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Sustainable Valorisation of Biowaste for Soilless Cultivation of Salvia Officinalis in a Circular Bioeconomy

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Abstract: The aim of this work is to assess the usefulness of biowaste deriving from Circular Bioeconomy (CBE) processes (i.e., vermicompost, compost and digestate), as growing substrates for the partial or total replacement of peat, by measuring the vegetation biometric parameters of sage (*Salvia officinalis* L.)—leaf area; Soil Plant Analysis Development (SPAD) value (index of chlorophyll concentration); fresh and dry weight of leaves; stem weight; root length. The results showed that vermicompost positively influenced most of above parameters (+16.7% for leaf area, +7.3% for fresh leaf weight, +6.4% for dry leaf weight, +8.5% for fresh stem weight, +0.9% for dry stem weight, +16% for root length) and, therefore, can be used as a sustainable growing substrate, alternative to peat, for the sage soilless cultivation. Yet, the results of some biometric parameters are better with peat rather than with compost (−7.2% for SPAD value, −47.3% for fresh leaf weight, −46.8% for dry leaf weight, −32.9% for fresh stem weight, −39.1% for dry stem weight, −52.4% for fresh root weight, −56.6% for dry root weight) and digestate (−30.2% for fresh leaf weight, −33.6% for dry leaf weight, −23.9% for fresh stem weight, −27% for dry stem weight, −51.8% for fresh root weight, −34.4% for dry root weight, −16% for root length). Therefore, these results are interesting for potted plants in nursery activity, while the above differences must be verified also after the transplanting of the tested plants in open field. However, the use of all the above growing substrates alternative to peat allows the sustainable valorization of food industry by-products, plant biomass, animal manure and the Organic Fraction of Municipal Solid Waste (OFMSW).

Keywords: Renewable Energy Sources (RES); vermicompost; compost; digestate; peat; nutraceutical species

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1. Introduction

Continuous population growth, increasing consumption and linear economy are driving global food demand, so that agricultural activity is expanding to keep pace. Modern agriculture is wasteful, so that Europe generates 700 million tons of agricultural and food waste every year.

Therefore, one of the major challenges humanity faces nowadays is the increasing production of solid waste. This is a result of a linear economy and growing urban population. Biowaste or organic waste represents a significant Renewable Energy Source (RES), providing added-value products such as organic fertilizers [1].

Biowaste is a core issue of Circular Bioeconomy (CBE) policy. Circular economy applied to food system implies reducing the amount of generated waste, food reuse, use of by-products and food waste, nutrient recycling and diet changes towards more variable and efficient food patterns. Applying Circular Bioeconomy principles currently represents a valuable opportunity for CBE society, which is called to cope with complex and important challenges, such as food security, competition for natural resources, dependence on fossil fuels and climate change. The link between food waste management and sustainable food/biomass production is therefore a key element of Circular Bioeconomy [2,3].

Soilless plant cultivation is a method of growing plants without using soil as a rooting medium and generally involves containerization of plant roots within a porous rooting medium known as growing substrate. Compared with soil-based cultivation, soilless cultivation can be more cost-effective, producing higher yields and earlier harvests from smaller land areas. In fact, soilless cultivation has also (generally) higher water and nutrient use efficiency. As far as an appropriate physical structure, a growing substrate must provide a suitable biological and chemical environment where plant roots can effectively access nutrients [2,3]. It also needs to meet the practical and economic requirements of the grower—it must be affordable, easy to obtain and manageable.

In terms of high performance and low cost, peat is an ideal constituent of soilless growing substrates. The term peat encompasses many different types of plant material that have been partially decomposed under anaerobic and water logged conditions. It is low in plant nutrients but able to adsorb and release them when added as fertilizer. Even if peat has a low rewetting capacity, it generally tends to possess excellent physical, chemical and biological properties for plant growth, as well as a low bulk density, which makes it light and relatively cost effective for transport. Widespread reserves of peat exist in the Northern hemisphere, making it a readily available and relatively cheap resource [2,3].

Yet, nowadays the production cost of peat for the soilless cultivation of plants has become higher and higher but, above all, it has a high environmental impact. In fact, the exploitation of peat bogs is contested, because they are sites of high ecological and sometimes archaeological value, while peat is a fossil (not renewable) resource, needing thousands of years to be created. Peat extraction processes have reduced sustainability, both from environmental and economic points of view—mining activities carried out in peat bogs determine not only substantial economic burdens but also progressive and irreversible damage to the bogs themselves, which are true natural biodiversity heritages [2,3]. During the last 20 years, peat extraction has therefore come under increasing scrutiny throughout Europe and, above all, in the UK [2,3]. As a consequence, alternative substrates to peat, deriving from the processing of plant biowaste, were used for flower cultivation and nursery activities in recent years [2,3].

Sage (*Salvia officinalis* L.) is a perennial, herbaceous and nutraceutical plant of small size, belonging to the family of Lamiaceae. Plants of this species are widely used for the presence of essential oils, contained in glands and secreting hairs on its stem and leaves [4].

Vermicomposting is a way to treat solid organic waste—it involves the bio-oxidation and stabilization of organic material under aerobic and mesophilic conditions through the combined action of earthworms and bacteria. Therefore, suitable organic waste or feedstock for earthworms is crucial to ensure a successful and efficient vermicomposting process. Earthworms can consume most organic materials with a pH of 5–8, a moisture content of 70–90% and an initial C/N ratio of 30 ca. [2,3,5].

Vermicompost or humus of earthworms is produced through the digestion of organic materials by these worms. This digestion process removes pathogen agents, by adding humic acid, nutrients and enzymes. The humus of earthworms also includes eggs, that will open and increase the amount of worms contained in vermicompost. The bacteria contained in vermicompost also modify the soil nitrogen, in order to create nitrates, used by plants for their growth. Moreover, the use of vermicompost, that is a stable and pollutant free material, contributes to carbon sequestration, as its organic matter is incorporated into the soil. The humus produced has a very high quality, is odorless and increases plant growth.

