Sphagnum moss as a growing media constituent: some effects of harvesting, processing and storage

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SUMMARY

The *Sphagnum* material used in horticulture so far has been harvested manually, and most of the available data about *Sphagnum* properties have been obtained from this material. A question that remains unanswered is how changes during harvesting and processing, as well as the use of mechanical methods, affect the important properties of *Sphagnum* moss as a growing media constituent. Some of the effects have been evaluated in Sphagnum farming projects in Germany during the past ten years, and are described in this article. Different possibilities for drying, screening and cleaning the *Sphagnum* material are described. The results obtained indicate that *Sphagnum* moss can be dried and processed using mechanical methods without negative impacts on its quality as a growing media constituent.

KEY WORDS: drying methods, paludiculture, quality criteria, screening, *Sphagnum* field

INTRODUCTION

Peat has been the most important constituent of growing media for several decades because it combines many favourable properties (e.g. low pH and nutrient content, lack of pests, pathogens and weed seeds) and is easy to process (Schmilewski 2008). Slow decomposition and stability of physical properties are also important (Aubé *et al*. 2015). *Sphagnum* moss has been used in horticulture mostly for the cultivation of orchids, which have special growing media requirements like good aeration and adequate water holding capacity (Amberger-Ochsenbauer 2010). Undecomposed *Sphagnum* has also been used to improve the quality of peat-based growing media (Jobin *et al*. 2014), for example as a replacement for peat.

Until now, the *Sphagnum* moss used in horticulture has always been harvested by handpicking. The peat bogs of Chiloé Island, Chile, are a well-known source of *Sphagnum* harvested in this way (Díaz & Silva 2012). The harvest takes place in natural mires where *Sphagnum* occurs as part of the typical biota, and a huge amount of manual labour is used in further processing (Tilling 1995). This is necessary because access for heavy machinery is very difficult or impossible in natural mire areas. The *Sphagnum* moss harvested in Chile comes dried and pressed into bales. For transport overseas the dry material has the advantage of low weight combined with volume compression, but it must be submerged in water to regain moisture before it can be used for potting. This kind of processing is economically feasible only when labour costs are rather low and the price of the product is much higher than that of other growing media constituents which are available in Europe at the present time.

The research presented here is part of the current effort to establish ‘wet use’ of cultivated peat bogs in north-west Germany (“paludiculture”; Gaudig *et al*. 2013). Paludiculture is seen as a major possibility for reducing greenhouse gas emissions from organic soils while still providing sustainable income from the land. Additional benefits include flood control and positive effects on biodiversity (Joosten *et al.* 2016). Growing *Sphagnum* as an agricultural crop - so-called “Sphagnum farming” - is one example of paludiculture. Sphagnum farming could also supersede the harvesting of *Sphagnum* mosses from natural mires.

To be adopted as a growing media constituent, *Sphagnum* moss must meet more stringent criteria than are required for orchid cultivation. Also, to bring prices down to a level where *Sphagnum* mosses can compete on the market for growing media constituents in Germany, mechanisation of all processes is absolutely necessary. The company Torfwerk Moorkultur Ramsloh has carried out extensive trials to develop and optimise production techniques for farmed *Sphagnum* as a growing media constituent. The steps involved are listed, and associated issues are described for each step, below.

1. Maintenance and harvesting of *Sphagnum* fields
In natural mire a well-trained operative, perhaps equipped with a rake, is able to manually harvest *Sphagnum* material which contains only small amounts of other plant species (impurities). This is done by selecting a suitable harvesting location and sorting the material immediately in the field, before packing into containers (e.g. bags or boxes). Using the mechanical harvesting techniques that are currently being tested by Torfwerk Moorkultur Ramsloh - for example, an excavator with mounted mowing basket - this is not possible. Unless the material is already very clean before harvesting, impurities are harvested with the mosses. This means that the area to be harvested must have a very high percentage cover of *Sphagnum* mosses. The required cover can be achieved with proper establishment (Krebs *et al*. 2012) and maintenance management of the *Sphagnum* lawn. In this case, maintenance involves regular mowing so that other plants cannot overgrow the *Sphagnum*, and keeping the water table a few centimetres below the *Sphagnum* surface.

