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Alternative substrates in the cultivation of ornamental and vegetable plants

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Abstract

Research objective: The aim of this research was to evaluate different types of innovative substrate mixtures as an alternative to traditional growing media with peat and pumice on vegetable and ornamental plants

Materials and Methods: The experiments, which began in November 2022, were conducted in the CREA-OF greenhouses in Pescia (Pt), Tuscany, Italy (43°54′N 10°41′E) on seedlings of *Arbutus unedo*, Photinia red robin, *Fragaria vesca* and *Crassula sarcocaulis*. The plants were placed in 14 diameter pots, 6 plants per 3 replications, for a total of 18 seedlings per experimental thesis. The test was divided into two parallel trials with different substrates. The first trial on *Crassula sarcocaulis* involved the following theses (irrigated and fertilised): peat 70% + pumice 30%; peat 65% + pumice 30% + biochar 5%; compost 60% + biochar 5% + insect humus 5% + pumice 30%; compost 60% + biochar 5% + earthworm humus 5% + pumice 30%. The second trial on *Arbutus unedo*, Photinia red robin and *Fragaria vesca* involved the following theses (irrigated and fertilised): peat 70% + pumice 30%; alternative soil 72% + biochar 5% + 3% humus + 20% pumice.

On 18 May 2023, plant height, vegetative weight, root volume and length, number of fruits (strawberry) and number of microorganisms were determined.

Results and Discussion: The experiment showed that the use of alternative substrates can effectively improve the vegetative and root growth of *Crassula sarcocaulis*, *Fragaria vesca*, Photinia red robin and *Arbutus unedo*.

In general, in the first experiment on *Crassula sarcocaulis*, a significant increase in plant height was observed with the biochar-only substrate, followed by the insect and earthworm humus-based theses. All the theses were significantly better than the control with peat and pumice. In the second trial on *Fragaria vesca*, Photinia red robin and *Arbutus unedo*, the thesis with altenative soil, biochar and humus was significantly better in all plant species for plant height, vegetative and root weight and root length. All alternative substrates showed a significant increase in microbial biomass compared to the control. Several materials have been evaluated as substitutes for or combination with peat in growing media formulation. They include coir dust, pine bark, and wood fiber as well as sand, tuff, and pumice processed materials (expanded clay, perlite, and vermiculite). Besides satisfying the relevant technical requirements, these alternatives have to be readily available at reasonable prices and be readily available in sufficient quantities. In addition to meeting specific plant requirements, these materials have been used to create tailored growing media that are environmentally friendly and reduce production costs.

Conclusions: The results of research on growing substrates must be translated into agricultural practice through various steps, in cooperation with horticultural companies. To ensure the best growing conditions for seedlings,

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nurseries should conduct a thorough analysis of the specific composts they use. As organic farming practitioners argue, greater involvement of compost producers and end-users could improve the quality of growing media by adding additional valuable characteristics and reducing the use of peat, which would allow for a more sustainable regime.

Keywords: Alternative substrates; Microorganisms; Plant growth; Ornamentals; Rhizosphere

