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RENEWABILITY, USE AND PROPERTIES OF SPHAGNUM BIOMASS FOR GROWING MEDIA PURPOSES

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SUMMARY

Horticultural peat is a microbiologically active growing medium, which also binds nutrients and water well because of its favourable cation exchange capacity and porosity. Unfortunately, horticultural peat is a slowly renewable biomass and good quality horticultural peat is rather uncommon even in peatland-rich countries. According to our results from two experimental *Sphagnum* biomass harvesting sites in Central Finland, harvested sites will regenerate rapidly. Areas with light *Sphagnum* removal (to depth of < 25 cm) clearly regained their function as carbon sinks within three years, and no statistically significant detrimental effects on watercourses were observed during the water quality monitoring period. Excluding *S. riparium*, all other *Sphagnum*-based growing media led to 30─47% higher seedling growth than rockwool or horticultural peat.

KEYWORDS: *Sphagnum* biomass, renewability, growing media

INTRODUCTION

Nowadays, the two primary growing media used in greenhouse cultivation are rockwool and white horticultural peat. Horticultural peat is a microbiologically active growing medium, which also binds nutrients and water well because of its favourable cation exchange capacity and porosity. The risks of plant diseases are also markedly lower than when using synthetic growing media. Unfortunately, horticultural peat is a slowly renewable biomass and good quality horticultural peat is not so common even in peatland-rich countries. Thus, good quality and simultaneously renewable growing media alternatives are needed. The alternative that we have studied is based on *Sphagnum* biomass which is harvested and regrown within 20─30 years on the same peatland.

Sphagnum biomass is harvested from the mire surface down to a maximum depth of 25 cm, but ideally only to 10-15 cm (Silvan 2008, 2009, 2010). The maximum harvesting depth of 25 cm ensures the renewability of *Sphagnum*. The best harvesting period is during winter, when the depth of soil frost is approximately similar to the harvesting depth. Wintertime *Sphagnum* biomass harvesting is "tidy" and economical. However, *Sphagnum* biomass harvesting can be carried out successfully with suitable machinery also in the summertime, although it is then more expensive.

For growing media purposes, hummock-forming and some lawn species (*Sphagnum fuscum*, *S. rubellum*, *S. magellanicum* and *S. papillosum*) are most suitable (Silvan 2008, 2009, 2010). The best habitats for these species are pristine nutrient-poor treeless or sparsely wooded bogs. However, many forestry drained nutrient-poor peatlands also contain adequate amounts of *Sphagnum* for harvesting. To respect public opinion, *Sphagnum* biomass harvesting should generally be directed at nutrient-poor forestry drained peatlands. This does not pose a problem in Finland, for almost one million hectares of nutrient-poor forestry drained peatlands exist, which in any case will remain outside forestry use. Additionally, *Sphagnum* biomass harvesting with partial tree removal may serve as an effective restoration method for nutrient-poor drained peatlands. However, the precise extent of area suitable for *Sphagnum* biomass harvesting is unknown, since it depends considerably on the available technology, harvesting economics as well as legislation, and whether or not *Sphagnum* biomass is truly considered as a renewable biomass in the future.

In any case, suitable peatland areas for *Sphagnum* biomass harvesting will be sufficiently available since the peatland area required for replenishing the horticultural peat demand in Finland's domestic markets (ca. 500 000 m^3 a^{-1}) is only approximately 9000 hectares over a rotation time of ca. 30 years. This is provided that the average harvesting depth is max 25 cm and two-thirds of the harvestable area is actually harvested while one-third remains intact. Furthermore, if international demand for *Sphagnum* biomass based growing media is adequate, the peatland area suitable for *Sphagnum* biomass harvesting in Finland will also enable much larger harvesting volumes .

MATERIALS AND METHODS

Study sites

The study was carried out on two nutrient-poor forestry-drained peatland sites, Keisarinneva and Tunkiosalonneva, Central Finland (62˚12´N, 23˚18´E and 62˚11´N, 22˚48´E, respectively) during 2006─2008 (Keisarinneva) and 2009─2011 (Tunkiosalonneva).

Sphagnum capitula regeneration monitoring

The regeneration of *Sphagnum* capitula was monitored over three years on both sites. For this, 90 systematic monitoring plots of 0.007 m^{-2} were established on the *Sphagnum* biomass harvesting sites. Regeneration monitoring was carried out in August of each study year.

Carbon sequestration and greenhouse gas analyses

To analyze the carbon sequestration and thus rehabilitation and growth of *Sphagnum*, CO_2 exchange measurements employing the closed chamber technique, which relies on a portable infra-red gas analyzer (Alm *et al.* 2007), were carried out on the study sites after harvesting. Methane (CH_4) and nitrous oxide (N_2O) fluxes were measured by means of the static closed chamber method, where successive air samples are drawn into four syringes *in situ* from the headspace of the chamber (Alm *et al.* 2007).

