Effects of Additives to Peat Media and Root Dieback Incidence on Scots Pine and Norway Spruce Seedlings

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Abstract

Pure *Sphagnum* peat is known for its good physical and chemical properties for growing container seedlings. However, it may not always provide the optimal water and aeration conditions for container seedlings raised on open fields especially during rainy summers, when waterlogging may occur. An excess water content in the growth medium favours fungal root infections as the infection by the root dieback pathogen *Ceratobasidium bicorne*. The use of perlite and mineral sand in formulating growth media mixtures has been in common use for a long time. Recently, use of composts in growth media mixtures has increasingly gained ground because of environmental interests to recycle organic wastes. Compost microflora might also decrease the growth of root pathogens. In this study, these additives were used in peat medium to produce different physical properties and conditions for testing their effect on root dieback and seedling growth.

Scots pine and Norway spruce seedlings were grown from seed in separate containers in a greenhouse in central Finland. In the first experiment containers were filled with light, low-humified *Sphagnum* peat or mixtures of peat and coarse perlite and/or fine quartz sand. The experiment was repeated with an additional treatment of composted forest nursery waste as a component in the growth medium. When the seedlings were two–month–old, a part of them were inoculated with *C. bicorne*. The seedlings were examined at the end of the first growing seasons and in the following springs.

The amendments altered the physical properties of the *Sphagnum* peat. The organic matter content of all the mixtures was lower, and the bulk density higher, than the corresponding values for pure peat. The addition of quartz sand especially increased the bulk density of the growth media. The total porosity and water retention capacity of the peat and peat-compost were higher than those of the perlite or/and quartz sand-mixtures. However, the study showed that none of the growth media limited the pathogenicity of *C. bicorne* under normal irrigation practice.

Key words: *Ceratobasidium bicorne*, uninucleate *Rhizoctonia*, *Pythium*, *Picea abies*, *Pinus sylvestris,* physical properties, growth media.

Introduction

Since the early 1980's, the proportion of container-grown Scots pine (*Pinus sylvestris* L.) production in Finland has increased from 34.0 to 100% and that of Norway spruce [*Picea abies* (L). Karst.] from 5.6 to 99.9% at the expense of bare root seedlings (Anonymous 2012). Light, low-humified *Sphagnum* peat is the predominant growth medium used in containers in the Nordic countries, as is the case in many other countries favouring container-grown seedlings (Landis et al. 1990, Heiskanen 1993). In general, *Sphagnum* peat as a growth medium provides relatively favourable growth conditions for conifer seedlings in nurseries (Heiskanen 1993, 1995a, b, 2013). However, the physical properties of pure peat may not always provide optimal water and aeration conditions under all management regimes and growth phases of the seedlings (Langerud and Sandvik 1987, Heiskanen 1994, 1995a, b). For example, during rainy summers container seedlings raised on open fields are susceptible to waterlogging.

According to several studies, an excess water content in the growth medium favours fungal root infections, including root dieback (Venn et al. 1986, Lilja et al. 1998). In Scandinavia, root rot of Norway spruce and Scots pine seedlings was first recorded in Norway and termed the root dieback (Galaaen and Venn 1979). Disease symptoms on young Scots pine and Norway spruce seedlings infected in mid or late summer include retarded root and height growth and the patchy occurrence of diseased plants (Venn et al. 1986, Lilja 1994, Hietala 1998). In Norway, disease symptoms of 10-day-old Norway spruce seedlings inoculated with a *Pythium dimorphum* J. W. Hendrix and W. A. Campbell have related to the accumulation of lignin and the distribution of flavanols and condensed tannins; however, these defense responses occurred too late to prevent the death of seedlings (Børja et al. 1995). In Sweden, *Cylindrocarpon destructans* (Zins.) Scholt and *Pythium* spp. were the most common fungi isolated from diseased roots (Unestam et al. 1989). As regards of Finland, in inoculation trials none of the *Cylindrocarpon* species isolated from Finnish material were pathogenic (Lilja et al. 1992); both uninucleate *Rhizoctonia* sp. and *Pythium* spp. caused damping off like disease on seedlings younger than 5-6 weeks, having a sparse root system (Lilja et al. 1992, Lilja 1994). In older seedlings, only *Rhizoctonia* sp. spreads throughout the root system resulting in stunted growth of shoot and roots (Lilja 1994, Hietala 1998). The diseased seedlings might be, however, alive and green, and have a normal apical bud at the end of growing season (Lilja et al. 1996, Hietala 1998). The agents of damping off in Nordic countries include, at least, species of *Pythium*, *Cylindrocarpon* and uninucleate *Rhizoctonia* (Galaaen and Venn 1979, Unestam et al. 1989, Lilja et al. 1992, Lilja 1994). In contrast with the other pathogenic species of *Rhizoctonia*, that exhibit bi- or multinucleate cells, cells taken from hyphae that were actively growing in seedlings suffering from the root dieback were uninucleate (Hietala 1998). Furthermore, the *in vitro* formed fruiting body and DNA comparisons suggest that the uninucleate *Rhizoctonia* actually is the anamorph of *Ceratobasidium bicorne* Erikss. and Ryv. (Hietala 1998, Hietala et al. 2001). The all known anamorphs of other *Ceratobasidium* spp. have binucleate cells (Sneh et al. 1991), and in a RAPD analysis, uninucleate *Rhizoctonia* sp. isolates from Norway and Finland had banding patterns that were different from *Ceratobasidium* testers with binucleate anamorphs or other binucleate isolates of *Rhizoctonia* isolated from root dieback seedlings (Lilja et al. 1996).

