Internal Porosity, Water Availability, and Root Penetration of Pine Bark Particles

F.A. Pokorny and Hazel Y. Wetzstein
Department of Horticulture, University of Georgia, Athens, GA 30602

Abstract. Internal porosity, availability of internally adsorbed water, and root growth within a pine bark particle were studied. Internal pore spaces comprised about 43% to 44% of the volume of a pine bark particle. Scanning electron microscopy (SEM) of Coleus blumei Benth. and Vaccinium ashei Reade showed roots anchored on the exterior surface and developing within the bark particle. Seedling development (Raphanus sativus L.) in water-saturated pieces indicated that internally adsorbed water was available provided that roots developed within the bark particle. The quantity of available water remains to be determined.

Milled pine bark is a major organic component of nursery and greenhouse potting media used in the southeastern United States. Utilization of pine bark is advantageous because: a) it is readily available at comparatively low cost (10); b) it is resistant to rapid decomposition (3, 8); c) it suppresses certain plant pathogens (6, 7); and d) it is a renewable resource (9).

Bark is essentially a porous medium component. Its structure, after hammer-milling, has been described (1). Airhart et al. (1) have shown that openings exist externally, allowing entry of water to the internal structure of the bark particle. In addition, large openings (5–60 nm) are found on obliterated phloem surfaces, and interconnecting channels exist within the internal structure of the particle. Found less commonly are minute (5–10 nm) openings on phellogen surfaces (1). As postulated by Brown and Pokorny (4), and confirmed by Airhart et al. (2), these openings and pores within bark particles are filled with water and nutrients which may be retained for plant use. Water adsorbed internally by porous amendments such as vermiculite, hardwood bark, and others, however, is not considered available for plant use (12). This study was conducted with the following objectives: a) to quantify the internal porosity of a pine bark particle, and b) to determine if water adsorbed by a bark particle is available for plant use.

Twenty pieces of mulch grade (particle size > 2.5 cm) bark (Pinus taeda L.) were oven-dried at 80°C. Ten pieces were reduced to 2.5 cm² while 10 pieces were left intact. Thickness of particles ranged from 7 to 10 mm. Water adsorbed to external surfaces of a bark particle was determined by treating oven-dried bark particles with 0.13% surfactant solution and removing the excess. Surfactant-treated particles were weighed, and volume of bark pieces was determined using a water pycnometer.

Oven-dried particles were submerged in water in a vacuum desiccator and kept in a vacuum (~150 mm Hg) for 96 hours to wet the particles thoroughly (2). The moistened bark particles were weighed, and internal porosity (percentage of volume) was calculated as: 

\[ P_j = \left( \frac{W_j - W_2}{V_j} \right) \times 100 \]

where \( P_j \) = internal pore space (% volume); \( W_j \) = internal wet weight; \( W_2 \) = saturated weight; \( V_j \) = volume of pine bark particle.

Radish seeds (Raphanus sativus L. ‘Cherry Belle’) were placed on moistened Whatman No. 1 filter paper in covered, disposable Petri dishes (100 × 15 mm). Seeded dishes were placed under fluorescent light (49.3 μmol m⁻² s⁻¹) at 20° to 25°C for germination.

Fifty pieces of mulch grade bark were reduced to 25 mm long × 19 mm wide × 9 mm thick. Cut pieces were forced air-dried at 80°C and then saturated with deionized water in a vacuum desiccator as previously described. Twenty-five water-saturated bark pieces were placed on absorbent paper to remove excess surface water. A radish seed with emerging radicle was inserted into a predrilled hole in each bark piece. Oven-dried pieces were seeded similarly. Each seeded piece was covered with moistened paper and sealed.

Table 1. Internal porosity of 2 types of pine bark particles obtained from mulch grade bark (P. taeda L.).

<table>
<thead>
<tr>
<th>Particle size</th>
<th>Vol (%)</th>
<th>SE</th>
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<tr>
<td>Intact particle</td>
<td>&gt; 2.5 cm</td>
<td>44.0 ± 2.8</td>
</tr>
<tr>
<td>2.5 cm² particle</td>
<td>42.7 ± 2.4</td>
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</table>

Values are the means of 10 replications.

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Fig. 1. Internal structure of a pine bark particle showing numerous pores (×610).
bark piece was placed into a culture tube, sealed with a plastic cap, and placed on a lighted shelf (49.3 μmol s⁻¹m⁻²) at 20° to 25°C. Light was provided by cool-white fluorescent lamps from 0800 hr to 2400 hr daily. The experiment was conducted as a completely randomized design with 25 replications on 24 Apr., and repeated on 5 May. Plant fresh weight was determined at the conclusion of the experiments.

