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Evaluating Compost from Digestate as a Peat Substitute in Nursery for Olive and Hazelnut Trees

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Abstract: This study deals jointly with three aspects of environmental, agricultural and energy sustainability: (a) Biogas is a booming energy source worldwide, resulting in an increasing production of digestate, its main by-product; (b) The extraction of peat, mainly used for nursery substrates, is being banned due to the destruction of natural habitats and release of GHGs; (c) Compost can represent a replacement of peat and contributes to the containment of GHGs. This study has verified how a compost obtained from digestate can be used as a substitute for peat in the nursery sector. While previous studies have evaluated compost use on just one species at a time, this study compared the same compost on two very different species: olive tree and hazelnut tree, both with growing interest for new tree plantings. Two concentrations of compost in the potting substrate of nursery seedlings were evaluated: 30% and 45% by weight, measuring the effect on some growth parameters during the growing season. The trials showed responses positive for olive and substantially negative for hazelnut: olive trees manifested better growth parameters with 45% compost, as opposed to hazelnut, where the addition of 45% compost worsened all growth parameters. A general conclusion can be drawn: in the nursery sector, compost can be used to replace peat, but this replacement can almost never be 100 percent, having instead to calibrate the percentage of replacement according to the characteristics of the compost and the individual edaphic needs of the plant species.

Keywords: compost; digestate; biogas; peat; nursery; olive tree; hazelnut tree

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1. Introduction

In the past three decades since the UN published the Brundtland Report [1], the concept of "sustainable development", introduced with determination by that report, although with a considerable degree of ambiguity in its definition [2], has been continuously updated, moving from the eminently ecological-environmental vision to a more general vision, including also the social and economic aspects of development, the so-called three pillars of sustainability [3].

This led to the definition of the 17 Goals of Sustainable Development (SDGs), specified by 169 targets that indicate, in a detailed manner, the actions to be taken to achieve the goals [4].

SDG No 2 directly calls agriculture into question: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture". In addition, agriculture is also of great importance in other SDGs: 13—"Take urgent action to combat climate change and its impacts"; 15—"Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss." It is also involved in several other SDGs, in particular:

6—“Clean water and sanitation”; 7—“Affordable and clean energy”; 12—“Ensure sustainable consumption and production patterns.”

1.1. Biogas Production and Digestate Use

The concept of sustainable development is linked to that of a circular economy. Many of the targets of the SDGs can be pursued also thanks to the contribution of the circular economy, such as when it concerns the reduction of environmental impact, thanks to the 3R practices (Reduce, Reuse & Recycle), with waste management that leads to the elimination of waste burning and, at the same time, allows the creation of new job opportunities related to both recycling and repair of durable consumer goods, as well as the reuse of organic materials. Within this context, biogas production might be considered a sustainable strategy for waste management. Biogas production has seen considerable growth worldwide; according to data from the International Renewable Energy Agency [5], in 10 years it has gone from a production capacity of 11,434 MW in 2011 to 20,108 MW in 2020. Anaerobic digestion allows the production of green energy from the treatment of wastes, and a biogas residue, e.g., digestate, which is normally used as a soil improver in agriculture, given its richness in organic matter and plant nutrients. However, the use of digestate as such in the soil can sometimes cause concern due to some undesirable chemical or biological characteristics. Therefore, it is often advisable to process the digestate, especially by composting before spreading it on agricultural soil [6].

1.2. Compost as a Peat Substitute in Nursery

Among the various agricultural sectors, the nursery sector requires careful attention in terms of environmental sustainability. The agricultural nursery sector is of fundamental importance for the production of plants to be used in crops, forestry, and urban green areas. This sector is very natural-resource-intensive and peat is one of the most important used resource. Peat is widely used in plant nursery for substrate preparation due to its constant chemical and physical characteristics [7]. In recent decades, the cost of peat has increased due to the transport and extraction costs, and this affects the plants’ price in the nursery [8–11]. In addition, the environmental impact related to peat extraction is receiving increasing attention [12]. Indeed, peat extraction leads to the destruction of highly fragile ecosystems (peatlands are protected by Directive 92/43/EC [13]), and leads to consistent C emissions in the air [14]. Moreover, peat availability will decrease in the near future since it is a non-renewable resource [15]. This is why many efforts are being made to try to limit the use of peat and promote the use of cheaper and more environmentally friendly materials for the preparation of plants’ growing media [11,12]. Among the materials that can be used, compost seems to be particularly interesting and, thus, its use in the substitution of peat in horticulture has been the object of various studies [16]. Indeed, compost is less environmentally damaging than peat and, being rich in nutrients, can also partially replace chemical fertilization [17,18] and enhance C sequestration [19]. It represents a tool to improve the economic and social sustainability of production activities in rural areas. The composting process allows valorizing organic by-products in a new production cycle with positive effects also on the C balance [18,20,21]. Furthermore, by reducing waste volumes, killing potentially dangerous organisms [22], and reducing phytotoxicity [23], composting decreases environmental issues related to waste management. Moreover, many studies have pointed out that composting is a useful treatment for digestate and allows to use it as a soil improver, reducing phytotoxicity, immobilizing microelements, and increasing enzymatic activity, especially by co-composting with other organic materials [24,25].