In the greenhouse experiments with severe root dieback in Norway, seedlings grown in a mixture of peat and mineral wool have been shown to have less root damage than seedlings grown in pure peat (Venn et al. 1986). Globally, the use of perlite and mineral sand in formulating growth media mixtures has been in common use for a long time (Bunt 1988). Recently, use of composts in growth media mixtures has increasingly gained ground because of increased cost of imported *Sphagnum* peat and environmental interests to recycle organic wastes (Heiskanen 2013). In addition the use of compost to suppress soil-borne diseases such as damping off and root rots caused by *Rhizoctonia* and oomycetous pathogens has been successfully demonstrated in peat-based growth media (Scheuerell et al. 2005, Termorshuizen et al. 2006). For controlling fungal infections in tree nurseries, there is a need to assess the methods used for manipulating the moisture and aeration conditions as well as microbial fauna in the growth media. The aims of this study were to determine if the effects of coarse perlite and/or quartz sand additives as well as composted nursery waste on the physical properties of low-humified *Sphagnum* peat can alter the growth of seedlings (i) and decrease the symptoms caused by *C. bicorne* (ii).

Materials and Methods

Growth media

Four and five growth media based on medium-textured, low-humified *Sphagnum* peat (Vapo D1K2, Vapo Corp., Finland) were prepared in an experiment 1 and 2, respectively. The peat (= P) was prefertilized (N 16%, P 8%, K16% plus micronutrients, 0.8 kg m^{-3}) and limed (Mg-rich limestone, 2 kg m^{-3}), resulting in a pH of 4.7 and electrical conductivity (EC) of 1.5 mS cm^{-1}. The additives mixed into peat were coarse perlite (= Pr, particle size 0.5-6.0 mm, Nordisk perlite Corp., Denmark) and/or fine quartz sand (= Q, particle size < 0.2 mm, Nilsiän kvartsi Corp., Finland). Composted forest nursery waste (= C) mixed with peat was also tested as growth medium in the experiment 2. The compost originated from three-year-old stacked compost made from rejected container seedlings together with their peat growth media, weeds and horse manure (Veijalainen et al. 2008). The proportions (% by volume) of the components in the different growth media were as follows: 1) 100% peat, (P100), 2) 50% peat + 50% perlite (P50Pr50), 3) 50% peat + 30% perlite + 20% quartz sand (P50Pr30Q20), 4) 60% peat + 40% quartz sand (P60Q40), and 5) 75% peat + 25% compost (P75C25).

The main physical properties of the prepared growth media were determined on 2-3 samples taken from each growth medium. The organic matter content (LOI,% dry mass) was determined as the loss of mass on ignition at 550°C for 3 hours. Bulk density (BD, g cm^{-3}) was determined as the ratio of dry mass (dried at 105 °C for 24 hours) to saturated volume (Heiskanen 1993). Particle density (DS, g cm^{-3}) was measured using a liquid pycnometer method (Heiskanen 1992). Total porosity (TP, vol.%) was estimated as (DS - DB)/DS. Volumetric water-retention capacity (WC10, vol.%) of the media was determined at desorption (from -0.1 to -100 kPa) using a pressure plate apparatus (Soilmoisture Equipment Corp., USA). The test cylinders were filled with a mixture at the same bulk density as the mixture used to fill the containers in practice (Heiskanen 1993).

