Effect of Peat-Based Container Media on Establishment of Scots Pine, Norway Spruce, and Silver Birch Seedlings

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Growth of container seedlings grown in pure sphagnum peat and in peat mixtures containing coarse perlite and/or fine sand (25% by volume) was studied after out planting to forest sites. Relatively small differences in height growth and mortality were found among seedlings grown in the different media. Differences in postplanting success were greater among tree species and between sites than among media types. Cold soil, due to long-lasting soil frost in spring, could contribute to the increased mortality and lowered growth, especially that found in Norway spruce seedlings during the 1st growing season after planting. In practice, seedling establishment after planting cannot be expected to benefit from the addition of the constituents used here to a peat container medium in proportions less than 50%. Tree Planters' Notes 50(1): 28-33; 2003.

After outplanting, seedlings are commonly exposed to drought (Hallman and others 1978; Burdett 1990). Container seedlings are usually not as affected by water stress after outplanting as bareroot seedlings (Grossnickle and Blake 1987; Nilsson and Orlander 1995). This is due to the root system remaining undisturbed within the container. Container seedlings are commonly grown in media of low-decomposed peat and other coarse-textured materials (Landis and others 1990). Upon drying, these media may shrink in volume and have low unsaturated hydraulic conductivity and large air-filled porosity (Heiskanen 1993a,b, 1995). These factors can inhibit water uptake by seedlings after outplanting due to poor hydraulic contact between the roots and the container medium (Orlander and Due 1986; Bernier and others 1995). Moreover, soon after planting, moist peat-based media may lose large amounts of water into drier surrounding soil (Day and Skoupy 1971; Nelms and Spomer 1983; Heiskanen and Rikala 2000).

Hydraulic interactions between the container medium and the surrounding soil and the effects of these interactions on water stress and seedling establishment after outplanting are poorly understood (Hellum 1982). Water movement from the surrounding soil into peatbased container media (Heiskanen 1999), water availability to seedlings (Orlander and Due 1986; Ben-tier and others 1995), and rooting of seedlings into the soil (Heiskanen and Rikala 1998, 2000) can, to some extent, be modified by using suitable constituents in the peat medium. However, no substantial effects of growth media on the actual establishment of container seedlings after outplanting have yet been shown in practice.

The aim of this study was to test whether different peat-based container media affect establishment of container seedlings.

Materials and Methods

We studied 4 different media based on light, medium-grade, premix-fertilized sphagnum peat (Vapo E D1K2`~, Vapo Oyj., Finland) with coarse and fine constituents. Mixed with the peat (P), the coarse component was perlite (Pr, particle size 0.5-6.0 mm, 0.02-0.24 in, Nordisk Perlite Aps., Denmark) and the fine component was quartz sand (Q, particle size <0.2 mm, 0.008 in, Partek Oyj., Nilsian Kvartsi, Finland). The proportions of the components hand-mixed into the peat were determined by volume (P100, P75Pr25, P50Pr25Q25, P75Q25) (table 1). A detailed description of the properties of these media has been presented previously (Heiskanen 1995, 1999; Heiskanen and Rikala 2000).

Scots pine *(Pin us sylvestris L.),* Norway spruce *(Picea abies (L.)* Karst.), and silver birch seedlings *(Betula*

Table 1—*Mean composition by volume and bulk density of the growth media*

Medium	Peat (%)	Coarse perlite (%)	Fine sand (%)	Bulk density (g/cm^3)
P100	100	0	0	0.09
P75Pr25	75	25	0	0.11
P50Pr25Q25	50	25	25	0.49
P75Q25	75	0	25	0.45

pendula Roth) were grown from seed in a greenhouse using standard culturing procedures (Heiskanen and Rikala 2000). The container types used for the conifers and birch were hard plastic PL-81F trays (64 cells of 85 cm^3, 5.2 in^3) and PL-25 trays (25 cells of 380 cm^3, 23 i_n), respectively (Lannen Oyj., Finland). In July, the seedlings were moved to open fields, where they remained for winter storage under the snow cover. The next spring, the 1-year-old seedlings were planted onto forest sites in central Finland during the 3rd week of May. Seedling height at planting varied somewhat by medium (table 2).