Several composted organic materials derived from both plant and animal waste can be used in soilless growing substrates. Composting is an aerobic process, during which a mixture of organic materials is degraded by several microorganisms and organisms (i.e., insects), in order to produce compost, representing a potential alternative to peat.

In 2010, a study was initiated to assess the feasibility of a circular chain aiming at using green waste from nursery activities (mowing and pruning operations) for producing green compost on farm and on farm evaluating its beneficial effect on the growth and production of commercial plants. This approach is the basis of the concept of Circular Bioeconomy, which keeps the added value inside products for as long as possible and eliminates waste [2,3].

Compost, which can be used as a soil improver, organic fertilizer and growing substrate, according to Italian Legislative Decree 75/2010, has not to exceed limit values of human and animal indicator pathogens, as well as potentially toxic elements (heavy metals), aerobic biological activity, physical contaminants (impurities) and weed seeds. Compost tends to have an alkaline pH (7–9), which can affect the availability of nutrients. The spreading of compost, that is a stable and pollutant free material, also contributes to carbon sequestration, as its organic matter is incorporated into the soil. Any compost to be used in a growing substrate must be obtained after a lengthy enough process, that makes it sufficiently stable and mature. Growing substrates used to germinate seeds should have compost only for 5–10% by volume, while multipurpose growing media can contain it for 20–40% by volume [3].

Anaerobic Digestion (AD) is a process for converting organic wastes, for example, animal husbandry effluents; plant biomass [6], food industry by-products, sewage sludge and Organic Fraction of Municipal Solid Waste (OFMSW), including food waste, into biogas and digestate [4,6–15].

Digestate, that is above all, the liquid but also the solid fraction derived from AD process, can be used as an organic fertilizer or a component of growing substrates, as it determines some advantages—increase of nitrogen, phosphorous and potassium, without applying mineral synthesis fertilizers; spreading of a stable and pollutant free material (even if it depends from organic substrates).

However, the digestate usually has unbalanced nutrient ratios for plant growth [2]. Generally, on farm vermicomposting/composting/Anaerobic Digestion and the use of the end-product of these processes for partially or totally substituting peat in nursery activity allow to reduce the environmental and economic costs for producing potted plants. The production of the on farm vermicompost/compost/digestate can be considered as a model replicable in nurseries and soilless cultivations. In fact, within the agro-food chain, the Circular Bioeconomy aims at reducing waste, while making its best use and, therefore, increasing its value, through economically viable processes.

The aim of this work is to assess the usefulness of growing substrates deriving from processes of Circular Bioeconomy, that is, vermicompost (produced from cattle and horse manure), compost (obtained from the OFMSW, differentially collected according to door-to-door method) and digestate (derived from the AD process of chicken manure, cattle slurry, cheese whey, citrus industry by-product and oil pomace, as well as sorghum, corn and triticale silage), for the partial or total replacement of peat, by measuring the vegetation biometric parameters of sage.

2. Materials and Methods

The survey was carried out from April to October 2019 at the Council for Agricultural Research and Agricultural Economy Analysis (CREA), Research Centre for Plant Protection and Certification of Bagheria (Palermo, Italy), inside an open greenhouse, covered by a 30% shading net, which was also equipped with a mulching cloth and an automated irrigation plant with a very low flow rate. At the beginning of the survey, young plants of sage grown in polyethylene pots, with a diameter of 12 cm and a volume of 1.2 l (Figure 1), were repotted into polyethylene pots, with a diameter of 18 cm and volume of 4 l, and, then, filled in with four substrates—vermicompost, compost, digestate and peat [3].

Figure 1. Young plants of *Salvia officinalis* L. grown in pots having diameter of 12 cm.

The very thin (5 mm) vermicompost tested in this work was produced by the "Red Worm Sicily" company, located in Milazzo (Messina), inside litters, through a slow digestion process of cattle and horse manure, operated by earthworms of *Eisenia fetida* and *Eisenia andrei* species. This process has a duration of 120 days.

The compost tested in this work was produced inside the composting plant owned by the Green Planet company and located in Ciminna (Palermo), by using the OFMSW, differentially collected according to door-to-door method. The steps of the composting process carried out inside the above plant are described in Figure 2. The whole process, that has a total duration of 90 days, produces compost, whose high quality is tested by an external laboratory and biogas, that is converted into electrical and thermal energy by means of a Combined Heat and Power (CHP) plant. Because of the low thermal conductivity of biomass, the heat accumulated inside it reaches and exceeds 55 °C, so that it assures the complete sanitation of biowaste, by inactivating microorganisms pathogenic for man and plants.

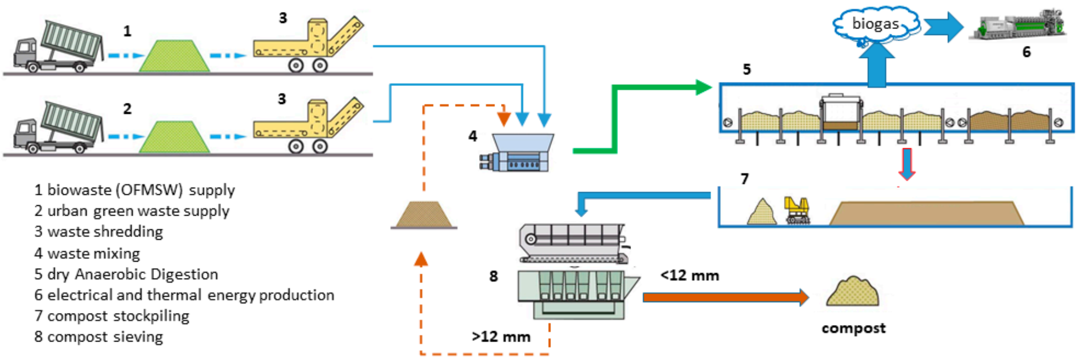

Figure 2. Steps of the composting process carried out inside the plant owned by Green Planet and located in Ciminna (Palermo).