Hard plastic container trays (type Plantek81F, Lännentehtaat Co., Finland) were filled with the growth media. Each container tray contained 9 cells in 9 rows, in a total of 81 cells (85cm^3 $cell^{-1}$, 549 cells m^{-2}).

Seedling material

Scots pine and Norway spruce seeds of regional origin were sown in separate containers in mid-May. After sowing, the container trays were arranged in a greenhouse using a randomized design, in which there were 4 replicates for each growth medium for both conifer species, and the experimental trays were surrounded by additional trays. In both years there was an air layer between the trays and the concrete base of the greenhouse. The seedlings were irrigated with a mobile irrigation boom, the water content of the growth media being maintained between 40-50% by weighing the container trays. A commercial water-soluble fertilizer (9-Suprex, Kekkilä Co., Finland), containing 19% N, 5% P,20% K and micronutrients, was applied in the irrigation water (0.15% solution) eight times during the growing season to give a total application of 35 mg N for each seedling.

Inoculation of the pathogen

In mid-July, 27 pine and 27 spruce seedlings in each container tray in four blocks were inoculated with the anamorph of *C. bicorne* (uninucleate *Rhizoctonia* sp. strain 264. This pathogenic strain was isolated from the roots of Scots pine seedlings with root dieback symptoms in Lapinlahti nursery in Central Finland (Lilja et al. 1992, 1996). The strain was maintained as sclerotia in sterile soil in cool (2±2 °C). Each seedling was inoculated by placing an agar block (2 mm × 2 mm), cut from a 2-week-old *Rhizoctonia* culture grown on water agar (12 g Bacto agar 1^{-1}, Difco, USA), at the corner of the container cell, being c.a. 2.3 cm from the seedling stem, and buried at a depth of 3 cm. Control seedlings were inoculated with pure agar blocks. The inoculated and non-inoculated control seedlings were in the same container tray in rows 1-4 and 6-9, respectively. The seedlings in row 5 formed a barrier between the inoculated and non-inoculated seedlings.

Seedling measurements

Seedling height was measured (from root collar to tip of the terminal leader) at the time of inoculation, and at the end of the growing season in late-September. The seedling mortality was determined in the autumn and the following spring after one winter under the snow cover in an outdoor field. The dry masses of roots and shoots were also determined in the following spring. Shoots and roots were oven-dried at 60°C for two days before weighing. The pine seedlings in the experiment 2 became infected by *Gremmeniella abietina* (Lagerb.) Morelet and it was not possible to use the seedlings for the dry mass measurements.

Fungal isolations were also made in spring from the roots of 3 randomly selected seedlings, from both the control and inoculation treatment in each growth medium, in order to check for the presence of *C. bicorne*. For the isolation the roots were washed under running tap water for 1 h, whereupon a 1.5 x 2 mm root segment was cut from the main root and two laterals and plated on water agar. The plates were incubated at 20°C and examined daily under a microscope for one week. Only hyphal tips typical for anamorph of *C. bicorne* and *Pythium* spp. were re-isolated on water agar. A vegetative compatibility test based on the ability to obtain hyphal anastomosis was carried out in order to verify the origin of the *Rhizoctonia* isolates (Sneh et al. 1991). In addition, a safranin stain (Bandoni 1979) was also used to determine the nuclear condition of the *Rhizoctonia* isolates.

Data analysis

Analysis of variance (ANOVA) was used to determine the significance of differences in height before inoculation, final height, and growth after inoculation, dry mass of shoots and roots in different treatments and growth media. The experiment and tree species had a statistical effect on the growth of the seedlings, and tests were made separately for the two experiments and tree species. All calculations were performed using block means. The seedling height at the time of inoculation was used as a covariate when differences in final height and dry mass of the shoots and dry mass of the roots were calculated in the individual treatments. In the tests the model was growth media, inoculation, blocks, and growth media x inoculation x blocks. Multiple comparisons were performed with Tukey's test ($p < 0.05$).