1. Introduction

The floriculture sector is characterised by the use of a wide range of different substrates and their mixtures according to the different uses, both in terms of production sector (young plants, cut flower crops, ornamental shrubs) and in terms of physiological needs (acidophilic and non-acidophilic plants) [1,2]. At present, peat is the main component of substrates for the sector, despite the environmental implications of its use, i.e. the exploitation of peat bogs. The numerous studies aimed at the use of alternative matrices to peat, as well as the increasing demand from target markets and public administrations for peat-free plants are some evidence of this issue [3,4]. The production of substrates for the horticultural sector in EU countries, both for the professional and hobby market, is about 34.6 million m^3, of which peat accounts for 75.6% of the total. A recent survey promoted by AIPSA (Associazione Italiana Produttori Substrati di Coltivazione e Ammendanti - Italian Association of Growing Substrates and Amendants Producers) confirmed this figure, with peat accounting for around 74% of the substrates used in Italy, within a market of around 4.3 million m^3. Despite the fact that the main EU peat producers (Finland, Ireland, Germany, Estonia, Latvia, Lithuania, Sweden, Poland and the United Kingdom) are also able to supply or otherwise source and/or market alternative and more environmentally sustainable matrices to peat, these cover only 18.7% of European demand [5,6,7]. The main alternative materials include composted green manure, coconut and wood fibre, with compost standing at around 7.9% and an increasing trend for coconut derivatives and wood fibre. Among other things, it is worth pointing out in this context that green compost and wood fibre also represent an important opportunity from the point of view of a proactive use of the circular economy through waste recycling, as also advocated and requested by the EU [8,9,10]. It is also important to remember that at present, the materials allowed as substrates are regulated by Italian law and must therefore comply with defined quality characteristics, while adherence to system certification systems, such as Ecolabel, is voluntary [11,12]. More generally, the choice of substrate is more oriented towards the use of a single matrix, often peat, for the production of young plants, while for cut flower production, mixtures of peat and coco with an inorganic component, such as perlite or pumice, are more commonly used [13,14]. Mixtures are also used for the production of outdoor plants: among these the most common are those based on two organic components and one inorganic component [15,16,17]. Recently, particularly in outdoor ornamental nurseries, coco has found widespread use both because of its cost, initially lower than peat, and for phytosanitary reasons, i.e. because it is nematode-free [18]. For a correct choice of substrate, however, it is necessary to take into account both the specific requirements of the cultivated species and the cultivation system adopted. The main functions that the substrate must perform are those of anchoring the plant via the root system and of reservoir for water and nutrient uptake; these functions are closely linked to the intrinsic characteristics of the chosen matrix [19,20,21].

1.1. Agronomic aspects related to the growing medium

The growing medium is one of the fundamental elements for successful cultivation, in fact it influences: the absorption of mineral elements and the availability of water and air and determines the development of a more or less balanced root system [22,23,24]. The growing medium must fulfil two fundamental functions: to provide support and anchorage for the plant and to make water and nutrients available to the plant [25,26]. The substrate must have the following characteristics:

- Stable structure: i.e. It must be compact and physically support the plants;
- High porosity: for aeration of the root systems, but also to contain weight and promote drainage;
- Water retention: good, so as to avoid too frequent watering;
- Sanitary condition: free of parasites, however, it can be sterilised chemically or with steam without undergoing substantial changes;
- Presence of macro- and micro-nutrients;
- Sufficient absorbent power;
- Chemical reaction appropriate to the needs of the cultivated species.

The growing medium must also provide support, anchorage and make water and nutrients available to the plant. Finally, it must be well mixed so that the various components are evenly distributed in the mass so that they are easily assimilated by the roots [27,28,29]. The main raw materials frequently used in mixtures for the formulation of growing media can be divided into:

- Organic materials: peat, composted soil conditioners, coconut fibre, wood fibre, pine bark, rice husks, straw, algae, Posedonia oceanica deposits;
- Synthetic materials: polyurethane foam, expanded polystyrene, used tyres;
- Draining materials: sand, perlite, pumice and lapilli, vermiculite, expanded clay, rock wool, zeolites, pozzolan.

Recently, other secondary products have also been added, such as biochar, which is a charcoal obtained by pyrolysis of crop residues, or the same shredded and partially composted pruning residues, and finally also other secondary organic materials such as olive pomace [30].

It is clear that the search for new materials, even differentiated by territory, can be an important contribution to the search for less impactful and more economical production techniques. These raw materials are normally mixed, according to specific doses defined, almost always, empirically and on the basis of personal experience by individual companies [31]. These are the so-called 'recipes' used in ornamental nurseries. The most frequent mixtures, regardless of the percentage ratios, are:

- Blond peat, pumice, rice husk, coconut fibre;
- Black peat, pumice, organic matter;
- Fibrous peat, vermiculite, coconut fibre;
- Swedish peat, rice husk, coconut fibre.

It is clear that this type of industrial plant and one that works to precise company requirements can only be located within districts with a high concentration of companies and a significant demand for substrate. From an agronomic point of view, the availability of suitable quality cultivation substrates is decisive for the sustainable development of nurseries, especially ornamental ones [32,33].

