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Compaction of growth media based on *Sphagnum* peat during one-year culturing of container seedlings

Turvepohjaisten kasvualustojen tiivistyminen yksivuotisessa paakkutaimikasvatuksessa

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Changes in bulk density and water retention during one-year culturing of container seedlings were studied in pure, low-humified *Sphagnum* peat and in peat-based two-component growth media. In all growth media, the bulk density increased slightly with time. The corresponding decrease in total porosity was negligible (< 1 %-unit for pure peat). At matric potentials < –1 kPa, water retention of growth media tended to increase somewhat with time. On the other hand, shrinkage at desorption decreased during seedling culturing. The results suggest that, from the standpoint of seedling growth, the structure of growth media based on *Sphagnum* peat does not markedly change or deteriorate during one-year culturing of seedlings. However, in seedling culturing peat growth media containing hydrogel may possess restricted aeration due to excess water retention, while addition of coarse textured materials, such as perlite, to peat can increase aeration.

Key words: nursery management, soil physical properties, shrinkage, substrate, water retention

INTRODUCTION

In tree nurseries, seedlings are exposed to varying atmospheric conditions and irrigation, which result in repeated wetting and drying cycles and in changing water and aeration conditions in the growth medium (Puustjärvi 1977, Langerud and Sandvik 1988, Heiskanen 1995a). Moreover, fertilization, decomposition and mycorrhizas may markedly affect these conditions (Puustjärvi 1977, Duddridge et al. 1980). In addition, the water and aeration conditions, and thus the availability of water and oxygen to seedling roots, are largely determined by the structure and water retention characteristics of the growth medium (Puustjärvi 1977, Currie 1984). These physical properties have, to some extent, been studied for milled light *Sphagnum* peat, which is commonly used in greenhouse culturing of plants in the Nordic countries (Puustjärvi 1977, Heiskanen 1993a). In time, the structure of peat growth media tends to become compacted (Puustjärvi 1975, Langerud

1986). However, the temporal changes in the physical properties of peat growth media during tree seedling culturing and their implications for seedling growth are poorly known.

The aims of this study were to determine the changes in the structural properties of pure, low-humified *Sphagnum* peat and peat-based two-component growth media during culturing of one-year-old container seedlings and to evaluate the implications of these changes for seedling growth.

MATERIAL AND METHODS

Peat-based mixtures of growth media were prepared by hand mixing 25% (by volume) of one of the additive materials used and 75% peat. The pure peat growth media and the peat component of the mixtures were low-humified, medium grade and premix-fertilized (3 kg m^{-3} dolomite lime and 0.8 kg m^{-3} fertilizer, cf. Rikala & Heiskanen 1995) *Sphagnum* peat (Vapo E1K2, Vapo Corp., Finland), which is commonly used in Finnish forest tree nurseries. The additive component of growth media was coarse perlite (cPr), fine perlite (fPr), loose, water-repellent rockwool (rRw), absorbent rockwool granulate (aRw) or hydrogel (Gel) (in the abbreviations of the growth media, prefix P will be used to indicate peat-based mixtures). The perlites, rockwools and hydrogel were produced by Nordisk Perlite Corp. (Denmark), Grodania Corp. (Denmark) and Waterworks America Corp. (USA), respectively. The growth media were filled into containers and compressed with a pressure of 10 g cm^{-2} (Heiskanen 1990, 1995b). The containers used were type TK-708 (Lännen Corp., Finland), which are straight, open-ended cubes made of polystyrene and having an average cell volume of 345 cm^3.

The Scots pine seedlings (*Pinus sylvestris* L.) used in this study were grown from seeds, which were sowed in the growth media in a greenhouse in 1992. During culturing, the air temperature varied within 35°C (day) and 15°C (night). At the start of culturing, the pH of the growth media was < 5.0. Seedlings were irrigated and fertilized using the culturing practices described elsewhere (Heiskanen 1994). At the end of the first culturing season, the seedlings were about 10 cm tall and had a shoot dry mass of 600–900 mg and a root dry mass of 100–200 mg. Root density was thus < 0.6 kg m^{-3} (dry root mass in the container). After the first culturing season and exposure to a hardening phase, the seedlings were stored at –4°C for three months. Thereafter, the second culturing season was started.

