

# Physical properties of Oregon substrates

---



Dr. James Altland



# Today's talk

---

- Important physical properties
- The parent materials
  - Douglas fir bark
  - Pumice
  - Peat
- Substrate mixing

## A good container media must:

---

- Provide anchorage for the plant
- Provide a reservoir for water
- Allow oxygen/gas exchange for roots
- Retain nutrients for uptake

These are the 4 functions of a container substrate. Consider these criteria when selecting or changing a substrate for your container crops.

# What makes a container media?

---

- Media.....or.....Substrate
- Media is composed of one or more components
- Components
  - Bark
  - Perlite
  - Peat
  - Vermiculite
  - Etc.



A substrate, media, or potting mix, is a combination of one or more components.

- 
- “Making media is similar to making soup.”
  - “Learn to shift your thinking from ingredients and components to properties and parameters.”

– William Fonteno



When you add ingredients to make soup, the ‘components’ meld together so that often the original ingredients are not even recognizable. Similarly, when you add components of a container mix, the resulting substrate cannot be described simply by the additive properties of the original components. The new substrate is a unique substance.

For example, mix 1 cubic yard of bark and 1 cubic yard of sand, and you will NOT have 2 cubic yards of the resulting substrate. The sand settles between the pores of the bark to create mix that will be much less than 2 cubic yards.

Similarly, the physical properties of the resulting substrate are not the additive properties of the two original components.

# Physical properties

---

- Primary characteristics
  - Bulk density
  - Total porosity
  - Air space
  - Water holding capacity
- Secondary characteristics
  - Moisture retention

These are the primary physical properties that are often measured for container substrates. Moisture retention, or moisture release curves are also important, but very difficult to execute accurately. Data from moisture release curves should be interpreted cautiously.

# Bulk density

---

- Bulk density
  - Weight per unit volume
    - Styrofoam beads – very low bulk density
    - Sand – very high bulk density
  - Ideal bulk density
    - 70-90 lb/ft<sup>3</sup>
    - 0.15 – 0.3 g/cm<sup>3</sup>

# Bulk density

---

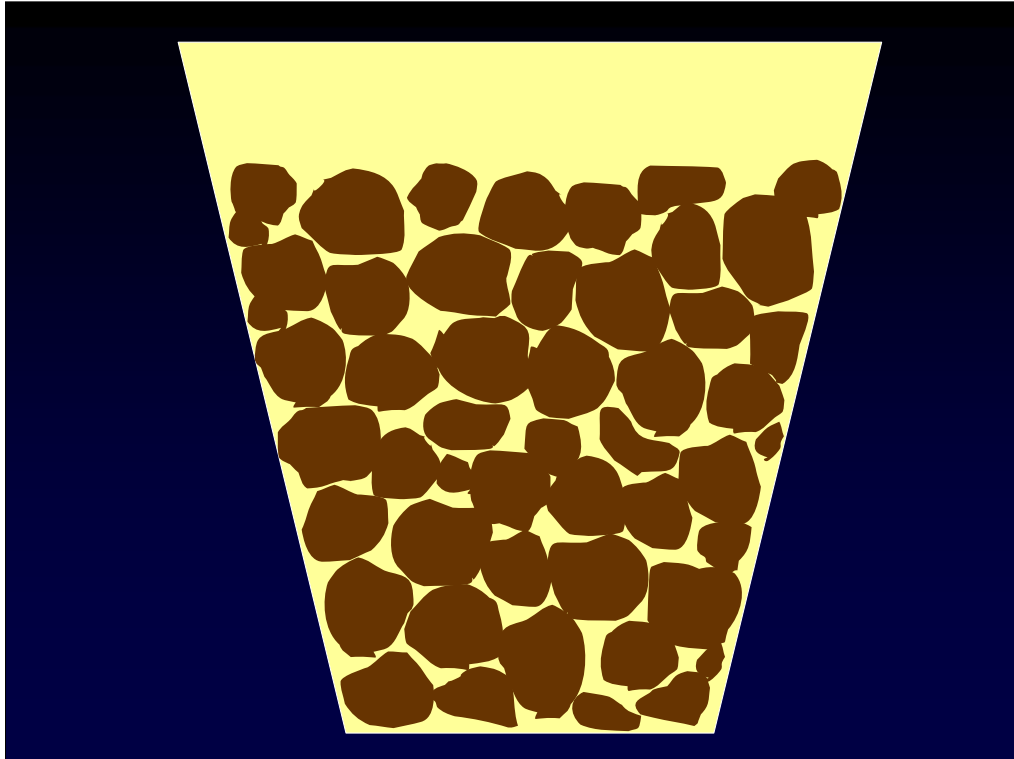
- Increased bulk density
  - More stable pots, less blow-over
  - Heavier pots for moving
  - Heavier pots for shipping (freight cost)
  - Talstar incorporation based on BD