The main advantages of using compost as a component of the growing substrate are the nutrient content and the positive impact on microbial community composition [26]. However, the high salinity and bulk density, residual phytotoxicity, and pH can represent a potential limitation to the use of compost as a growing medium [27]. In general, the raw materials used and the composting process itself affect the compost quality and, therefore, the possibility to use it as a component of the growing substrate [16]. Compost obtained from cow manure, if it replaces more than 50% of the peat in the media due to the high salt content and bulk density, caused the immediate mortality of tomato plants [28]. On the contrary, a vermicompost from pig manure was able to totally substitute peat in growing media [28].

These results are consistent with those of Clark et al. [29], who found that compost derived from food waste is suitable for replacing peat in growing media, while horse-manure-derived compost leads to worse results due to high salinity content. Regni et al. [15] evaluated the effect of peat replacement with a two-phase olive mill pomace (characterized by a high moisture content) and the derived compost on the olive trees grown in pots, finding that compost can substitute peat by up to 50% without a reduction in the plants' growth. For potted olive trees, compost derived from pruning wastes was also tested and it can replace 15% or 30% of the peat providing results similar to the control (peat-based) substrate [11]. Papafotiou et al. [30] used olive-mill-waste-derived compost for peat substitution for *Codiaeum variegatum* (L.) A. Juss, *Syngonium podophyllum* Schott and *Ficus benjamina* L. and observed different results for the tested species. The 50% peat replacement with compost gave the best growth for *C. variegatum*, while *S. podophyllum* was more sensitive to peat replacement, and only 25% of peat could be replaced by compost. In *F. benjamina*, 75% of peat in the substrate could be replaced by compost without negative effects on plant height and the number of lateral shoots. Compost obtained from the olive mill caused a reduction in plant growth only during the first 30 days of cultivation if it replaced 25 to 50% of the peat in the substrate, while at a higher percentage (75%), growth decrease occurred during the entire cultivation time of *Euphorbia pulcherrima* cv. Peterstar [31]. Green compost can replace up to 50% of peat in geranium (*Pelargonium zonale* L.) cultivation [32]. The total substitution of peat with green compost increased some plant growth parameters (biomass accumulation, morphology of roots, leave nutrient and chlorophyll content) in *Calathea insignis* [33]. Ceglie et al. [12] in the organic cultivation method evaluated peat substitution with green compost and palm fiber trunk waste for tomato, melon, and lettuce plants and found out that a mixture composed by 20% green compost, 39% palm fiber and 31% peat allowed to obtain the best plant growth.

However, plant responses to peat substitution with compost depend on the plant species, the amount of compost applied, and its chemical-physical characteristics [32,33]. Therefore, it is very difficult to establish the most appropriate compost and its quantity to achieve good results in terms of plant growth.

In this context, the present study aimed at exploiting the digestate of agricultural biogas plants through on-farm composting and the evaluation of the feasibility of the obtained composts in partial replacement of the peat for potted olive and hazelnut trees.

1.3. Olive and Hazelnut Tree Cultivation and Nursery

Worldwide, about 11.5 million hectares are cultivated with olive trees of which about 54% are in Europe [34]. In the EU, the olive grove is the first tree crop in terms of surface area, covering about 40% of the total area devoted to tree crops (about 4.6 out of 11.4 million hectares), while in the Mediterranean EU countries it accounts for 45% of the area under tree crops [35]. The cultivation of olive trees is undergoing a vast modernization of the types of planting, which are moving towards intensive or super-intensive cultivation.