In the first culturing season, the growth media were randomly sampled from the containers in seedling trays at 32 (time = 1), 65 (time = 2) and 105 (time = 3) days after sowing. At the beginning of the second culturing season, the fourth (time = 4) sampling was made. For laboratory measurements, the whole undisturbed samples of growth media, which had been collected with seedling roots intact from containers, were placed in separate, individual TK-708 containers. For comparison, preculture laboratory samples (time = 0) without any seedling culturing practice were also taken. They were compressed into the containers in the same way as had been done for the media in which the seedlings were actually grown. Each sampling time, three random samples were collected from each medium. Thus, a total of 90 samples (6 × 5 × 3) were collected and analyzed.

Volumetric water retention as a function of decreasing matric potential (desorption) was measured for each medium in the separate TK-708 containers using procedures described elsewhere (Heiskanen 1993a). Total porosity was estimated as (particle density–bulk density) / particle density. Particle density was measured using pycnometers with water bath (Heiskanen 1992).

To test the differences of the means between groups, one-way and two-way analysis of variance (ANOVA) and Tukey's test were used. Levene's test was used to ascertain the homogeneity of the variances. Due to independent random sampling, samples from the same media were assumed not to correlate with each other in time. Multivariate analysis of variance (MANOVA) was used to test repeated measurements (water retention at desorption) between sampling times. In order to test the temporal change only in samples during actual culturing, preculture laboratory samples were not used in (M)ANOVA.

RESULTS

The bulk density differed significantly between the growth media studied ($p < 0.001$) and

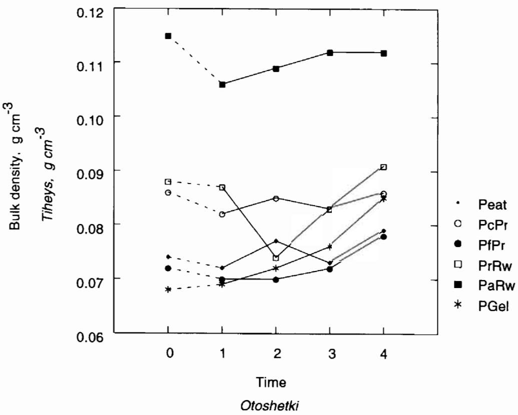

Fig. 1. Temporal change in the bulk density of the growth media studied. The standard deviation was 0.001–0.013 g cm^{-3} for different media at different times. Mixture amendment (25%) in peat was coarse perlite (PcPr), fine perlite (PfPr), water-repellent rockwool (PrRw), absorbent rockwool (PaRw) or hydrogel (PGel).

Kuva 1. Tutkittujen kasvualustojen tiheyden ajallinen muutos. Keskihajonta oli 0.001–0.013 g cm^{-3} eri otoshetkillä. Seosaineena (25%) turpeessa (Peat) oli karkea perliitti (PcPr), hieno perliitti (PfPr), vettä hylkivä irtonainen kivivilla (PrRw), imevä kivivillagranulaatti (PaRw) tai hydrogeeli (PGel).

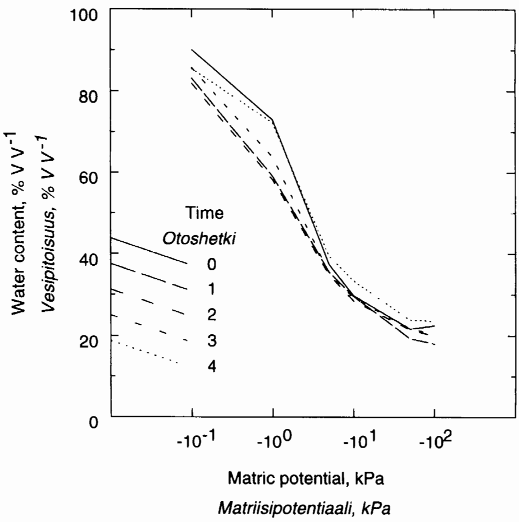

Fig. 2. Temporal change in water retention at desorption for the pure peat growth medium studied. The standard deviation was 0.5–10 %-units at different matric potentials.

