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https://doi.org/10.3390/horticulturae9080919

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Peat Substitution in Horticulture: Interviews with German Growing Media Producers on the Transformation of the Resource Base

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Abstract: Peat is the major constituent of horticultural growing media. Due to its high climate footprint, its extraction and use are controversial and the need to limit its use is widely recognised. The Peat Use Reduction Strategy of the German government aims to phase out its use and replace it with renewable materials. Despite large potential, stakeholders consider the availability of peat substitutes in sufficient quantity and quality as a critical issue. The goal of this research is to systematically investigate the challenges and opportunities for substituting peat in the resource base of the growing media industry. Based on deep-dive interviews with German growing media producers, the factors determining the supply and use of the main growing media constituents—peat, green compost, wood fibres, composted bark and coir products—were analysed. The results show the critical role of the processing infrastructure on transportation distances and the quality and quantity of the market supply. Additionally, competition with other sectors affects the availability of materials for the growing media industry. Moreover, peat is still economically advantageous compared with its substitutes. Even if this advantage declines due to consumer awareness and the end of domestic extraction, the end of peat use would probably imply new policy measures.

Keywords: peat; peat substitute; compost; wood fibres; growing media; industrial production; interviews

Citation: Hirschler, O.; Thrän, D. Peat Substitution in Horticulture: Interviews with German Growing Media Producers on the Transformation of the Resource Base. *Horticulturae* **2023**, *9*, 919. https://doi.org/10.3390/horticulturae9080919

Academic Editors: Nazim Gruda, Rui Manuel Almeida Machado and Erik van Os

Received: 27 June 2023
Revised: 26 July 2023
Accepted: 27 July 2023
Published: 11 August 2023

1. Introduction

The present paper focuses on the replacement of peat in horticultural growing media with alternative constituents based on biomass.

The process of extracting and using horticultural peat from peatland soils is a significant source of greenhouse gas (GHG) emissions that accounts for about 12.6 Mt CO2-eq for the European Union (Convention) and 2.2 Mt CO2-eq for Germany (Data 2019, [1]). Peat extraction only represents a small share of the total GHG emissions from peatlands but generates, through the fast destruction of the soil carbon stock, by far the highest climate impact per hectare compared with any other human activity on peatlands. The climate footprint of peat is also by far the highest among all other horticultural growing media constituents [2,3]. Moreover, peat extraction potentially represents a threat to ecosystems in regions where the extraction takes place on living mires and without renaturing measures afterwards [4]. In Europe, Germany ranks first for the extraction of peat for horticultural purposes, second for peat imports, first for the use of peat in growing media production, first for exports of peat and peat products and first for the use of peat in horticulture [5]. As presented in Figure 1, Schmatzler [6] forecasted an almost complete end to peat extraction in 2040 in Lower Saxony, where German peat extraction is concentrated [7]. The reasons behind this trend are the limitation of land availability through competition with agriculture

and restrictions on the issuance of new extracting permits. Despite important uncertainties concerning data on German peat extraction [5], a long-term trend of decrease in the amount of domestically extracted peat can be observed, compensated by increasing imports from other EU states, especially the Baltic states.

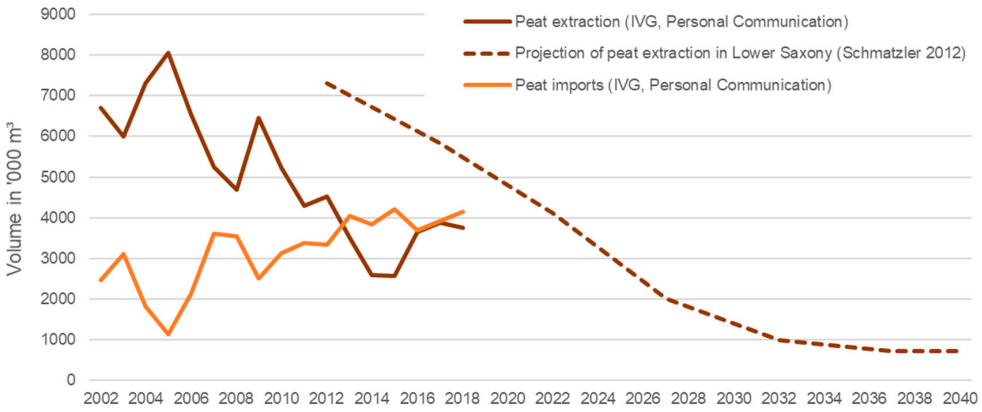

Figure 1. Evolution of peat extraction, peat imports and projection of peat extraction in Germany.

In a context of rising awareness regarding climate change [8] and the importance of protecting peatland carbon stocks [9–11], the extraction and use of peat are increasingly controversial. In the last decade, the horticultural sector increasingly acknowledged its role in limiting its climate footprint, especially by reducing peat use in growing media [12–18]. Against this background, in 2016, the German government set a goal to end peat extraction and reduce peat use in the Climate Action Plan 2050 [19]. The targets of the Peat Use Reduction Strategy developed by the Ministry of Food and Agriculture are to end peat use in hobby gardening by 2026 and reduce it as much as possible for professional horticulture by 2030 [20]. This strategy includes discussions with stakeholders, research funding, extension on alternatives and public awareness programs. Governments in other European countries have also committed to reduce the use of peat, namely the United Kingdom, Switzerland, Norway, the Netherlands and Austria [21–25]. An overview of the political initiatives to reduce peat use in Europe is presented in Hirschler et al. [26] and Gruda et al. [27]. Furthermore, discussions on a European strategy to reduce peat use in horticulture have started, as proposed by Germany at the EU Agriculture and Fishery Council in May 2022 [28]. Furthermore, the inclusion of the emissions of peat extraction in the mitigation targets of the EU member states through the LULUCF Regulation (EU) 2018/841 [29] is expected to further increase their relevance for climate policy. However, outside of Germany, there are no initiatives on a national or EU level to address the extraction of peat for horticulture in the currently extracting countries. Therefore, even if domestic peat extraction is expected to stop in Germany, the supply constituted by peat imports is expected to continue being available in the foreseeable future.

Peat is by far the most used constituent for the production of growing media in Germany and in Europe [30,31]. Growing media is defined in the fertilising products regulation (EU) 2019/1009 [32] as "a product other than soil in situ, the function of which is for plants or mushrooms to grow in". They are mixtures of organic constituents, sometimes complemented by mineral constituents, in which the plant roots develop and constitute the supporting medium for fertilisation and water supply. According to the Industrieverband Garten e.V. (IVG), the German industry produced around 8.1 million cubic meters of growing media in 2022 [33]. In the last decade, this volume has remained relatively stable between 8 and 10 million cubic meters. Blok et al. [34] forecasted an important increase in the need of growing media worldwide between 2017 and 2050. It is unclear to what extent this demand will be able to be met and, since this trend mostly concerns Asia, how this development will apply to the German industry. Growing media are used by hobby gardeners as potting soil; this represents 66% of German production for the domestic market. The rest is mostly used in a wide range of professional horticultural systems such

as in the production of flowers, nursery stock, vegetable seedlings and mushrooms. A smaller proportion of growing media is also used in the landscaping sector. Around 28% of German production is exported, mostly for professional horticulture.

The other main growing media constituents apart from peat, also referred as peat substitutes or alternative constituents, are green compost, wood fibres, composted bark and coir products. As presented in Figure 2, the share of alternative constituents used in growing media in Germany has regularly increased, especially for the hobby sector.