According to FAO statistics [36], globally, the area under hazelnut tree cultivation increased from 607,632 hectares in 2009 to 966,196 hectares in 2018. The demand for hazelnuts is globally driven by the Italian company Ferrero, which aims to modernize hazelnut cultivation, promoting the realization of new hazelnut plantations according to criteria of higher quality, productivity, and sustainability at the same time [37].

Table 1 shows the comparison of some characteristics of the two species in wild growing conditions.

Table 1. Olive and hazelnut trees: comparison of some characteristics of the two species in wild growing conditions.

	Olive Tree	**Hazelnut Tree**
natural distribution area	Steno-Mediterranean	European-Caucasian
life form	Bushy phanerophyte or Arboreal phanerophyte	Bushy phanerophyte
vegetative altitude limits (meters above sea level)	0–900	0–1700
leaf life span	evergreen	deciduous
flowering time	late spring	late winter
description	It is a typically thermophilic and heliophilic species; it prefers dry, arid environments and climates, and is sensitive to low temperatures. It thrives in loose, coarse, or shallow soils with rocky outcrops and, among fruit trees, is one of the most salinity-tolerant species	It avoids the hottest and driest areas. It prefers calcareous, well-drained, fertile, and deep soils and semi-shaded places. Its natural habitat is hardwood forests, especially mixed mesophyll oak forests, clearings, and margins.

1.4. Novelty of This Study

Based on the above, an increased demand for plantlets for transplanting both olive and hazelnut trees can be expected in the coming years. Therefore, research on the use of compost in potting media for these two species, mainly aimed at peat replacement, is of great interest. In this regard, many studies have been carried out in recent years on the olive tree [11,15,38], while it has not been possible to find studies on the hazelnut tree potting substrates with compost. So, a comparative study about a compost from digestate use in the nursery of these two species is considered very interesting. It should also be noted that no studies could be found that simultaneously have compared the use of the same compost on two or more different tree species. Therefore, the novelty of this study was threefold: (1) Testing a compost in the hazelnut tree nursery; (2) Simultaneously comparing it with another species, the olive tree; (3) Using a compost from digestate for this test.

2. Materials and Methods

The trial carried out in this study involved the use of a compost obtained from digestate, produced in a biogas plant located on a livestock farm. The compost was used to prepare the substrate for the cultivation of olive and hazelnut seedlings growing in pots in a nursery as a partial substitute for peat, comparing two different concentrations of compost in the substrate and a control without compost. The comparison involved a series of physiological data measured during the growth of the seedlings to verify the effects of each growing substrate.

2.1. Obtaining, Description, and Materials Analysis

The biogas plant was located in Trevi (Umbria, Italy) on a dairy farm and operated under wet and mesophilic conditions (35–40 °C), as described in detail in [39]. Organic livestock materials produced in the farm (cattle slurry and cattle manure), maize silage, and other by-products from nearby companies (poultry manure, cereal processing waste, olive pomace, grape marc, and whey) after their anaerobic digestion, resulted in a liquid residue, named digestate, which is sent to a mechanical separator to obtain a liquid and solid fraction.

2.2. Composting and Compost Analysis

The liquid fraction of digestate, obtained from the separation of digestate, is used as a co-substrate with lignocellulosic materials (cereal straw) in the composting plant, in the proportion of 75% and 25%, respectively. The composting plant takes place in a concrete trench (14 m × 70 m × 1.5 m), equipped with an overhead crane on which the screws that are used to mix the feedstock and keep aerated the pile move. The turning occurs during the active phase, and the frequency depends mainly on the moisture content and the porosity of the mixture. However, these parameters alone do not guarantee the proper development of the process [40] and the use of new software tools is recommended for a better formulation of the initial mixtures [20]. A mature compost was obtained after 6 months in a static pile.

Tables 2 and 3 show some physical and chemical parameters of digestate and cereal straw, respectively. Table 4 shows the physical and chemical parameters of the compost obtained.

Table 2. Chemical analysis of digestate (liquid fraction) used to produce the compost.

Parameter	Value
Moisture (%)	94.0
TKN (%)	10.0
Organic matter (%)	71.2
Total P (%)	1.3
Total Pb (mg kg^{-1})	2.5
Total Cd (mg kg^{-1})	0.26
Total Ni (mg kg^{-1})	10.2
Total Zn (mg kg^{-1})	490.8
Total Cu (mg kg^{-1})	112.4
Total Hg (mg kg^{-1})	0.12
Total VI Cr (mg kg^{-1})	<0.1

Except moisture, all data are expressed on a dry basis. TKN: Total Kjeldahl nitrogen.