Results

Effect of the growth media on seedling growth before inoculation

During the two first months (before inoculation) the effect of the peat-based growth media mixtures on seedling growth was not significant for pine in the first experiment (Table 1). In the second experiment, the pine seedlings grown in the peat-compost (75P25C) mixture were shorter than those in the other growth media except for P50Pr30Q20. However, the difference was not statistically significant between the 75P25C and the peat-quartz sand (P60Q40) mixture (Table 1). In the first experiment, the height of the spruce seedlings grown in peat (P100) or the peat-perlite (P50Pr50) mixture were greater than that of seedlings grown in other media (Table 1). In the second experiment, pure peat was a better growth media for spruce than the other mixtures. In the peat-compost the seedlings were the shortest (Table 1). The effects of amendments on the physical prosperities of the *Sphagnum* peat are given in Table 2.

Table 1. Seedling height in the different growth media before inoculation in two experiments carried out in a nursery. P100 = 100% peat, P50Pr50 = 50% peat + 50% perlite, P50Pr30Q20 = 50% peat + 30% perlite + 20% quartz sand, P60Q40 = 60% peat + 40% quartz sand, P75C25=75% peat + 25% composted nursery waste. Mean ± *SD*. Different letters within columns indicate a significant difference ($p < 0.05$) between the growth media

Tree species	Growth medium	Exp 1 Height, cm	Exp 2 Height, cm
Scots pine	P100	7.6±0.5a	6.6±0.9a
	P50Pr50	7.5±0.6a	6.1±0.9a
	P50Pr30Q20	7.2±0.4a	5.9±0.7ab
	P60Q40	7.5±0.4a	6.4±0.8a
	P75C25	-	5.6±3.3b
Norway spruce	P100	10.4±0.3ab	11.6±2.0a
	P50Pr50	10.8±0.7a	8.9±1.7b
	P50Pr30Q20	9.7±0.6ab	9.2±1.6b
	P60Q40	9.6±0.8b	9.0±1.8b
	P75C25	-	8.2±1.4b

Table 2. Mean values of the physical properties of the growth media (replicates n = 2-3). P100 = 100% peat, P50Pr50 = 50% peat + 50% perlite, P50Pr30Q20 = 50% peat + 30% perlite + 20% quartz sand, P60Q40 = 60% peat + 40% quartz sand, P75C25=75% peat + 25% composted nursery waste. Abbreviations: LOI (loss on ignition), BD (bulk density), TP (total porosity), WC10 (water content at -10 kPa matric potential)

Growth medium	LOI, % dry mass	BD, g cm^{-3}	TP, vol.%	WC10, vol.%
P100	95.8	0.087	95.2	37.3
P60Q40	7.4	0.586	70.3	28.9
P50Pr50	34.8	0.104	88.6	33.2
P50Pr30Q20	10.9	0.363	85.9	26.5
P75C25	53.6	0.152	92.1	37.2

Effect of the growth media on seedling growth after inoculation

Control

At the end of the growing season, the height growth of seedlings after inoculation and dry mass of the shoots and roots measured after winter of all the control seedlings of spruce and pine were in most cases greater in pure peat than in any of the other mixtures in both experiments (Table 3, 4 and 5). The higher bulk density of peat-sand (P60Q40) was seen as lower growth after inoculation as well as low root dry mass but this different was not in all cases significant between peat (P100) and peat-sand (P60Q40). The shoot and root dry masses of the pine and spruce control seedlings correlated with the final height (data not shown) of the seedlings ($p < 0.01$).

Inoculated seedlings

The effect of inoculation on the height and dry masses of the pine and spruce seedlings was clear in both experiments and in all the growth media ($p < 0.05$) (Tables 3, 4 and 5). The shoot and root dry masses of the inoculated pine and spruce seedlings correlate with the final height of the seedlings ($p < 0.05$). The growth reduction caused by inoculation varied between 12-19% (Table 3).