1.2. Sustainability of substrate cultivation

The sustainability of container cultivation in environmental terms is evidently linked to the possibility of developing the use of raw materials available in or near the production districts to reduce the negative impact of transport, to the possible reuse of secondary materials from the same nursery sector or from other sectors that can be used as such or after transformation into compost or other materials. It goes without saying that for the assessment of environmental sustainability it is also necessary to know the CO_2 emissions associated with the production and transport of the raw materials as well as for the production of the growing medium [34]. Sustainability in economic terms is clearly different when assessed on a company level or on more general spatial plans at various levels. On a company level, it must also be seen with reference to the target market of the nursery product: professional or hobbyist for recultivation, for time-limited use or for long-term use such as the creation of parks and gardens [30]. In fact, while for the former the search for less expensive substrates can be a winner even if they are of lower quality, for the latter it is also important to have quality for the best success of the plants once planted. Undoubtedly, the age of the plants and their size have a direct influence on the possible adaptability of breeding in substrate as opposed to subsequent final planting in the ground [29]. Global sustainability is directly linked to limiting the depletion of raw material stocks and reducing the CO_2 emissions associated with their use. Local sustainability is linked to the reduction of material movements, the use of local and reproducible raw materials, and the recycling of by-products and production waste. In this respect, there is a clear advantage for companies located within a production district with a well-organised supply chain [31]. Business sustainability is linked to reducing direct and indirect costs and improving productivity per unit area and product quality [32].

1.3. Research Objectives

The aim of this research was to evaluate different types of innovative substrate mixtures as an alternative to traditional growing media with peat and pumice on vegetable and ornamental plants.

Figure 1 Details of the substrates and plants used in the experiment at CREA-OF

2. Material and methods

The experiments, which began in November 2022, were conducted in the CREA-OF greenhouses in Pescia (Pt), Tuscany, Italy (43°54′N 10°41′E) on seedlings of *Arbutus unedo*, Photinia red robin, *Fragaria vesca* and *Crassula sarcocaulis*.

The plants were placed in 14 diameter pots, 6 plants per 3 replications, for a total of 18 seedlings per experimental thesis.

All plants were fertilised with a controlled-release fertiliser (2 kg m^{-3} Osmocote Pro®, 9-12 months with 190 g/kg N, 39 g/kg P, 83 g/kg K) mixed with the growing medium before transplanting. The trial was divided into two parallel trials with different substrates. The first trial on *Crassula sarcocaulis* involved the following theses (irrigated and fertilised)

- Peat 70% + pumice 30% (CTRL)
- Peat 65% + pumice 30% + biochar 5% (BIO)
- Compost 60% + biochar 5% + insect humus 5% + pumice 30% (HUMIN)
- Compost 60% + biochar 5% + earthworm humus 5% + pumice 30% (HUMLO)

The second trial on *Arbutus unedo*, Photinia red robin and *Fragaria vesca* involved the following theses (irrigated and fertilised):

- Peat 70% + pumice 30% (CTRL2)
- Alternative soil 72% + biochar 5% + 3% humus + 20% pumice (BIOHUM)

The plants were watered once a day and grew for eight months. The plants were drip-irrigated. Irrigation was activated by a timer whose programme was adjusted weekly according to the weather conditions and the leaching fraction.

On 18 May 2023, plant height, vegetative weight, root volume and length, number of fruits (strawberry) and number of microorganisms were determined.

2.1. Analysis methods

Microbial count: directly determining total microbial count by microscopy cells contained in a known sample volume using counting chambers (Thoma chamber). The surface of the slide is etched with a grid of squares, with the area of each square known. Determination of viable microbial load after serial decimal dilutions, spatula seeding (1 ml) and plate counting after incubation [30];

2.2. Statistics

The experiment was carried out in a randomized complete block design. Collected data were analyzed by one-way ANOVA, using GLM univariate procedure, to assess significant ($P \leq 0.05$, 0.01 and 0.001) differences among treatments. Mean values were then separated by the LSD multiple-range tests ($P = 0.05$). Statistics and graphics were supported by the programs Costat (version 6.451) and Excel (Office 2010).