The solid digestate tested in this work was produced inside a biogas plant having a power of 600 kW and built by AB Group agricultural company in Vittoria (Ragusa, Italy) in 2013. Inside this bioreactor, the dry AD process of chicken manure, cattle slurry, cheese whey, citrus industry by-product and oil pomace, as well as sorghum, corn and triticale silage, is carried out in order to produce biogas and, then, electrical and thermal energy by means of a CHP plant. The steps of the AD process carried out inside the above plant are described in Figure 3. The biomass is firstly fed into the bioreactor doser, where it is subjected to a physical-mechanical pre-treatment of homogenization, in order to increase the contact area with bacteria. Downstream of the bioreactor, a SEPCOM® vertical solid-liquid separator by

WAMGROUP S.p.A. Modena Italy, (consisting by a feed device and two vertical screws, mounted inside two cylindrical sieves) continuously divides the digestate into solid and liquid fractions. The solid fraction is used as biofertilizer and soil structure improver, while the liquid fraction is partially recycled inside the bioreactor, for improving the physical-mechanical parameters of the incoming biomass and is partially used as a biofertilizer (having a high concentration of ammonia nitrogen), according to Nitrate Directive 91/676/EEC [16].

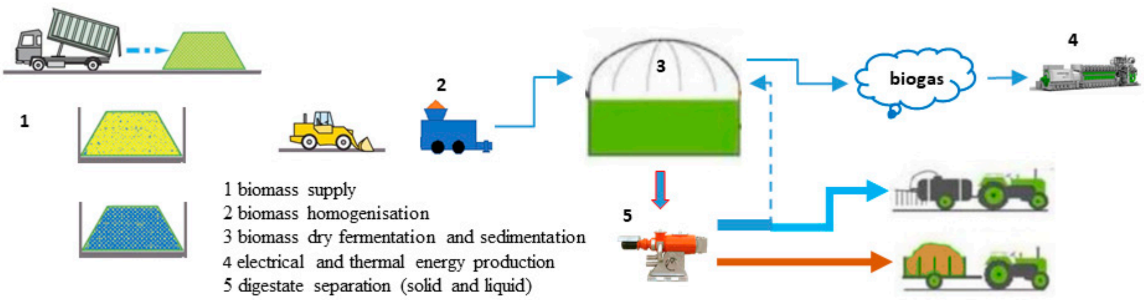

Figure 3. Steps of the dry Anaerobic Digestion process carried out inside the bioreactor built up by AB Group agricultural company in Vittoria (Ragusa).

The peat substrate tested in this work is produced by the company Vigorplant Italia srl (Fombio, Italy) and has the commercial name "Radicom". It is composed of a mixture of blond sphagnum peat, black swampland peat and green compost.

After mixing the three substrates (vermicompost, compost and digestate) with the peat substrate (Radicom), by using the composition shown in Table 1, the sage plants were manually repotted into pots with diameters of 18 cm containing four different compositions of mixed substrates—Substrate Composition SC1 (40% vermicompost and 60% peat); SC2 (40% compost and 60% peat); SC3 (40% digestate and 60% peat); SC4 (100% peat).

Table 1. Four Substrate Compositions (SC) (%) used for growing the sage plants.

Substrate	SC1 (%)	SC2 (%)	SC3 (%)	SC4 (%)
Vermicompost	40			
Peat (Radicom)	60	60	60	100
Compost		40		
Digestate			40	

The presence of the main nutrients in the four substrates is shown in the Table 2.

Table 2. Chemical composition of the four substrates used for growing the sage plants.

Nutrient Content	SC1	SC2	SC3	SC4
Nitrogen (%)	1.32	1.46	1.12	1.3
Phosphorus (%)	0.69	0.72	0.39	0.8
Potassium (%)	0.62	0.86	0.10	0.83

After repotting operations, the sage plants were moved for cultivation into a greenhouse (Figure 4), connected to a microirrigation plant, which applied water for 10 min 2–3 days a week in April–May and 3–4 days a week in June, July, August, September and October.

Figure 4. Sage plants repotted into pots having diameter of 18 cm.

At the end of the seven months, destructive tests were carried out, to determine the main biometric parameters, that is, leaf area, Soil Plant Analysis Development (SPAD) value (index of chlorophyll concentration) [16], maximum root length, fresh and dry weight of roots, stems and leaves.

The complete plants were soaked in water and the soil was gently removed from the roots. In order to measure the weight of dry roots, stems and leaves, two different methods were used for drying the samples. The stems and roots, after being enclosed inside paper envelops, were placed inside an oven and subjected to a drying cycle at 70 °C for 48 h. The leaves, however, after being collected and separated from the stalks, were transferred to a local warehouse and arranged over a trellis for drying, for about seven days.

A digital balance Omega Bilance Smally (Manchester, United Kingdom), able to weigh from 4 g to 12 kg, was used for weight computation, while a ruler with a millimeter scale was used to determine the maximum root length and leaf area.

Four replications were carried out for each Substrate Composition. All the results of the destructive tests are shown as mean values. The effects of the four different Substrate Compositions (SC) were determined by means of a one-way Analysis of Variance (one-way ANOVA) technique. The Siegel-Tuckey test was used for comparing the means when the effect of the SC was significant ($p < 0.05$). All statistical analyses were performed using the software SigmaPlot 12 (Systat Software Inc., San Jose, CA, USA).

3. Results

In order to evaluate the main biometric parameters of sage plants in the destructive tests, the mean results of leaf area, SPAD value, fresh and dry weight of roots, stems and leaves, as well as maximum root length, were calculated and compared (Table 3).

Table 3. Mean values of the main biometric parameters of sage plants, calculated for the four Substrate Compositions (SC). The percentage values (+/−) are computed for each SC with reference to SC4.