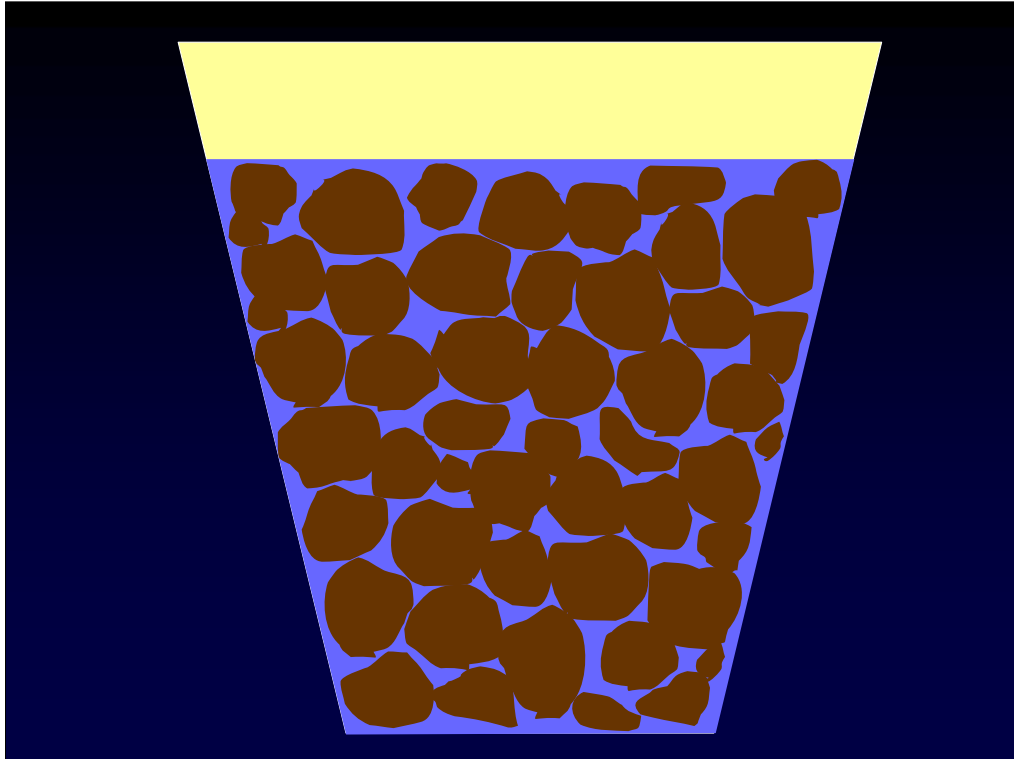
# Provide a reservoir for water

---

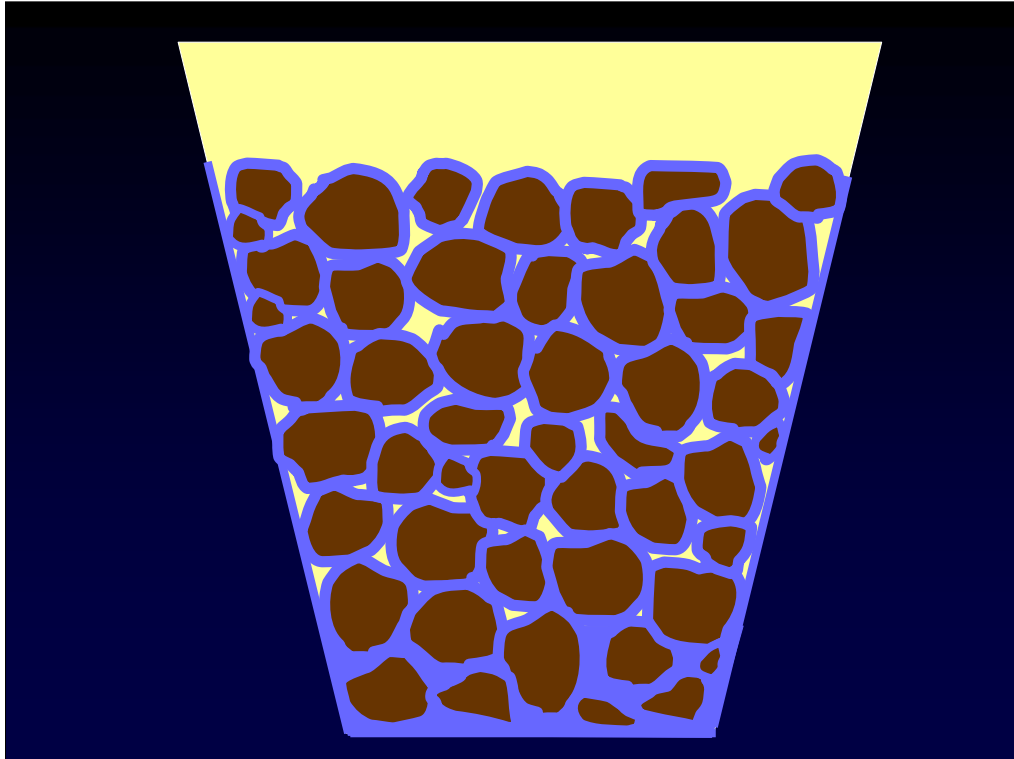
- Total porosity (%)
  - The percent of a container composed of pore spaces
  - Total porosity (TP) is composed of :
    - Air space (AS)
    - Water (WHC)
- $TP = AS + WHC$



When bark (or any substrate) is added to a container, a portion of the container is filled with solids, and a portion is empty spaces. The total of the empty spaces is called 'Total Porosity'.



