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Growing Growing Media: Promises of *Sphagnum* Biomass

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Keywords: *Sphagnum* farming, growing media, renewable resource, peat, cut-over peatlands

Abbreviations: NLÖ: Niedersächsisches Landesamt für Ökologie (Ecological Survey of Lower Saxony), NLfB: Niedersächsiches Landesamt für Bodenforschung (Geological Survey of Lower Saxony)

Abstract

The most important raw material in professional horticulture is white peat, which has developed from peatmosses (*Sphagnum*) in living bogs. About 30 millions m³ of white peat are globally used for this purpose annually.

The use of (white) peat involves two main problems:

1. **Peat extraction destroys the important functions of bogs for nature conservation and climate regulation (as carbon storage).**
2. **Peat is a finite raw material. In most countries of Western and Central Europe the stocks of fossil white peat are nearly depleted.**

Therefore a non-polluting alternative ensuring a lasting and sustainable supply of raw material has to be developed. This alternative could be the cultivation of peatmosses (*Sphagnum* farming). Fresh peatmoss biomass has the same physical and chemical properties as white peat and enables plant cultivation without a loss of quality (Emmel, 2008).

In a three year research project "Peatmoss as a renewable resource" (financed by the German governmental Agency of Renewable Resources FNR), the University of Greifswald in cooperation with the Institute of Soil Technology in Bremen and the German peat industry, studied the optimal conditions for *Sphagnum* growth.

The first promising results show that with aimed measures and nursing (e.g., water level regulation) peatmoss growth can be encouraged.

INTRODUCTION

Fossil peatmosses of the genus *Sphagnum* are the main constituents of slightly humified *Sphagnum* peat ("white peat"). This peat is currently - with a worldwide consumption of 30 M m³ annually - the most important raw material for high-quality growing media in professional horticulture (Joosten and Clarke, 2002). As the stocks of white peat in Western and Central Europe are nearly depleted, peat extraction increasingly moves into the Baltic States, Scandinavia and Canada (Joosten, 1995a, 2003). Not only is peat a finite, non-renewable resource (Joosten, 2004), peat extraction also destroys important nature conservation (biodiversity) and climate regulation (carbon storage) functions of bogs irreversibly (Joosten, 1995b, 1998).

Therefore, a more sustainable and less destructive alternative has to be found that meets the high standards of professional horticulture.

Such alternative could be the cultivation of peatmosses (*Sphagnum* farming). Fresh peatmoss biomass has the same physical and chemical properties as white peat, has an additional bactericide and fungicide effect and enables plant cultivation without loss of quality (Emmel, 2008). Potential areas for implementation of *Sphagnum* farming include cut-over bogs, former bog grasslands (Deutsche Hochmoorkultur) and open water areas in abandoned lignite strip mines (Gaudig and Joosten, 2002).

Until now no research has focused on maximizing *Sphagnum* primary production for commercial purposes. Studies in *Sphagnum* ecology under natural conditions or for bog restoration, however, indicate that *Sphagnum* productivity can be increased by:

* high water tables, i.e., by growing "hummock" species under "hollow" conditions (Clymo and Reddaway, 1974; Lütt, 1992; Rydin, 1993),
* phosphate and potassium fertilisation, as under conditions with high atmospheric nitrogen deposition (such as Western Europe) peatmoss growth is not nitrogen-limited (Malmer, 1990; Aerts et al., 1992; Verhoeven et al., 1996; Risager, 1998; Limpens et al., 2000; Limpens and Berendse, 2000),
* some shading (Pedersen, 1975; Clymo and Hayward, 1982; Lütt, 1992) and
* increased CO_2 availability (Silvola, 1990; Paffen and Roelofs, 1991; Smolders et al., 2001).

In this paper, we report on the first results of greenhouse experiments on the effects of water level, phosphate and potassium fertilisation, shading and enhanced CO_2 availability on *Sphagnum* growth.

MATERIALS AND METHODS

Samples of *Sphagnum magellanicum, S. papillosum, S. palustre, S. fimbriatum* and *S. rubellum* were cut out from natural peatmoss lawns in Northwestern Germany and the Netherlands and placed in pots (12x12x12 cm) maintaining their natural configuration. Cultivation took place under controlled conditions in a greenhouse (6 h light at least 400 lux, 21°C; 6 h light, 18°C; 12 h dark 12°C) in a nutrient solution with a composition similar to that of rainwater (Table 1).

Stable water tables of 5 cm and 2 cm below the capitula were maintained by irrigating with demineralised water several times a day. Fertilisation (variants C, P2, P5, K2, K5 and P2K2, see Table 2) was provided every third week with a watering can. A 20% shading treatment was provided by a screen (type Planta Net® transparent). All treatments comprised six replicas.