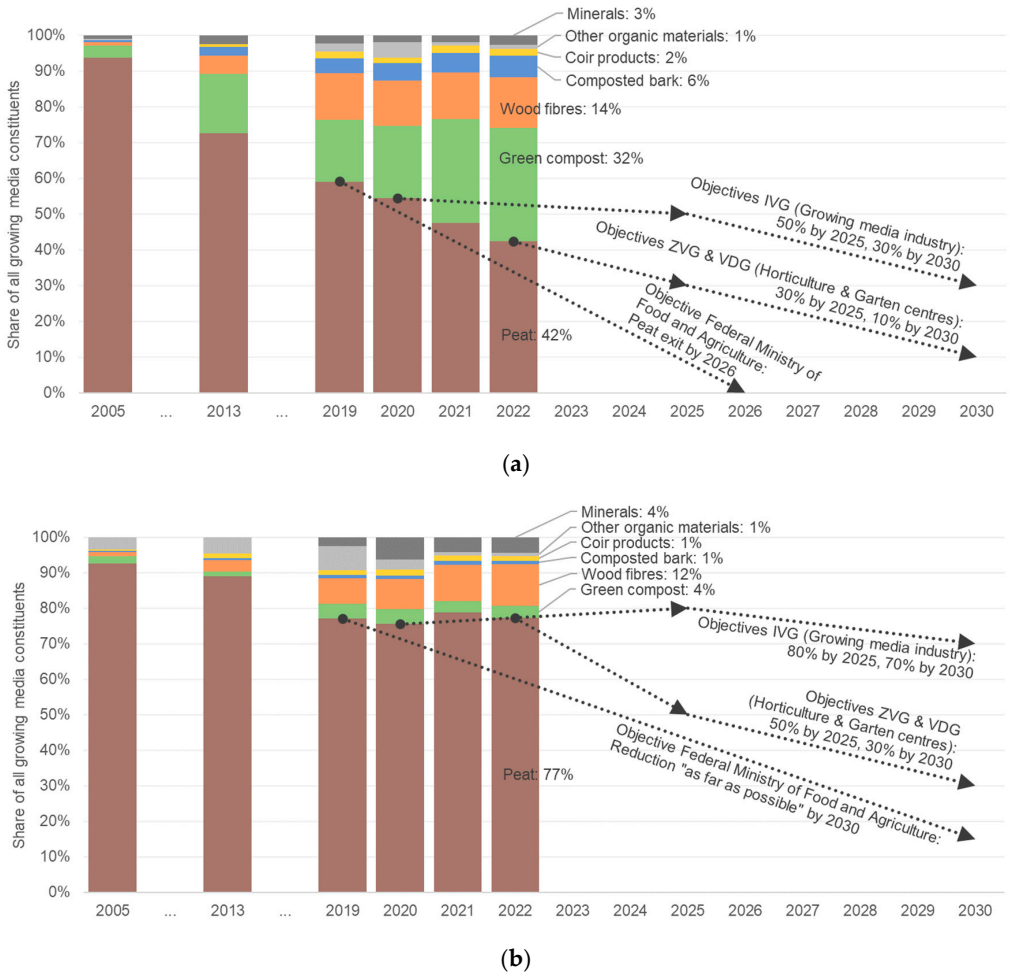

Figure 2. Evolution of the composition of growing media in Germany in (**a**) the hobby sector and (**b**) the professional sector and peat use reduction objectives set by stakeholders. For the years 2005 and 2013: total growing media production in Germany (source: [31,35]). For the years 2019–2022: growing media production in Germany for the domestic market (source: [33]). Objectives apply for growing media used in Germany. The curve starts at the year of decision.

The properties of growing media constituents and their use in horticulture are largely documented in the literature [15,17,36–43]. Green compost is produced from green waste though a composting process. After shredding, mixing and sieving, the material is left loose on a surface and turned over several times. For a good quality product, the process needs to attain a certain temperature and last several months. The properties of green compost are generally limited by its high pH, nutrient content and bulk density. Neumaier and Meinken [38] set a general limit of 40% of green compost in growing media. Wood fibres are produced from coniferous wood chips through a thermomechanical process carried out with a machine (in general an extruder or refiner). Wood fibre use in growing media has increased significantly in the last years, especially in the professional sector. The use of wood fibres is said to be mostly limited by nitrogen immobilisation, which

complicates fertilisation. A rate of 40% wood fibres in growing media is set as a limit by Neumaier and Meinken, but other sources and projects showed successful experiences with 50% rates and even at 100% as stand-alone substrate [44–47]. The composting of bark is conceptually comparable with the composting of green waste. The use of composted bark is generally limited by its water holding capacity and, in some cases, heavy metal concentrations. According to Neumaier and Meinken, it should not be used at a rate of more than 50% in growing media. Uncomposted bark can also be used in growing media but does not represent important quantities in Germany [33]. Coir products for growing media are by-products from the processing of coconut fibres, themselves by-products of coconut production. Coir pith, also named "cocopeat", and coir fibres are both part of coir products. Before arriving in Europe, coir products are washed to decrease salinity. Coco pith is supplied compressed in blocks and needs to be processed in order to obtain a loose material usable for mixing in growing media. In some cases, coco pith is further processed by buffering to improve fertilisation. Coir products can be limited by their salt content, but good quality products have been shown to be used as stand-alone growing media [38,48]. Other growing media constituents are investigated but do not represent significant amounts in Germany yet, notably fresh *Sphagnum* moss [49], fibres from *Miscanthus*, flax, reed, hemp and various plants [50–53], biochar [54], biogas digestate [55,56] or rice hulls.

Although the necessity to reduce peat use seems to be accepted by the vast majority of stakeholders in Germany, the extent and speed of this transformation are subject to intense debate. As a result, the IVG and representatives of the horticultural sector have expressed doubts about the governmental goals and set their own targets on peat reduction [57,58], as presented in Figure 2. According to discussions between stakeholders, the reduction of peat in growing media composition seems to face two main categories of problems. The first category of problems relates to the challenge of using growing media in horticulture with different properties due to the change in its composition. In addition to the extensive research on the subject, plant production in peat-reduced and peat-free growing media has been the subject of successful investigations in practice in Germany [59,60]. The second challenge concerns the supply of alternative constituents in case of an increase in their demand as a consequence of peat replacement and is often designated as the problem of the "availability" ("Verfügbarkeit" in German) of peat substitutes, further referred to as the "availability problem". This latter problem is presented as critical by industry stakeholders. Investigations on the potential amounts of bio-based constituents show largely sufficient resources for the replacement of peat in Germany and in Europe [26]. The results of the approach based on the potential amounts imply that the growing media industry will encounter difficulties in accessing the existing amounts of raw materials and peat substitutes, limiting the effective available supply. Factors such as competition with the energy sector for the access to biomass or the quality of compost are mentioned in the many discussions surrounding the reduction of peat use between stakeholders and based on specific situations.

In this context, the goal of the present paper is to systematically investigate and list the factors enabling and limiting the use of growing media constituents and the transformation of the resource base of the industry for the reduction of peat use.

2. Materials and Methods

2.1. General Method

The research was conducted specifically on the German industry. Given the limited scientific literature on the subject and that the orientation of the research question focused on the concrete situation in the industry, the investigations were based on the experience of growing media producers. For this, in-depth expert interviews were carried out and analysed following qualitative methods.

The method is presented as it was carried out, based on the following steps: (1) sampling, (2) questionnaires and interviews and (3) qualitative analysis.

2.2. Sampling

The sample was prepared based on a list of growing media producers in Germany. This list was created using an internet search completed by the list of the members of the German industry group IVG and personal contacts. As a result, 83 companies were identified.

The goal of the sample selection was to include a variety of companies regarding size (number of employees, production), geographical region, own peat extraction activities (with/without), outlet market (hobby/professional/landscaping sector) and public argumentation of the company. These elements were assumed to be potentially linked to the situation and the readiness of the companies regarding peat substitution. The information on these criteria was collected or estimated, when possible, using the companies' websites. Four companies refused to take part of the interviews. In order to complete the sample, other companies were selected. In accordance with the goals set, 9 growing media producers were surveyed.

2.3. Questionnaires and Interviews

The interviewees were either heads of the companies or members of the management teams. In some cases, two people represented one company. Before the interview, the interviewees were asked to fill out a questionnaire in order to collect data on the situation of the company and to produce the first elements of discussion for the interview. The questionnaire is available in Table A1.

The questionnaire and interviews were conducted in German and took place between November 2022 and January 2023. The interviews were carried out via videoconference and mostly lasted between 1 and 1.5 h. They were led in a semi-directed form inspired by the concept of the "problem-centered interview" proposed by Witzel [61].

The structure of the interview aimed to (1) obtain an overall understanding of the supply and production chain for growing media and growing media constituents in the company, (2) understand and gather the factors determining and potentially limiting the use of growing media constituents and (3) obtain the perspective of the company regarding the reduction of peat use in Germany. The list of themes and questions can be found in Table A2.

We focused on the main organic constituents used in growing media in Germany: (1) peat, (2) green compost, (3) wood fibres, (4) composted bark and (5) coir products. In case one of these five main constituents was not mentioned actively in an interview, the interviewer explicitly asked about it. When mentioned by the interviewee, information on other materials was included in the analysis.

2.4. Qualitative Analysis

The interviews were entirely recorded, transcribed and qualitatively analysed using MAXQDA following the method of the thematic analysis described by Braun and Clarke [62]. The approach mixed deductive and inductive processes, and the coding system was adapted along the analysis in order to gain relevance.

On this basis, factors determining the supply and the use of growing media constituents were systematically listed and explained. For each element, the number of interviewees mentioning it and the number of times mentioned are used as indicators of the relevance of the element in the current situation. These mentions are often pointing problems. Some elements, although potentially important, could have not been mentioned because they were not considered problematic in the current situation. Therefore, the relevance of an element in the current situation should not be confounded with its importance. Moreover, due to the limited sample, those mentioned should not be considered statistically representative.