Parameter			SC1	SC2	SC3	SC4
Leaf Area		(cm^2)	14	12.1	13.3	12
		(%)	+7.3	−47.3	−30.2	–
SPAD Value		–	36	34.7	32.2	37.4
		(%)	+6.4	−46.8	−33.6	–
Leaf Weight	Fresh	(g)	177	87	115.2	165
		(%)	+8.5	−32.9	−23.9	–
	Dry	(g)	50	25	31.2	47
		(%)	+6.4	−46.8	−33.6	–
Stem Weight	Fresh	(g)	88.8	55.2	62.4	82.4
		(%)	+8.5	−32.9	−23.9	–
	Dry	(g)	23.2	14	16.8	23
		(%)	+0.9	−39.1	−27.0	–
Root Weight	Fresh	(g)	438	381	386	800
		(%)	−45.3	−52.4	−51.8	–
	Dry	(g)	169	118	178.4	272
		(%)	−37.9	−56.6	−34.4	–
Root Length		(cm)	29	25	21	25
		(%)	+16.0	0.0	−16.0	–

As shown in Figure 5, the highest mean value of leaf area, equal to 14 cm^2, was obtained with SC1 (vermicompost), while the lowest mean value, equal to 12 cm^2, was obtained with SC4 (100% peat). The differences between the mean values of leaf area were not statistically significant ($p = 0.363$), so that the influence of the substrate compositions alternative to peat was not significant on leaf area.

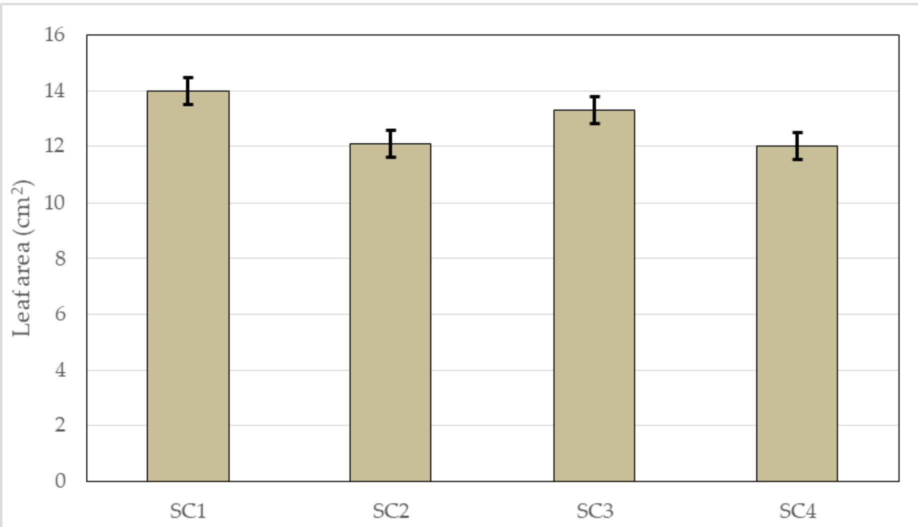

Figure 5. Mean value of leaf area related to the four Substrate Compositions (SC). The bars stand for standard deviation values ($n = 4$).

Figure 6 shows the mean SPAD values obtained with the four substrate compositions (SC). Statistically non-significant mean values ($p = 0.821$) were obtained with SC3 (digestate) in comparison with those obtained with SC4 (100% peat). Moreover, different but not statistically significant mean values ($p = 0.901$) were obtained with SC1 (vermicompost) and SC2 (compost) in comparison with those obtained with SC4 (100% peat).

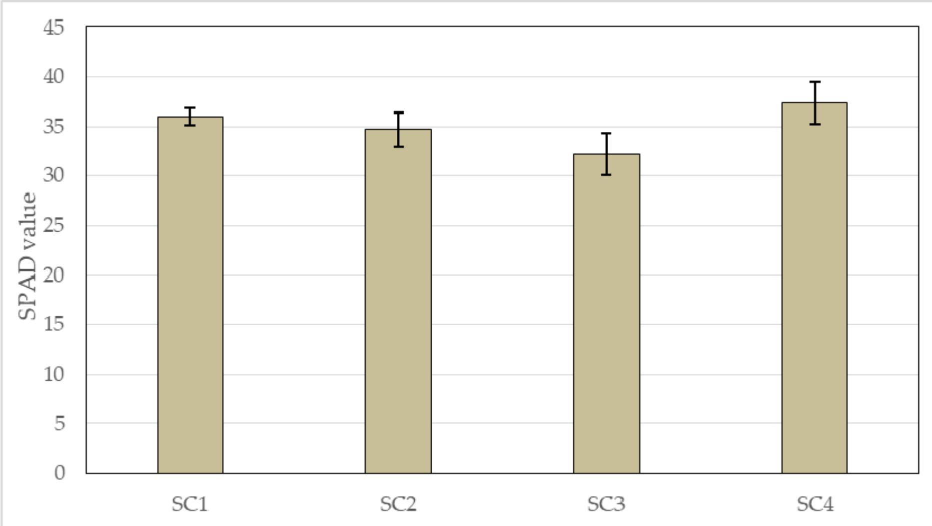

Figure 6. Mean SPAD value related to the four Substrate Compositions (SC). The bars stand for standard deviation values (n = 4).

The mean values of leaf weight obtained with the four substrate compositions are compared in Figure 7. Fresh leaf weight was 177 g with SC1 (vermicompost) and was similar to that of SC4 (100% peat). The lowest mean value, equal to 87 g, was obtained with SC2 (compost). The mean values of SC2 (compost) and SC3 (digestate) were lower than those obtained with SC1 and SC4. Therefore, both compost and digestate did not allow a high level of leaf growth. The mean values of both fresh and dry leaf weight obtained with SC1 (vermicompost) and SC4 (100% peat) were similar to each other and much higher than the mean values obtained with SC2 (compost) and SC3 (digestate).