Table 3. Effect of *Ceratobasidium bicorne* on the height growth of Scots pine and Norway spruce seedlings after inoculation in different growth media in two experiments carried out in a nursery. Inventory was done P100 = 100% peat, P50Pr50 = 50% peat + 50% perlite, P50Pr30Q20 = 50% peat + 30 % perlite + 20% quartz sand, P60Q40 = 60% peat + 40 % quartz sand, P75C25=75% peat + 25% composted forest nursery waste. Mean ± *SD*. Different letters within columns indicate a significant difference ($p < 0.05$) between the growth media in the control or in the inoculation treatment with *C. bicorne*

Treatment	Growth medium	Scots pine		Norway spruce	
		Height growth after inoculation cm			
		Exp 1	Exp 2	Exp 1	Exp 2
Control	P100	6.7±0.5a	6.3±0.4a	6.9±0.9a	6.8±0.5a
	P50Pr50	5.2±0.3a	5.6±1.0ab	6.2±0.7ab	6.9±0.4a
	P50Pr30Q20	4.5±0.2b	5.3±0.7ab	5.6±0.5abc	5.9±0.8ab
	P60Q40	4.3±0.5b	4.6±1.0b	4.5±0.6c	4.9±0.4b
	P75C25	-	4.7±0.4b	-	5.0±0.4b
C. bicorne	P100	4.4±0.2a	4.2±0.5a	4.4±0.6a	4.5±0.7ab
	P50Pr50	4.6±0.4a	4.2±0.5a	3.3±0.7ab	5.2±0.2a
	P50Pr30Q20	3.7±0.5a	3.9±0.7a	3.4±0.6ab	3.7±0.2b
	P60Q40	2.5±0.5b	2.9±0.5b	2.8±0.5b	2.9±0.5c
	P75C25	-	3.2±1.9ab		2.9±0.8c

Table 4. Effect of *Ceratobasidium bicorne* on the shoot and root dry masses of Scots pine seedlings in different growth media in the first experiment. P100 = 100% peat, P50Pr50 = 50% peat + 50% perlite, P50Pr30Q20 = 50% peat + 30% perlite + 20% quartz sand, P60Q40 = 60% peat + 40% quartz sand. The measurements were made the following spring. Mean ± *SD*. Different letters within columns indicate a significant difference ($p < 0.05$) between the growth media in the control or in the inoculation treatment with *C. bicorne*

Treatment	Growth medium	Shoot dry mass, g	Root dry mass, g
Control	P100	0.79±0.05a	0.40 ±0.02a
	P50Pr50	0.75±0.03a	0.37±0.01a
	P50Pr30Q20	0.73 ±0.02ab	0.36±0.05a
	P60Q40	0.64 ±0.05ab	0.32±0.05a
C. bicorne	P100	0.65±0.02a	0.28±0.05a
	P50Pr50	0.62 ±0.03a	0.28±0.02a
	P50Pr30Q20	0.57±0.01a	0.26±0.04a
	P60Q40	0.56 ±0.07a	0.24±0.07a

Table 5. Effect of *Ceratobasidium bicorne* on the shoot and root dry masses of Norway spruce seedlings in different growth media. P100 = 100% peat, P50Pr50 = 50% peat + 50% perlite, P50Pr30Q20 = 50% peat + 30% perlite + 20% quartz sand, P60Q40 = 60% peat + 40% quartz sand, P75C25= 75% peat + 25% composted nursery waste. The measurements were made the following spring. Mean ± *SD*. Different letters within columns indicate a significant difference ($p < 0.05$) between the growth media in the control or in the inoculation treatment with *C. bicorne*

Treatment	Growth medium	Shoot dry mass, g		Root dry mass, g	
		Exp 1	Exp 2	Exp 1	Exp 2
Control	P100	0.82±0.11a	0.79±0.10a	0.44±0.07a	0.45±0.07a
	P50Pr50	0.79±0.08a	0.74±0.07ab	0.39±0.04b	0.38 ±0.06ab
	P50Pr30Q20	0.78±0.09a	0.71±0.01ab	0.32±0.07b	0.36±0.06ab
	P60Q40	0.74±0.03a	0.69±0.08ab	0.32±0.14b	0.34±0.07b
	P75C25	-	0.62±0.06b	-	0.30±0.01b
C. bicorne	P100	0.63±0.14a	0.62±0.09a	0.33±0.08a	0.29±0.05a
	P50Pr50	0.64±0.14a	0.62±0.09a	0.32±0.07a	0.27±0.07a
	P50Pr30Q20	0.62±0.13a	0.64±0.07a	0.30±0.06a	0.31±0.10a
	P60Q40	0.60±0.05a	0.63±0.02a	0.28±0.05a	0.29±0.05a
	P75C25	-	0.50±0.11a	-	0.25±0.09a