The number of interviewees mentioning a specific idea are presented in the results in the following form: (N = X), where X is the number of interviewees mentioning the idea. When it applies, the number of times an idea is mentioned, Y, is added to the number of interviewees, X, using the following form: (N = X, n = Y).

2.5. Interest and Position of the Interviewees

In a potential conflictual political situation due to different interests, it seems important to acknowledge the position of the researcher and the perception of the role of the research team and of the subject by the interviewees. The research team of the first author is mandated by the Ministry of Food and Agriculture to carry out investigations on the possibilities and the consequences of the Peat Use Reduction Strategy in order to support decision-making processes. Therefore, the perspective and goals of the present research focus on the transformation towards peat reduction and not, for example, on questioning its relevance. Moreover, the debate surrounding the preliminary research of the research team published in the Thünen Working Paper 190 [26] on the potential amounts gave an insight into the sensitivity of research on the subject. However, all companies that were asked to take part in the investigation showed an interest for the research and the interviewees answered the questions very openly. The four companies refusing to take part in the interviews attested it was due to time constraints and not linked to any defiance toward the research team or the subject. The conclusions of the potential analysis were mentioned as background at the beginning of each interview and accepted by all interviewees. The relevance of the research was not questioned.

3. Results

3.1. Description of the Sample

3.1.1. Company Characteristics

Based on answers of the questionnaire and completed by information from the interviews, the characteristics of the sample were analysed. The results are presented with the intention to preserve the anonymity of the participating companies. As presented in Figure 3, the fact that the company extracts peat or not and the major outlet market (plant production vs. hobby and landscaping) were directly linked to each other and were also strongly linked to the geographical position, the size and the average peat rate in growing media.

As presented in Table 1, the approach prioritising diversity leads to an overrepresentation of the perspective of bigger companies. Since the peat reduction goals focus on amounts, the sample can be considered a good balance between a diversity of situations and the significance regarding the amounts of growing media produced.

Table 1. Comparison of structural parameters between the sample and the whole German industry.

	Sample	**German Industry**
Total companies	9	83
Total growing media production (m^3/a) *	3.15×10^6	8.1×10^6
Average growing media production per company * (m^3/a)	350,550 m^3	97,590 m^3
Number of companies above 20 employees *	56% (5/9)	29% (24 **/83)
Number of companies with majority of production in North-Western Germany *	56% (5/9)	48% (40/83)

Source: own analysis. * Activity of the company within Germany. ** Source: [63].

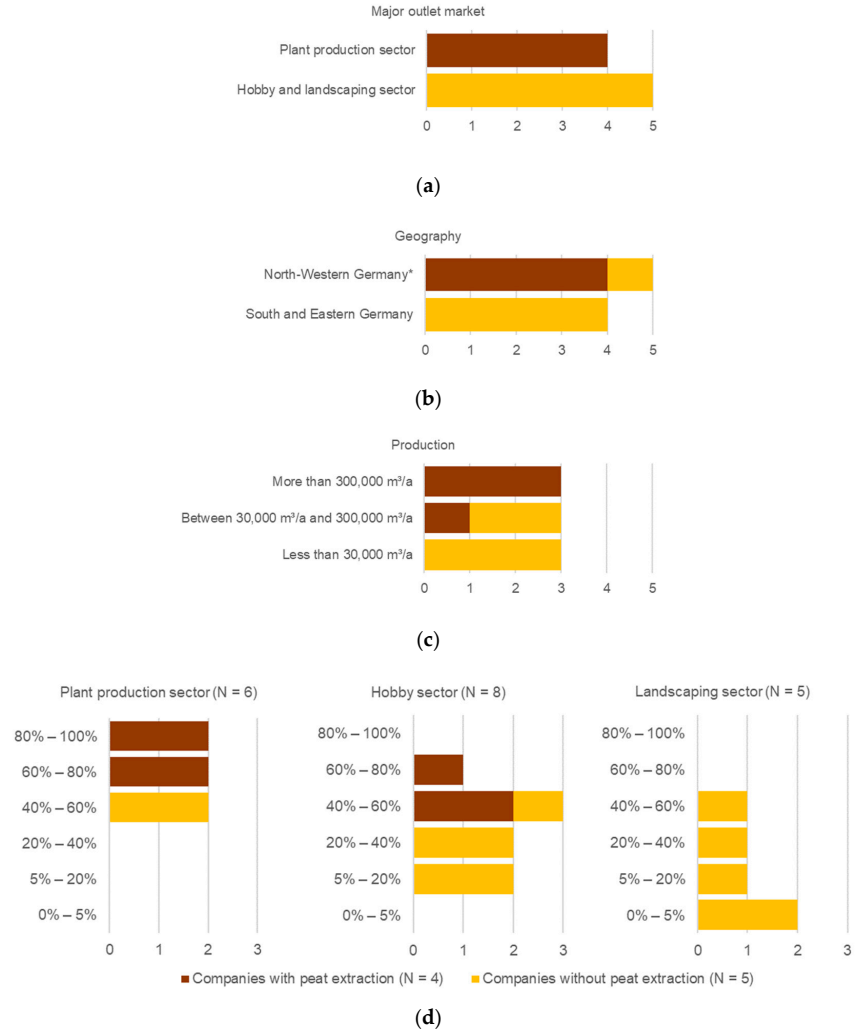

Figure 3. Number of surveyed companies (N = 9) depending on (**a**) major outlet market of growing media, (**b**) geographical location of the majority of the production sites (* Lower Saxony, Schleswig-Holstein, Bremen, Hamburg, Nord Rhine-Westphalia), (**c**) yearly volume of growing media production and (**d**) peat rate and outlet market of produced growing media.

3.1.2. Supply and Processing of Growing Media Constituents

The numbers of companies surveyed using and processing the different growing media constituents considered are presented in Figure 4. All companies surveyed used peat and compost. Most of them (N = 8) used wood fibres and composted bark. Coir products were used by N = 4 companies, from which N = 3 produced growing media mostly for plant production. Some companies had their own facilities to process wood fibres (N = 1), compost bark (N = 6) and compost green waste (N = 3). Green waste was either brought by private gardeners and collected directly in a facility of the company or obtained from waste disposal facilities. All wood chips and bark used by the growing media producers came from sawmill companies. Coir products were bought from distributors importing them from Asia, mostly India and Sri Lanka. The transport to Europe was carried out by sea, mostly to the Netherlands, and then by truck to the growing media producer.

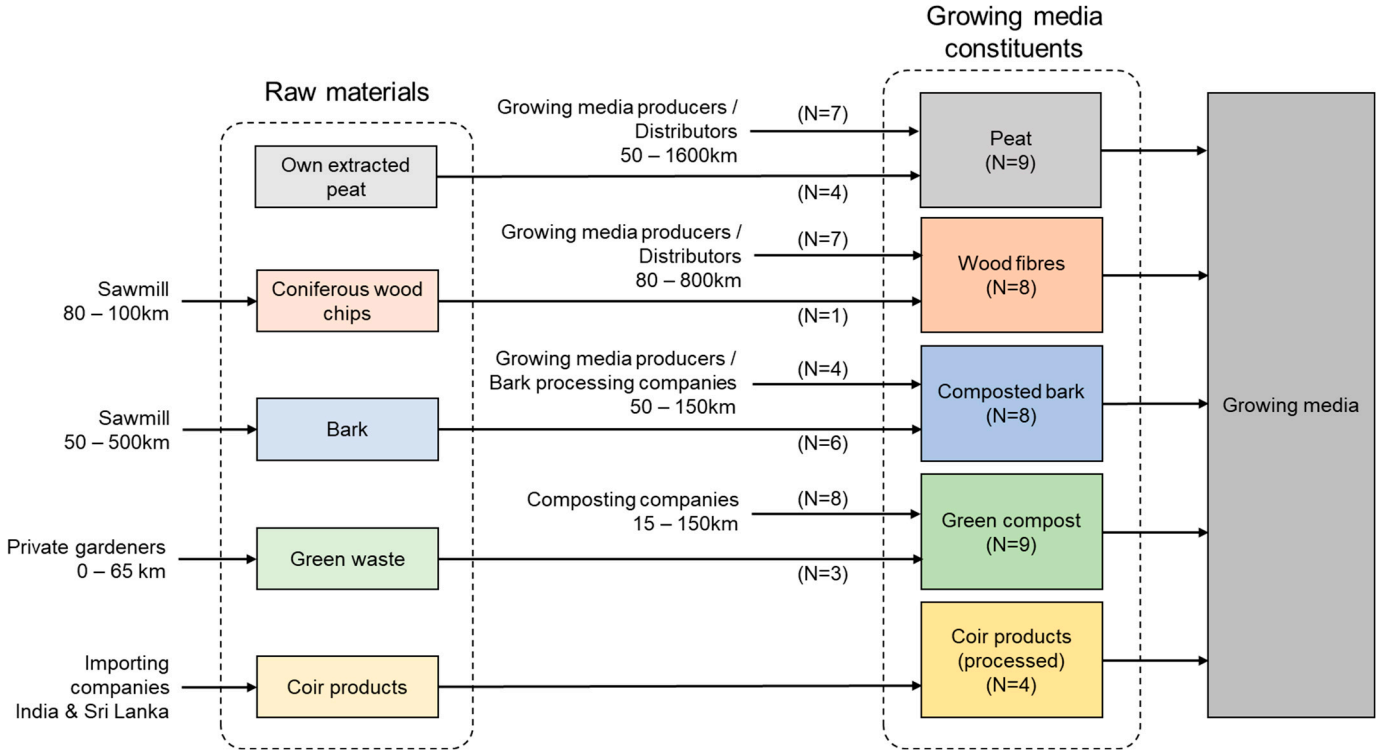

Figure 4. Supply chains of raw materials and growing media constituents in the companies surveyed (N = 9).