Kuva 2. Puhtaan turvekasvualustan vedenpidätyskyvyn ajallinen muutos. Keskihajonta oli 0.5–10 %-yksikköä eri matriisipotentiaaleilla.

increased with time ($p = 0.002$). There was no interaction between medium and time ($p = 0.537$, two-way ANOVA, time = 0 excluded) (Fig. 1). Within media, however, the changes in bulk density with time were not significant. For pure peat, for example, the difference in bulk density between time 1 (0.072 g cm^{-3}) and time 4 (0.079 g cm^{-3}) was small ($p = 0.543$, one-way ANOVA) and caused only < 1 %-unit decrease in total porosity.

Water retention at desorption differed between sampling times (e.g. $p = 0.003$ for pure peat medium, Wilks' lambda, MANOVA, time = 0 excluded). Compared with earlier times, at time 4 water retention was increased in all media at matric potentials < –1 kPa (for example, see Fig. 2). At time 4, water retention at desorption for PGel was somewhat larger than for other media (Fig. 3) ($p = 0.010$ between media, Wilks' lambda, MANOVA). At –0.1 kPa matric potential, the water retention of PGel differed from that of PrRw and PcPr and at matric potentials < –10 kPa, from that of PaRw (Tukey's tests, $p < 0.05$). Although not significantly, at a matric potential of –1 kPa, PfPr seemed to retain less water than pure peat.

Water retention differences between different consecutive matric potentials (which describe the volume of different pore size classes, see Heiskanen 1993a) for the media did not change consistently over time (data not shown). The greatest variation in water retention occurred at a matric potential of –1 kPa (Figs. 2, 3).

Shrinkage of the media at desorption also differed between different times (e.g. $p = 0.027$ for peat, Wilks' lambda, MANOVA, time = 0 excluded). Shrinkage tended to be less at times 3 and 4 than at times 1 and 2 (Fig. 4). Water retention and volume shrinkage at desorption for the various preculture media samples are described in detail by Heiskanen (1993a, 1994, 1995a, b).

DISCUSSION

Puustjärvi (1975, 1977) reported a slight increase in bulk density and decrease in total porosity for light *Sphagnum* peat during two-year plant culturing, which was similar to that found here. According to the latter study (Puustjärvi 1977), the thickness of a peat bed may decrease by 20

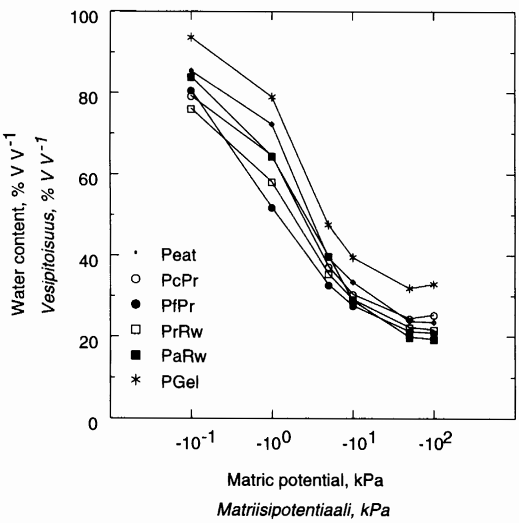

Fig. 3. Water retention for the growth media studied at time 4. The standard deviation was 0.8–12 %-units at different matric potentials. Mixture amendment (25%) in peat was coarse perlite (PcPr), fine perlite (PfPr), water-repellent rockwool (PrRw), absorbent rockwool (PaRw) or hydrogel (PGel).

