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Efficiency Factors for Bark Substrates: Biostability, Aeration, or Phytotoxicity

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In Quebec (Canada), approximately 3.5 million tons of bark are produced annually, most of which are burned or buried without being used or recycled, whereas they could be used as basic components in growing media. However, growing media made of fresh bark often inhibits plant growth due to high concentrations of phenols, terpenes, organic acids, and heavy metals or by creating physical barriers to gas exchange. Therefore, the objectives of this study were: first, to evaluate the phytotoxicity of barks from seven different tree species on lettuce (*Lactuca sativa* L. 'Grand Rapids') germination and tomato (*Lycopersicon esculentum* Mill. 'Trust') growth; and second, to identify the possible physical (aeration, water availability), chemical, or biochemical (heavy metal, phenol, terpene, and sugar concentrations) factors causing those reductions. Results show that bark origin affected both lettuce germination and tomato dry matter production. Best results were obtained with raw paper birch (*Betula papyrifera* Marsh.; PB) bark, which outperformed the control (rockwool). Among bark substrate properties, air-filled porosity (θ_a) was significantly correlated to shoot dry weight (SDW) and germination index (GI). Plant growth parameters were correlated most strongly to biological stability, and then to θ_a, likely reflecting microbial competition for oxygen during the decomposition of organic matter. No relationships were found with terpenes, organic acids, or nutrient elements. These findings seemed to indicate that the apparent phytotoxicity of some barks could be explained by insufficient aeration in the substrate.

Abbreviations: θ_a, air-filled porosity; θ_c, volumetric water content at container capacity; B, unwashed bark; BF, balsam fir; BS, black spruce; EC, electrical conductivity; GI, germination index; HPLC, high-performance liquid chromatography; IBS, index of biological stability; JP, jack pine; LIC, lignin and cutine; MWD, mean weight diameter; PB, paper birch; SDW, shoot dry weight; SOL, soluble fractions; TA, trembling aspen; WB, washed bark; WC, white cedar; WS, white spruce.

In Canada, recent work in greenhouse production has indicated that bark and sawdust are potential replacements for the two leading commercial substrates, rockwool and slightly decomposed sphagnum peat (Desbiens, 2004; Allaire et al., 2005; Juneau et al., 2006). Because barks are inexpensive and biodegradable, they present both economical and environmental advantages over rockwool and peat. Indeed, rockwool is costly to produce in terms of energy, is not a biodegradable material, and must be renewed from year to year. Peat, the second most important substrate, is not readily renewable. Growing media manufacturers prefer slightly decomposed peat, which constitutes only 20% of the peat volumes available in peatlands. Accordingly, peat producers are prompted to continuously open new peatlands, which in turn threatens the biodiversity of long-term ecosystems. Bark, indeed, remains cheap and is largely available. In the province of Quebec only, approximately 3.5 million tons of bark are produced annually (Gouvernement du Québec. Ministère des Ressources naturelles et de la Faune, 2005), most of which is burned or simply buried without any energetic reuse. These forestry by-products could become a valuable secondary product. Indeed, bark generally contains large quantities of extractable products including a wide variety of natural compounds (phenolic compounds, sugars, terpenes, glycosides, alkaloids, etc.).

Bark can also be used in growing media as peat additives or, after composting, as a main substrate component (Reis et al., 1998; Morel et al., 2000). In both France and the United States, composted pine bark is already a basic component of soilless substrates used for container nursery production (Rivière et al., 1990; Naasz et al., 2005).

However, despite their availability, bark and sawdust also present some important limitations. Growing media made with fresh coniferous bark or sawdust may, in certain conditions, reduce plant growth due to high concentrations of organic molecules such as phenolic compounds (Wang et al., 1967; Zhu and Mallik, 1994; Parvez et al., 2004), terpenes (Aaron, 1982), or organic acids. Phytotoxic effects can be particularly important during a nutritional deficiency period (Politycka et al., 1985). This potential toxicity principally depends on the species of tree from which the material comes. For example, western red cedar (*Thuja plicata*) sawdust has toxic properties in contrast to that of Douglas fir (*Pseudotsuga menziesii*) or Western hemlock (*Tsuga heterophylla*; Desbiens, 2004). Moreover, high concentrations of heavy metals may cause metabolic disorders and inhibit

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