The size of the company and the fact that the company has no peat extraction activities seem to be positive linked to the presence of processing capacities for peat substitutes. Among the companies surveyed, a majority concretely declared planning investments to process raw materials for the production of peat substitutes (N = 5).

3.1.3. Position on the Peat Use Reduction Strategy

All companies surveyed declared that they were aiming to reduce peat use in their growing media production. When asked about their position regarding the goals of the Ministry of Food and Agriculture on the reduction of peat use, more interviewees said that it was very favourable (N = 2) or favourable (N = 2) than unfavourable (N = 3). For companies that expressed reservations, the reason was that these goals were considered too ambitious and not realistic given the actual conditions and measures. There was no apparent link between the position regarding peat reduction and the considered variables (peat extraction, growing media production, major outlet sector or geography).

3.2. Challenges and Requirements of the Growing Media Sector

In the following section, the factors determining the choices of the interviewed growing media producers in the supply of growing media constituents are presented and explained based on the analysis of the interviews.

3.2.1. Products Requirements for Final Use

The requirements for growing media and growing media constituents are strongly influenced by their specific utilisation. This has implications for the choices of growing media producers in supplying the materials they work with. In some cases where the production is carried out for another company, the growing media producer has limited to no latitude on the constituents used (N = 3, n = 4).

Because of their influence on nutrient and water supply as well as root development, the properties of growing media are critical for plant health and development. The suitabil-

ity for plant growth is by far the most mentioned quality criteria for growing media and its constituents (N = 9, n = 52). For this purpose, peat is considered to bring particularly favourable, uniform and constant properties (N = 8, n = 21). As a consequence, the reduction of the peat share in growing media is associated with quality challenges (N = 9, n = 33). Among the four main peat substitutes, the potential of coir products was underlined due to its properties and its ability to replace peat by up to 100% (N = 2, n = 2). For the plant production sector, in which the economic viability requires a successful and uniform plant growth and quality, the suitability of growing media for plant growth is critical to avoid outages in production. Within plant production, the importance of these requirements was said to be higher for the production of vegetable seedlings than for ornamental plants (floriculture and nursery stock) (N = 3, n = 6). The importance of quality was said to be lower for the hobby sector than for the plant production sector (N = 6, n = 11) and lower for the landscaping sector than for the hobby sector (N = 1, n = 3). The differences in the quality requirements between the different sectors were confirmed by the different peat rates in the sample (Figure 3) and in the whole German growing media production, as well as the differentiated reduction goals set by the stakeholders (Figure 2). Higher quality requirements for growing media imply relying on more specific materials and thus augment the challenge of supply.

In order to compare growing media constituents, we chose to differentiate comments on the suitability for plant growth between two perspectives: (1) the general suitability that applies to the maximal potential quality for this constituent and (2) the actual quality available, which refers to the quality of materials currently available on the market. Problems regarding the general suitability can only be overcome by research and development, whereas the actual quality can be increased up to the general suitability by improved practices. The actual quality of green compost available was often identified as a problem (N = 5, n = 12). These issues were due to the presence of biowaste and impurities in the green waste, as well as the seasonal variability of the composition of green waste. In order to achieve the requirements for growing media, green compost needs to be based on a limited amount of lawn cuttings, bringing high salt content and a minimal amount of woody material bringing structure. Growing media producers generally use external certification systems to assure the quality of growing media constituents bought from other companies. Although information on the certification was not systematically collected, almost all interviewees (N = 8) said they used certification for green compost.

The interviewees reported the increasing attention of customers regarding environmental and social standards, leading to an increasing demand for peat-free and peat-reduced products (N = 7, n = 13). Unlike for the plant production and landscaping sectors, where growing media only constitute a part of the product supplied to the end customer, sustainability standards play a significant role in the demand for hobby growing media. The attention to sustainability was also mentioned as a moral driver for the growing media producers themselves, playing a role in their choices additionally to their economic logic (N = 7, n = 16).

As another quality criterion for users, the interviewees also mentioned the weight of the product sold in bags for hobby gardeners (N = 3, n = 4). The biological safety for human health was mentioned once as a potential issue (N = 1, n = 1). The presence of viable weed seeds or plant pathogens was not mentioned. The interviewees also mentioned criteria linked to habits with peat products but not influencing its performance, such as the appearance (N = 2, n = 4).

3.2.2. Price of Materials

The plant production sector is generally exposed to a strong competition, including on an international level, and depends on small margins compared with the production costs. For this reason, the growers require a low price for growing media. However, the professional sector also uses growing media with more expensive components, such as coir products or sod peat, than the hobby sector and the landscaping sector. Therefore, the

readiness to pay more for a growing media with specific quality standards seems to be higher in the professional sector than in the hobby sector. Some information on prices was gathered during interviews but this was not systematically collected.

The price of raw materials first depends on their production costs. The production costs of the raw materials used for peat substitutes were not mentioned, which could be explained by the fact that these materials are generally by-products or wastes from other activities. However, the interviewees underlined the importance of the competing uses of these raw materials by other sectors as a critical factor influencing their price (N = 7, n = 30). This competition is mostly linked to the energy use of wood chips (for example in form of pellets), bark and the woody part of green waste (N = 7, n = 27). The subsidies for the energy use of biomass were said to exacerbate this competition (N = 2, n = 3). Other competing sectors mentioned were the use of wood chips and bark for construction material (N = 3, n = 4) and green compost for agriculture (N = 2, n = 2).

In addition to the price of raw materials, processing costs play a role in the price of the finished growing media constituent. These costs can be direct, such as the energy input needed for the production of wood fibres (N = 3, n = 3), or indirect, through space and time requirements, which constitutes a logistical challenge, for example in the case of the composting of green waste and bark or the loosening of coir products (N = 6, n = 13).

3.2.3. Transportation

The qualitative and quantitative importance of commentaries related to transportation issues (N = 9, n = 81) suggests that this aspect is critical in the assessment of the availability of materials. This confirms that transportation costs are a "substantial part" of the overall costs of materials, as was explicitly stated by an interviewee. The importance of transportation costs is confirmed by the difference in the use of peat between North-Western Germany, where it is extracted, and Southern Germany, where it needs to be transported. The transportation distances are determined by the regional market availability of the material considered. In addition to their effect on costs, long transportation distances also affect the reliability of the supply by increasing the risk of incidents as well as the transport time and thus the necessary notice to obtain a material (N = 5, n = 10). The interviewees also underlined the sustainability issue of long transportation distances and the importance of a local or regional supply (N = 6, n = 9). This aspect was also underlined to defend local peat over imports from the Baltics.

The transport of material for growing media is generally carried out by truck for all products, except in specific cases where companies have access to a port terminal and import peat via shipments. In addition to transportation distances, transportation costs are also directly influenced by the transportability of the material (N = 6, n = 16), which can be defined by the cost per volume unit per kilometre. The transportability of the material seems to be determined by the density of the material, which can limit the amount of material per load and increase the fixed costs per cubic meter transported. Especially for green compost, the high bulk density was presented as a limiting factor for its transportation (N = 2, n = 4). For material for which the density does not limit the volume to be transported, the possibility to compress it can lead to a decrease in the fixed costs per load, as it is the case for peat, wood fibres or coir products. The transport of some materials, such as peat or coir products, over long distances (>1000 km), when others are only locally sourced, such as green compost or transported bark (<150 km), can be explained by their properties and thus their value as growing media constituents, in addition to their transportability. The possibility to optimise logistics by avoiding return trips can be a factor to reduce costs, which is enabled by exchanges with partners or suppliers.