To investigate the effects of possibly increased CO_2-supply from decomposing peat, *Sphagnum papillosum* was cultivated in an open greenhouse (only protected from rainfall) in pots (Ø 19 cm, 25 cm high, 7,3 L) with the following substrates:

* sterilised highly-decomposed *Sphagnum* peat (HDP) (pH 3,2), or
* sod of bog grassland (pH ca. 4,5) (SOD), or
* highly-decomposed *Sphagnum* peat (LIP) (pH 3,2) limed up to pH 8,1 with 10 g CaO L^{-1} peat.

The substrates were covered with 10 cm of sterilised highly-decomposed *Sphagnum* peat over which *Sphagnum papillosum* fragments were spread and subsequently covered with a layer of straw mulch to provide a suitable microclimate (Quinty and Hood, 1998; Quinty and Rochefort, 2000, 2003). Water levels in all variants were kept on 0 and 5 cm below capitulum by irrigating with demineralised water two times a day. Fertiliser solution was applied every three weeks with a dispensette.

All treatments, including all fertilisation variants (Table 2), comprised three replicas.

After 18 or 39 weeks the length of the mosses was measured and its increase tested against the various parameters using a three way factorial ANOVA (R Development Core Team, 2004).

RESULTS

Both a high water level (-2 cm), some shading (20%) and their combination stimulate the length growth of *Sphagnum magellanicum* highly significantly for all fertilisation levels under fully controlled conditions ($p < 0.005$, Fig. 1).

The effect of water level is less significant ($p < 0.05$) for *S. papillosum* on substrate.

From all *Sphagnum* species, *S. magellanicum* shows the smallest length growth under standard controlled conditions, against *S. palustre* the largest (Fig. 2a). The effect

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of fertilisation depends on the *Sphagnum* species. The length growth of *S. palustre* and *S. papillosum* is stimulated by P5 and even more by PK fertilisation, whereas fertilisation has a negative effect on *S. fimbriatum* and *S. magellanicum* (Fig. 2b).

Sphagnum length growth is significantly ($p < 0.005$) larger on sterile highly-decomposed peat (HDP) than on both other substrate types (Fig. 3a) but substantially lower than under fully controlled greenhouse conditions on hydroculture (Fig. 2a). Also in combination with various fertilisation levels, length growth is generally largest for the HDP substrate and lowest for limed peat (LIP) (Fig. 3b). The fertilisation variants P5, PK and K3 stimulate length growth on the standard substrate HDP significantly ($p < 0.005$, Fig. 3b), similarly to what was found under completely controlled conditions (Fig. 2b).

Whereas limed highly-decomposed peat (LIP) generally leads to a strongly reduced growth under various fertilisation options, the variants P2 and P3 show a small increase compared to the HDP standard (Fig. 3b). Length growth is not stimulated by fertilisation on the sod substrate (SOD) (Fig. 3b).

DISCUSSION

In this paper we used length growth as a measure for growth performance, as no information about the moss structure is available yet. With data on biomass increase (that will be available after final harvest) combined with data on length increase it will be possible to calculate a better proxy for the structure that is relevant for growing media.

The differences in length increase between the various experimental designs (Figs. 2 and 3) can be attributed to the moss plants growing steadily in the closed greenhouse, in contrast to the open greenhouse where temperatures periodically dropped considerably.

The positive effect of high water level on length growth of *Sphagnum magellanicum* is significant for all fertilisation levels ($p < 0.005$, Fig. 1). This effect is found less clearly for *S. papillosum*. Both results confirm the observations in nature (Lütt, 1992).

P and K fertilisation has no effect on the length growth of *S. magellanicum*. Because *Sphagnum* growth is under natural conditions N-limited (Twenhöven, 1992; Lee et al., 1993) and therefore nitrogen is the first limiting element (Malmer, 1993), this may indicate that the N-concentration in our nutrient solution (11,9 kg ha^{-1} y^{-1}) is too low to offset N-limitation. Differences with observations in the field may be ascribed to our experiment using *bulk* deposition values, whereas in the field the higher *total* deposition is relevant. This general absence of fertilisation effects contradicts the fact that the fertilisation variants P5 and P2K2 stimulate length growth of *S. papillosum* on hydroculture (Fig. 2b) and on HDP (Fig. 3b): For *S. papillosum*, however, hardly any data are available in the literature for comparison.