One could imagine filling all the empty pore spaces with water.



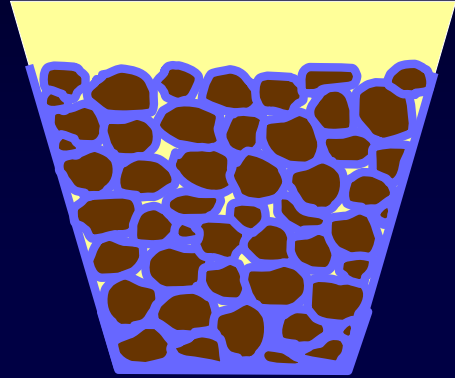
When the water is drained, a portion of the container pore spaces retains water. This fraction of the container is called the Water Holding Capacity (WHC).

The fraction of the container from which water drains and is subsequently filled with air is called Air Space.

# Air space

---

- The portion of the container filled with air, after the media is thoroughly irrigated, then allowed to drain.



# Air space

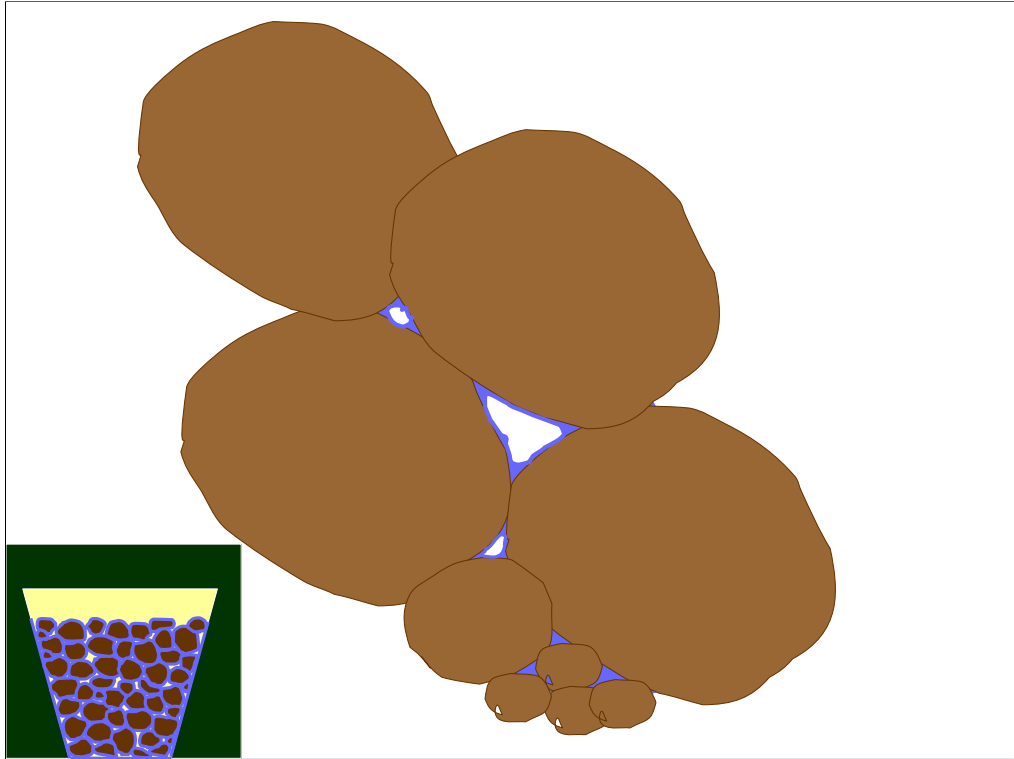
---

- Roots require oxygen for respiration.
  - Respiration is a biological process that converts sugars into energy.
- Roots exude  $\text{CO}_2$ , which must be diffused away from the root surface.

# Water holding capacity

---

- WHC of a media
  - The portion of the container that is water, after irrigated and allowed to drain.
- The amount of water held in a container depends on 2 things
  - Media particle size
  - Container height

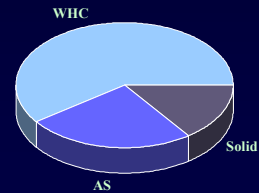
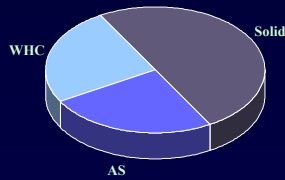


Small pore spaces are completely filled with water. Larger pores are partially filled with air, with water forming a film around the soil particles.



# Normal ranges – soil vs. container

- Field soil (typical)
  - Solids – 50%
  - Total porosity – 50%
    - Air space – 25%
    - Water holding cap. – 25%
- Container (1 gallon)
  - Solids – 15%
  - Total porosity – 85%
    - Air space – 25%
    - Water holding cap. – 60%



Compare and contrast the porosity, air space, and water holding capacity of a typical soil and typical container substrate.