2. Drying of harvested *Sphagnum* material
Most of the *Sphagnum* moss currently on the market is harvested from natural mires in Chile and New Zealand, and is dried and compressed for easier transport. After harvesting, it is dried by sunshine and wind. The process involves manually spreading the moss onto wooden benches under a plastic cover, after which it is periodically turned by hand. This traditional drying method would be too costly under German conditions, especially in view of the much larger quantities of *Sphagnum* material that we shall need to process. Therefore, the amount of manual labour must be reduced and the cost for heating should be low. A technique that involves harvesting pure *Sphagnum* in autumn followed by storage in small piles over winter has been tested previously. The *Sphagnum* was dried during springtime, in stacks on the mire in central Finland, and the moisture content of *Sphagnum* material used for the horticultural trials which followed was around 70 % (Reinikainen *et al*. 2012). This method is of interest especially for circumstances where transport costs are of lesser importance and the priority is for the growing media producer to receive a ready-to-use product without costly and time-consuming rewetting procedures.

3. Cleaning and screening of the dried material
An important quality criterion for established uses of *Sphagnum* moss is the length of the strands. The definition of growing media quality for plant species other than orchids is more complicated. There are physical, chemical, biological and economic criteria, but the most important is suitability for the intended use (Schmilewski 2008). Another big issue, especially in producing growing media for the professional horticulture market, is the question of weeds. According to the two most important certification standards for growing media in Europe (Stichting RHP in The Netherlands and RAL Quality Assurance Association Growing Media for Plant Cultivation (GGS) in Germany) the number of germinating seeds or other viable plant parts in the growing media constituents is strictly limited, e.g. to one plant *per* litre of growing medium (GGS 2015). So for materials which are manufactured from plant residues like compost, rice hulls, *etc*. it is important to implement processing procedures which destroy unwanted seeds (and seedlings), bulbs or other plant parts. For the production of *Sphagnum* as a growing media constituent this means that regrowth of the moss itself, as well as any other living plant material that it contains, has to be prevented. *Sphagnum* material intended for use in the production of orchids is commonly treated with gamma radiation, but this method is expensive and unlikely to be acceptable in substrates for organic foodstuffs.

4. Storage of the processed *Sphagnum* material
The properties of growing media constituents should be maintained during transport and a reasonable period of storage. Therefore, it is very important for the growing media industry that they are able to guarantee important properties of their products for a certain amount of time. *Sphagnum* moss itself has few readily biodegradable components and contains antifungal and antibacterial substances (Klavina *et al*. 2012). Moreover, the export figures for moss shipped from Chile to the USA, Taiwan and Europe indicate that drying is a commonly accepted and reliable way to prepare *Sphagnum* for storage and transport. For example, the Instituto Forestal (INFOR) states in its *Boletin 14* that 3,500.6 tonnes of *Sphagnum* moss with a value of $ 10,928,606 (USD FOB) was exported from Chile during 2011 (Fuentes *et al*. 2012). However, what happens in a growing media mix with fertiliser and other constituents is a different question that requires clarification.

This article describes the various trials that have been carried out in Germany so far, towards developing suitable production techniques for farmed *Sphagnum* as a growing media constituent.

METHODS

Locations

Our first Sphagnum farming test field was located on an active peat extraction field at Ramsloh, Saterland (53° 04' 17″ N, 7° 38' 53″ E), and since 2011 the development of growing systems compatible with mechanical maintenance and harvest has taken place at the Torfwerk Moorkultur Ramsloh Research Site on Hankhauser Moor, Rastede (53° 15' 50″ N, 8° 16' 22″ E) (Figure 1). Processing techniques are tested at our production facility in Ramsloh.

Maintenance and harvesting

The test fields at Ramsloh and Hankhausen were very different in size, accessibility and installation. The Ramsloh field was rather small (1000 square metres). For drainage/irrigation, pipes were installed at 1 m depth and 10 m spacing. This field was part of an active peat extraction site, which meant that part of the peat layer around the test field was progressively removed during the Sphagnum farming trial. The total area of the Hankhausen research site was about 3 ha. It was surrounded by intensively used grassland on bog peat. The site itself was previously used as grassland for 70 years, and this had caused peat degradation in the topsoil and subsidence of about 70 cm over 50 years. The fields were divided into 10 m wide strips separated by ditches. Two strips were prepared for *Sphagnum* growing and the third was to be a dam. In preparation for Sphagnum farming, the topsoil on the *Sphagnum* strips was removed and used to build the dams. Drainage/irrigation was provided by open ditches.

The maintenance of test fields at both locations included mowing with a brush cutter at monthly intervals from April to October every year. The water level at both sites was controlled by a simple overflow system in which water was pumped into the system and any surplus was discharged *via* an overflow. The height of the overflow could be altered to allow adjustments in water level for the growing *Sphagnum* carpet.