Pine and spruce seedlings were planted onto 2 different planting sites located in central Finland at 62°18'N and 27°16'E. One site was a Vaccinium type (VT), which was drier, coarser textured, and less fertile than the other site, a Myrtillus type (MT) (Cajander 1949; table 3). Both sites had been clear-cut and disc-scarified. Birch was planted on the MT site and on a tilt-plowed former field designated for afforestation (62°53'N, 28°20'E). Seedlings were planted at the intersection points of a grid 2 X 2 m (6.6 x 6.6 ft) on the VT and MT sites and on grid 1 X 1 m (3.3 X 3.3 ft) on the field site. Within sites, each species was planted alone into 6 blocks, each of which was further divided into 4 plots. Seedlings grown in different container media were randomized separately to different plots (that is, 1 container medium in each plot). VT and MT blocks measured 16 X 20 m (52.5 x 65.6 ft) each, and field blocks were 8 X 10 m (26.3 X 32.8 ft). VT and MT plots measured 8 X 10 m each; field plots were 4 X 10 m (13 X 32.8 ft). In each plot, there were 20 seedling replicates. Thus, in all, there were 480 seedlings planted per species on each site (total of 2880). Initial planting height in spring 1997, as well as height growth and mortality of the seedlings, were measured in autumn 1997 and 1998.

Soil texture on the MT site was finer than on the VT site, but the field soil had the finest texture (table 3). Thus, the field soil had higher water-retention capacity at -10 kPa matric potential (around field capacity) than the VT and MT soils did. Based on 1 measurement period (4 through 9 Aug 1998), soil-water content (`Y° by volume) below the organic horizon was, on average, 21 (range 18-24) on the VT site, 27 (25-29) on the MT site, and 26 on the field site. Thus, due to the moist measurement time, the VT soil seemed to be wetter than the field capacity. The rather low water content in relation to the water-retention capacity in the field soil was most likely due to the heavier tilt plowing compared with that done on the forest sites.

Weather conditions at the time of planting were relatively cool, and the soil was still frozen in some places. Soon after planting, the weather became warmer and precipitation was fairly low, which likely increased water stress in the seedlings. The summer after planting (1998) was clearly cooler and moister than the summer

Table 2—*Seedling height range at outplanting for 3 species grown in 4 container media*

Species	Container media[a]							
	P100		P75Pr25		P50Pr25Q25		P75Q25	
	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)
Pine	8-14	3.1-5.5	8-14	3.1-5.5	8-14	3.1-5.5	8-14	3.1-5.5
Spruce	12-20	4.7-7.9	12-20	4.7-7.9	10-18	3.9-7.1	10-18	3.9-7.1
Birch	50-80	19.7-31.5	50-80	19.7-31.5	30-60	11.8-23.6	40-70	15.7-27.6

[a]P100=100% peat; P75Pr25=75% peat, 25% perlite; P50Pr25Q25=50% peat, 25% perlite, 25% sand; P75Q25=75% peat, 25% sand.

Table 3—*Soil texture, pH, organic matter content, bulk density, total porosity, and water retention on the study sites ($\bar{x} \pm s$)*

Site	Soil texture (mass %)							
	>0.6 mm	0.6-0.06 mm	<0.06 mm	pH	Organics (mass %)	Density (g/cm^3)	Porosity (volume %)	Water retention[a] (volume %)
VT	10.9±8.2	84.9±7.9	04.1±0.8	5.25±0.15	3.0±0.8	1.31±0.06	50.8±1.9	16.3±2.3
MT	36.7±8.1	51.8±5.8	11.5±3.1	5.09±0.19	6.5±1.7	1.09±0.01	59.0±3.4	29.3±3.8
Field	06.9±2.1	60.6±3.0	32.5±1.5	5.77±0.03	7.4±1.1	1.03±0.08	61.1±2.3	40.1±3.2

[a] Measured at -10 kPa matric potential

of 1997. Weather information was estimated from the regional data of the Finnish Meteorological Institute (table 4).