3.2.4. Reliability of the Supply

The demand for growing media is seasonal (N = 4, n = 7), with most of it occurring between January and May. Especially for plant growers who need to optimise their cultivation system and have limited storage capacity, a reliable supply of the growing media is

crucial. As a consequence, in order to assure the reliability of their delivery and production (time, quality and amounts), growing media producers are dependent on two strategies: a reliable supply in the short term and the storage of materials in advance.

When relying on a short-term supply, growing media producers can be exposed to supply shortages when the market offer is limited (N = 4, n = 11), which was mentioned for wood fibres, bark, green compost and certain qualities of peat. The competition with other sectors can lead to limited amounts being available on the market and induce shortages. In opposition to transactions on the free market, a long-term relationship with suppliers, formalised through contracts, cooperation or shareholding, is a facilitating factor for the organisational challenges and risk management (N = 9, n = 28). A long-term relationship with the supplier also enables optimisation of the products to the producer's needs and brings security in the quality of the product. Long-term contracts for the supply guarantee price stability but imply higher prices. The relationship with the supplier is also facilitated by the local nature of the relationship. The supply can also be facilitated when assured by companies within the same consortium or group (N = 5, n = 7). Some interviewees also mentioned the number of vehicles available for transport (their own or from freight companies) as potentially limiting during the production season (N = 3, n = 3).

3.2.5. Internal Storage and Processing Capacities

The possibility of storing material in advance is another way to gain flexibility and to avoid production shortages due to the difficulties linked to problems in logistics, market availability or high material prices (N = 4, n = 8). The storability of the material can be a problem or imply a specific form of storage (packed, under roof). In particular, the sensibility of wood fibres to biological activity represents an inconvenience for open-air storage (N = 2, n = 4). Some packaging, such as big bales, can also provide more efficiency in storage and a better storability.

The ability to process raw materials themselves also constitutes a strong advantage for growing media producers (N = 8, n = 32). This enables a reduction in transportation distances and gives more control over the quality of the product through process monitoring, which is particularly interesting for compost to limit quality problems and transportation. The control over the process gives more flexibility in terms of the quality of the raw materials used, as opposed to buying a finished product. Raw materials are also generally more available on the market than finished products. For example, wood chips can be locally sourced, whereas wood fibres generally have to be transported over long distances (Figure 4). Moreover, processing capacities limit costs by internalising the added value. In some cases, space is scarce for the companies planning to increase processing capacity or increasingly relying on external supply. The relevance of space availability and management was summarised by an interviewee by the following statement: "Almost every problem [. . .] can be solved with space".

The development of processing and storage facilities implies investments, for which the decision is based on the costs, the volume of material needed, the future market situation of materials and the time needed for the equipment to be usable (N = 5, n = 7). The regulatory processes needed to obtain authorisations were mentioned as a burden for the construction of composting facilities and machinery equipment for the production of wood fibres (N = 3, n = 5).

In the current situation, growing media producers are dependent on the activity of the sawmill industry for the supply of wood chips and bark and on the disposal of green waste from gardens and green spaces for green compost (N = 4, n = 15). Only through peat extraction can growing media producers have control of the production process. This possibility, in addition to the storage of peat on the extraction site in form of piles, constitutes a considerable advantage for the flexibility and the reliability of the supply (N = 1, n = 3).

3.2.6. Political and Long-Term Situation

The interviewees underlined the importance of the future evolution of resources (N = 7, n = 16) and the evolution of the political context (N = 7, n = 21) on their long-term strategy for a reliable supply. In particular, the interviewees identified the development of policy in Germany and potentially in Europe in the future as a threat for sourcing and using peat and an important driver of change (N = 7, n = 18). This was summarised by an interviewee in the following: "without this political pressure, the peat industry would never move". The environmental and social concerns are the drivers behind this political factor, as it is for the evolution in customer demand. Some interviewees see political threats to the future use of coir products due to environmental critics, as it is the case in Switzerland (N = 2, n = 3). Additionally, growing media producers mentioned the risk, in the long term, of relying on only peat and the security brought by an enlargement of the resource base (N = 4, n = 5). Questions on the evolution of raw material resources due to economic evolutions, especially for wood chips and bark due to the decreasing activities of the sawmill industry or the decreasing amounts of coniferous trees in German forests were mentioned (N = 5, n = 6). Even if potential amounts are unlikely to limit the supply, these evolutions could trigger economic competition for these resources.

3.3. Assessment of Materials

All the relevant factors for the use of growing media constituents are not only linked to the nature and the situation specific to the constituents but often also depends on the internal resources of the companies, for example space. In order to assess each constituent, the critical factors specific to growing media constituents were selected in order to create the matrix available in Figure 5.

Criteria	Comments	Wood fibres	Composted bark	Green compost	Coir products	Peat
General suitability for plant growth	(N=8, n=33) more important for plant production	Negative (N=3, n=5) limited share possible, N-immobilisation / Positive (N=1, n=1) good structure	Positive (N=2, n=2) stability, pH / Negative (N=1, n=1) limited share	Negative (N=4, n=6) limited share possible, Salt content, high pH	Positive (N=2, n=2) fibre structure, necessary to replace peat / Negative (N=2, n=2) structure	Positive (N=8, n=21) structure, pH, water capacity, considered as reference / Negative (N=1, n=1) quality limitation of black peat
Actual quality available	(N=7, n=19) including aspects regarding uniformity, constancy of quality		Positive(N=1, n=1) constancy / Negative (N=1, n=1) small production units	Negative (N=5, n=12) lack of qualitative production, share of biowaste, impurities	Positive (N=1, n=1) constancy / Negative (N=1, n=1) lack of transparency	Negative (N=3, n=3) quality depends on weather conditions, quality problems Baltic peat
Market demand	(N=7, n=13) concerns more directly the hobby sector (direct commercialisation of growing media)				Negative (N=1, n=1) label cocopeat-free	Negative (N=7, n=13) increasing demand label peat-free and peat-reduced
Competition with other sectors	(N=7, n=30) influence on price of raw material, market availability	Negative (N=6, n=17) wood chips, Energy, pellets, wood product industry	Negative (N=5, n=7) energy use of bark (although low energy value)	Negative (N=5, n=7) energy use of green waste, agriculture use of compost		Negative (N=2, n=2) energy use of peat (Finland)
Transportation distances and reliability	(N=9, n=58) including regional market availability and transport reliability. Direct influence on transportation costs	Positive (N=5, n=7) local/nationally produced product / Negative (N=2, n=3) lack of regional production wood fibres	Positive(N=1, n=1) local / Negative (N=1, n=1) lack of regional production	Positive (N=5, n=8) local product / Negative (N=1, n=1) lack of regional production	Negative (N=6, n=13) high costs and long transportation time from Asia, insecurity	Negative (N=5, n=10) imported peat / Positive (N=4, n=4) local peat in Northern Germany, estabished supply chain
Transportability	(N=6, n=16) direct influence on transportation costs, bulk density also a criteria for users	Positive (N=2, n=3) wood fibres: light and compressible / Negative (N=2, n=2) wood chips : heavy	Negative (N=1, n=1)	Negative (N=2, n=4) heavy	Positive (N=2, n=2) compressible	Positive (N=3, n=3) light and compressible
Market availability	(N=4, n=12) limit of market offer in current situation	Negative (N=2, n=4) shortages	Negative (N=1, n=1) shortages	Negative (N=2, n=2) not enough for demand	Positive (N=2, n=2) always available on the market	Negative (N=1, n=1) shortage specific quality
Resources necessary for processing	(N=7, n=29) including costs, space, time, work, knowledge. Influence of time and space on logistics	Negative (N=3, n=3) energy input / Positive (N=1, n=1) short processing time	Negative (N=3, n=4) time and space	Negative (N=6, n=14) necessary space, time and know-how	Negative (N=2, n=5) water for loosening, time and space	Positive (N=1, n=1) easy to process
Costs and conditions For processing equipment	(N=6, n=12) influence the readiness to invest for new processing facilities	Negative (N=3, n=3) investment for machine, regulatory process for permit		Negative (N=4, n=4) long regulatory process for permit for composting, investment in composting hall		
Storability	(N=2, n=10) can be influenced by storage form: big bales or roofed area	Negative (N=2, n=4) needs to stay dry	Negative (N=1, n=1) needs to stay dry	Negative (N=1, n=1) needs to stay dry		Positive (N=2, n=6) in big bales, stability, storage on extraction site
Long-term evolution of resources	(N=9, n=41) evolution of resources and of the political context	Negative (N=4, n=4) uncertainty on evolution of the activity of saw mill industry, wood use in other sectors, forest composition (less coniferous) / Positive (N=1, n=1) large amounts	Negative (N=1, n=2) uncertainty on evolution of the activity of saw mill industry		Negative (N=2, n=3) risk of political action to restrain imports (example Switzerland)	Negative (N=9, n=26) political action and expected coercive measures to restrain use, end of extraction rights in Germany / Positive (N=1, n=1) large resources in Scandinavia

Number of participants mentioning the idea: N (Positive) – N (Negative)

-9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9

Figure 5. Assessment of growing media constituents based on the interview data and using the critical criteria identified.