After some harvesting trials, the final harvest at Ramsloh took place in August 2014 because the field had to be returned to its owner. The harvest was done with a mowing basket (Figure 2), a device built for excavators to clear plants and mud from ditches and drains. It is equipped with a sickle bar in front of the excavator dredger bucket. The bucket is made of steel rods so that water can flow off the harvested material. The first test harvest at Hankhausen took place in October 2015, on an area of 100 square metres. The mowing basket cut a top layer of moss carpet approximately 15 cm thick. This layer was harvested in strips 1 m wide. The material was put into wooden boxes of capacity ~ 1 cubic metre for transport and storage.

For comparison we used Finnish *Sphagnum* material harvested in September 2015. The Finnish harvesting took place on nutrient-poor forestry drained peatlands where maintenance before the harvest was not possible. The categories used in the comparison were:

- dry matter weight percentage of plants that were not *Sphagnum* (called “other plants”);
- dry matter weight percentage of vascular plant residues (called “non-moss”); and
- percentage dry matter (weight basis) of *Polytrichum* spp. for the samples from the Hankhausen research site.

Figure 1. The Ramsloh Test Field in October 2007 (left) and the Hankhausen Test Field in September 2012 (right). Photos: Silke Kumar.

Figure 2. Excavator with mowing basket harvesting *Sphagnum* on the Ramsloh Test Field, October 2015.

We used the last category because *Polytrichum* spp. were clearly distinguishable and an assessment of quantity was relevant to possible future research into the influence of other mosses on product quality.

The ‘other’ plant material was separated out by hand. Samples of the material were sorted in both fresh and dried condition in order to assess the difference in dry matter content of the different fractions, as well as to find out which method was easier. Three samples of each material were sorted separately and the mean was calculated.

Drying

For low-cost drying of *Sphagnum* material to meet commercial standards, that would be practical in Germany, we considered the four methods described below. All humidity measurements were taken according to DIN (2007) unless otherwise stated.

1. Drying with heat from a biogas plant

In the county of Cloppenburg there are many biogas plants on farms which produce, in addition to energy, a surplus of hot air for drying all kinds of materials. Therefore, we tried to dry the *Sphagnum* moss in the drying container of a 500 Megawatt biogas plant. The container was a standard 40-foot transport container. Hot air from the biogas plant was blown into this at one end and the outlet for the air was at the other end. The temperature of the hot air was 40–45 °C. The *Sphagnum* was placed in wooden crates and the crates were placed in the container for two days, then we turned the *Sphagnum* material to avoid drying only on the surface.

2. Commercial conveyor dryer

To dry at higher temperatures we tried a 500 KW commercial conveyer dryer rented from RIELA, Riesenbeck which used wooden pellets for heat production. The *Sphagnum* material was placed on an elevator which transported it into the dryer and onto a conveyor belt made of mesh material so that hot air could be blown through the material from below.

3. Drying in thin layers on concrete in sunlight

A manure spreader was used to spread out the moss on a clean concrete surface in summer heat (temperature 25–30 °C). The material was turned with a tractor and hay rake, once or twice depending on weather conditions. At the end of the day the mosses were collected by a grader with a rubber blade.

4. Storage of Sphagnum in small piles over winter

We tried a slight modification of the method of Reinikainen *et al*. (2012). Our harvest took place in autumn and the drying followed during winter and spring. However, instead of leaving the material in the mire, we stored it in 1 m high piles on a concrete platform from October to May. The moss was harvested with a mowing basket and simply put in rows about 1 m high on a concrete surface. The material was left in the rows for six months before the cleaning process continued.

Cleaning and screening

We cleaned the *Sphagnum* moss in two steps, which are described below.

1. Limiting unwanted plant growth

For the first step we used our facility for continuous vapour treatment of peat, which was built by Scheper Maschinenbau GmbH, Lohne. During this treatment the material is heated to more than 80 °C with hot vapour and kept at a temperature above 75 °C for 25 minutes. This is sufficient to kill all plant seeds, living plant parts, nematodes and other plant parasites that can be found in peat taken from the upper layers of extraction fields formerly used for agriculture. To check the success of the vapour treatment we used the weed test ‘LUFA Method A 13.5.2’ (VDLUFA 2000), executed by the LUFA soil analysis laboratory in Oldenburg. For this test, five litres of damp test material was mixed with calcium carbonate and a water-soluble fertiliser with balanced N-P-K, e.g. 15-10-15, so the mixture had pH about 5.5 and contained one gram of fertiliser *per* litre of material. The material was then placed in small plastic tubs (minimum dimensions: base area 1500 cm^2, depth 5 cm) and the tubs were arranged in full light under gauze, plastic or glass covers in a glasshouse at 21 °C where they were watered regularly so that germinating seeds would have good growing conditions. After three weeks, germinating and growing plants were counted and the results were calculated as number of plants *per* litre of substrate.