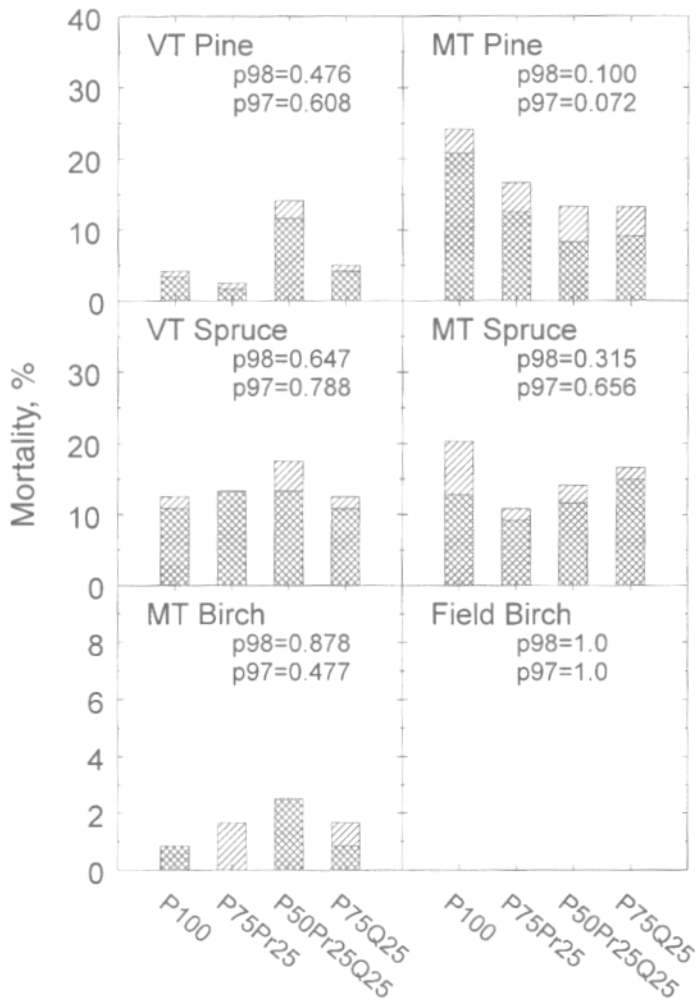
Soil texture was analyzed by dry sieving and organic matter content as loss on ignition (at 550 °C, 1022 °F). Bulk density was estimated from cylinder samples as dry mass / wet volume and total porosity as (particle density - bulk density) / particle density (Heiskanen 1993a). Water retention at -10 kPa matric potential was measured using a pressure-plate apparatus (Heiskanen 1993a). Soil-water contents were measured on 4 through 9 September 1998 using a time domain reflectometer (IMKO TRIME-FM, Germany) (Maliki and others 1992, 1996). Soil measurements were replicated 3 times (from different blocks) within species and sites.

Differences in mortality among seedlings grown in different container media were analyzed from block means (n=6) using nonparametric Kruskal-Wallis ANOVA. Differences in height growth were analyzed within sites and species using parametric ANOVA and Tukey's test, in which container media and blocks were used as fixed effects and initial planting height as a covariate.

Results

Mortality after the 1st growing season (1997) differed (P = 0.072) among pine seedlings grown in different container media on the MT site, where the seedlings grown in pure peat (P100) had the highest mortality (figure 1). On the VT site, pine mortality was highest in the P50Pr25Q25 medium, although not significantly (P = 0.608). For the other sites and species and the next year (1998), there were no differences in mortality among media (P > 0.10). In general, pine seedlings had greater mortality on the MT site than on the VT site. The mortality for spruce seedlings was, on average, higher than that for pine. Birch had very low mortality.

During the 1st and 2nd seasons after outplanting, average height growth (expressed as 1st season growth + 2nd season growth) of pine seedlings differed very little between the sites: 4.3 + 11.2 cm (1.7 + 4.4 in) on VT,



Container Media

Figure 1-Mean seedling mortality the 1st (1997, cross-hatch) and 2nd (1998, diagonal) growing seasons after outplanting on the study sites. Vaccinium type (VT) and Myrtillus type (MT) sites were discscarified, and the former field (Field) was tilt-plowed. Blocks (n=6) were used as observations. P-values for both growing seasons (p97, p98) are from Kruskal-Wallis ANOVA of mortality as a function of 4 container media (P100=100% peat; P75Pr25=75% peat and 25% perlite; P50Pr25Q25=50% peat, 25% perlite, and 25% sand; P75Q25=75% peat and 25% sand).