To account for possible humidity differences between radish seedlings grown in tubes containing oven-dried bark and water-saturated bark, the above experiment was repeated with an additional treatment. An identical piece of unseeded, water-saturated bark was suspended in the top of the culture tube of the oven-dried bark treatment.

Intact, oven-dried bark particles were cut or broken to expose internal areas and mounted on aluminum stubs for SEM. Pieces were sputter-coated with approximately 300 Å gold-palladium. For observations of root development in bark, plants exhibiting 2 types of root systems were utilized: Coleus blumei Benth., with fibrous roots and numerous root hairs, and Vaccinium ashei Reade, with small, fine, lateral roots. Plants were grown in a 100% pine bark medium in 10-cm, plastic pots. Roots were washed free of loose bark, and those with adhering bark were dissected. Root-bark pieces were prepared by fixing in 2% glutaraldehyde in 0.1 M cacodylate buffer (pH 7.2) for 2 hr, dehydrated in an ethanol series (20%, 35%, 50%, 60%, 75%, 85%, 95%, and 100%), mounted on aluminum stubs and sputter-coated with approximately 300 Å gold-palladium. Specimens were observed with a Cambridge Mark IIA SEM.

Internal porosity of pine bark particles was 42.7% to 44.0% by volume (Table 1). Reducing particle size from its original configuration did not affect internal porosity. These values are similar to those obtained by Spomer (11) for soil amendment grade hardwood bark. Pregerminated radish seed planted in water-saturated bark continued the germination process and were harvested when the 1st true leaves appeared. Pregerminated seed in dry bark ceased development. Increasing the humidity in culture tubes containing dry bark did not enhance germination (Table 2). Plants in water-saturated bark were well-anchored, indicating that roots had penetrated the particles and were absorbing water contained within the pores as postulated by Airhart et al. (1).

SEM photomicrographs revealed that the internal structure of pine bark consisted of numerous cellular cavities. It was not uncommon for these cavities to measure 78 μm in diameter (Fig. 1).

Observations of plants cultured in bark showed root-bark interactions. Coleus roots had numerous root hairs on lateral roots, and bark particles were attached primarily through root hair connections. SEM photomicrographs showed an abundance of lateral roots along the exterior of the particle (Fig. 2A); penetration and anchorage of root hairs at the bark surface were found. Coleus roots appeared less frequently within fractures or crevices formed presumably during the bark milling process (Fig. 2B). Roots were found growing through and terminating in the particles. Vaccinium roots generally were devoid of root hairs. Finely fibrous roots penetrated the bark particle (Fig. 2C), and

Table 2. Availability of water within a pine bark particle to support growth of Raphanus sativus L. ‘Cherry Belle’.

<table>
<thead>
<tr>
<th>Date</th>
<th>Top fresh wt (mg)</th>
<th>Oven-dried pine bark</th>
<th>Water-saturated pine bark + humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 Apr.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 May</td>
<td>0.0</td>
<td>---</td>
<td>39.7**</td>
</tr>
<tr>
<td>5 May</td>
<td>0.0</td>
<td>---</td>
<td>36.0**</td>
</tr>
<tr>
<td>12 May</td>
<td>0.0</td>
<td>0.0</td>
<td>38.0**</td>
</tr>
<tr>
<td>14 May</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 May</td>
<td></td>
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</table>

**Significantly different at 1% level.
lateral roots often occurred at irregular surface areas (Fig. 2D).

In soil, roots grow through spaces existing between soil particles, aggregates, cracks, and crevices (14). Water is absorbed by roots from that retained in soil capillary pores and that adsorbed on particle surfaces (5, 13). Root development and water absorption in a container medium is thought to occur in essentially the same manner as in soil, since water held internally by porous components is considered unavailable for plant use (11, 12). The invasive nature of plant roots in a bark medium, however, illustrates that water and nutrient uptake is not solely a passive mechanism. Growth (movement) of roots in bark pores and a consequent encounter with water and nutrients is termed "root interception" in soil science. Root penetration into a bark particle increases the quantity of water taken up by the plant above that supplied by capillary water and simple diffusion gradients dictated by moisture gradients within a particular particle. The total quantity of internally held water available for plant use remains to be determined.

Literature Cited