2. Detecting and removing impurities
A second test was carried out by LUFA Oldenburg according to VDLUFA (2000), to check the quality of the treated *Sphagnum* material as a growing medium. This test used Chinese cabbage, which is a good and fast indicator for the presence of plant-damaging substances in growing media (Gossow *et al*. 1995a,b). The test material and a standard seedling growing medium were put in small containers and Chinese cabbage (defined number of seeds) was sown into both materials in parallel (normally three replicates). The containers were then kept under standard growing conditions until the seedlings reached a previously defined stage of development. The germinating seeds were counted, then plant material above the substrate surface was cut off and weighed immediately. The development of leaves and roots was rated on a scale of one to nine (best).

To get physical impurities (e.g. weeds) out of the *Sphagnum* material we used a garden shredder (for small amounts) or a straw mill driven by a tractor. Our screening line for peat products (constructed by Albert Zubrägel GmbH, Lohne) could not be used if we had insufficient quantities of *Sphagnum* material. For this reason the screening line was tested only with *Sphagnum papillosum* harvested from the Ramsloh field in 2014.

Storage
Since growing media are stored in bulk or packed in plastic bags on pallets we tested these two variants. For these tests a growing media mix (see Table 1), which was also used in plant trials, was produced on a professional mixing line.

We stored the material loose or packed in 70 L plastic bags (by Klasmann Deilmann AG Sedelsberg) on Euro pallets with three bags *per* layer, ten layers *per* pallet. Storage was in a closed steel building without direct sunlight, although temperatures were nearly the same as outside. Samples were taken from the lowest, middle and upper layers of stored peat with a hand auger and mixed together. The mosses and growing media samples were analysed at LUFA Oldenburg according to VDLUFA (2000).

Table 1. Composition of the growing media mix.

Material	Ingredients	
	%	kg m^{-3}
Sphagnum moss	50	n.d.
Baltic Peat from Estonia, H 2–H4*, 20–40 mm fraction	25	n.d.
Baltic Peat from Latvia, H2–H4*, 7–20 mm fraction	12.5	n.d.
German Peat, H5–H8*, 7–20 mm fraction	12.5	n.d.
Lime (Carbocal, > 85 % $CaCO_3$, particle size 0–0.2 mm)	n.d.	6.5
Clay, fine (particle size < 1 mm; minimum of 10 % volume < 0.02 mm)	n.d.	6
Water-soluble fertilizer, PG Mix 14-16-18**	n.d.	1
Radigen fertiliser***	n.d.	0.1

*Humification scale following following von Post & Granlund (1926), indicating degree of peat humification, ranging from H1 (not humified) to H10 (fully humified).

**Composition of water-soluble fertiliser PG mix: 14.0 % N; 7.0 % P (16.0 % P_2O_5); 14.9 % K (18.0 % K_2O); 0.50 % Mg (1.0 % MgO); 0.03 % B; 0.15 % Cu; 0.09 % Fe; 0.16 % Mn; 0.20 % Mo; 0.04 % Zn.

***Composition of Radigen fertiliser: 2.0 % Fe, as 0.9 % Fe EDTA chelate and 0.9 % Fe HEDTA chelate; 1.0 % Cu; 1.0 % Mn; 0.8 % Mo (water soluble molybdate); 0.6 % B; 0.5 % Zn; 5.0 % MgO.

RESULTS

Maintenance and harvesting

The proportions of ‘other’ plant material in the first mechanical *Sphagnum* harvest from the Hankhausen research site are shown in Figure 3. We found a high percentage of *Polytrichum* spp. with (mostly) parts of *Juncus effusus*. The impurities in the moss from Finland were more typical mire plants (e.g. Ericaceae, *Eriophorum* spp.). Because the fresh mosses had higher water content than ‘other’ plant material, the percentage of impurities was lower when calculated on a fresh weight basis, as opposed to dry weight basis. Figure 4 provides an impression of the volumes of impurities encountered in the dry material.