Table 3. Properties of bulking agent (cereal straw) used in the composting.

Parameter	Value
Bulk density (kg L^{-1})	0.05
Moisture (%)	14.0
TOC (%)	46.1
TKN (%)	0.6

TOC: total organic C; TKN: total Kjeldahl N.

Table 4. Physical and chemical parameters of the compost.

Parameter	Value
Moisture (%)	27.8 ± 0.0
pH	7.6 ± 0.0
EC (mS cm^{-1})	3.5 ± 0.0
TOC (%)	17.2 ± 0.8
TKN (%)	1.9 ± 0.0
Total organic N (%)	1.7
C/N	9.0
Humic + fulvic acids (%)	10.8 ± 0.0
Ammonium N (%)	0.2 ± 0.0
Total P (%)	0.5 ± 0.0
Total K (%)	2.3 ± 0.7
Total Cd (mg kg^{-1})	0.1 ± 0.0
Total Cu (mg kg^{-1})	29.4 ± 10.8
Total Hg (mg kg^{-1})	10.0 ± 3.1
Total Ni (mg kg^{-1})	5.6 ± 0.6
Total Pb (mg kg^{-1})	0.8 ± 0.0
Total Zn (mg kg^{-1})	103.3 ± 10.8
Cr VI (mg kg^{-1})	<0.1 [b]
Germination Index (%)	64.8

Except moisture, all data are expressed on a dry basis. Values represent the mean ± SD. [b] Limit of sensitivity of the used method. EC: electrical conductivity; TOC: total organic C; TKN: total Kjeldahl N.

2.3. Characterization of Organic Materials

Moisture was measured on fresh samples by weight-loss during drying at 105 °C for 24 h. Total organic carbon (TOC) was analyzed according to the standard method [41]. The pH and the electrical conductivity (EC) were measured after the extraction of fresh samples (solid/water ratio of 1:10 *w*/*v*). Fresh samples of organic materials were used for the determination of total Kjeldahl-N and ammonium N using Kjeldahl distillation methods [41]. Total organic N was calculated by the difference between TKN and ammonium N.

The mature compost was analyzed for the main chemical properties. The humic-like substances were extracted and purified as described by Ciavatta et al. [42], and C quantification in the extracts was carried out using high-temperature combustion (805 °C, Pt catalyzed) followed by CO_2 infrared detection using multi N/C 2100S® (Analytik Jena GmbH, Überligen, Germany). The germination index was determined by using cress seeds (*Lepidium sativum* L.), which is the most commonly adopted standard test worldwide to evaluate the potential phytotoxicity in compost, as described by Zucconi [43] and modified by Said-Pullicino et al. [44]. For the metals' determination, compost was digested in HNO_3 and H_2O_2 at 200 °C in a microwave oven (maximum power 800 W, Milestone Inc. ETHOS One, Sorisole, Italy) and analyzed by using plasma emission spectrometry (Optima 2000 DV, Perkin Elmer Italia Spa). Total P was measured spectrophotometrically after digestion [41], while total K was determined through the flame photometric method. Total Hg was determined using a cold-vapor generator coupled to a plasma emission spectroscopy apparatus.

2.4. Substrate Composition

Compost was tested on a series of pot-raised plantlets. In the nursery where the test was carried out, a commercial substrate is normally used for potting the seedlings, consisting of 3 components: peat (about 75% by volume), pumice (about 25% by volume), and an organo-mineral fertilizer (less than 1% by volume).

To carry out the test, two additional mixtures were prepared in which the above-mentioned commercial substrate was partially replaced with 30% and 45% compost, respectively. Consequently, three distinct potting substrates were used:

Sub30: containing 30% compost and 70% commercial substrate (by weight),

Sub45: containing 45% compost and 55% commercial substrate (by weight),

Sub0: the commercial substrate, used alone as a control.

The 30% and 45% peat replacement ratios were chosen because for the olive tree and other species it is not suitable to exceed 50% replacement of peat with compost, as highlighted in previous experiences, reported in Section 1.2.

The three used substrates were analyzed to determine the main physical and chemical parameters at the beginning of cultivation. Table 5 shows the values found.

Table 5. Main physical-chemical parameters of the potting substrates.