3. Results

The experiment showed that the use of alternative substrates can effectively improve the vegetative and root growth of *Crassula sarcocaulis*, *Fragaria vesca*, Photinia red robin and *Arbutus unedo*.

In general, in the first experiment on *Crassula sarcocaulis* (**Table 1** and **Figure 2**), a significant increase in plant height was observed with the biochar-only (BIO) substrate, followed by the (HUMIN) and (HUMLO) insect and earthworm humus-based theses. All the theses were significantly better than the control (CTRL) with peat and pumice. The same trend was observed with regard to vegetative development, root development and root length. An increase in microbial biomass was also observed in the substrates of the alternative theses compared to the control.

In the second trial on *Fragaria vesca*, Photinia red robin and *Arbutus unedo*, the thesis with altenative soil, biochar and humus was significantly better in all plant species for plant height, vegetative and root weight and root length (**Table 2,3,4** and **Figure 3,4,5**). Also in this trial, an increase in microbial biomass was observed in the alternative substrates compared to the control. A significant increase in the number of fruits was also found on strawberry compared to the untreated control.

Table 1 Evaluation of the use of different substrates on *Crassula sarcocaulis*

Groups	Plant height (cm)	Substrate total bacteria (Log CFU/g soil)	Vegetative weight (g)	Roots volume (cm³)	Roots length (cm)
CTRL	12.01 d	1.54 c	18.68 d	14.34 d	3.36 d
BIO	14.87 a	3.42 a	22.37 a	17.79 a	6.57 a
HUMIN	13.56 b	2.26 b	20.75 b	15.88 b	5.10 b
HUMLO	13.09 c	2.09 b	19.50 c	15.14 c	4.72 c
ANOVA	***	***	***	***	***

One-way ANOVA; n.s. – non significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05).Legend: (CTRL) control; (BIO) peat 65% + pumice 30% + biochar 5%; (HUMIN) compost 60% + biochar 5% + insect humus 5% + pumice 30%; (HUMLO) compost 60% + biochar 5% + earthworm humus 5% + pumice 30%

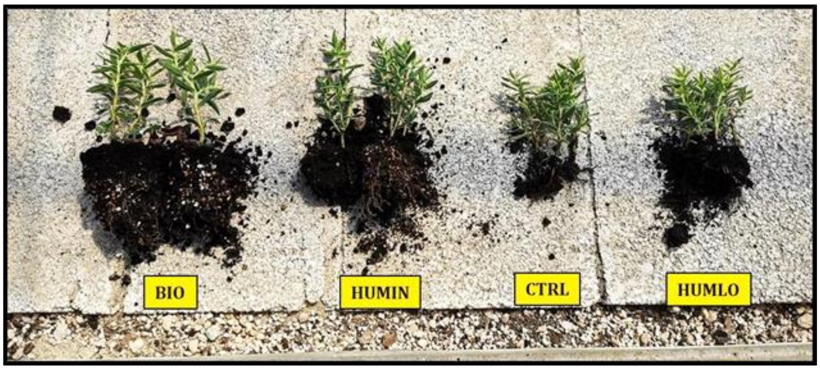

Figure 2 Comparison between the thesis with peat 65% + pumice 30% + biochar 5% (BIO), compost 60% + biochar 5% + insect humus 5% + pumice 30% (HUMIN), compost 60% + biochar 5% + earthworm humus 5% + pumice 30% (HUMLO) and the control on the vegetative development of *Crassula sarcocaulis*

Table 2 Evaluation of the use of different substrates on *Fragaria vesca*

Groups	Plant height (cm)	Substrate total bacteria (Log CFU/g soil)	Vegetative weight (g)	Roots volume (cm³)	Roots length (cm)	Fruits number (n°)
CTRL2	24.07 b	1.45 b	44.17 b	29.23 b	4.76 b	5.61 b
BIOHUM	26.67 a	3.50 a	47.77 a	32.72 a	6.79 a	10.40 a
ANOVA	***	***	***	***	***	***

One-way ANOVA; n.s. – non significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05).Legend: (CTRL2) control; (BIOHUM) alternative soil 72% + biochar 5% + 3% humus + 20% pumice