Drying

The *Sphagnum* mosses were dry after two days in the biogas air dryer. Moisture content could be reduced to about 16 %. Using this method, we could not control the drying process or the drying temperature. To avoid great variations in moisture content the crates containing the mosses had to be taken out of the drying container and turned manually. The drying process was much better controlled in the conveyor

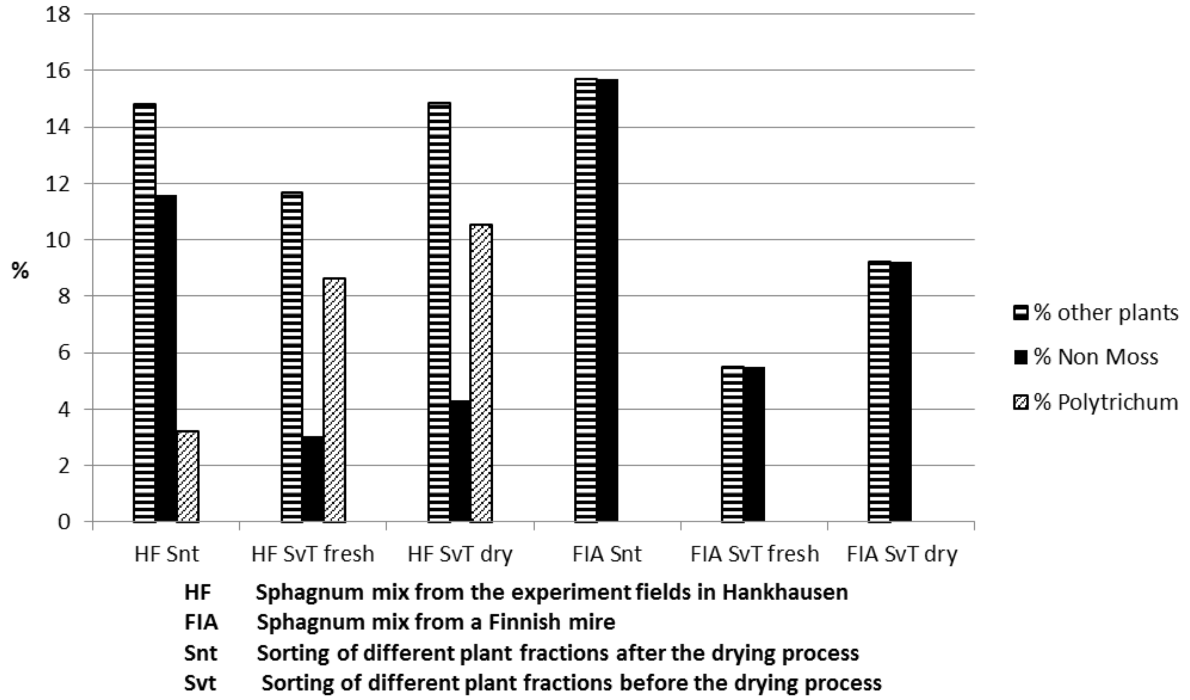

Figure 3. Non-S*phagnum* fractions as percentage by weight.

Figure 4. Fractions of *Sphagnum* moss (left dish) and other plant material (right dish) sorted after drying. *Sphagnum* from the Hankhausen test site (HF) and Finnish *Sphagnum* (FIA) (Silke Kumar 2015).

dryer. Very low moisture contents (down to 13.65 %) were reached within five hours. When drying in thin layers, drying took one or two days depending on weather conditions and we reached moisture contents of 24–30 %. The final moisture content of moss dried in a pile on concrete (following the Finnish method) was 70–80 %. In the following paragraphs, moss with moisture content below 30 % will be called "dry moss" and that with moisture content 70 % or more will be referred to as "wet moss", because there are differences in the handling of these two categories.

Cleaning and screening

Processing the dry material in the vapour treatment facility was somewhat difficult. The transport parts had to be adjusted to the light material, and the *Sphagnum* material reached high temperatures (more than 90 °C) very quickly because of its low density. As we did not want to cook it, we had to increase the speed of the transport spirals. In the end the material did not remain inside the facility for the required time of 25 minutes, and it took three days to cool down below 55 °C afterwards. However, the results of the subsequent pot growth test showed that the *Sphagnum* material was as good as the peat based seedling mix used as a control (Table 2). Treatment at 75 °C for 20 minutes was sufficient to kill all plant parts which would have germinated otherwise. Living *Sphagnum* was not recorded in the growth test, but in the first two samples there was regrowth of *Sphagnum* moss as well as a greenish algal layer. No regrowth was noticed following the vapour treatment.