At the end of the interviews, the interviewees were systematically asked to rank constituents depending on the difficulties associated with the increase in their use. The results are presented in Figure 6. Wood fibre was generally assessed more critical than other peat substitutes, but the answers do not permit us to establish a general ranking for the constituents. For composted bark and green compost, the fact that the company processes the product seems to be linked to a less critical assessment of the situation. This

can be interpreted as a confirmation of the advantages provided by processing. The opinion on coir products was notably split between interviewees, with some mentioning its great potential for peat substitution and the good market availability (N = 2) and others not considering it viable based on the long transportation distances and ecological and social considerations (N = 3).

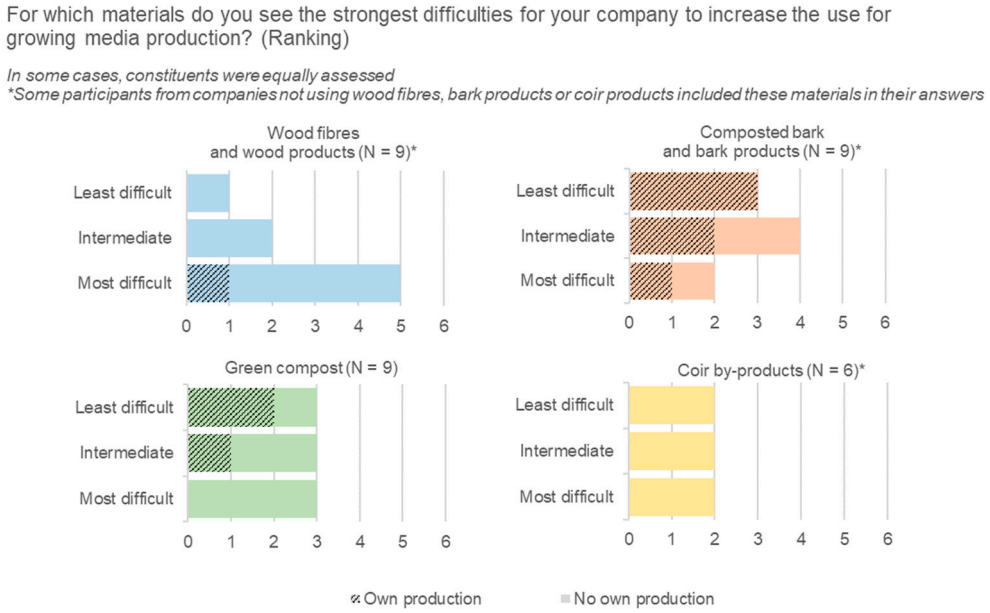

Figure 6. Ranking of growing media constituents based on the difficulty of increasing their use.

The interviewees mentioned the development or the use in limited amounts of other constituents. Among them, fresh *Sphagnum* moss from paludiculture or semi-natural mires (N = 3) and products based on *Miscanthus* (N = 3), hemp fibres (N = 3) and digestate from biomass fermentation (N = 2) were considered as having the potential to play a significant role in replacing peat in the future. In the current situation, the use of new constituents was generally said to be limited either by their price or by their quality, limiting the development of their production in significant amounts for growing media. The development of new alternative constituents was mentioned as an important and, for some participants, necessary element for the success of the future transformation towards the reduction of peat use (N = 5, n = 8).

3.4. Assessment of the Transformation

3.4.1. The "Availability Problem" as a Future Challenge

During the discussions, the interviewees expressed their general assessment of the situation of the availability of growing media constituents. Although a lot was said about the challenges, a large majority of the interviewees (N = 8) explicitly presented their current situation regarding the supply of peat substitutes for their company as not problematic. The other interviewee did not mention being in a problematic situation.

However, the majority of interviewees (N = 6, n = 31) expressed general concerns about the availability of materials in the future perspective of an increased demand for alternative constituents, often referring to the situation of the market in Germany in general. In a lot of cases, the problem was presented in terms of available amounts being limited for the whole industry, leading to an increased competition within the growing media sector. In particular, concerns were expressed that after the expected end of peat use in the hobby sector, the availability of alternative resources will be limited for the transformation of the plant production sector, which is expected to occur later. The concerns on the transformation also included a temporal aspect, with a repeated mention that solutions

would need time to develop and could not happen "overnight" ("von heute auf morgen") (N = 6, n = 13).

When asked about the difficulty of the transformation of the companies towards peat-free growing media production in 2030 as presented in Figure 7, the vast majority estimated that a complete replacement of peat was possible (N = 8); however, for some of them, only under strong changes to the current conditions (N = 3). The answers were polarised depending on the presence of peat extraction. The higher difficulty mentioned by companies with peat extraction facilities can be interpreted as the specialisation of their infrastructure and supply on peat and their focus on the professional sector.

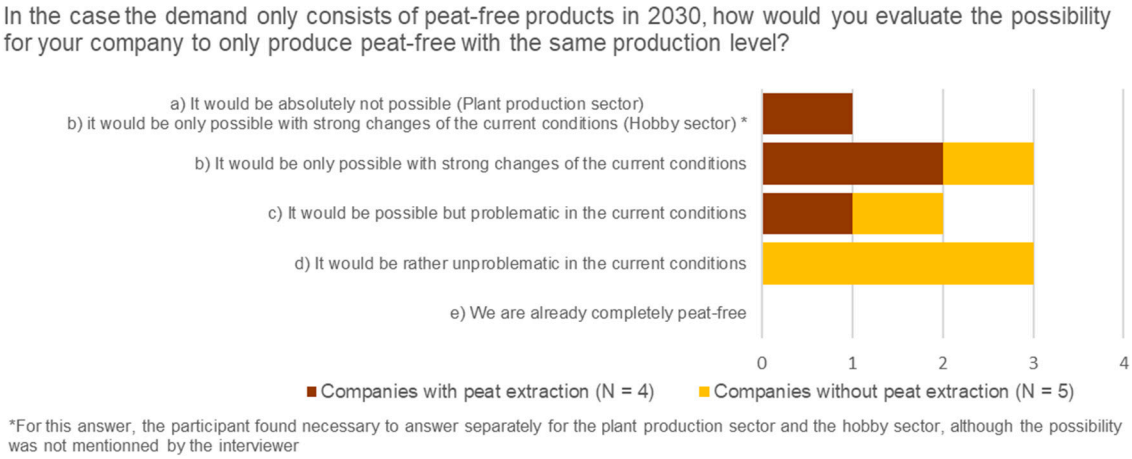

Figure 7. Assessment of the difficulty for the company to only produce peat-free products by 2030.

3.4.2. Current Limiting Factors of the Transformation

In the following paragraphs, we propose a causal chain explaining the limitation of the transformation of the resource base towards peat substitutes for the production of growing media. This causal chain is illustrated in Figure 8. This interpretation enables us to redefine the "availability problem" as the limit of the amounts of material on the market of sufficient quality, at a reasonable price and within a transportation radius allowing the growing media producers to competitively produce growing media. The amounts and quality of constituents available on the market as well as the transportation distances necessary to source these amounts are directly linked to the development of the processing infrastructure and the attention of the suppliers to the requirements of the growing media production. Additionally, the price and the market availability of the material is affected by competition with other sectors, itself exacerbated by state subsidies for the energy use of biomass. In the current situation, these aspects limit the economic interest in using more peat substitutes, which itself limits the interest of suppliers or growing media producers for producing these constituents and developing the corresponding infrastructure. In addition, regulatory burdens can slow down, disincentivise or prevent the development of new processing facilities and additional storage space.

The relative advantageous situation of peat represents a disincentive for the use of its substitutes (N = 7, n = 13). This advantage does not necessarily imply a lower price for peat compared with the other constituents but a higher ratio between quality and price.

3.4.3. Current Drivers of the Transformation

The results show that the current drivers behind the increased use of peat substitutes are apparently not due to the positive evolution of the quality and availability of growing media constituents but by the necessity to reduce peat use. Three drivers behind this current trend are identified: (1) the increasing demand for peat-reduced and peat-free products (N = 7, n = 13) triggered by the growing awareness of consumers, (2) a degradation of the economic situation of peat due to the end of peat extraction in Germany (N = 5,

n = 10) bringing numerous new disadvantages for its supply: longer transportation distance, dependence on new stakeholders abroad, loss of storage areas on extraction sites, bringing higher costs and more insecurity concerning the supply and the quality of peat (N = 5, n = 10) and (3) the threat of future coercive policy measures on peat at a German or European level (N = 7, n = 18).