Table 4—*Mean monthly temperature and precipitation in the study regions*

Region	May		June		July		August		September	
	°C (°F)	mm (in)	°C (°F)	mm (in)	°C (°F)	mm (in)	°C (°F)	mm (in)	°C (°F)	mm (in)
1997										
VT + MT	6.7 (44.1)	26.5 (1.0)	16.0 (60.8)	31.0 (1.2)	18.6 (65.5)	45.5 (1.8)	17.0 (62.6)	16.5 (0.6)	9.6 (49.3)	66.5 (2.6)
Field	6.1 (43.0)	15.0 (0.6)	15.0 (59.0)	60.0 (2.4)	17.6 (63.7)	66.0 (2.6)	15.6 (60.1)	23.0 (0.9)	8.3 (46.9)	85.0 (3.3)
1998										
VT + MT	8.3 (46.9)	44.5 (1.8)	13.9 (57.0)	101.0 (4.0)	16.4 (61.5)	135 (5.3)	13.1 (55.6)	94.0 (3.7)	10.3 (50.5)	28.0 (1.1)
Field	8.0 (46.4)	57.0 (2.2)	13.8 (56.8)	120.0 (4.7)	15.7 (60.3)	159 (6.3)	12.7 (54.7)	78.0 (3.1)	10.0 (50.0)	32.0 (1.3)

and 4.6 + 11.1 cm (1.8 + 4.4 in) on MT (figure 2). During the 1st season, pine height growth differed (P < 0.0005) among container media on the MT site but not on the VT site. The pine seedlings grew best in pure peat (P100). The next summer, however, height growth in pure peat no longer differed. Spruce seedlings grew better on the VT site the 1st season, but the next season they grew better on the MT site: 3.7 + 5.7 cm (1.5 + 2.2 in) on VT, and 2.7 + 7.3 cm (1.1 + 2.9 in) on MT. During