It was not possible to use our normal screening line for *Sphagnum* material directly after harvesting (i.e. at field moisture content) because it clogged the screens. On the other hand, the very dry material created a huge amount of dust and very fine dusty material which was of use only in growing media for seedlings. We tried a straw mill for the very dry material, with good results. The screening line separated the wet material into fine and coarse fractions very successfully.

Storage

Table 3 shows the nutritional composition of the *Sphagnum* based growing media mix at the time of production and after two, four and seven months in storage, both loose and in bags. Plant available nutrient content following the mild extraction (VDLUFA 2000) did not show strong variation. There was a slight reduction in the amount of nitrogen after four months, but phosphorus and potassium stayed at the same level throughout the trial. Comparing with total nutrient content, the main difference is in the amount of phosphorus, which is apparently not plant-available in all forms. This is most probably due to fixation of phosphorus to the clay which is part of the mixture. The variation in total potassium content can be explained by the variation in volume weight. The only real change in total nutrients during storage was a slight increase in the nitrogen content. Overall, we did not observe real changes in the nutrient composition of a growing media mix containing a 50 % fraction of *Sphagnum* moss during a storage period of more than seven months.

DISCUSSION

The procedures we have tested cannot yet be regarded as standard. However, we have shown that throughout the processing chain there are possibilities for improving the quality of *Sphagnum* moss so it can be used in professional growing media. Shortage of material has so far prevented more detailed research, and many questions remain.

Maintenance and harvesting

To facilitate mechanical harvesting, the *Sphagnum* fields must be properly prepared and their maintenance, especially during the first years of growth, is very important. It is necessary to limit the growth of vascular plants, mainly *Juncus* species, until the *Sphagnum* mosses are properly established. Because (so far) it has not been possible to collect the cut plant residues left over from mowing, this material was included with the first mosses harvested mechanically at Hankhausen. Even so, it was possible to keep the impurities down to an acceptable level. Removal of residues during or after mowing could improve the quality of the *Sphagnum* material in future.

Drying

Three of the methods we trialled enabled us to reach moisture contents similar to the 17.3–19.2 % value reported for baled *Sphagnum* moss from Chile (S. Amberger-Ochsenbauer, personal communication December 2015). Processing in the Biogas Air dryer was possible. The heat needed for drying was not expensive because of the subsidies for biogas in Germany, but quite a lot of manual labour was required. The conveyor belt dryer gave good drying results, but a few amendments in construction of the machine would improve its performance for *Sphagnum* material, which frequently got stuck on its way through. For faster and more efficient drying, this dryer should have three drying levels and a heating system should be fitted. One or two turnover

Table 2. Results of vapour treatment for *Sphagnum papillosum* grown at the research site in Ramsloh (referred to as wet material).

Material	Water content	Organic matter content	Total pore Volume	Air volume	Water capacity	Germination rate	Fresh matter yield	Number of growing plants	Vol. dry weight
	%	%	Vol.%	Vol.%	g 100 g DM^{-1}	%	%	plants L^{-1}	g L^{-1}
14 W	80.3	91.5	98	50	1187	97	152	37	30
14 WW	78.2	93.3	97	41	1322	97	154	38	40
14 WD 20	80.1	91.6	92	35	1127	99	121	2	50
14 WD 20 T 3	82.4	91.9	96	42	933	96	107	0	60
Method*	DIN EN 13040 (DIN 2007)	DIN EN 13039 (DIN 2000)	DIN EN 13041 (DIN 2006)			VDLUFA I A 10.2.1		VDLUFA I A 13.5.2	VDLUFA I A 13.2.1

* VDLUFA methods following VDLUFA (1991).

14 W	Harvested 2014, stored in plastic bags in cool conditions.
14 WW	Harvested 2014, stored in rows on concrete outdoors.
14 WD 20	14WW after 20 minutes of vapour treatment at temperature > 75 °C.
14 WD 20 T 3	14WD 20 after 3 days of cooling down.

Table 3. Nutrient levels, pH and salt content for a *Sphagnum* based growing medium (*Sphagnum* GM) over a storage period of seven months following the VDLUFA extraction procedures (VDLUFA 2000).