# Water holding capacity

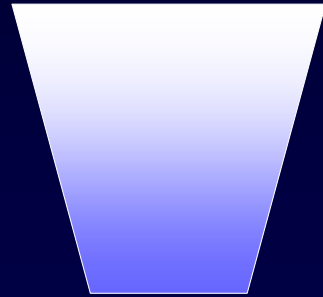
---

- Unavailable water
  - Volume of water in a container not available to plants
  - Water in very small pores ( $<0.03$  mm)
  - Water that adsorbs to the surface of soil particles in large pores.
- Available water
  - Water available to plants
  - In most container media, roughly  $\frac{1}{2}$  the volume of water is available (so  $\frac{1}{2}$  is unavailable).

# Under pressure!!!!

---

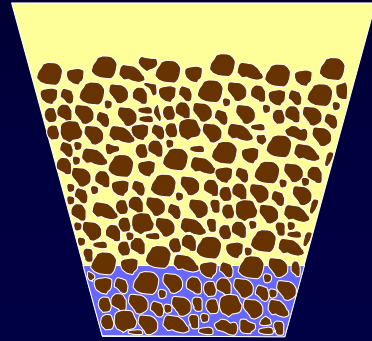
- Gravitational potential
  - Water runs down hill
  - Gravity pulls water down, and through drain holes in the container bottom
- Matric potential
  - Water resists gravity by:
    - Hydrogen bonding to solid particles
    - Capillary action



# Perched water table (PWT)

---

- At bottom of container, matric potential of media exerts greater pull than gravitational potential
- A perched water table is formed at the bottom of containers



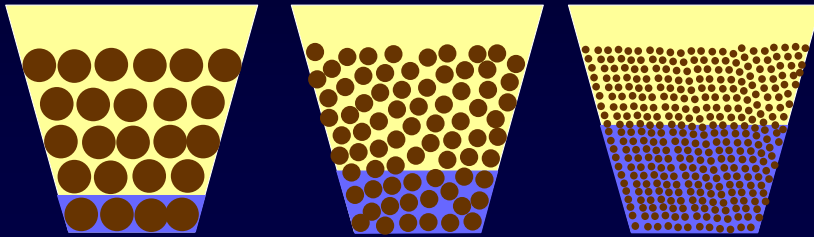


Notice the volume of water that occurs in each section of a container. From top to bottom, the amount of water gradually increases and forms a zone of saturation near the bottom of the container.

# Factors affecting perched water table

---

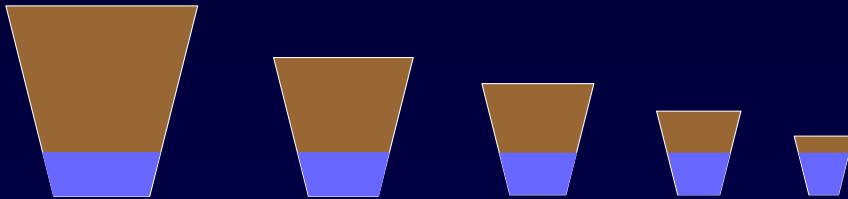
- Coarse particles
  - Large pores
  - Lower PWT
- Fine particles in media
  - Small pore spaces
  - More capillary action
  - High PWT



# Height of container

---

- Perched water table will be at the same height, regardless of container height.
  - Assuming the same media



# Ideal ranges for container crops

---

- Total porosity
  - 50-85%
- Air space
  - 10-30%
- Water holding capacity
  - 45-65%

These are listed as ideal ranges for containers in the southeast U.S.

Should Oregon follow the same recommendations?

Some Oregon nursery producers believe our substrates should have more Air space and less WHC to allow for winter drainage.



# Substrate mixes

---

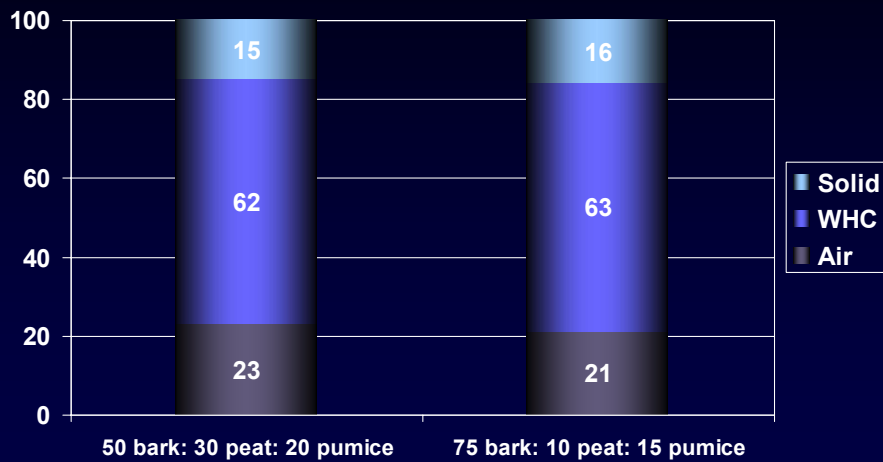
- How does pumice and peat affect container physical properties?
- How does bark particle size affect physical properties?

## Two popular Oregon mixes

---

- 50% bark      30% peat      20% pumice
- 75% bark      10% peat      15% pumice
- Which has greater porosity?
- Which has greater water holding capacity?

# Physical properties of 2 substrates



These are the measured physical properties of the two previously listed substrates. Despite drastically different component rates, their physical properties are very similar.