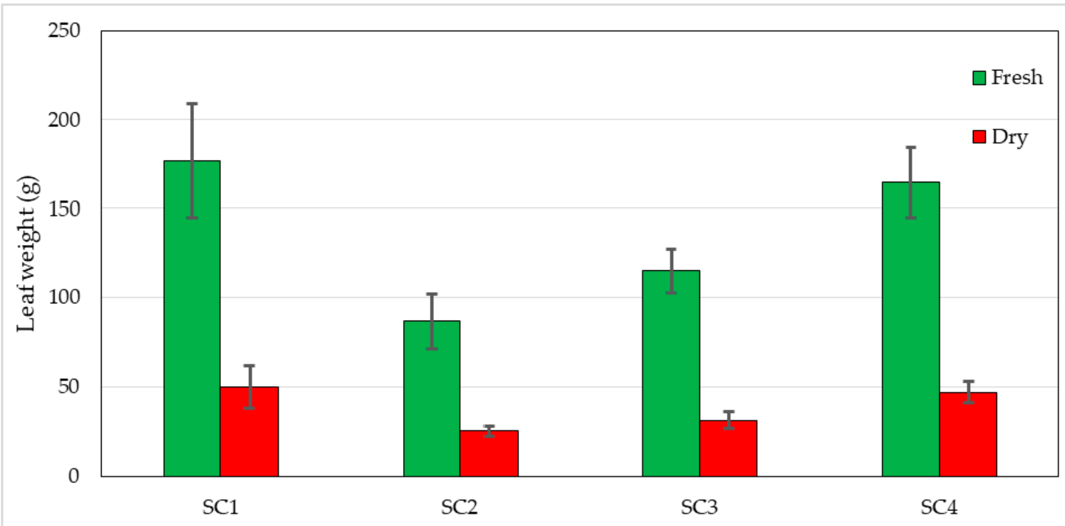

Figure 7. Mean values of fresh and dry leaf weight (expressed as g/potted plant) related to the four Substrate Compositions (SC). The bars stand for standard deviation values (n = 4).

The mean values of fresh and dry stem weight obtained with the four substrate compositions are shown in Figure 8. The highest mean value of fresh stem weight, equal to 89 g, was obtained with SC1 (vermicompost) but it is not statistically significant (p = 0.180) in comparison with the mean values obtained with SC4 (100% peat). The lowest values of fresh stem weight were obtained with SC2 (compost) and SC3 (digestate) and were statistically significant, so that they negatively influenced this biometric parameter.

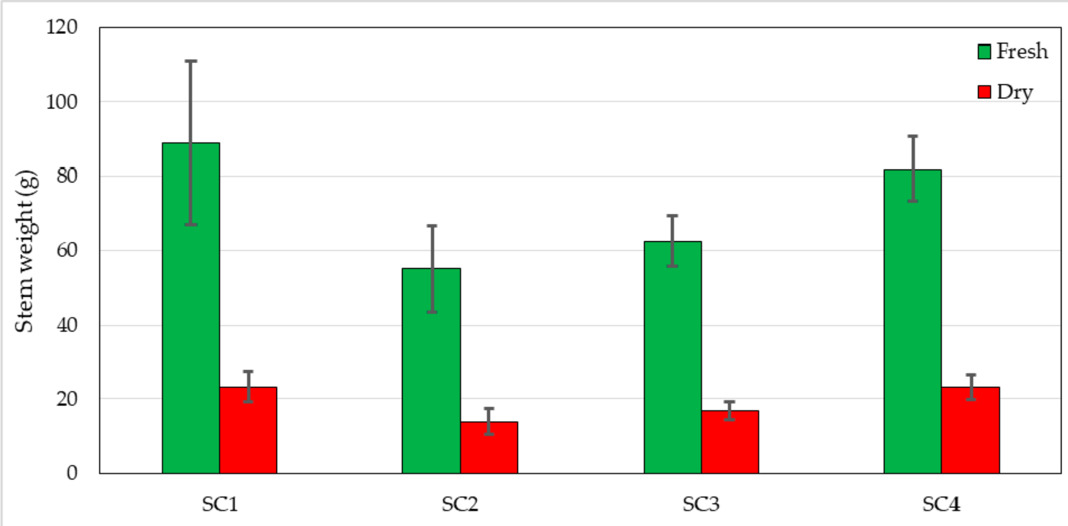

Figure 8. Mean values of fresh and dry stem weight (expressed as g/potted plant) related to the four Substrate Compositions (SC). The bars stand for standard deviation values (n = 4).

The dry stem weight obtained with SC4 (100% peat) was 23 g and was similar to that of SC1 (vermicompost). The lowest mean value of this biometric parameter was obtained with SC2 (compost) and SC3 (digestate). Therefore, both compost and digestate did not allow a high level of stem growth.

The mean values of fresh and dry root weight obtained with the four substrate compositions are compared in Figure 9. The highest mean values of fresh root (800 g) and dry root weight (272 g) were obtained with SC4 (100% peat). These values (both fresh and dry roots) were higher than those obtained with SC1, SC2 and SC3. These differences were not statistically significant (p = 0.256), so that all of the tested substrates alternative to peat negatively influenced this biometric parameter.