		Vol. weight	pH ($CaCl_2$)	Salt content	Total nutrient content					Plant available nutrient content				
					Nitrogen			Phosphorous	Potassium	CAT				
					N ($CaCl_2$)	NO_3^- N	NH_4^- N	P_2O_5 (CAL)	K_2O (CAL)	N tot.	NO_3^- N	NH_4^- N	P_2O_5	K_2O
Sphagnum sample	Date of sampling	g L^{-1}	n/a	g L^{-1}	mg L^{-1}					mg L^{-1}				
GM Day 1	25.06.2010	110	5.9	1.08	156	99	57	121	288	167	92	75	75	244
GM stored loose	26.08.2010	110	5.9	1.02	139	81	57	130	295					
	03.11.2010	110	5.9	1.08	176	103	73	128	301	156	97	59	73	249
	07.02.2011	120	5.9	1.25	175	130	46	130	312					
GM stored in 70 L bags	26.08.2010	130	5.9	1.10	130	65	65	130	317					
	03.11.2010	110	5.8	1.09	163	106	57	117	264	143	99	44	75	235
	07.02.2011	130	5.8	1.20	174	120	55	110	343					
	VDLUFA methods	I A 13.2.1	I A 5.1.1	I A 13.4.1		I A 6.1.1.1	I A 6.1.2.1	I A 6.2.1.1		I A 13.1.1				

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shafts are also advisable to loosen the mosses and mix them constantly. This would lead to good distribution of the warm air and an efficient and thorough drying process. Drying on a concrete floor in bright sunshine was easy to implement with already-available agricultural machinery. The disadvantages of this kind of drying process are its dependency on good weather conditions and the danger of introducing impurities from wind, the surroundings and the concrete surface into the moss.

Storage in piles or crates (the Finnish method) can lead to sufficient water loss to enable further processing in screening lines, but the water content after this treatment (70–80 %) was much higher than for the other drying methods.

Low moisture content and fast drying resulted in a very brittle *Sphagnum* material which was much more difficult to handle in the processing lines than material with higher moisture content. Also, when the material was very dry, the fraction of very fine, dusty material increased considerately with every processing step; and the rewetting of material with moisture content below 20 % was difficult and time-consuming (E. Ueber, Education and Research Station for Horticulture, Bad Zwischenahn, personal communication). So although we found that *Sphagnum* moss can be dried sufficiently in our test setups, the question of the optimal moisture level for *Sphagnum* as a growing media constituent is not yet solved and may also depend on the intended use and transport conditions.

Cleaning and screening

Results on this aspect have been rather satisfying. The quality of the material was already surprisingly good. However, because we were able to test only one type of *Sphagnum* material, further data are needed for a full evaluation. Tests with other *Sphagnum* provenances and species are necessary to prove that the use of already-available commercial equipment is really suitable for *Sphagnum* moss.

Storage

The first test gave a good result without unwanted changes in the nutritional values. Loss of nitrogen, especially, could have caused real problems for growers, but in our trials it did not occur. As there are many growing media constituents and growing media mixes for a lot of different purposes, more tests with other growing media mixes are necessary to provide full information on the performance of *Sphagnum* mosses. Certainly, other *Sphagnum* species must be tested, because they may not all have the same properties (Emmel 2008).

Our results so far have not indicated any reason why *Sphagnum* moss should not become a good growing media constituent in the future. But these are just the first steps, so our current project ("SPHAKO") on *Sphagnum* moss as a growing media constituent and the next project ("MOOSWEIT") at the Hankhausen research site will be very important for further development of this application.

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REFERENCES

Amberger-Ochsenbauer, S. (2010) Evaluation of growing media components for *Phalaenopsis*. *Acta Horticulturae*, 878, 355–360.

Aubé, M., Quenum, M. & Ranasinghe, L.L. (2015) Characteristics of Eastern Canadian cultivated Sphagnum and potential use as a substitute for perlite and vermiculite in peat-based horticultural substrates. *Mires and Peat*, 16(03), 1–18.

Díaz, M.F. & Silva, W. (2012) Improving harvesting techniques to ensure *Sphagnum* regeneration in Chilean peatlands. *Chilean Journal of Agricultural Research*, 72(2), 296–300.

DIN (2000) Soil improvers and growing media - Determination of organic matter content and ash. DIN EN 13037:2000-2. Now superseded. https://www.beuthe.de, accessed 11 Sep 2017.

DIN (2006) Soil improvers and growing media - Determination of physical properties - dry bulk density, air volume, water volume, shrinkage value and total pore space. DIN EN 13041:2006-09. Latest German version is EN 13041:2011. https://www.beuthe.de, accessed 11 Sep 2017.

DIN (2007) German version of: Soil improvers and growing media - Sample preparation for chemical and physical tests, determination of dry matter content, moisture content and laboratory compacted bulk density. DIN EN 13040:2008-01. https://www.beuthe.de, accessed 11 Sep 2017.