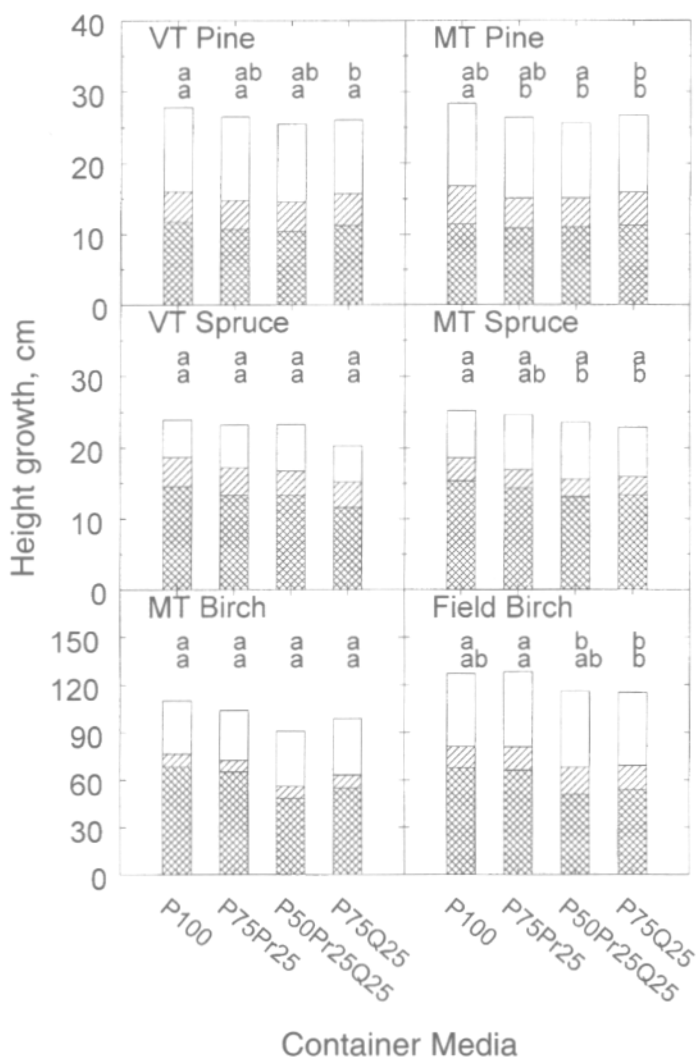


Figure *2-Mean seedling planting height (lowest partition), 1styear-growth (1997, middle partition), and 2nd-year-growth (1998, top partition) for 3 species by growth medium. Media compositions were: P100=100% peat; P75Pr25=75% peat and 25% perlite; P50Pr25Q25=50% peat, 25% perlite, and 25% sand; and P75Q25=75% peat and 25% sand. Study sites were a Vaccinium type (VT), a Myrtillus type (MT), and a former field (Field). Different letters among growth media denote different growth rates (Takey, P < 0.05, planting height used as a covariate, dead seedlings excluded). The lower row of letters indicates the 1st season (1997), the upper row, the 2nd season (1998).*

the 1st season, spruce seedlings in pure peat medium grew best on the MT site (P = 0.026), but during the following season, there were no differences among media. On the VT site, there were no differences in spruce growth among media either season. In both seasons, birch seedlings grew better on the field site: 7.9 + 33.8 cm. (3.1+13.3in)onMT,and15.1+46.7(5.9 + 18.4 in) on the field. On the field site, height growth of birch differed among media (P = 0.012) and was greater with smaller initial planting height, which occurred with seedlings that had quartz sand added to the peat container medium.

Discussion

Relatively small differences in height growth and mortality were found among seedlings grown in the different peat-based growth media used. On the other hand, the postplanting success of tree species seemed to differ somewhat between the sites. Pine seedlings had lower mortality on the VT site than on the MT site, which was flatter and wetter and had later soil frost after planting than the VT site did. Therefore, the increased mortality on the MT site might have been caused by low soil-water availability and by drying before the seedlings were able to grow roots into the surrounding soil after planting. In addition, the increased mortality of pine seedlings grown in pure peat on the MT site was probably contributed to by poor hydraulic contact with the surrounding soil (Heiskanen and Rikala 1998; Heiskanen 1999; Heiskanen and Rikala 2000).

The mortality of spruce seedlings was almost equally high on both outplanting sites, although the VT site was, in general, drier during the growing season and was not a typical site for spruce. In comparison with pine, this high mortality for spruce on the drier VT site may have been due to the weaker drought tolerance of spruce during the rather dry 1st summer. Birch seedlings had very low mortality, which indicates sufficient water uptake. This may have been because birch seedlings were leafless at the time of planting, and did not need as much water for transpiration immediately after planting. Thus, soil frost and dryness did not cause water stress or weak root growth since the roots of birch seedlings begin to grow only after the onset of bud burst and leaf growth (Abod and Webster 1991; Rikala 1996). The higher growth rate on the field site was presumed to be due to the higher soil fertility.

In principle, water flow between the surrounding soil and the container medium is affected by the coarseness of the soil and of the container medium, as well as by the hydraulic gradient (that is, the difference in dryness between medium and soil) (Heiskanen 1999; Heiskanen and Rikala 2000). Thus, to improve the water uptake of seedlings after outplanting, it may seem reasonable to modify a peat container medium with additives. In general, however, the water potential in boreal forest soils is commonly close to the field capacity (about -10 kPa matric potential), although in some years it may reach the wilting point (about -1500 kPa) after summer droughts (Heiskanen 1988; Norden 1989). Therefore, in practice, boreal forest soils can be expected to provide sufficient water for seedling uptake, especially when seedlings are outplanted in springtime. On the other hand, in spring, low soil temperatures may retard water uptake by seedlings (Lopushinsky and Max 1990; Ryyppo and others 1998), but this apparently cannot be affected much by modification of peat container media. Modification of peat container media with suitable additives may, however, be more effective with summer planting, when forest soils are warmer and drier.

Conclusions

Addition of the sand and perlite constituents used here to peat container media in proportions of 25% or 50% did not lead to any clear benefit for height growth or establishment of seedlings on the studied sites after early spring planting. However, under different weather and soil conditions, more distinctive effects may result with different additions of constituents to the peat medium or with different container types.

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