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Thermal conductivity of low-decomposed *Sphagnum* peat used as growth medium

Kasvualustana käytetyn heikosti maatuneen rahkaturpeen lämmönjohtavuus

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The thermal conductivity of low-decomposed *Sphagnum* peat, used as a growth medium for container seedling production in tree nurseries, and of a sandy mineral soil was studied using the single thermal probe method in the laboratory. The thermal conductivity of the peat was low and decreased from 0.5 to 0.05 W $m^{-1}K^{-1}$ when the water content decreased from near saturation to air-dry. In comparison, the thermal conductivity of the sandy soil was much higher, decreasing steeply from 1.5 to 0.5 W $m^{-1}K^{-1}$ with decreasing water content. Results are in accordance with those reported earlier for similar organic media. The results suggest markedly weaker and more delayed temperature fluctuations in pure peat media compared with media containing mineral soil, which is in agreement with observations made in tree nurseries.

Keywords: peat substrate, sandy soil, thermal soil properties, water content, water retention

INTRODUCTION

Soil temperature is an important factor for many ecological processes (McHale et al. 1998, Zak et al. 1999) and the growth of plant roots (Söderström 1976, Vapaavuori et al. 1992, McMichael & Burke 1998) and it is determined by energy fluxes between the atmosphere and the soil. Thermal conduction is in turn the major mechanism of heat transfer in soils and it is dependent on the physical properties of the soil (Farouki 1986, Hopmans & Dane 1986, Campbell et al. 1994). Thermal conductivity mainly increases with increasing soil water content, bulk density and temperature. At very high water contents, thermal conductivity may start to decrease. Increasing ice fraction usually increases thermal conductivity.

It is a common practice in tree nurseries in Fennoscandia to culture tree seedlings in containers filled with low-decomposed *Sphagnum* peat. Temperatures in the greenhouses are relatively high, but this can be adjusted by irrigation and shading. Outdoors the seedlings are more exposed to hot spells in the summer, as well as to frost beginning in late autumn. The seedlings are typically outplanted to forest sites in the spring when the soil temperatures are often too low (< 10°C) for optimum root growth (Söderström 1976, Ryyppö et al. 1998a). During all these stages, the peat container medium is likely to contribute to the temperature variations in the seedling root zone.

Relatively few studies have been carried out on the thermal conductivity of organic soils (e.g.

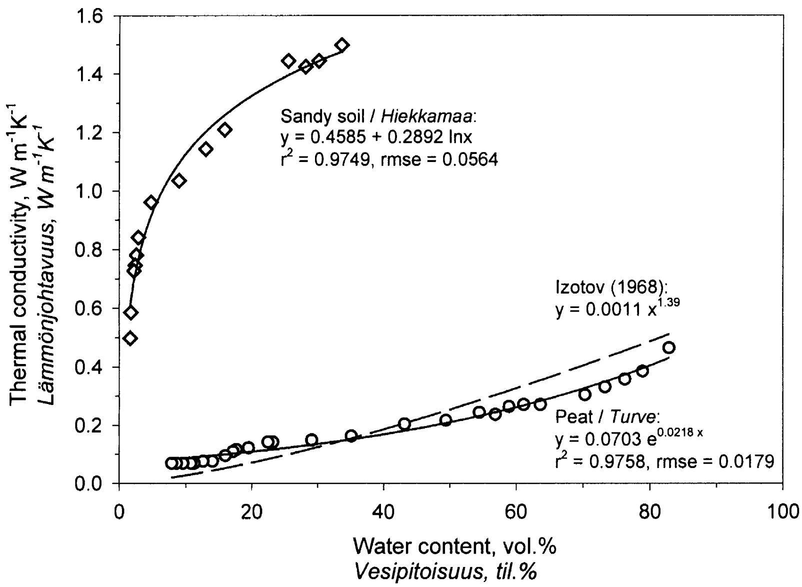

Fig. 1. Thermal conductivity of the studied media measured at desorption.

Kuva 1. Tutkittujen kasvualustojen lämmönjohtavuus mitattuna vesipitoisuuden aletessa.

de Vries 1963, Izotov 1968, Laurén 1997), especially on different organic growth media (Martin & Ingram 1991, Brovka & Rovdan 1999). Therefore, information about this property in peat growth media is needeed. The aim of this study was to determine the thermal conductivity of *Sphagnum* peat used as a container growth medium in tree nurseries and, as a reference, of a sandy soil.