The assumed higher decomposition rate of the SOD and LIP substrates seems to have no effect on length growth. Measurement of CO_2 output is indispensable to check whether these variants, as supposed, indeed lead to a higher rate of CO_2 production.

CONCLUSIONS

The first results of Sphagnum cultivation show that with water level regulation the length growth of *S. magellanicum* and with fertilisation that of *S. papillosum* can be increased.

Final conclusions about the effects of fertilisation, water level, shading and substrate on *Sphagnum* growth are only possible when biomass and nutrient content data are available after final harvest.

For the next phase of pot experiments in the closed greenhouse, it is necessary to use the total deposition (instead of the bulk deposition actually) to better approach field conditions and to consider other *Sphagnum* species in more detail.

ACKNOWLEDGEMENTS

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Tables

Table 1. Composition
bulk deposition 19
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macro elements	Ca	Cl
mg L^{-1}	0.42	4.18
kg $ha^{-1}y^{-1}$	3.31	33.26
micro elements	Ti	Sn
µg L^{-1}	1.65	0.74
g $ha^{-1}y^{-1}$	13.1	5.9

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Tables

Table 1. Composition of the fertilisation solution. Macro-elements according to mean bulk deposition 1991–2001, 795 mm precipitation per year, in North Western Germany (A. Jankowski NLÖ Hildesheim, pers. commun., 2004), Fe after Database of NLfB Hannover 2004, micro-elements after Rudolph et al. (1988).

macro elements	Ca	Cl	K	Mg	N	Na	oPO4	S	Fe			
mg L^{-1}	0.42	4.18	0.29	0.35	1.50	2.59	0.018	1.01	0.01			
kg $ha^{-1}y^{-1}$	3.31	33.26	2.33	2.79	11.9	20.57	0.14	8.06	79.5			
micro elements	Ti	Sn	Li	Mn	B	Zn	Cu	Co	Ni	Al	I	Br
µg L^{-1}	1.65	0.74	0.23	5.40	5.37	1.11	0.70	0.56	0.62	0.22	1.08	0.94
g $ha^{-1}y^{-1}$	13.1	5.9	1.8	42.9	42.7	8.9	5.6	4.4	4.9	1.8	8.6	7.5

Table 2. Fertilisation variants.

Code	Variant	P (kg P ha^{-1} y^{-1})	K (kg K ha^{-1} y^{-1})
C	Control: no additional fertiliser	0.14	2.33
P2	Phosphorus availability 2 x C	0.28	2.33
P3	Phosphorus availability 3 x C	0.42	2.33
P5	Phosphorus availability 5 x C	0.70	2.33
K2	Potassium availability 2 x C	0.14	4.66
K3	Potassium availability 3 x C	0.14	6.99
K5	Potassium availability 5 x C	0.14	11.65
P2K2	Both phosphorus and potassium availability 2 x C	0.28	4.66

Figures

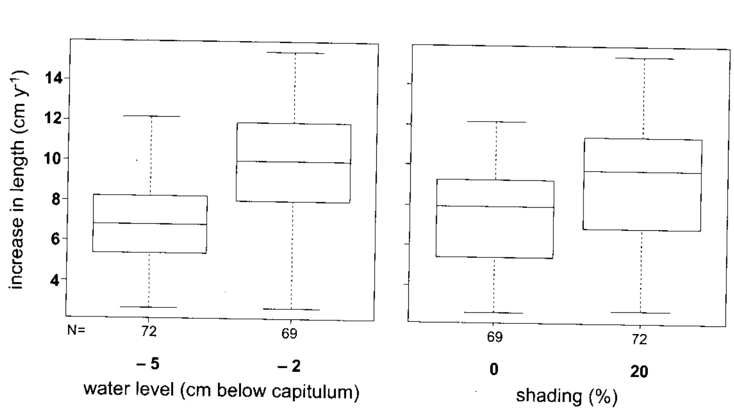

Fig. 1. Increase in length (cm y^{-1}) of *Sphagnum magellanicum* as a function of water level (2 or 5 cm below capitulum) and shading (0 or 20% shading) for all fertilisation levels under fully controlled conditions.

a)

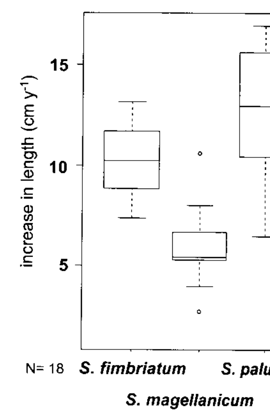

Fig. 2. a) Length growt
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b) mean length
below capitulum

a)