# The raw materials

---

- Douglas fir bark
- Pumice
- Peat moss

# Where does bark come from?

---



Doug Page, USDI Bureau of Land management, [www.forestryimages.org](http://www.forestryimages.org)



David P. Shorthouse, University of Alberta, [www.forestryimages.org](http://www.forestryimages.org)



Chris Schnepf, University of Idaho, [www.forestryimages.org](http://www.forestryimages.org)

Trees are harvested by lumber mills virtually year-round. Bark removal is easy during the spring when water flows readily through xylem. However, during fall and winter, bark is more difficult to remove thus lumber mills scrape more wood off the tree in an effort to remove all the undesirable bark. Higher concentrations of wood in bark supplies is just one way that chemical and physical properties of bark change throughout the year.



Large bark piles at a local (Oregon) bark supplier.

It's important to note that Douglas fir bark is often 'aged', or stored in large piles for 3 to 7 months. It is not composted. Composting would require that it be stored in piles about 8 feet high, irrigated, turned occasionally, aerated, etc. The process shown above is not composting.



In the foreground is aged bark, in the background is fresh bark. Notice the change in color. The aging process is poorly understood with Douglas fir bark in Oregon. One of our goals was to document the differences in fresh and aged Douglas fir bark with respect to its physical properties.

# Introduction

---

- Douglas fir bark
  - Primary container component
- Fresh and aged bark are used
- Aged bark
  - Large piles sit undisturbed for several months.
  - Not composted.



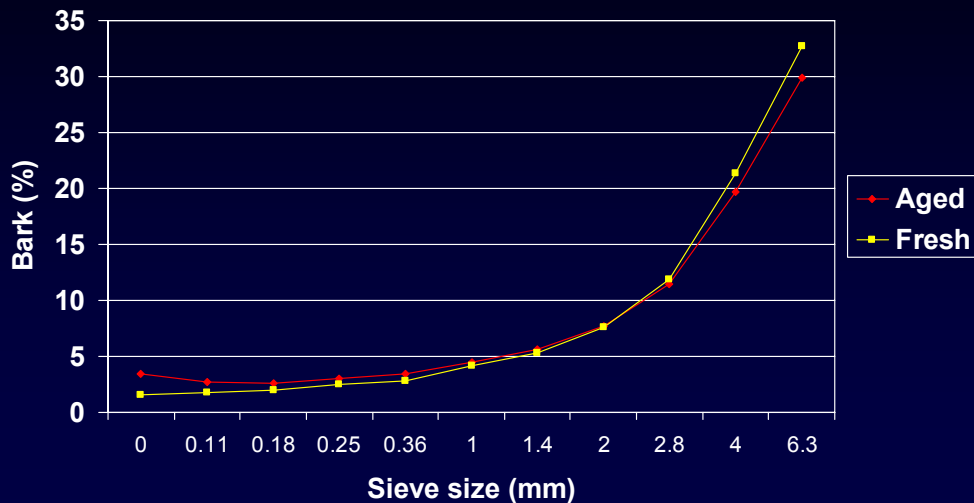
DF bark is the primary container component in Oregon nurseries.

Aged bark refers to large piles of this material that have been sit undisturbed for several months.

It is important to note that the aging process is not a true composting process.



# Particle distribution of raw bark

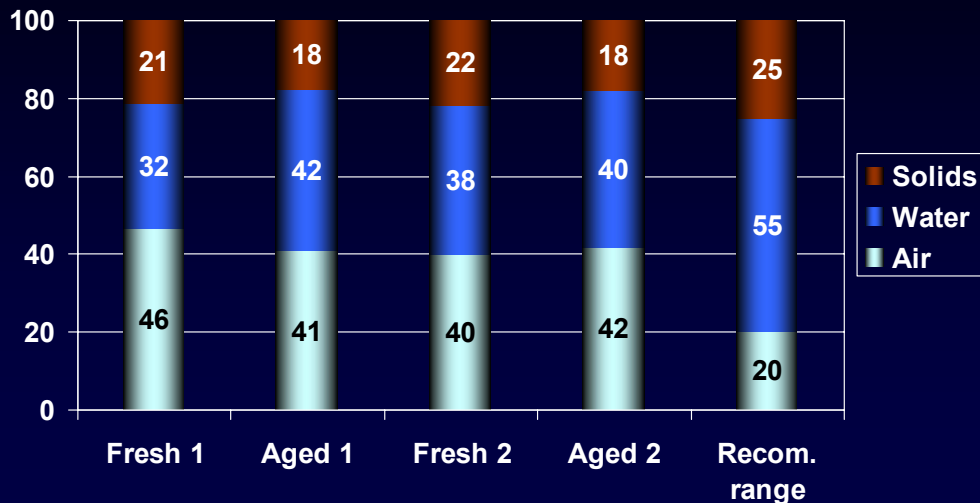


Particle size distribution:

Along the X axis is the sieve size in mm. Along the Y axis is the percent by weight that was retained in each sieve size.

Fresh bark has a slightly higher percentage of large particles, while aged bark has a slightly higher percentage of fine particles. Differences are very minor.

# Physical properties of raw bark



Aluminum porometer:

Along the x axis are listed the bark types and the recommended range of physical properties for container media.