The anamorph of *C. bicorne* was successfully isolated from the roots of seedlings that had been inoculated with the pathogen (Table 6). *Pythium* spp. were also present in the roots but only in those seedlings grown in peat or the peat-compost mixture. No *Rhizoctonia* were present in the roots of the control seedlings. All the *Rhizoctonia* isolates from infected seedlings were uninucleate, and 48 out of 50 of the tested isolates anastomosed with strain 264 used for inoculation showing perfect fusion, indicating that 48 isolates are of the same vegetative compatibility group, i.e. the same isolate, while two are not deriving from that artificially inoculated.

Table 6. The number of root pieces, out of a total of nine, from which uninucleate *Rhizoctonia* (the anamorph of *Ceratobasidium bicorne*) (Cb) and *Pythium* (P) were isolated

Treatment	Growth medium	Scots pine				Norway spruce			
		Exp 1		Exp 2		Exp 1		Exp 2	
		Cb	P	Cb	P	Cb	P	Cb	P
Control	P100	0	1	0	0	0	1	0	0
	P50Pr50	0	0	0	0	0	0	0	0
	P50Pr30Q20	0	0	0	0	0	0	0	0
	P60Q40	0	0	0	0	0	0	0	0
	P75C25			0	3			0	2
C. bicorne	P100	6	0	7	1	8	1	6	2
	P50Pr50	6	0	4	0	6	0	5	0
	P50Pr30Q20	7	0	8	0	5	0	5	0
	P60Q40	5	0	3	0	7	0	6	0
	P75C25			5	6			7	3

Discussion and conclusions

In this study, the material added to the *Sphagnum* peat slightly decreased the growth of non-inoculated control seedlings. Similarly, the shoot and root dry masses were higher in the seedlings grown in peat than in the other growth media. For spruce the difference was in most cases statistically significant.

Light *Sphagnum* peat has a high water retention capacity but, under dry conditions, it has a low hydraulic conductivity, which may indicate low water availability to plants. Therefore, additives can be used to alter the physical properties of peat (Heiskanen 1999). Coarse-textured additives in peat are known to increase the bulk density and air-filled porosity, which allows increased aeration and removal of excess water through increased infiltration (Langerud and Sandvik 1987, Heiskanen 1994, 1995a, 1999). Fine mineral particles added to peat have the opposite effect; they increase the unsaturated hydraulic conductivity, water retention and thus water availability to the roots (Heiskanen 1999). In our study, the perlite constituent alone or as a mixture with quartz sand did not improve the physical properties as aeration or water availability of the peat to such an extent that it would have been reflected as better growth. None of the additives, including compost, increased the organic matter content of growth media. However, the beneficial effects of compost utilization on plant growth and health have been reported in many greenhouse- and nursery-crop production systems including woody ornamentals (Bugbee 2002, Scheuerell et. al. 2005, Termorshuizen et al. 2006). Earlier studies indicate that the forest nursery waste compost has a relatively fine texture and high density compared with peat and it may, therefore, lower the air-filled porosity and oxygen diffusion rate of the mixture (Veijalainen et al. 2008). However, this type of compost has been used successfully as a minor component (25% by volume) in peat-based growth medium as here for Norway spruce seedlings. These seedlings subsequently can have the same level of out-planting survival, height and stem diameter as seedlings grown in pure peat (Veijalainen et al. 2007, Heiskanen 2013).

According to a previous study, *C. bicorne* is capable of infecting Scots pine and Norway spruce seedlings at a variety of irrigation levels in *Sphagnum* peat although wet conditions caused more severe symptoms (Lilja et al. 1998). In our study, the root dieback infection was found to be detrimental in all the peat-based growth media used. The differences in the physical properties of the growth medium mixtures, caused by the additives in the peat, did not decrease the pathogenicity of *C. bicorne*. At the end of the growing season, the pine and spruce seedlings, that had been inoculated with the pathogen in mid July, were shorter than the controls in all the growth media. A few spruce seedlings also died in the inoculated media. The retarded growth and low mortality found in our study is in agreement with the findings of earlier studies, in which the seedlings at the time of inoculation had a root system large enough to survive despite infection (Lilja et al. 1996, Hietala 1998).