Emmel, M. (2008) Growing ornamental plants in

Sphagnum biomass. *Acta Horticulturae*, 779, 173–178.

Fuentes, V., Soto, D., Loewe, V. & Benedetti, S. (2012) *Productos Forestales No Madereros* (*Non-wood Forest Products*). Bulletin 14, Instituto Forestal (INFOR), Ministry of Agriculture, Government of Chile, Santiago de Chile, 7 pp.

Gaudig, G., Fengler, F., Krebs, M., Prager, A., Schulz, J., Wichmann, S. & Joosten, H. (2013) Sphagnum farming in Germany - a review of progress. *Mires and Peat*, 13(08), 1–11.

GGS (2015) *RAL Gütesicherung GZ 250 Substrate für Pflanzen* (*RAL Quality Assurance GZ 250 Growing Media for Plants*). RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V (RAL German Institute for Quality Assurance and Characterisation Registered Society), Sankt Augustin, Germany, p. 56.

Gossow, W., Grantzau, E. & Scharpf, H.-C. (1995a) Keimpflanzentest zur Substratprüfung (1) (Germinating plant test for checking growing media (1)). *Deutscher Gartenbau* (*German Horticulture*), 26, 1568–1571.

Gossow, W., Temming, W., Scharpf, H.-C. & Grantzau, E. (1995b) Keimpflanzentests zur Substratprüfung (2) (Germinating plant test for checking growing media (2)). *Deutscher Gartenbau* (*German Horticulture*), 28, (28), 1702–1706.

Jobin, P., Caron, J. & Rochefort, L. (2014) Developing new potting mixes with *Sphagnum* fibers. *Canadian Journal of Soil Science*, 94(5), 585–593, doi: 10.4141/cjss2013-103.

Joosten, H., Gaudig, G., Krawczynski, R., Tanneberger, F., Wichmann, S. & Wichtmann, W. (2016) Managing soil carbon in Europe: paludicultures as a new perspective for peatlands. In: Banwart, S.A., Noellemeyer, E. & Milne, E. (eds.) *Soil Carbon: Science, Management and Policy for Multiple Benefits*. CABI, Wallingford, 297–306, doi: 10.1079/9781780645322.0297.

Klavina, L., Silamiekele, I., Bikosvens, O. & Vizma, N. (2012) Chemical properties contributing towards the antimicrobial'. Abstract No. 21, *Proceedings of the 14th International Peat Congress (Stockholm)*, International Peat Society Jyväskylä, 5 pp.

Krebs, M., Gaudig, G. & Joosten, H. (2012) Sphagnum Farming on Bog Grassland in Germany - first results. Abstract No. 294, *Proceedings of the 14th International Peat Congress (Stockholm)*, International Peat Society Jyväskylä, 5 pp.

Reinikainen, O., Korpi, J., Tahvonen, R., Näkkilä, J., Silvan, N. & Silvan, K. (2012) Harvesting of *Sphagnum* biomass and its use as a growing medium constituent. Abstract No. 137, *Proceedings of the 14th International Peat Congress (Stockholm)*, International Peat Society Jyväskylä, 5 pp.

Schmilewski, G. (2008) The role of peat in assuring the quality of growing media. *Mires and Peat*, 3(02), 1–8.

Tilling, A.J. (1995) Sphagnum moss : issues associated with the sustainable development of a non-timber forest product in New Zealand. *New Zealand Forestry*, February, 30–34.

VDLUFA (1991) *VDLUFA Methodenbuch, Band I: Die Untersuchung von Böden* (*VDLUFA Book of Methods, Volume I: The Analysis of Soils*). Part A, Methods 5.1.1, 6.1.1.1, 6.1.2.1, 6.2.1.1, 10.2.1, 13.1.1, 13.2.1, 13.4.1, 13.5.2. VDLUFA Verlag, Darmstadt.

VDLUFA (2000) *VDLUFA Methodenbuch Band II.2 Die Untersuchung von Sekundärrohstoffdüngern, Kultursubstraten und Bodenhilfsstoffen* (*VDLUFA Book of Methods Volume II.2 The Analysis of Organic Fertilisers from Recycling Processes, Growing Media and Soil Additives*). VDLUFA Verlag, Darmstadt.

von Post, L. & Granlund, E. (1926) Södra Sveriges Torvtillgångar I (Peat resources in southern Sweden I). *Sveriges Geologiska Undersökning*, C 335, 19, 1–128 (in Swedish).

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