Along the y axis is the percent of the container volume attributed to solids, air space, and water holding capacity.

When used as the sole substrate, the four bark types have less than ideal water holding capacity and high air space. However, there is no difference between the four.

# Pumice

---

- Raw volcanic material
  - Mined
  - Graded to size
- Contains vesicles
  - Light weight (when dry)
  - Porous



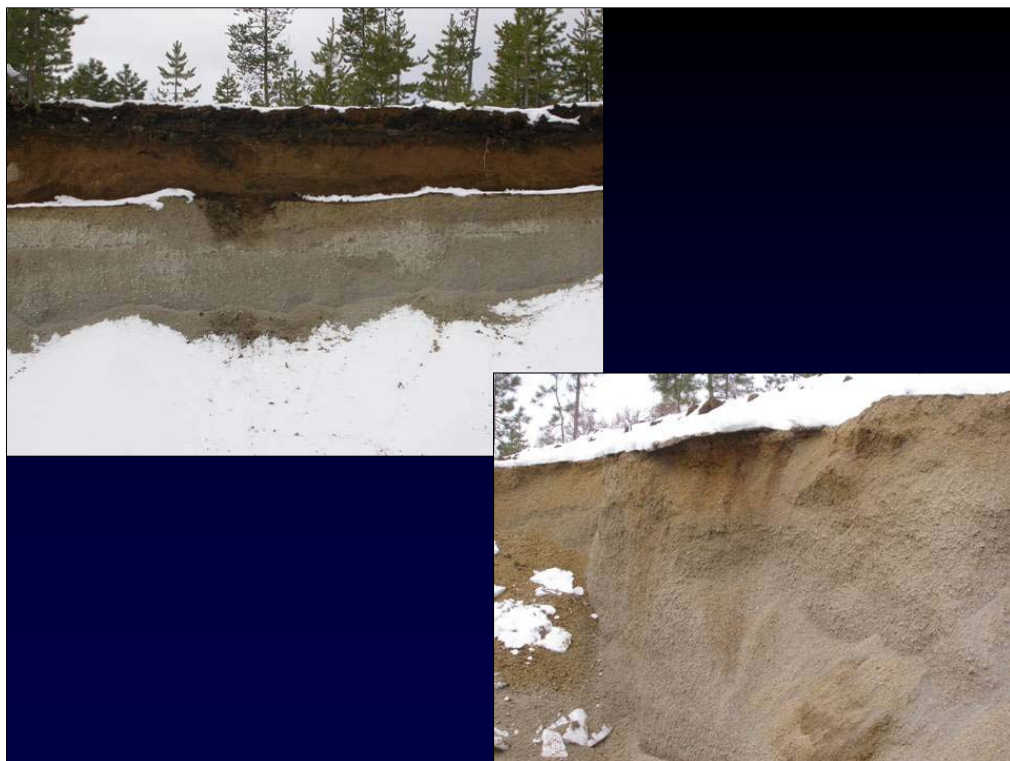
A pumice mine in Oregon (near Bend). The grey ribbon of pumice at the bottom is about 20 feet thick. A layer of volcanic ash sits on top of this ribbon and can range from 20 to 100 feet thick.



Up close to the ribbon layer.



Pumice in the mine appeared grey in color, however, when it dries it turns more white. (Note that this and the previous slides showed pumice from a mine near Bend, OR).



These photos were taken from another mine further south in Chemult, Oregon. This ribbon of pumice is closer to the surface.





Machinery used to grade pumice to a particular size.





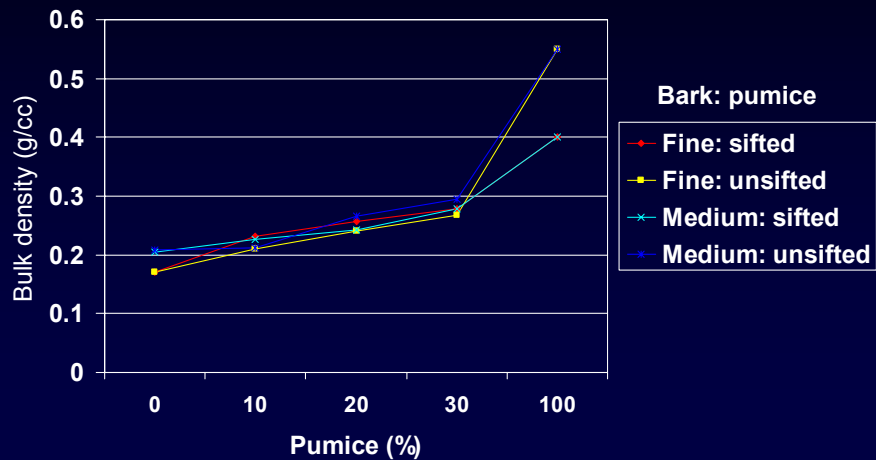
Pumice and the various particle sizes from the mine near Bend.



Notice the slight yellow color in the pumice from the mine near Chemult, OR. This difference in color is mostly due to its slightly lower  $\text{SiO}_2$  content.