MATERIAL AND METHODS

The studied growth media were low-decomposed *Sphagnum* peat (Kekkilä M6, Finland) and fine sandy mineral soil. About 51% (by mass) of the peat particles were smaller than 1 mm. 39.5% of sandy soil particles were larger than 0.6 mm and 6.7% smaller than 0.06 mm. For the peat, bulk density was 0.075 g cm^{-3} (dry mass ratio to saturated volume) and total porosity 95.6%. The respective values for the sandy soil were 1.61 g cm^{-3} and 39.1%. The peat properties were very similar to those reported earlier for *Sphagnum* peat growth media (Heiskanen 1993).

Soil thermal conductivity was measured from two sample replicates using the single probe (Soilmetric Ky., Finland) method in the laboratory (Farouki 1986). The measurement system was calibrated against polystyrene, an agar suspension and quartz sand of known thermal conductivities using a constant 251 mA heating current. The samples were placed in a 400 ml glass vessel, into which the 100 mm long probe was installed vertically. Measurements were made during drying at room temperature at least once a day, beginning from near saturation until air-dry. After each measurement period (ca. 20 min), the vessel with the sample was weighed. Mean volumetric water contents were calculated from these weighings and dry masses in relation to saturated sample volumes. The mean thermal conductivity of the soil was examined against its mean water content.

RESULTS AND DISCUSSION

The thermal conductivity of the studied *Sphagnum* peat growth medium decreased on average from 0.5 down to 0.05 W m^{-1}K^{-1} when water content decreased from near saturation to air-dry (Fig. 1). In comparison, the thermal conductivity of the studied sandy soil decreased rather steeply from 1.5 down to 0.5 W m^{-1}K^{-1} with decreasing water content. The thermal conductivity of the peat was of a similar magnitude as reported earlier by Izotov for natural peat (1968) (Fig. 1). Similar conductivities have also been found for the organic layer in a Scots pine stand (Laurén 1997) and for the forest floor in red pine stands (Pennypacker et al. 1975), but sligthly lower conductivities for the forest floor in black spruce stands (Sharratt 1997). In general, the thermal conductivity of pure organic media is lower than that of water (0.60 W $m^{-1}K^{-1}$ at 20°C). The thermal conductivity of the sandy soil studied here was rather typical for medium-textured mineral soils (de Vries 1975, Farouki 1986).

The low thermal conductivty of peat or bark growth media have been found to increase by adding sand to the medium, which also decreases temperature gradients within the medium (Martin & Ingram 1991, Brovka & Rovdan 1999). In containers (Plantek 81, volume 85 cm^3) filled with a similar peat growth medium as that studied in this paper, mean temperature difference of about 1°C has been found between the middle and side edges of the container under the snow cover in winter during changes in temperature (unpubl. part of data from Ryyppö et al. 1998b). This shows that even the thermal conductivity of frozen peat is low enough to cause a marked insulating effect in the growth medium, which may be of significance for the frost resistance of seedling roots. This may also be important in the cold storage of seedlings, when freezing (or thawing) results in a delay in the decrease (increase) in temperature in the peat medium due to the released (retained) energy. Since thermal conductivity is higher in frozen than in non-frozen peat (in pure ice 2.1 W $m^{-1}K^{-1}$ at – 4°C), a more marked insulating effect of peat can be expected during the summer.

In conclusion, the thermal conductivity of the *Sphagnum* peat growth medium was found to be relatively similar to natural peat and forest floor media and clearly lower compared with that of mineral soil. As also confirmed by observations made in tree nurseries, the results suggest markedly weaker and more delayed temperature fluctuations in pure peat container media compared with media containing mineral soil.

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TIIVISTELMÄ

Kasvualustana käytetyn heikosti maatuneen rahkaturpeen lämmönjohtavuus

Metsäpuiden taimitarhoilla käytetyn vaalean rahkaturpeen ja hienon hiekkamaan lämmönjohtavuutta tutkittiin yksianturi-menetelmällä laboratoriossa. Turpeen lämmönjohtavuus oli alhainen ja laski 0.5:sta 0.05:een W $m^{-1}K^{-1}$ vesipitoisuuden laskiessa lähes kyllästystilasta ilmakuivaan. Hiekkamaan lämmönjohtavuus puolestaan laski jyrkästi 1.5:stä 0.5:een W $m^{-1}K^{-1}$ vesipitoisuuden laskiessa. Arvot ovat yhdenmukaisia samantyyppisille kasvualustoille aiemmin esitetyjen tulosten kanssa. Tulokset viittaavat siihen, että turvepaakuissa lämmönvaihtelut ovat heikompia ja viivästyneempiä kuin kasvualustoissa, jotka sisältävät myös mineraalimaata. Päätelmää tukevat myös havainnot käytännön olosuhteista taimitarhoilla.

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