Vegetative compatibility test based on anastomosis test was used to study the origin of the pathogen in inoculated seedlings. The anastomosis test is based on paring the isolates from diseased seedlings with the isolates used in inoculations and observing the hyphae for fusion. The related isolates are capable of recognizing each other and are able to undergo hyphal fusion (Sneh et al. 1991, Carling 1996). In uninucleate *Rhizoctonia* sp. (anamorph of *C. bicorne*), as in other *Rhizoctonia* spp., perfect fusion occurs only in a self or clone paring (Carling 1996, Hietala et al. 2003). Two of the tested 50 isolates from the roots of test seedlings were somatically incompatible with the inoculated isolate. This showed that the pathogen was present in the experimental area and the air layer between trays and floor could not inhibit outside infection or the pathogen as well as *Pythium*s were present in the growth medium or container cavities (Venn et al. 1986, Kohman and Børja 2002). *Pythium* spp., which thrive under wet conditions, were isolated from both the roots of the control and the inoculated seedlings grown in peat or peat-compost mixtures at the end of the experiments. The presence of *Pythium* spp. and the high water retention capacity of peat and peat-compost, as determined here, suggest that the water content in these media was higher than that in other media.

In conclusion, pure *Sphagnum* peat has shown to be the best growth medium for container seedlings of pine and spruce in nurseries, and it was not possible to control the root dieback by means of used additives, perlite and quartz sand, under normal irrigation practice. The nursery waste compost did not increase the organic matter content of the growth medium nor did it have suppressive effect on *C. bicorne.*

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ВОЗДЕЙСТВИЕ ДОБАВОК НА ТОРФЯНУЮ ПОЧВУ И ЧАСТОТА ВОЗНИКНОВЕНИЯ ОТМИРАНИЯ КОРНЕЙ СЕЯНЦЕВ СОСНЫ И ЕЛИ ОБЫКНОВЕННОЙ

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Резюме

Чистый торфяной мох *Sphagnum* известен своими хорошими физическими и химическими свойствами для выращивания сеянцев в контейнерах. Однако он может не всегда предоставлять оптимальные условия по влажности и аэрации для контейнерных сеянцев, выращенных на полях, особенно в дождливые лета, когда возможны случаи затопления. Повышенное содержание воды в питательной среде способствует возникновению грибковых инфекций корней, как в случае отмирания корней, вызванного патогенным микроорганизмом *Ceratobasidium bicorne*. Использование перлита и минерального песка при подготовке питательных смесей осуществляется уже давно. В последнее время использование компостов в качестве питательной среды набирает все большую популярность ввиду экологических интересов по утилизации органических отходов. Микрофлора компоста также могла бы подавлять рост корневых патогенов. В настоящем исследовании указанные добавки были использованы в торфяной почве для разработки различных физических свойств и условий в целях тестирования их воздействия на факты отмирания корней и рост сеянцев.

Сеянцы сосны и ели обыкновенной были выращены из семян в отдельных контейнерах в теплице, расположенной в Центральной Финляндии. В первом эксперименте контейнеры были заполнены легким, маловлажным торфяным мхом *Sphagnum* или смесями с торфяным мхом и крупным перлитом и/или мелким кварцевым песком. Повторный эксперимент был проведен с добавлением компостированных отходов лесного питомника в качестве компонента питательной среды. В возрасте двух месяцев часть сеянцев была привита на *C. bicorne*. Сеянцы были обследованы в конце первого периода роста и весной следующего года.

Добавки привели к изменению физических свойств торфяного мха *Sphagnum*. Показатели содержания органических веществ во всех смесях были ниже, а общая плотность выше, чем соответствующие показатели чистого торфяного мха. Особенно добавление кварцевого песка способствовало увеличению общей плотности питательной среды. Общая пористость и водоудерживающая способность торфа и компостированного торфа были выше чем у песчаных смесей с перлитом и/или кварцем. Исследование, однако, показало, что ни одна из питательных сред не подавляет патогенность *C. bicorne* при нормальном режиме орошения.

Ключевые слова: *Ceratobasidium bicorne*, мононуклеарный *Rhizoctonia*, *Pythium*, *Picea abies*, *Pinus sylvestris,* физические свойства, питательная среда.