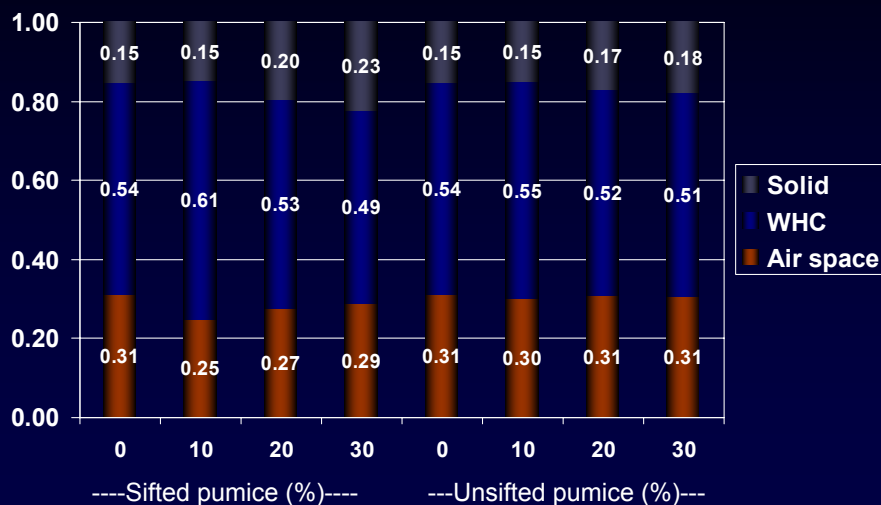
# Bulk density of bark + pumice

---



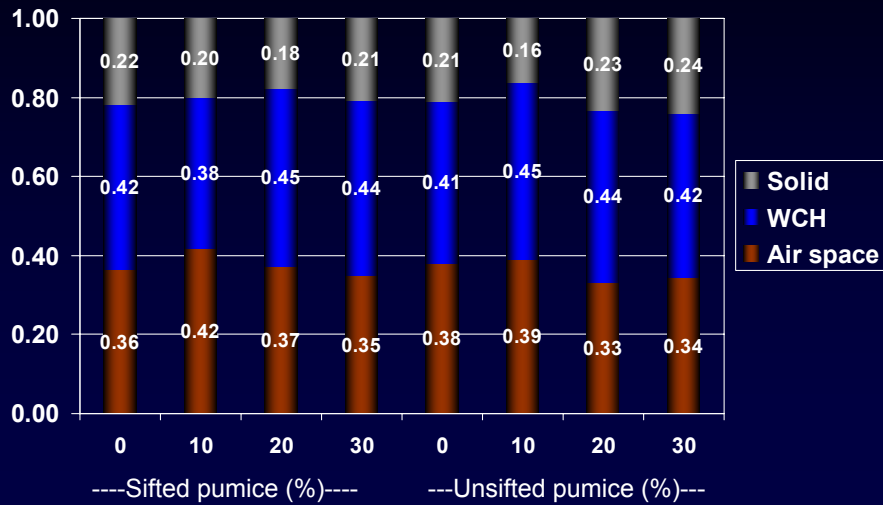
Adding pumice to bark increases the bulk density of the mix, regardless of the bark type used.

# Fine bark + pumice



Adding pumice to bark does not significantly change the physical properties of the resulting substrate.

# Medium bark + pumice



Same data for medium grade bark, again no change in physical properties from additions of pumice.

# Pumice

---

- Adding pumice to Douglas fir bark
  - Increases bulk density
    - Stability
    - Increased weight
  - Has little or no impact on container physical properties (AS, WHC, P)
  - Does it reduce compaction over time?
  - Does it improve moisture retention?

# Peat moss

---

- Peat – organic residues of plants, incompletely decomposed due to lack of oxygen
- Peat used in Oregon is primarily *Sphagnum* peat moss
  - Other types not used
    - Hypnum peat, reed peat, sedge peat

- 
- Sphagnum peat moss
    - Derived from peat bogs, composed of >60% mosses in the genus *Sphagnum*
    - Considered the highest quality type of peat moss for horticulture