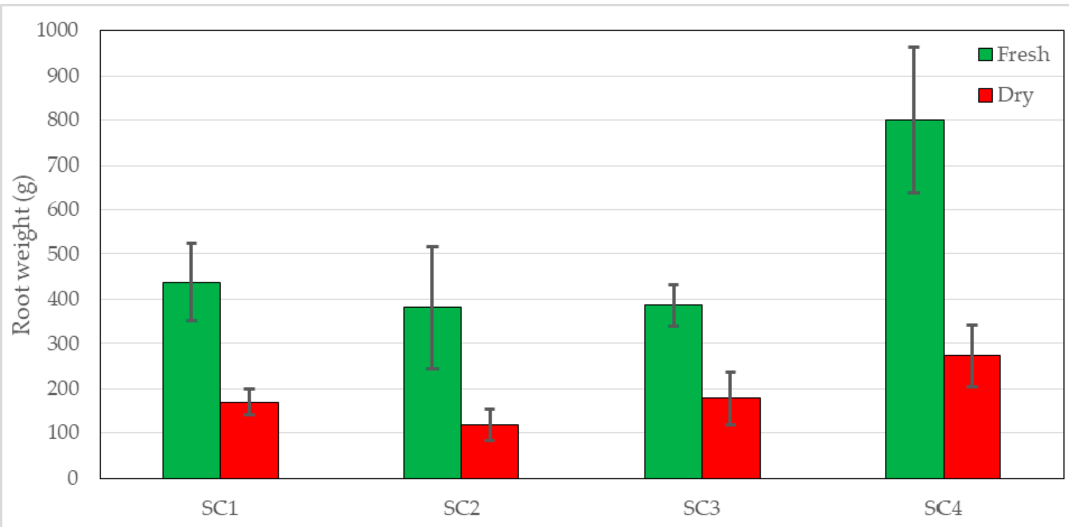

Figure 9. Mean values of fresh and dry root weight (expressed as g/potted plant) related to the four Substrate Compositions (SC). The bars stand for standard deviation values (n = 4).

As shown in Figure 10, the highest mean value of root length, equal to 29 cm, was obtained with SC1 (vermicompost), while the lowest mean value, equal to 21 cm, was obtained with SC3 (digestate). The mean value obtained with SC1 (vermicompost) was 4 cm higher (+16%) compared to that achieved with SC4 (100% peat). Instead, the mean value obtained with SC2 (compost) was equal to that achieved with SC4. Finally, the mean value obtained with SC3 (digestate) was 4 cm lower (−16%) than that achieved with SC4. Therefore, vermicompost positively influenced the root growth, while digestate negatively affected it.

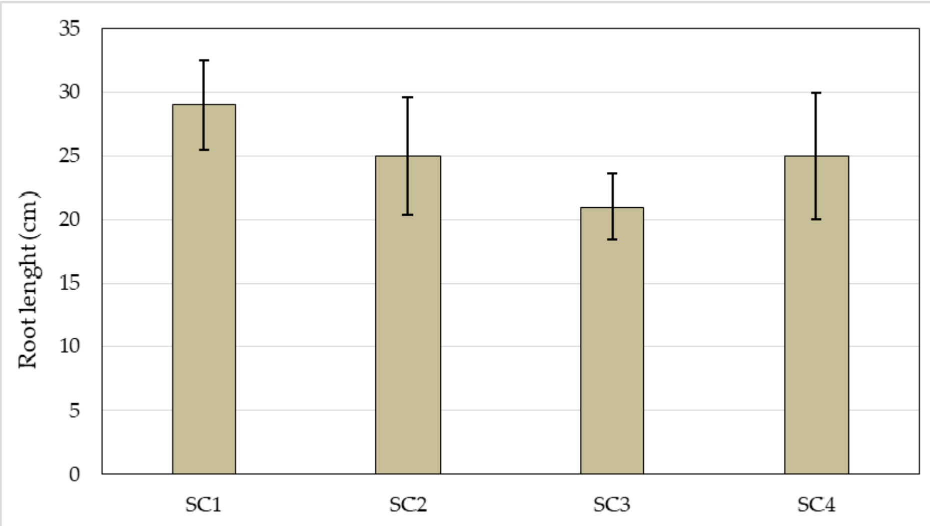

Figure 10. Mean values of root length related to the four Substrate Compositions (SC). The bars stand for standard deviation values (n = 4).

4. Discussion

The tested growing substrates were selected because they are all derived from Circular Bioeconomy (CBE). Moreover, these sustainable growing substrates alternative to peat are available in the surroundings of the cultivation area for meeting the needs of nursery operators and farmers [2,3].

The vegetation biometric parameters show that vermicompost can be an effective growing substrate alternative to peat. Apart from the fresh and dry root weight (Figure 9), the other biometric parameters were similar among each other and much lower compared to peat.

Vermicompost determined most of biometric parameters higher rather than peat, so that it provided higher performance rather than the control test.

According to Tharmaraj et al. (2010), who experimented with black gram (*Vigna mungo*), in the cultivation where earthworms were applied there was an increase in leaf length and number, as well as root length and plant height [17]. A samba rice cultivation study revealed that the maximum leaf length and number, as well as root length and plant height were recorded in vermicompost applied pots. Tharmaraj et al. (2011) [18] and Indira et al. (2010) [19] also reported the enhancement of growth and biometric parameters such as leaf area, fresh and dry weight in vermicompost added black gram cultivation. A significant rise in plant width, leaf number, size and width, as well as fresh weight, was observed by increasing the doses of vermicompost applied to lettuce cultivation [20,21].

The observations in this study are in accordance with previous reports. In fact, an increase in the yield of certain vegetable crops such as brinjal, okra and tomato have been reported by Guerrero [22], Gupta [23], Sinha et al. [24], Elumalai et al. [25], respectively. The soil amended with vermicompost provides the required nutrients, which are not available in chemically treated soil [26]. This increased nutrient uptake by plants may have contributed to the maximum growth in vermicompost treated plants when compared to other treatments [27].

The remarkable growth obtained in vermicompost treated plants may be due to favorable and optimum temperature. Moisture and a balance between organic and inorganic nutrients in vermicompost have significantly aided increased plant growth. The enhanced plant growth may be due to improved soil health and the physico-chemical properties of soil were enhanced, leading to an increase of microbial activity, as well as macro-and micro- nutrients. Vermicompost treatment enhanced the availability of nutrients in the soil [28,29].

Vermicompost treatment improves the micronutrient levels in the soil [30]. Vermicomposted soils were found to slowly release the nutrients and thereby aiding the plants to absorb the available nutrients themselves [31,32].

Instead, compost and digestate determined lower biometric parameters rather than peat, unless leaf area. Yet, the sage plants showed a sufficient vegetation growth.