Kuva 3. Tutkittujen kasvualustojen vedenpidätyskyky otoshetkellä 4. Keskihajonta oli 0.8–12 %-yksikköä eri matriisipotentiaaleilla. Seosaineena (25%) turpeessa (Peat) oli karkea perliitti (PcPr), hieno perliitti (PfPr), vettä hylkivä irtonainen kivivilla (PrRw), imevä kivivillagranulaatti (PaRw) tai hydrogeeli (PGel).

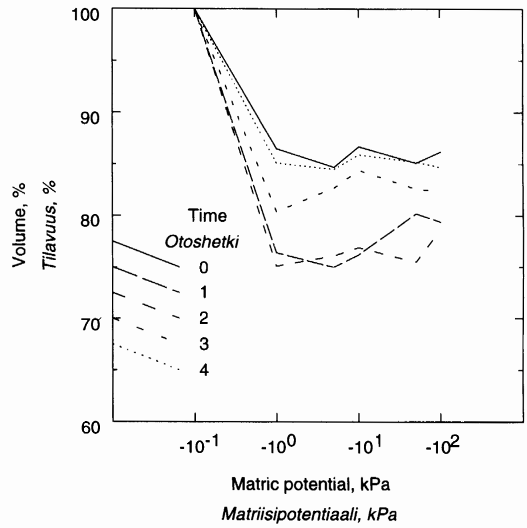

Fig. 4. Temporal change in sample volume at desorption for the pure peat growth medium studied. Reference volume is that at –0.1 kPa = 100%. The standard deviation was 0.5–5 %-units at different matric potentials.

Kuva 4. Puhtaan turvekasvualustan tilavuuden ajallinen muutos kuivumisen yhteydessä. Vertailutilavuutena on tilavuus matriisipotentiaalilla –0.1 kPa. Keskihajonta oli 0.5–5 %-yksikköä eri matriisipotentiaaleilla.

to 25% during two-year culturing, but the total porosity may remain almost unaltered.

Water retention of preculture, peat-based growth media at desorption has been reported to be rather similar to that of the preculture media studied here (Heiskanen 1993a, 1994, 1995b). However, the water retention in preculture media tends to be somewhat larger at high matric potentials (> –1 kPa) and lower at low matric potentials (< –1 kPa) than in the culture media. Variation in water retention for the preculture peat media studied by Heiskanen (1993a, 1994, 1995b) was slightly less than that found here for the culture media. The lowered shrinkage at desorption found here during culturing was probably due to compaction and also to increased amount of roots, which likely elevated the stability of the growth media. The preculture samples studied can, however, be considered to provide applicative structural properties for practice, since they possessed average properties relatively similar to those of the peat-based growth media during culturing (Figs. 1, 2, see also Heiskanen 1990).

During seedling culturing, settling and compaction caused by gravity and irrigation obviously contributed to the increase in the bulk density of the growth media studied. In practice, however, various irrigation frequencies may differ in their effect on compaction (Langerud and Sandvik 1988). Furthermore, the slightly increased compactness during culturing was probably contributed by a loss of organic matter due to decomposition of peat and seedling roots. The decomposition of lignin (if present) yields amorphous humic acids, which can compact the peat medium (Puustjärvi 1975, 1977). However, since the decomposition products of pure light peat are mainly water and carbon dioxide, the structure can remain almost the same for few years (Puustjärvi 1977). In addition, the texture of peat may even become temporarily coarser, as fine peat particles tend to decompose first. This evidently occurs especially with elevated levels of nitrogen fertilization (Puustjärvi 1975). At the peat surface, however, the structure may be compacted due to crusting, which is the result of repeated drying and wetting during culturing (see Heiskanen 1993b).

