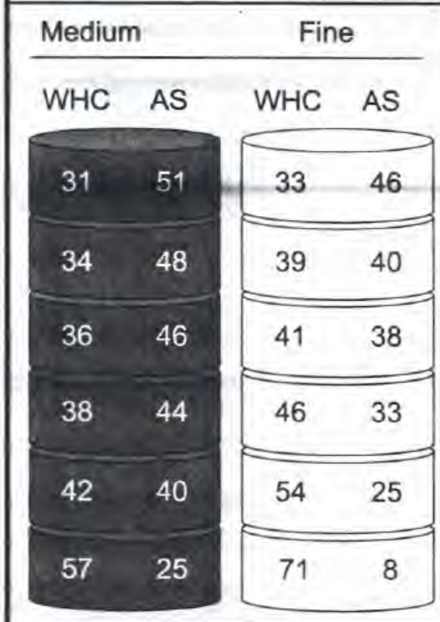
Bulk density is a measure of a substrate's weight to volume, usually expressed in lb/ft^3 or g/cm^3. The effectiveness of a soil or substrate to anchor plants is primarily a function of hulk density. Filling a 1-gallon container with sand weighs more than the same 1-gallon container filled with Styrofoam beads; sand has a higher bulk density. Imagine planting liners in containers filled with sand or Styrofoam beads. The liners will be better anchored in sand due to higher bulk density, as opposed to Styrofoam.

Bulk density has other consequences in nursery production aside from how well liners are anchored in the substrate. As bulk density of a substrate increases, so will the costs to ship a given number of container plants.

Another notable consequence of hulk density is the application rate of some insecticides. Talstar (bifenthrin) rates for container substrates must be increased with increasing substrate hulk density. Nursery producers must choose a substrate with sufficiently high bulk density to ensure adequate plant anchorage but low enough hulk density to moderate shipping costs and minimize some pesticide applications.

Bulk density of Douglas fir bark is 0.17 to 0.20 g/cm^3, and it is generally the same for fresh and aged hark. We found that bark of different grades (coarse and fine hark) have similar hulk densities. Our research has also shown that adding pumice (bulk density of 0.4 to 0.5 g/cm^3) to Douglas fir hark will increase hulk density with increasing rates (Table 2). In contrast, adding peat moss (hulk density of 0.08 g/cm3) gradually decreases hulk density.

Figure 1.
Water and air distribution in a 1-gallon container with medium- and fine-grade Douglas fir bark (aged bark).



WHC — Water-holding capacity
AS — Air space

Particle size distribution

Container substrates can be characterized by their particle size distribution. You can look at a substrate, move it around through your fingers, and intuitively gauge that substrate as being either fine or coarse in texture (or something in between). A more objective measure of particle size is performed with a series of screens. A pre-measured sample of substrate is dried in an oven and then shaken through a series of screens to determine the relative amount of each substrate at each particle size. Particle size distribution for fresh and aged bark differed slightly (Table 3).

Particle size distribution can be used to make judgments about a substrate's ability to hold water. The more small particles a substrate contains, the smaller the pores and the greater the water-holding capacity. Larger particles result in larger pores and less water-holding capacity (more air space). A general rule of thumb is that 70 percent to 80 percent of the particles should be within a range of 0.6 to 9.5 mm in diameter, and the remaining particles should be less than 0.6 mm. Douglas fir bark studied in our research is near the high end of this rule, which is a good thing, considering Pacific Northwest substrates should be slightly more coarse than what is expected in the southeastern U.S.

Conclusions

Physical properties of the substrate used by your nursery depend on the combination of components used in the mix. The physical properties described in this article are some of the properties you should be aware of when comparing and contrasting substrates. This article also provides basic physical properties for Douglas fir bark, which is the base of most Oregon container substrates. The physical properties described here can be modified with additions of peat moss, pumice, perlite and many other materials.

Table 2.
Bulk density (g/cm^3) of fine- and medium-grade Douglas fir bark alone or amended with Sphagnum peat moss and pumice.

	Fine	Medium
Bark		
100%	0.17	0.17
Peat		
10%	0.16	0.15
20%	0.15	0.14
30%	0.14	0.14
100%	0.08	0.08
Pumice		
10%	0.21	0.21
20%	0.24	0.27
30%	0.27	0.29
100%	0.55	0.55

Fresh and aged Douglas fir bark had similar bulk densities across all samples we collected.

Table 3.
Particle size distribution of fresh and aged Douglas fir bark of two different grades.

	Medium bark (<7/8 inch)		Fine bark (<3/8 inch)	
Screen size	Aged	Fresh	Aged	Fresh
19.00	0	0	0	0
12.50	1	2	0	0
6.30	25	28	7	3
4.00	20	20	16	15
2.80	12	13	14	17
2.00	8	9	11	12
1.40	6	6	9	9
1.00	5	5	7	8
0.71	4	4	7	8
0.50	5	4	7	8
0.35	4	3	6	6
0.25	4	3	6	5
0.18	3	2	4	3
0.11	2	1	3	3
Pan	2	2	2	3

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