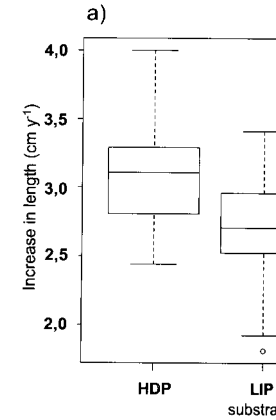

Fig. 3. a) Length growt
b) mean length
fertilisation level
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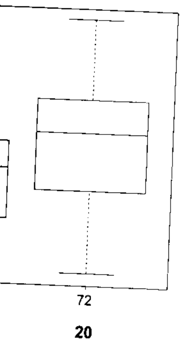
P (kg P ha^{-1} y^{-1})	K (kg K ha^{-1} y^{-1})
0.14	2.33
0.28	2.33
0.42	2.33
0.70	2.33
0.14	4.66
0.14	6.99
0.14	11.65
0.28	4.66



n as a function of water level
shading) for all fertilisation

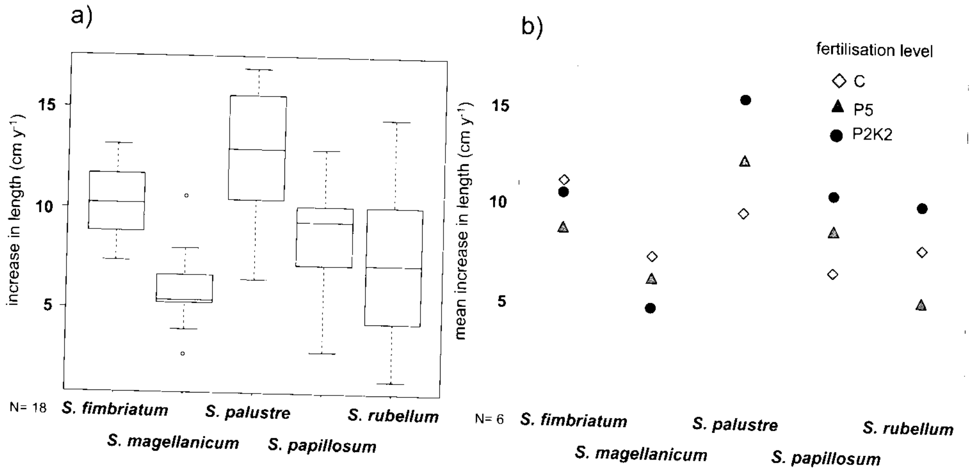


Fig. 2. a) Length growth (cm y^{-1}) of various *Sphagnum* species under standard conditions (water level 5 cm below capitulum, no shading, fertilisation levels C, P5, P2K2); b) mean length growth (cm y^{-1}) as a function of fertilisation (water level 5 cm below capitulum, no shading). For abbreviations, see Table 2.

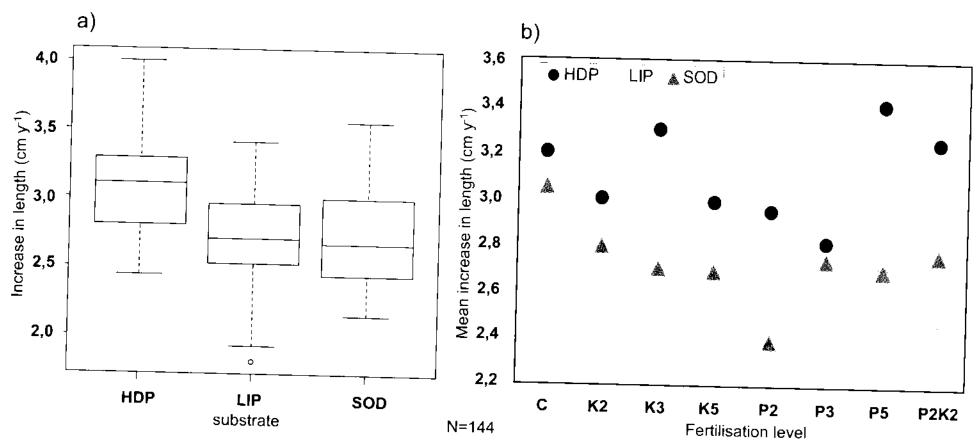


Fig. 3. a) Length growth (cm y^{-1}) of *Sphagnum papillosum* on different substrate types; b) mean length growth (cm y^{-1}) of *Sphagnum papillosum* as a function of fertilisation level (for abbreviations see Table 2) and substrate type (HDP = sterile highly-decomposed peat; LIP = limed sterile highly-decomposed peat; SOD = sod of former bog grassland).