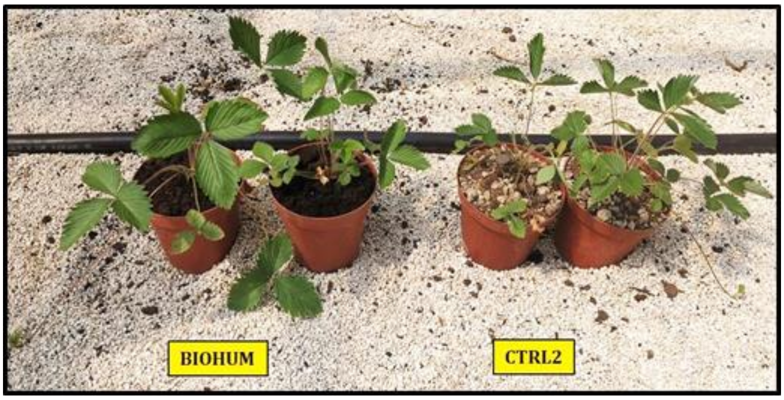

Figure 3 Comparison of the thesis with alternative soil 72% + biochar 5% + 3% humus + 20% pumice (BIOHUM) and the control on *Fragaria vesca*

Table 3 Evaluation of the use of different substrates on Photinia red robin

Groups	Plant height (cm)	Substrate total bacteria (Log CFU/g soil)	Vegetative weight (g)	Roots volume (cm3)	Roots length (cm)
CTRL2	36.33 b	1.32 b	44.88 b	36.23 b	5.70 b
BIOHUM	40.56 a	3.09 a	49.01 a	39.06 a	6.28 a
ANOVA	***	***	***	***	***

One-way ANOVA; n.s. – non significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05).Legend: (CTRL2) control; (BIOHUM) alternative soil 72% + biochar 5% + 3% humus + 20% pumice

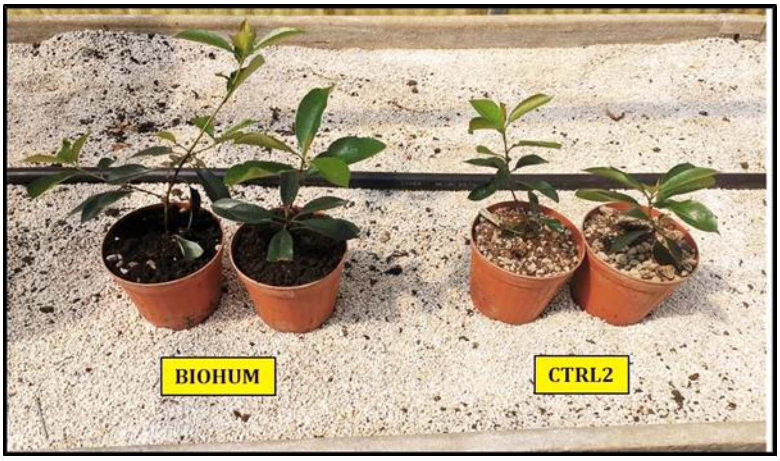

Figure 4 Comparison of the thesis with alternative soil 72% + biochar 5% + 3% humus + 20% pumice (BIOHUM) and the control on Photinia red robin

Table 4 Evaluation of the use of different substrates on *Arbutus unedo*

Groups	Plant height (cm)	Substrate total bacteria (Log CFU/g soil)	Vegetative weight (g)	Roots volume (cm^3)	Roots length (cm)
CTR	32.46 b	1.36 b	42.35 b	31.59 b	6.22 b
BIOHUM	34.70 a	3.51 a	44.62 a	35.20 a	7.15 a
ANOVA	***	***	***	***	***

One-way ANOVA; n.s. – non significant; *,**,*** – significant at P ≤ 0.05, 0.01 and 0.001, respectively; different letters for the same element indicate significant differences according to Tukey's (HSD) multiple-range test (P = 0.05).Legend: (CTRL2) control; (BIOHUM) alternative soil 72% + biochar 5% + 3% humus + 20% pumice

Figure 5 Comparison of the thesis with alternative soil 72% + biochar 5% + 3% humus + 20% pumice (BIOHUM) and the control on *Arbutus unedo*