Both compost and digestate did not allow a high level of leaf growth—the results of both fresh and dry leaf weight obtained with vermicompost and peat were much higher than the mean values obtained with compost and digestate.

The lowest mean values of fresh stem weight were obtained with compost and digestate and was statistically not significant ($p > 0.48$), so that they negatively influenced this biometric parameter. The lowest mean value of dry stem weight was obtained with compost and digestate—neither substrates allowed a high level of stem development.

The mean values of fresh and dry root weight were higher with peat rather than with the other substrates. These differences were not statistically significant ($p > 0.06$), so that all the substrates alternative to peat negatively influenced this biometric parameter.

The root length obtained by using the growing substrates alternative to peat (21–29 cm) was much higher than that measured by Traykova et al. in plants of *Salvia officinalis* (12.6 cm) [33].

5. Conclusions

From the results of this work it is possible to deduce that vermicompost positively influenced most of the biometric parameters of sage plants (+16.7% for leaf area, +7.3% for fresh leaf weight, +6.4% for dry leaf weight, +8.5% for fresh stem weight, +0.9% for dry stem weight, +16% for root length). Therefore, vermicompost can be used as a sustainable growing substrate, alternative to peat, for the soilless cultivation.

Yet, the results of some biometric parameters are better with peat rather than with the other tested alternative growing substrates, that is, compost and digestate.

In fact, peat provided, rather than compost and digestate—47.3% and 30.2% more leaf area; 46.8% and 33.6% more SPAD value; 32.9% and 23.9% more fresh leaf weight; 46.8% and 33.6% more dry leaf weight; 32.9% and 23.9% more fresh stem weight; 39.1% and 27.0% more dry stem weight.

Moreover, peat provided 16.0% higher root length rather than only digestate.

Yet, these results were obtained in pots, so that they are interesting in nursery activity. As sage plants are generally cultivated in open field, the biometric parameters must be measured also after transplanting the tested potted ones, for verifying the above differences.

However, the use of these growing substrates alternative to peat allows the sustainable valorization of food industry by-products (e.g., pomace from olive oil mills, grape marc from wineries, citrus industry by-product), plant biomass, animal manure and the OFMSW, through the production of vermicompost, compost, digestate and biogas (both products of AD process), instead of conferring them to landfills.

Therefore, the results of this work suggest the possibility of partially or totally replacing peat with alternative growing substrates such as vermicompost, having a lower ecological and economic impact.

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References

1. Attard, G.; Comparetti, A.; Febo, P.; Greco, C.; Mammano, M.; Orlando, S. Case study of potential production of Renewable Energy Sources (RES) from livestock wastes in Mediterranean islands. *Chem. Eng. Trans.* **2017**, *58*, 553–558.
2. Greco, C.; Comparetti, A.; Mammano, M.M.; Orlando, S. Sustainable, Circular and Innovative Value Chains Using Growing Substrata Alternative to Peat for the Cultivation of Nutraceutical Species. In Proceedings of the 9th International Scientific Conference "Rural Development 2019: Research and Innovation for Bioeconomy", Kaunas, Lithuania, 26–28 September 2019; pp. 13–20.
3. Greco, C.; Agnello, A.; La Placa, G.; Mammano, M.M.; Navickas, K. Biowaste in a circular bioeconomy in Mediterranean area: A case study of compost and vermicompost as growing substrates alternative to peat. *Riv. Di Studi Sulla Sostenibilità (Rev. Stud. Sustain.)* **2019**, *2*, 345–362.
4. Comparetti, A.; Greco, C.; Mammano, M.M.; Navickas, K.; Orlando, S.; Venslauskas, K. Valorisation of urban green areas for producing renewable energy and biochar as growing substrate of Sicilian aromatic and nutraceutical species in a circular economy. *Riv. Di Studi Sulla Sostenibilità (Rev. Stud. Sustain.)* **2019**, *2*, 299–314.
5. Munroe, G. *Manual of On-Farm Vermicomposting and Vermiculture*; Organic Agriculture Centre of Canada: Truro, NS, Canada, 2007; pp. 1–56.
6. Orlando, S.; Greco, C.; Tuttolomondo, T.; Leto, C.; Cammalleri, I.; La Bella, S. Identification of Energy Hubs for the Exploitation of Residual Biomass in an Area of Western Sicily. In Proceedings of the EUBCE 2017 Online Conference Proceedings, Stockholm, Sweden, 12–15 June 2017; pp. 64–69.
7. Comparetti, A.; Greco, C.; Navickas, K.; Venslauskas, K. Evaluation of potential biogas production in Sicily. In Proceedings of the 11th International Scientific Conference Engineering for Rural Development, Jelgava, Latvia, 24–25 May 2012; pp. 555–559.
8. Comparetti, A.; Febo, P.; Greco, C.; Orlando, S. Current state and future of biogas and digestate production. *Bulg. J. Agric. Sci.* **2013**, *19*, 1–14.
9. Comparetti, A.; Febo, P.; Greco, C.; Navickas, K.; Nekrosius, A.; Orlando, S.; Venslauskas, K. Sicilian potential biogas production. In Proceedings of the X National Conference of the Italian Association of Agricultural Engineering, Viterbo, Italy, 8–12 September 2013; pp. 522–525.
10. Comparetti, A.; Febo, P.; Greco, C.; Navickas, K.; Nekrosius, A.; Orlando, S.; Venslauskas, K. Assessment of organic waste management methods through energy balance. *Am. J. Appl. Sci.* **2014**, *11*, 1631–1644. [CrossRef]
11. Comparetti, A.; Febo, P.; Greco, C.; Orlando, S. Italian Potential Biogas and Biomethane Production from OFMSW. IV International Conference Ragusa SHWA on "Safety, Health and Welfare in Agriculture, Agro-food and Forestry Systems", Lodi, Italy, 8–11 September 2015; pp. 206–215.
12. Comparetti, A.; Febo, P.; Greco, C.; Mammano, M.M.; Orlando, S. Potential production of biogas from prinkly pear (*Opuntia ficus-indica* L.) in Sicilian uncultivated areas. *Chem. Eng. Trans.* **2017**, *58*, 559–564.
13. Comparetti, A.; Febo, P.; Greco, C.; Mammano, M.M.; Orlando, S. Sicilian potential biogas production from Citrus industry by-product. In Proceedings of the 11th International AIIA (Italian Association of Agricultural Engineering), Bari, Italy, 5–8 July 2017; pp. 169–173.
14. Comparetti, A.; Greco, C.; Navickas, K.; Orlando, S.; Venslauskas, K. LCIA applied to cactus pear crop production for generating bioenergy and biofertilizer. *Riv. Di Studi Sulla Sostenibilità (Rev. Stud. Sustain.)* **2019**, *2*, 315–329.
15. Greco, C.; Comparetti, A.; Febo, P.; Navickas, K.; Orlando, S.; Venslauskas, K. LCA applied to an anaerobic digestion plant for biomethane and digestate production. In Proceedings of the 9th International Scientific Conference "Rural Development 2019: Research and Innovation for Bioeconomy", Kaunas, Lithuania, 26–28 September 2019.
16. EU. *Council Directive 91/676/EEC of 12 December 1991 Concerning the Protection of Waters against Pollution Caused by Nitrates from Agricultural*; European Union: Bruxelles, Belgium, December 1991.
17. Tharmaraj, K.; Ganesh, P.; Kolanjinathan, K.; Suresh Kumar, R.; Anandan, A. Influence of vermicompost and vermiwash on physico chemical properties of black gram cultivated soil. *Inter. J. Recent Sci. Res.* **2010**, *3*, 77–83.