Discharge water geochemistry monitoring

Runoff ($l\ s^{-1}\ ha^{-1}$), pH, suspended solids (SS) and dissolved organic carbon (DOC) concentrations and total nitrogen (N_{tot}), ammonium-nitrogen (NH_4^+), nitrate-nitrogen (NO_3^-), total phosphorus (P_{tot}) and phosphate-phosphorus (PO_4^{3-}) were monitored in the study sites. Runoff rates were measured using manually monitored Thompson's (90°) measuring weirs.

Transplant production analyses

Sphagnum biomass was tested in the transplant production of greenhouse cucumber (*Cucumis sativus* L. 'Annica'), tomato (*Lycopersicon esculentum* Miller 'Encore' and leaf lettuce (*Lactuca sativa* var. *crispa* 'Grand Rapids Ritsa'). Seven growing media were used in the experiment: white peat (Kekkilä White 620 pH 6.0), mineral wool, three *Sphagnum* species separately (*S. fuscum*, *S. magellanicum* and *S. riparium*) and two admixtures of *Sphagnum* species (natural admixture of *S*. species and mixed admixture of *S. fuscum* 33,3 %(v/v), *S. magellanicum* 33,3 %(v/v) and *S. riparium* 33,3 % (v/v)).

RESULTS

According to our results, the *Sphagnum* carpet of harvested sites will regenerate rapidly. The best *Sphagnum* colonizer was *S. balticum*, especially at the start of succession, but during succession *S. fuscum* and *S. magellanicum* reclaimed the free area also. The regeneration of new *Sphagnum* capitula varied between 500–30000 capitula m^{-2}, while averaging ca. 8000 capitula m^{-2}.

Areas with light *Sphagnum* removal (to depth of < 25 cm) significantly regained their function as carbon sinks within three years, in the Tunkiosalonneva site to an almost pristine-like level (Fig.). However, on deep removal areas (25-50 cm), the rate of carbon sequestration was much smaller (Fig.). Light *Sphagnum* biomass harvesting had only a minor effect on the emissions of methane and nitrous oxide, but deep removal enhanced methane emissions significantly on the Keisarinneva site (Fig.). No statistically significant detrimental effects on watercourses were observed during the water quality monitoring period (Table 1).