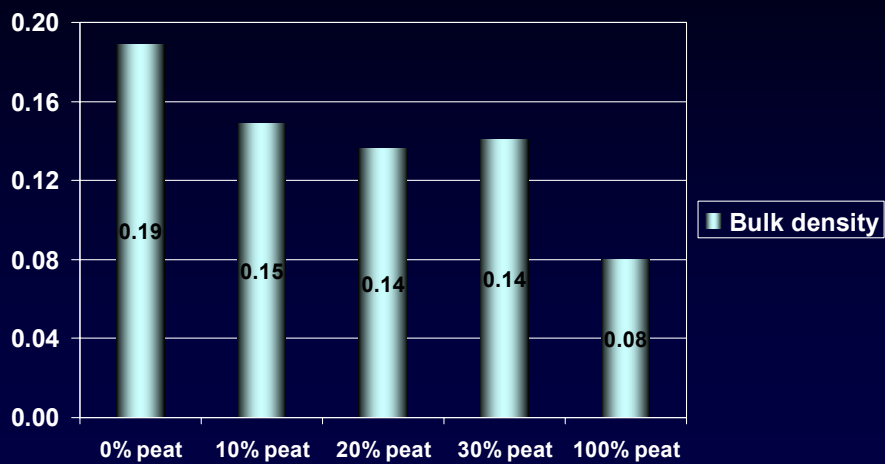
# Sphagnum peat moss

---

- pH: 3.6 to 4.6
- Weed content: 0
- Bulk density: 0.07 to 0.09 g/cc

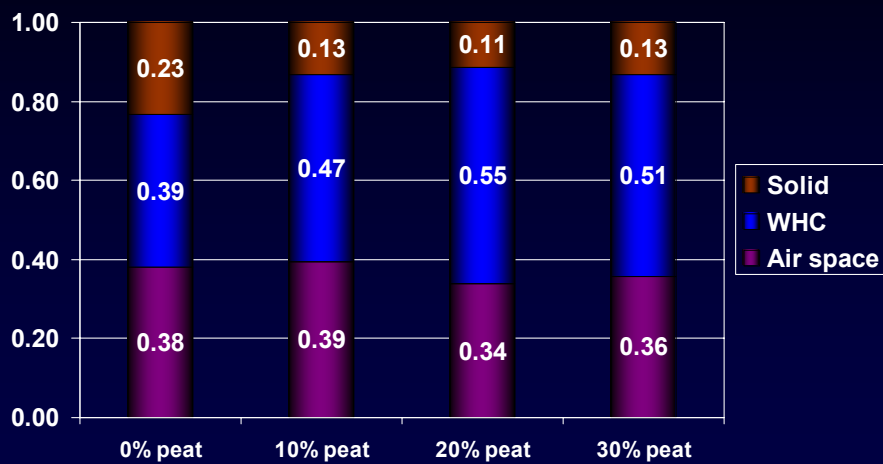
## Medium grade bark + peat

---



Adding peat to medium grade bark lowered its bulk density.

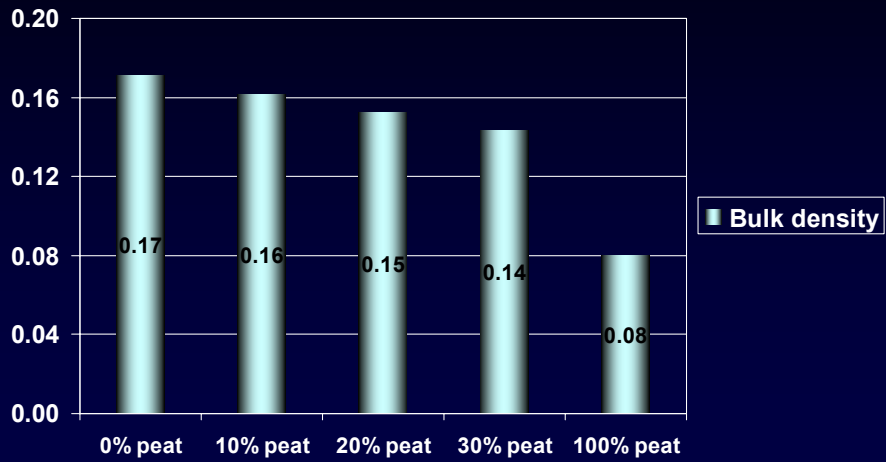
## Medium grade bark + peat



Adding peat to medium grade bark increased the WHC of the resulting substrate.

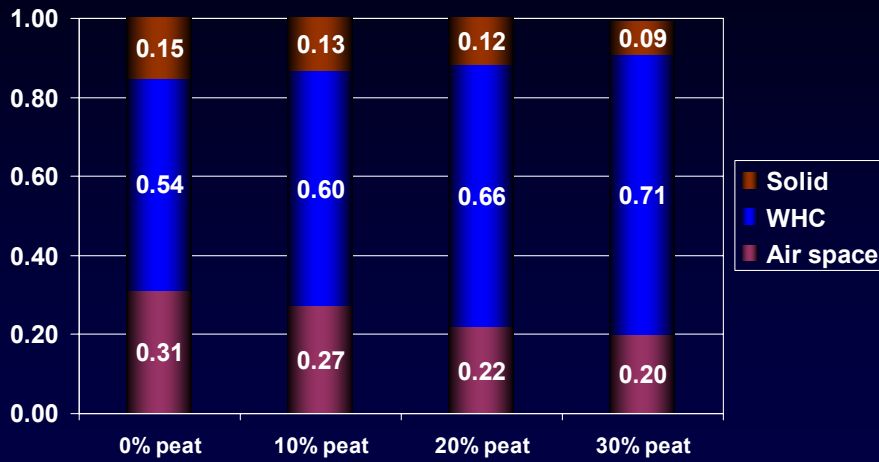
## Fine grade bark + peat

---



Peat also lowers bulk density of fine grade bark.

## Fine grade bark + peat



Adding peat to fine grade bark decreased air space and increases water holding capacity.

# Peat moss

---

- Spongy, fibrous material capable of storing large amounts of available water.
- Increases WHC of Douglas fir bark
  - Decreases air space
- Decreases bulk density

# Summary

---

- Physical properties of Oregon substrates are not well documented
- Future work
  - Further investigate interaction of primary substrate components
  - Develop better guidelines for Oregon nursery growers in selecting substrates.

# Website

---

- <http://oregonstate.edu/dept/nursery-weeds/>