Acoustic absorption by plants

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The aim of this work was to understand better the ability of a particular type of foliage to absorb sound in the absence of soil. For this purpose a shoot of a plant species was removed from the top of its root and placed in a 100mm impedance tube sample holder from which soil was absent. In this arrangement the plant specimen was hard-backed and we were able to separate the effect of the leaf-related absorption from that caused by the presence of porous soil. The absorption coefficient was measured in the frequency range of 50 – 1600 Hz. Six different plants were examined in these experiemnts: (i) *Pieris japonica;* (ii)green ivy, (iii) *Geranium*; (iv) *Rhododendron fantastica* (percy); (v) scarlet wonder; (vi) primrose.The following plant leaf characteristics were measured: (i) mean thickness of a single leaf; (ii) mean weight of a single leaf; (iii) mean area of a single leaf; (iv) number of leaves on a plant; (v) height of the plant; (vi) equivalent volume occupied by the plant. These characteristics were then used to determine: (i) the total area of leaves on the plant; (ii) surface density of a leaf; (iii) total weight of leaves on the plant; (iv) leaf area per unit volume. These characteristics were then used to interpret the results of the impedance tube experiments and mathematical modelling work.

The obtained absorption coefficient spectra showed a remarkable difference in the ability of different type of plant foliage to absorb sound. It is possible to draw several conclusions from the results of these experiments. Firstly, doubling the height of the plant specimen in the impedance tube did not produce a simple additive effect. Secondly, the absorption coefficient correlated very well with leave thickness and its surface density. Here we clearly observed a greater absorption coefficient in the case of a plant with higher leaf surface density and greater leaf thickness, ie. primrose and *Geranium* (leaf thickness: 0.74 and 0.60mm, respectively; leaf density: 0.5 kg/m^2 for the both plants). This improvement in the absorption is likely to associate with a stronger leaf vibration and acoustic scattering effects. Thirdly, plants with lowest total leaf area showed the highest variation in the absorption coefficient spectra (e.g. primrose and *Geranium*: total leaf area of these plants was 0.060 and 0.045 m^2, respectively). For these plants the spectra contained clear resonances which frequency depended on the height of the bundle of leaves introduced in the impedance tube. Plants with the largest leaf area (Japonica, Percy) exhibited less frequency dependence in their absorption coefficient spectra and showed a smaller but more consistent increase in the absorption spectra when their height is doubled.

In order to understand better the phenomenon of acoustic absorption by leaves in the absence of soil we simulated the visco-thermal effects which may be partly responsible

for the observed acoustic absorption behaviour. For this purpose we attempted to replace the stack of leaves with an equivalent acoustic impedance layer which properties can be predicted by the model detailed in (Horoshenkov and Swift, JASA 110(5), 2371-2378, 2001). This model does not account for the vibration of leaves and multiple scattering effects which can be important at frequencies of leaf resonance and in those regimes when the acoustic wavelength is comparable to dimensions of leaves. These effects can be accounted for heuristically by introducing a complex frequency-dependent wavenumber and characteristic impedance for the equivalent acoustic porous layer. The four non-acoustic parameters which are required for this model were deduced using a suitable optimisation analysis method. Typical values of the effective flow resistivity and porosity which were deduced from this analysis were in the range of 0.1 – 49.9 Pa s m^{-2} and 0.95 – 0.99, respectively. These values are consistent with those determined from the direct, non-acoustic measurements. A comparison of the measured and predicted absorption spectra show that in a majority of cases the model can capture well the general behaviour of the absorption coefficient of those plants which have a relatively small total leaf area and leaves with a relatively large mean leaf surface (primrose and *Geranium*). The predictions do not match well with the measured data for those plants in which the total leaf area is large (scarlet and *Rhododendron fantastica*). The absorption coefficient of these plants is more likely to be dominated by the scattering effects that are not accounted for in the adopted model.

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