The high water retention in wet conditions suggests that the aeration in compacted pure peat, and especially in PGel, may be slightly decreased as has also been indicated previously (e.g. Heiskanen 1994, 1995b). In plantless containers, a decrease in total and air-filled porosities in 100 days has also been reported for peat-based growth media mixtures (Langerud 1986, cf. Langerud and Sandvik 1988). During a longer culturing period, the increasing root density in containers may further elevate the bulk density slightly and decrease the total and air-filled porosity (Mannerkoski 1982). However, Mannerkoski (1982) estimated that the highest root density (ca. 20 kg root dry mass m^{-3} peat) caused only ca. 1.4 %-unit decrease in total porosity. In one- and two-year seedling culturing, root density is usually less than ca. 4 kg m^{-3} (Lähde and Savonen 1984, Rikala and Huurinainen 1990), which suggests that roots do not markedly decrease the porosity of their growth medium within a few years. In addition, in containers that have a cross-section which narrows towards the base, shrinkage and compaction, and thus the decrease in porosity, are evidently lower than in containers with straight walls, such as those used in this study (Heiskanen 1993b). Excess water retention and compaction of peat can also be decreased e.g. by addition of coarse textured materials, such as perlite (Heiskanen 1995b).

CONCLUSIONS

In one-year culturing of container seedlings, bulk density of the light *Sphagnum* peat-based growth media studied was found to increase and water retention to change. These changes were, however, considered to be relatively slight. Moreover, compared with pure peat, the peat-based mixtures showed no marked difference in water retention after one-year culturing. In wet conditions (–1 kPa matric potentials), however, peat media containing hydrogel may provide restricted aeration due to larger water retention. On the other hand, addition of coarse textured materials, such as coarse perlite, to peat may increase aeration. It was concluded that, after one-year culturing of tree seedlings, the root density in containers is not likely to markedly decrease the porosity of the peat-based growth media.

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TIIVISTELMÄ:

Turvepohjaisten kasvualustojen tiivistyminen yksivuotisessa paakkutaimikasvatuksessa

Vähän maatuneen rahkaturpeen (Vapo E1K2) ja siihen pohjautuvien kasvualustojen (seosainetta 25% tilavuudesta) tiheyden ja vedenpidätyskyvyn ajallista muutosta tutkittiin yksivuotisten paakkutaimien kasvatuksessa. Seosaineena oli karkea perliitti (cPr), hieno perliitti (fPr), irtonainen vettähylkivä kivivilla (rRw), imevä kivivillagranulaatti (aRw) tai hydrogeeli (Gel). Perliitit, kivivillat ja hydrogeelin olivat tuottaneet järjestyksessä Nordisk Perlite Corp. (Tanska), Grodania Corp. (Tanska) ja Waterworks America Corp. (USA).

Kasvualustat täytettiin taimipaakkuihin TK-708 (Lännen), joissa kasvatettiin männyntaimia. Ensimmäisen kasvukauden aikana kustakin kasvualustasta otettiin häiriintymättömiä näytteitä (n = 3) juurineen 32 (hetki = 1), 65 (hetki = 2) ja 105 (hetki = 3) päivän kuluttua kylvöstä. Näytteet otettiin vielä toisen kasvukauden alussa (hetki = 4). Lisäksi vertailun vuoksi laboratoriossa valmistettiin näytteet, jotka eivät käyneet läpi kasvatustoimenpiteitä. Näytteistä määritettiin tiheys, huokostila ja vedenpidätyskyky.

Kaikkien kasvualustojen tiheys lisääntyi hiukan ajan myötä. Vastaava kokonaishuokostilan vähentyminen oli hyvin vähäistä (< 1 %-yksikköä puhtaalla turpeella). Kasvualustojen vedenpidätyskyky matriisipotentiaaleilla < –1 kPa lisääntyi hieman ajan myötä. Kutistuminen kuivumisen yhteydessä taas väheni kasvatuksen aikana. Tutkittujen turvepohjaisten kasvualustojen rakenneominaisuuksien ei voitu katsoa merkittävästi heikenneen yksivuotisen taimikasvatuksen aikana taimien kasvun kannalta. Hydrogeelin lisäys turvekasvualustaan taimikasvatuksessa voi kuitenkin märissä oloissa heikentää kasvualustan ilmanvaihtoa suuren vedenpidätyskyvyn vuoksi. Toisaalta turvekasvualustan ilmanvaihtoa voidaan parantaa lisäämällä turpeeseen karkeaa seosainetta, kuten perliittiä.

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