Parameter	Sub45	Sub30	Sub0
pH	5.22 ± 0.57	5.33 ± 0.09	3.46 ± 0.02
TOC (% d.m.)	20.63 ± 0.38	16.60 ± 0.65	20.18 ± 0.38
Bulk density (kg L^{-1})	0.48	0.50	0.38

All data are expressed on a dry basis. EC: electrical conductivity; TOC: total organic C. Values represent the mean ± SD.

2.5. Species and Varieties Used in Testing and Sampling

In spring 2019, the above substrates were used for the potting of the two species considered for each of the previously prepared substrates. Substrates Sub30 and Sub45 were used for the potting of olive (cv. Frantoio) and hazelnut (cv. Tonda Giffoni) plants. All plants were transplanted into pots of a 3 dm^3 capacity. As a control, all the tests described were completed with a suitable number of plants of the same species, potted with only the commercial substrate, Sub0, without any compost.

This resulted in 270 plants, distributed as follows:

Olive: 45 plants with Sub45, 45 plants with Sub30, 45 plants with Sub0;
Hazelnut: 45 plants with Sub45, 45 plants with Sub30, 45 plants with Sub0.

2.6. Performed Surveys and Methods

2.6.1. Plant Growth, Leaves' Chlorophyll Content, Substrate EC and pH

During the 2019 growing season, several periodic surveys were performed to measure the degree of development of potted plants by measuring the following parameters: number of leaves, chlorophyll content, electrical conductivity, and the pH of the substrate leachate.

The number of leaves per plant was measured on three separate dates: in May (a few weeks after potting, which occurred in April), in mid-June, and in the second half of July.

Chlorophyll content was measured on two separate dates, starting about one month after potting. In particular, the chlorophyll content was measured on the middle part of 3 leaves from each plant, using a SPAD-502 Chlorophyll Meter (Minolta Camera Co. Ltd., Osaka, Japan).

Three pots per treatment were irrigated with 1 L of water, then the leached water was collected to determine the electrical conductivity (EC), using the conductimeter 'Hanna Instruments-HI 9033', and pH, using the pH-meter 'Radiometer Copenhagen-PHM 82'.

2.6.2. Destructive Measurements

In November 2019, a sample survey was performed to analyze differences in plant biomass produced in the various treatments, both in terms of fresh and dry weight, and in terms of distinguishing between leaves, stems and branches, and roots. A total of 10 plants per treatment were extracted from the substrate, and the roots were washed in distilled water. Then, roots, stems and branches, and leaves were separated to determine their fresh weight (FW) and dry weight (DW) by oven-drying at 95 °C until constant weight was reached.

2.7. Statistical Tests

During the growing season, the parameters Number of Leaves and Chlorophyll Content were measured in all 270 seedlings constituting the samples, while the parameters Electrical Conductivity and pH were measured in 18 plants (3 for each thesis). The mean and standard deviation of each parameter in each thesis and period was then calculated. ANOVA and Tukey test was then performed (confidence level = 0.95).

With regard to the destructive measurements made at the end of the growing season, 10 plants were randomly taken from each thesis on which the fresh and dry parameters described above were measured. The mean and standard deviation of each parameter in each thesis was then calculated. ANOVA and Tukey test was then performed (confidence level = 0.95).

All statistical analyses were carried out with the R software (version 4.1.2) with which all the graphs herein were also produced.

3. Results and Discussion

Tests on pot-grown plants gave very interesting and, in some cases, quite novel results compared to what can be found in the literature. The main result of the trials was that different species responded differently to the same percentage of compost in the substrate. The results summarized here show that it is necessary to evaluate for each individual species the percentage of compost that can be used in the substrate, carefully evaluating the characteristics of the different composts that can be used.

3.1. Olive Tree Growth

With regard to the olive tree, a positive response of the species to the addition of compost in the substrate was shown, as the viability of the plants increased with the highest percentage of compost in the substrate (Sub45), which was greater than or comparable to that of the control plants, as shown in Figure 1, which reports the evolution of the leaf number (Figure 1A) and the chlorophyll content (Figure 1B) during the period of maximum growth; it is also noted that the measurements taken in July show that the lowest viability was expressed by the Sub30 treatment (Figure 1B). One could infer a good tolerance by the olive tree to the addition of some composts from digestate in the substrate, at least by up to 45% used in the trials.