18. Tharmaraj, K.; Ganesh, P.; Kolanjinathan, K.; Suresh Kumar, R.; Anandan, A. Influence of vermicompost and vermiwash on physico-chemical properties of rice cultivated soil. *Curr. Bot.* **2011**, *2*, 18–21.
19. Indira, P.; Lenin, M.; Ravi Mycin, T. Efficacy of groundnut haulm compost on the growth and yield of blackgram (*Vigna mungo* L.) var. Vamban 1. *Curr. Bot.* **2010**, *1*, 1–3.
20. Adiloğlu, S.; Eryilmaz Açıkgöz, F.; Solmaz, Y.; Çaktü, E.; Adiloğlu, A. The effects of vermicompost on the growth and yield of lettuce plant (*Lactuca sativa L.* var. crispa). *Inter. J. Plant Soil Sci.* **2018**, *21*, 1–5.
21. Ramnarain, Y.I.; Ori, L.; Ansari, A.A. Effect of the use of vermicompost on the plant growth parameters of pak choi (*Brassica rapa* var. chinensis) and on the soil structure in Suriname. *J. Glob. Agric. Ecol.* **2018**, *8*, 8–15.
22. Guerrero III, R.D. Vermicompost production and its use for crop production in the Philippines. *Inter. J. Glob. Env. Issues* **2010**, *10*, 378–383.
23. Gupta, P.K. *Vermicomposting for Sustainable Agriculture*; Agrobios: Jodhpur, India, 2003; p. 188.
24. Sinha, R.K.; Herat, S.; Valani, D.; Chauhan, K. Vermiculture and sustainable agriculture. *Am. Eurasian. J. Agric. Environ. Sci.* **2009**, *5*, 1–55.
25. Elumalai, D.; Kaleena, P.K.; Fathima, M.; Hemavathi, H. Influence of vermiwash and Plant growth regulators on the exomorphological characters of *Abelmoschus esculentus* (Linn.) Moench. *Afri. J. Basic Appl. Sci.* **2013**, *5*, 82–90.
26. Ansari, A.A.; Ismail, S.A. Reclamation of sodic soils through vermitechnology. *Pak. J. Agric. Res.* **2008**, *21*, 92–97.
27. Rekha, G.S.; Kaleena, P.K.; Elumalai, D.; Srikumaran, M.P.; Maheswari, V.N. Effects of vermicompost and plant growth enhancers on the exo-morphological features of *Capsicum annum* (Linn.) Hepper. *Int. J. Recycl. Org. Waste Agric.* **2018**, *7*, 83–88. [CrossRef]
28. Agarwal, S.B.; Singh, A.; Dwivedi, G. Effect of vermicompost, farm yard manure and chemical fertilizers on growth and yield of wheat (*Triticum aestivum* L. var HD 2643). *Plant Arch.* **2003**, *3*, 9–14.
29. Singh, B.K.; Pathak, K.A.; Verma, A.K.; Verma, V.K.; Deka, B.C. Effects of vermicompost, fertilizer and mulch plant growth, nodulation and pod yield of French bean (*Phaseolus vulgaris*). *Veg. Crop Bull.* **2011**, *74*, 153–165. [CrossRef]
30. Gruda, N.S. Increasing Sustainability of Growing Media Constituents and Stand-Alone Substrates in Soilless Culture Systems. *Agronomy* **2019**, *9*, 298. [CrossRef]
31. Jaikishun, S.; Hunte, N.; Ansari, A.A.; Gomathinayagam, S. Effect of vermiwash from different sources (Bagasse, Neem, Paddy Straw in different combinations) in controlling fungal diseases and growth of tomato (*Lycopersicon esculentum*). *Fruits Guyana. J. Biol. Sci.* **2014**, *14*, 501–507. [CrossRef]
32. Ansari, A.A.; Sukhraj, K. Effect of vermiwash and vermicompost on soil parameters and productivity of okra (*Abelomoschus esculentus*) in Guyana. *Afr. J. Agric. Res.* **2010**, *5*, 1794–1798.
33. Traykova, B.; Stanilova, M.; Nikolova, M.; Berkov, S. Growth and Essential Oils of Salvia officinalis Plants Derived from Conventional or Aeroponic Produced Seedlings. *Agric. Conspec. Sci.* **2019**, *84*, 77–81.