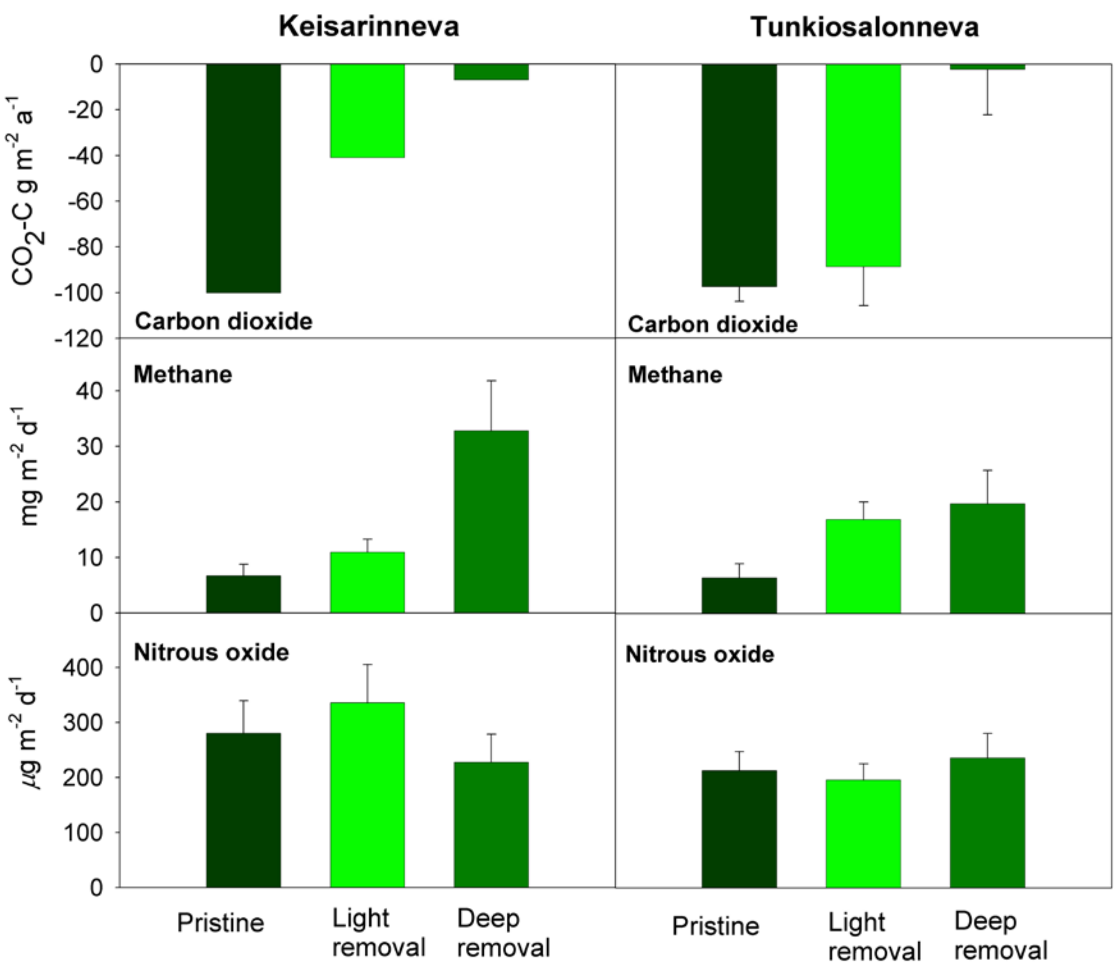

Fig. 1. Greenhouse gas dynamics on the *Sphagnum* biomass harvesting sites.

Table 1. Water geochemistry characteristics in upper and lower sampling weirs at Keisarinneva and Tunkiosalonneva *Sphagnum* biomass harvesting sites.

Indicator	Keisarinneva Upper	Keisarinneva Lower	Tunkiosalonneva Upper	Tunkiosalonneva Lower
SS, mg l^{-1}	2.5	2.8	3.0	3.2
DOC, mg l^{-1}	3.1	3.0	5.2	5.2
N_{tot}, μg l^{-1}	430	440	540	545
NH_4^+, μg l^{-1}	63	66	72	68
NO_3^-, μg l^{-1}	15	17	18	13
P_{tot}, μg l^{-1}	11	13	14	16
PO_4^{3-}, μg l^{-1}	2	2	3	3

Small tomato and lettuce seeds did not germinate in *S. riparium* substrate as fast as in other substrates (data not shown). Cucumber and tomato plants grew in white peat as well as in mineral wool (Table 2), but more slowly in *Sphagnum riparium* than in white peat. Cucumber and tomato grew faster in *S. fuscum*, *S. magellanicum* and both admixtures of *S*. species than in white peat. Leaf lettuce grew slower in mineral wool than in white peat, but nonetheless faster in all *Sphagnum*-based substrates compared to white peat.

Table 2. Fresh weight of cucumber, tomato and lettuce plants in different growing media. In each column, values followed by the same letter do not differ significantly.

Substrate	Cucumber	Tomato	Lettuce
White peat	79b	125b	5.8b
Mineral wool	80b	136b	3.9a
Sphagnum fuscum	100c	184c	8.1c
S. magellanicum	99c	170c	7.8c
S. riparium	71a	69a	7.3c
Natural S. admixture	98c	182c	7.8c
Mixed S. admixture	100c	183c	8.3c

DISCUSSION

According to our results, light *Sphagnum* biomass harvesting which extends down to a maximum depth of 25 cm will only disturb *Sphagnum* carpet coverage and carbon sequestration in the short term (under 5 years). Additionally, *Sphagnum* biomass harvesting has not been observed to cause detrimental effects on watercourses. Our preliminary estimate of a 30-year rotation time on the same harvesting site will probably be achieved. The end product, *Sphagnum* biomass based growing media will thus be truly renewable, with only negligible environmental effects compared to conventional horticultural peat. Therefore, this method for *Sphagnum* biomass harvesting is chiefly comparable with forestry, not peat production. Additionally, according to our preliminary results, *Sphagnum* biomass is a proven better growing medium than horticultural peat. *Sphagnum fuscum*, *S. magellanicum* and both mixtures of *S*. species are especially promising substrates in transplant production.

However, the regeneration of deep removal areas (over 25 cm) is remarkably poorer than light removal areas. On such areas, the recolonization of mire vegetation and thus also carbon sequestration recovery will probably not reach the same level as light removal areas during the rotation time, ca. 30 years. If harvesting depth exceeds 25 cm, the risk of *Sphagnum* dominant vegetation being replaced by sedge-like vegetation increases. For example, *Eriophorum vaginatum* may flourish while also potentially enhancing methane emissions (Tuittila *et al.* 2000). Moreover, degradation of scenery is greater the deeper the harvesting.

Although Finland is truly a Fenland where peat reserves are extensive, a shortage of good quality horticultural peat may become a reality already in the near future as demand markedly increases. Unfortunately, the best areas for good quality, horticultural peat production are large pristine raised bogs, which are likewise valuable as nature sanctuaries. In Southern Finland and especially Middle Europe, nearly all of the pristine mires large enough for horticultural peat production enjoy some level of protection nowadays. *Sphagnum* biomass harvesting as a natural and environmentally friendly method provides a renewable alternative for growing media production, which does not require the establishment of expensive ditching, harvesting field preparation or road construction.

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