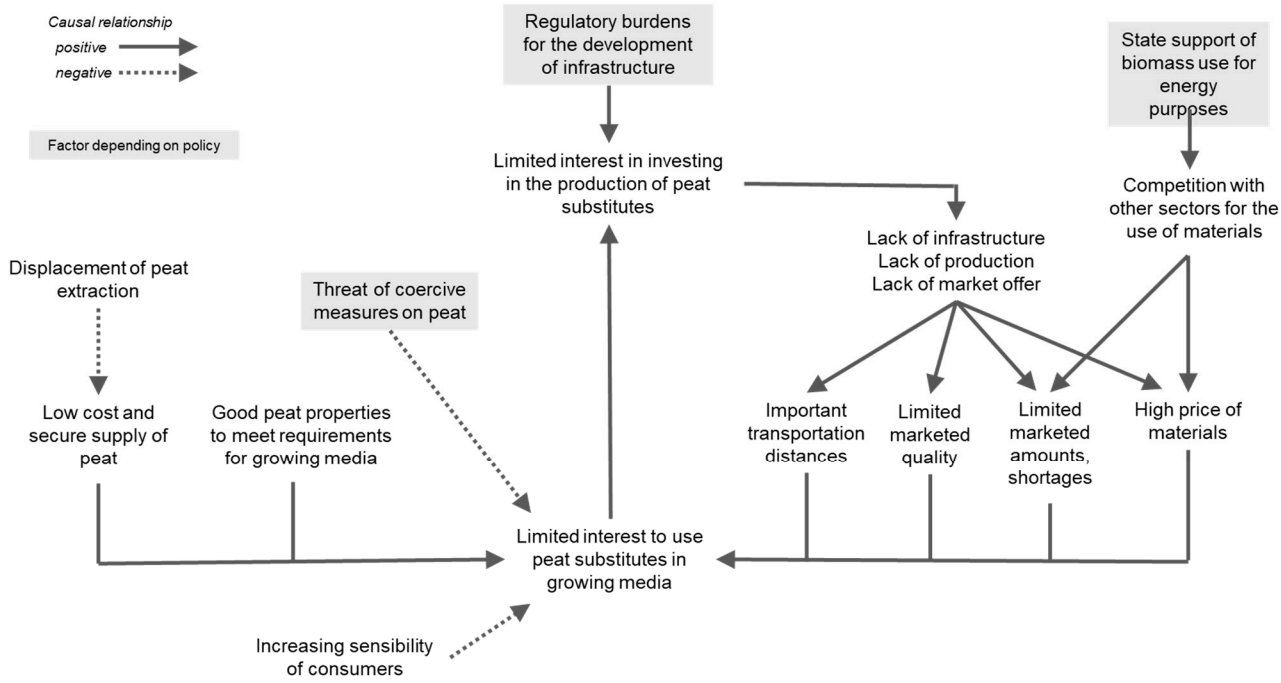

Figure 8. Causal chain explaining the limitation of the transformation of the resource base towards peat substitutes for the production of growing media.

3.4.4. Transformation in a Competitive Framework

Generally, the competitive framework within the growing media sector, especially internationally, seems to play an important role in the assessment of the difficulties related to the reduction in peat use (N = 5, n = 13). The interviewees explicitly stated, while supporting the idea of reducing peat use and even coercive measures, the need for such strategy to apply to all stakeholders, including importers of growing media (N = 5, n = 9). Thus, the price of growing media seems to be more critical due to the competition within the sector, nationally and internationally, than due to the willingness of customers to pay. This would also mean that for a company, increases in prices are not necessarily critical if they also affect the competition. For example, an interviewee noted that the strong price increase for growing media and other resources in 2022 concerning the whole market did not lead to negative changes in the demand for growing media for the company (in this case mostly for the professional horticultural sector).

3.5. Specific Situation of 2022

As for numerous sectors of the European economy, the year 2022 was a particular year for the German growing media industry due to the consequences of the war in Ukraine. A differentiation between aspects and their importance specifically linked to this situation and those applying more generally and in the long term was not completely possible. The interviewees mentioned several aspects specifically linked to the year 2022. First, they mentioned a general increase in material prices due to the energy crisis (N = 6, n = 9) leading to an increased competition for biomass, the abrupt stop of peat imports from Russia and Belarus (N = 1, n = 1) and competition for compost with the agricultural use due to high fertiliser prices (N = 1, n = 1). Additionally, an increase in transportation costs were mentioned due to high fuel prices and logistical problems (N = 2, n = 3). For the

interviewees, the situation had already improved compared with earlier in the year, but the time needed for a way out of the situation was uncertain. In general, the economic situation, although bringing difficulties, was not said to be particularly critical. There was one mention of good economic results during the COVID-19 period in the previous years (N = 2, n = 2), which were accompanied by a strong increase in growing media production in Germany. This could partially explain the capacity of the industry to overcome the crisis in 2022.

4. Discussion

4.1. Validity of Preliminarily Calculated Potentials

In this paragraph, we discuss, in the light of the present results, the validity of the potential amounts presented in Hirschler et al. [26], based on physical amounts of resources for the production of peat substitutes. The results show that quality problems for green compost represent a limitation for its use as a growing media constituent. The issues linked to the presence of biowaste and impurities can be considered avoidable by improving waste management in the future. In order to compensate for the seasonal variability of the composition of green waste, larger processing facilities could enable mixing of different charges of green waste to obtain a more suitable homogeneous quality. Therefore, the entire green waste supply can be considered as potentially usable for the growing media industry with a development of the supply chain. The potential for green compost presented in Hirschler et al. can be still considered valid. No further limitations due to the quality of raw materials were found for the other constituents—wood fibres, composted bark and coir products.

The results show further challenges linked to the economic situation that could be included in further work on the potential to identify possible limitations of a complete transformation and the conditions necessary to overcome them. In particular, the limitations due to transportation distances could be included by considering the geographic repartition of potential and the infrastructure for processing growing media and its constituents. Since the majority of the growing media production takes place in Lower Saxony, such research would assess the possibility to regionally source renewable materials or if substituting peat while maintaining production implies a decentralisation of the industry.

4.2. Future Evolution of Transformation Factors

In this paragraph, we discuss the evolution of drivers and limiting factors and their influence on the future reduction of peat use.

The first driver concerns the increasing price and insecurity of the peat supply associated with the end of domestic extraction. A total displacement of peat extraction is expected to occur after 2040. Since the peat industry in the Baltic states plans to extend peat extraction in order to supply the growing Asian market, it is to be assumed that peat resources in Europe will not be limited in the next decades. As a consequence, the displacement process is very likely to lead to a partial reduction in peat use, as the examples of other Western European countries relying on imports show [5]. A limitation could occur though political action and would be only feasible within the establishment of a European strategy. The evolution of market demand, another driver of the reduction in peat use, depends on the sensibility of consumers regarding peat-free products and the readiness of retailers to increase their offerings. According to the interviews carried out for the HOT project in Germany, a third of hobby gardeners consider peat-free as a criterion for their choice of potting soil [64]. It is questionable that this sensibility will apply to the entire consumer market in the future. The influence of these drivers is expected to be more important for the hobby market than for the professional market, with higher economic pressure and quality requirements, which can already be observed by the different evolutions of the peat rate between 2019 and 2022 (Figure 2).

Parallelly, the transformation will only be possible with the development of the infrastructure for the production, the processing and the storage of peat substitutes. The

rapidity of this transformation depends on the economic pressure on peat, the evolution of the competition with other sectors and the regulatory framework for the construction of facilities for the processing of peat substitutes. Due to the increasing need for biomass in the future in other economic sectors (for example energy and construction), in order to attain climate goals, it is unlikely that the market for bio-based raw material will, without intervention, advantageously develop for the growing media industry.

Finally, other aspects considered secondary in our analysis participate in enabling or accelerating the transformation and could gain importance in the future. Further education and more information on constituents and peat-free growing media could be needed, especially for consumers and professional users. Parallelly, the development of growing media analysis could also increase the capacity of professional growers to adapt to changing properties. Additionally, the development of technologies and market availability of other constituents could bring new possibilities. However, our research shows that even if new constituents can be developed, for example with processing technology, the limit to their use in growing media is generally because of their costs in comparison with the price of peat and ease of availability. This is typically the case for *Sphagnum* moss produced from paludiculture, which presents very good properties as a growing media constituent but whose production costs are high and whose development depends on a large-scale rewetting of peatlands [65].