4. Discussion

4.1. The environmental reasons behind the research for peat alternatives for transplant production

The most common constituent of growing media has been peat [35]. The water holding capacity of this substance is enhanced, it is good at cation exchange, it does not contain phytotoxic substances and it is relatively low in bulk density, so it is usually included in substrates. Due to the fact that almost 80% of European growing media is composed of peat materials [36], this is an issue that must be addressed. In an estimate, approximately 30 million m3 of white peat is consumed each year, half of which is used in commercial horticulture, while 25% is used extensively in conventional nurseries [37]. The use of peat and the expanding growing media industry in the European Union is estimated to be worth €13,000 million and generates approximately 11,000 jobs. There has been an increase in environmental and ecological concerns about peat as a growing medium because its harvest is jeopardizing endangered wetland ecosystems [38]. A Global Action Plan for Peatlands (GAPP) has been developed by several environmental organizations, including the International Mire Conservation Group (IMCG), the International Peatland Society (IPS), a growing media industry, the Society of Wetland Scientists (SWS), and the IUCN Commission on Ecosystem Management (CEM). It is recognized that peatlands contribute greatly to the maintenance of global biodiversity of ecosystems and species, to the conservation of carbon vital to the world’s climate system, as well as the wise use, conservation, and management of natural resources for the benefit of the public and the environment. Based on Regulation 834/2007 (EC 2007), peat utilization contradicts the fundamental principles of organic agriculture. In order to address this issue, the EGTOP report proposed that the following restriction be added to the listing of peat: 'maximum 80 % by volume of growing media'. The growing demand for peat in horticulture as a growing media has led to the search for more cost-effective and high-quality substrates. The industry's dependence on this sector implies fluctuating prices, but prices have been on the rise (13% rise over 2006–2010 [39]. Depending on the scarcity and non-renewability of peat, nursery and greenhouse growers might lose competitiveness in relation to soilless substrates due to its scarcity and non-renewability. As a result, it has become increasingly important to find inexpensive, readily available substrates that will replace peat moss. In nurseries, peat consumption has been decreasing, but not for growing media, where it remains dominant [37].

4.2. Production of transplants using compost

Several materials have been evaluated as substitutes for or combination with peat in growing media formulation [40,41,42]. They include coir dust, pine bark, and wood fiber [43,44] as well as sand, tuff, and pumice processed materials (expanded clay, perlite, and vermiculite). Besides satisfying the relevant technical requirements, these alternatives have to be readily available at reasonable prices and be readily available in sufficient quantities. In addition to meeting specific plant requirements, these materials have been used to create tailored growing media that are environmentally friendly and reduce production costs [45]. The term compost refers to a heterogeneous material created by the partial degradation of organic waste materials with various origins by aerobic microorganisms through an exothermic process. By recycling waste in agriculture, compost from various feedstocks can reduce the environmental impact of waste disposal. As a result of its physical, chemical, and biological properties, compost can reduce the amount of peat in growing media formulations to a significant extent [44]. In contrast, its utilization is hampered by a lack of uniformity in compost characteristics over time, mainly due to differences in feedstock availability and poor composting process control. In horticultural nurseries, however, the primary commercial objective is to produce healthy, standardized seedlings that cannot be affected by variables in growing media. Even so, compost is by far the most extensively studied component of growing media [46,47,48,49,50]. The term compost encompasses a wide variety of materials, and not all composts would make suitable growing media constituents, given the need for homogeneous properties. In addition to understanding the needs of nursery owners and farmers [51], compost producers should also understand the needs of nursery owners. The quality of the raw materials used in the formulation of the composting starting mixture and the quality of the composting process determine the composting performance [50]. The most frequently cited problems related to compost as a growing medium for vegetable transplants were highlighted by [42]. The results concerning the suitability of the tested composts varied significantly and weren't always satisfactory. Failures often resulted from the mixtures and materials used. A variety of factors have been attributed to them, including phytotoxins [52], high electrical conductivity (EC) [53], immaturity in hardwood bark compost [54], excess NH^{4+} in spent mushroom compost [55], heavy metal toxicity in urban solid wastes [56], or poor physical properties due to low aeration or low waterholding capacity [42,53]. Compost production with adequate quality standards for growing media formulation is more of a problem than incompatibility of compost as a growing medium in general.