4.3. Implication for the Peat Use Reduction Strategy

As stated in the previous paragraph, the consequences of the current drivers—displacement of peat supply and evolution of the sensibility of consumers—are unlikely to lead to a complete end to peat use in the timeframe set in the Peat Use Reduction Strategy. The threat of coercive measures beyond the voluntary policy is itself one of the drivers behind peat use reduction. However, this threat cannot be expected to have a sustainable effect on the industry if not followed by concrete measures.

Therefore, in the absence of measures affecting the economic situation of peat and/or its substitutes, the achievement of a peat exit can be considered unlikely or would depend on the emergence of other factors in the future.

Figure 9 illustrates, based on Figure 8, the positive evolution of the use of peat substitutes and the associated policy measures that could enable the transformation. Coercive measures could lower the attractiveness of peat, for example based on market-based instruments such as a carbon pricing on peat or a regulatory limitation or ban. Given the importance of international competition, it would be critical for such measures to affect all of the products sold in Germany including imports. A common EU policy would prevent international distortion of concurrence at a European level. Supporting measures for the use of biomass in the growing media sector could represent direct incentives and accompany the development of the supply chain of peat substitutes. This could also imply revising the distribution of subsidies between sectors in order to limit competition with the growing media sector. Such measures would need to be prepared in accordance with other policies on the use of biomass at the scale of the economy. Further investigations to reduce the regulatory burdens for the extension of the production, processing and storing infrastructure of biomass could facilitate its establishment. This especially concerns authorisation processes for composting plants and could also apply for the development of products from paludiculture such as fresh *Sphagnum* moss.

4.4. Conclusions and Further Research

Although the contribution of the reduction in peat use for the limitation of greenhouse gases emissions is widely accepted, this article brings a new perspective on the economic logic behind the use of materials in the growing media industry and the implication for the transformation toward a peat-free horticulture. This study confirms the role of environmental factors on the design of growing media, which has strongly gained importance in the last decade [12–18]. The origins of these considerations are explained from the

perspective of economic stakeholders: evolution of consumer demand and political risks as well as a focus on the local products to limit supply chain costs and insecurity. Additionally, critical factors determining the use of constituents are underlined, especially transportation distances and the competition with other sectors for the use of materials. The difficulties identified in the supply of peat substitutes are strongly linked to a lack of infrastructure for the storage and the processing of alternative materials. The results identify the economic advantage of peat over peat substitutes as a central challenge for the transformation of the growing media sector. Even if solutions for the technical implementations of the use of peat-reduced and peat-free growing media in horticulture exist and are largely documented, the factors identified in this study suggest that future evolutions will not lead to a complete substitution of peat. For this reason, political interventions making peat more expensive, for example through carbon pricing, or less available and/or supporting the use of peat substitutes and the development of the infrastructure are needed to achieve the targets of the Peat Use Reduction Strategy. Further research on the prices of materials and products would be needed to evaluate more precisely the influence of future trends and potential political measures on the relative economic advantages of constituents and on the reduction of peat use in horticulture.

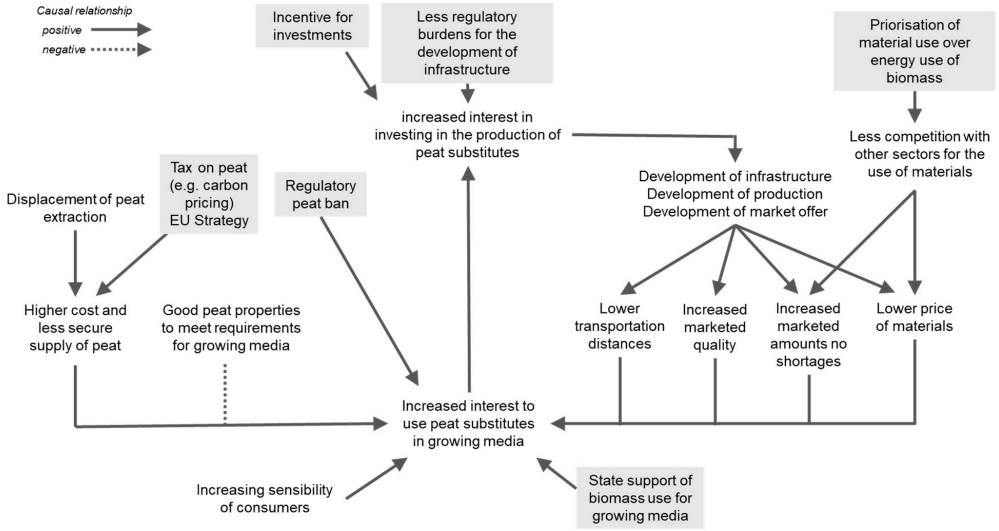

Figure 9. Causal chain explaining the potential transformation of the resource base towards peat substitutes for the production of growing media and associated policy measures.

Author Contributions: Conceptualisation, O.H. and D.T.; methodology, O.H.; investigation, O.H.; formal analysis, O.H.; visualisation, O.H.; writing—original draft preparation, O.H.; writing—review and editing, O.H. and D.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The interview data are not publicly available in accordance with privacy rights of interviewees and disclosure agreements with companies.

Acknowledgments: The authors would like to warmly thank all the interviewees for their time, their readiness to help and their very valuable expertise. The authors are grateful to Susanna Hönle, Bernhard Osterburg and Florian Denard for their support during the research process and their feedback on the first drafts of this article, to Susanna Hönle and Muriel Dudda for the transcription of one and two interviews, respectively, to Susanna Hönle, Franziska Lengerer, Larissa Deppisch and Annett Steinführer for their support on the implementation of qualitative methods and to Lena-Katharina Wrede for the organisation of legal and contractual formalities with the companies required for the interviews.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Structure of the questionnaire.

	Question	Type of Question/Choices
1	Name:	Open field
2	Company:	Open field
3	E-mail:	Open field
4	Is your company member of the Industrieverband Garten e.V. (IVG)?	Yes/No
5	How many employees are working in your company in the growing media sector in Germany?	Multiple choice: (a) 1–5 (b) 6–10 (c) 11–20 (d) 21–50 (e) 51–100 (f) 101–200 (g) more than 200
6	Is the growing media production the main activity of you company in Germany?	Yes/No
7	How much growing media do you produce annually in Germany? • For the hobby sector: • For the landscaping sector: • For the plant production sector:	For each: Open field
8	What is the average peat rate in your growing media? • For the hobby sector: • For the landscaping sector: • For the plant production sector:	For each, multiple choice: (a) 0–5% (b) 5–20% (c) 20–40% (d) 40–60% (e) 60–80% (f) 80–100%
9	Where are your production facilities located in Germany?	For each site: Open field
10	Does your company have own peat extraction sites?	Yes/No
10b	(If yes) where are they located?	Multiple answer: (a) In Germany (b) Outside Germany
11	Does your company have the goal to increase the use of peat alternatives in growing media?	Yes/No
12	Please indicate in case your company has quantified or timely defined goals on peat reduction or increase of use of peat alternatives	Open field
13	The strategy of the Ministry of Food and Agriculture aims to end the use of peat in Germany in the hobby sector by 2026 and to reduce it to the greatest extent in the professional sector. What is the position of you company regarding these goals?	Multiple choice: (a) Very favourable (b) Rather favourable (c) Neutral (d) Rather unfavourable (e) Very unfavourable
14	You can further explain the position of your company here:	Open field
15	Do you have additional commentaries?	Open field

Table A2. Structure of the interviews.

Step	Content/Questions
Introduction	Presentation of the interviewer Presentation of the project Presentation of the background including preliminary research on potentials Presentation of the research question Do you have any commentaries or question?
Clarifying questions	Questions related to the questionnaire, especially definition for growing media in the statistics
Supply and processing chain	Growing media constituents used Own processing or not Supply chain of materials Distance from suppliers Type of suppliers Relationship to supplier / contracts
Challenges linked to the constituents	Challenges linked to the availability and the use of constituents Reasons to reduce peat use
Closed question 1	"For which materials do you see the strongest difficulties for your company to increase the use for growing media production?" Ranking: (a) wood fibres and wood products (b) composted bark and bark products (c) green compost (d) coir products
Closed question 2	"In the case the demand only consists of peat-free products in 2030, how would you evaluate the possibility for your company to only produce peat-free at the same production level?" Multiple choice: (a) It would be absolutely not possible (b) It would be only possible with strong changes of the current conditions (c) It would be possible but problematic in the current conditions (d) It would be rather unproblematic in the current conditions (e) We are already completely peat-free
Closing discussion	What would be the solutions to the challenges mentioned regarding the reduction of peat use? Who would be responsible for implementing these solutions? Are there things that we did not mention in the interview and that would be worth mentioning?

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