4.3. Compost's physical and chemical properties make it an ideal growing medium

The composition and origin of composts vary significantly, e.g., agricultural waste, agro-industrial waste, and animal manures. Different residual biomasses, such as coconut coir (*Cocos nucifera* L.), husk fiber, rice (*Oryza sativa* L.) hulls [57], switchgrass (*Panicum virgatum* L.) [58], spent mushroom compost (*Agaricus bisporus* and *Pleurotus ostreatus*) [59], beached Posidonia residues (*Posidonia oceanica* L.), extracted sweet corn tassel (*Zea mays* L.) [60], and giant reed wastes (*Arundo donax* L.) [61], have been studied as partial or total substrate constituents. Compost has been used as a substitute for peat in potting media in numerous studies as well. There are a number of composts for municipal solid waste, animal manure compost, green waste compost, and agro-industrial composts. Compost-type utilization limitations can be overcome by identifying suitable input materials, standardizing the composting process to produce homogenous compost, and testing it for specific plant growth [21]. To achieve the expected compost quality, it is necessary to define the standard composting processes for specific raw materials and to establish the minimum number of parameters to determine compost quality. In terms of physical, chemical, and microbiological properties, salinity and maturity have been the most cited parameters [30]. Using different German, Austrian, and US bodies, presented a range of parameters and suggested end-use values for composts used in potting formulations. In addition to increasing plant availability of nutrients, compost can change physical properties, pH, and nutrient relationships in growing media, promote or suppress diseases, and affect seedling growth. In order to achieve the best results regarding plant growth and productivity, a new and different approach to optimizing growing media has been proposed [17]. There are only 15% of compost produced in Europe used as a base material for the formulation of commercial substrates for container cultivation, primarily for feeding soil with organic matter. In growing media, peat and compost work synergistically [38]. Peat improves aeration and water retention, while compost or other additives enhance fertilizing capacity. The porosity and aeration properties of specific by-products and composts are comparable to those of bark or peat, making them ideal propagating media [45]. Generally, composts accounted for only a relatively small percentage (25–50%) of nursery container medium mixtures, producing the greatest plant growth responses and yields. It has been found that growing mediums such as peat are in high demand and at high cost in horticulture [50]. The use of compost in organic growing media is increasing awareness about waste recycling, making it a common ingredient among organic growers. In this trial, the use of biochar, compost and insect and earthworm humus significantly improved the vegetative and root growth of *Crassula sarcocaulis*, *Fragaria vesca*, Photinia red robin and *Arbutus unedo*. There was also a significant increase in strawberry production and an increase in microbial biomass in the alternative substrates

5. Conclusion

As a result of replacing peat with compost or another proposed material supplemented with coir and minerals, the use of peat in growing media could be significantly reduced. As a result of the improvement of physical, chemical, and microbiological properties, this substitution would result in higher transplant biomass and plant growth. In addition to providing seedlings with macro- and micronutrients, these materials, such as added-value compost or tailored compost, would also provide beneficial microorganisms that help mineralize compounds into plant-available nutrients and suppress plant pathogens. Peat, on the other hand, cannot offer these value-added benefits. The producers of growing media, in particular compost producers, and nurseries do not have enough information, which must be bridged by providing trusted common information for both markets. Practical research is lacking, and more attention needs to be paid to the involvement of the entire chain of growers, from input and growing media producers to seedling and vegetable producers. Mixtures of growing media with added value can be scaled from laboratory to large amounts without losing their useful properties, taking into account the fact that several weeks of storage are unavoidable in commercial handling. The results of research on growing substrates must be translated into agricultural practice through various steps, in cooperation with horticultural companies. To ensure the best growing conditions for seedlings, nurseries should conduct a thorough analysis of the specific composts they use. As organic farming practitioners argue, greater involvement of compost producers and end-users could improve the quality of growing media by adding additional valuable characteristics and reducing the use of peat, which would allow for a more sustainable regime.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares no conflict of interest.

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