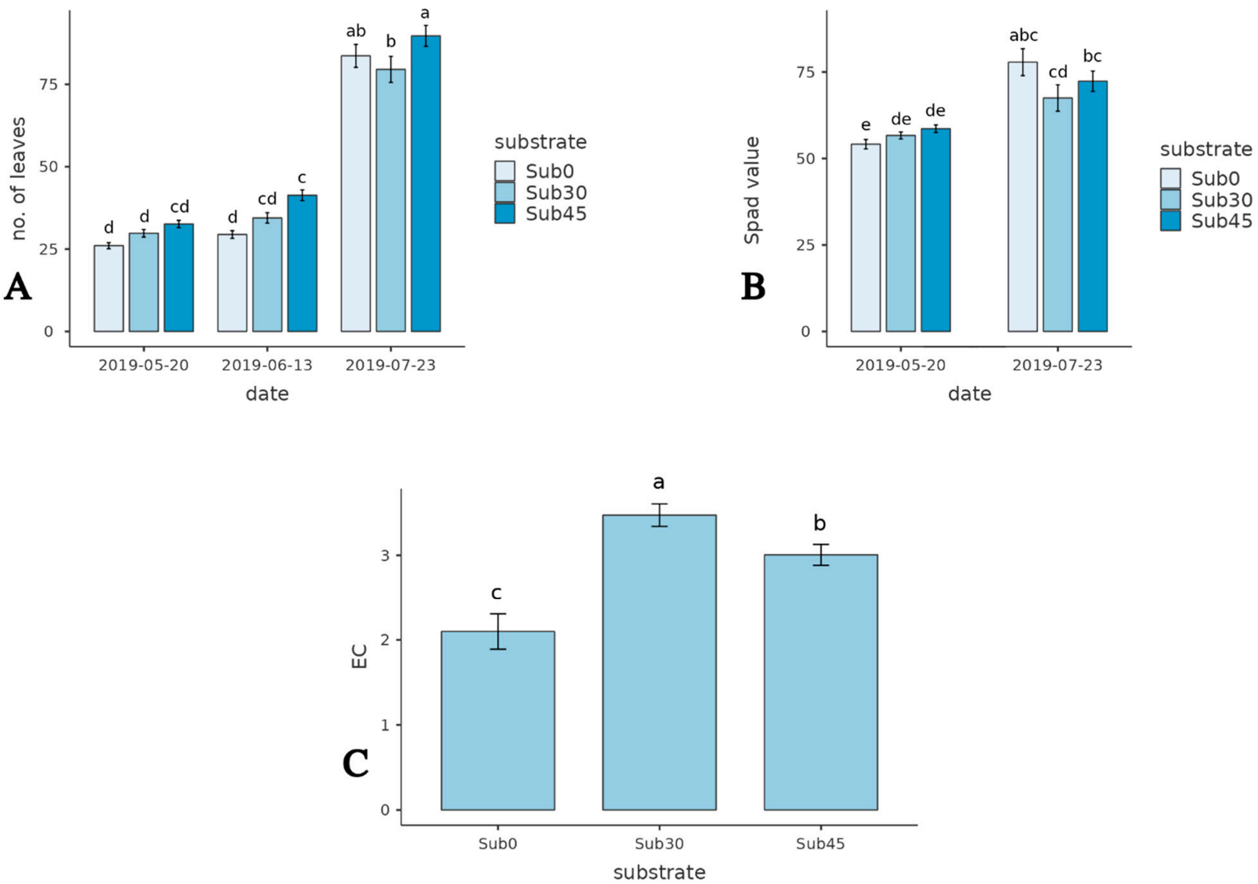

Figure 1. Olive tree pots—(**A**): trend in the number of leaves. (**B**): trend in the leaves' chlorophyll content. (**C**): substrate electrical conductivity (mS cm^{-1}). Within each graph, values with different lowercase letters indicate significant differences at post-ANOVA Tukey test ($p < 0.05$).

Figure 1C shows the differences in electrical conductivity in the three substrates, confirming the good adaptability of the olive tree to substrates with medium salinity.

A quick measurement of the leachate pH also showed that the addition of compost slightly shifts the pH of the substrate towards neutrality and alkalinity, but not significantly, the pH being around 7 in the three substrates.

3.2. Olive Tree at the End of the Growing Season

Looking at the results at the end of the growing season (Figures 2 and 3), it is clear that, in the case of the olive tree, the substitution of peat with this kind of compost from digestate by 30% and 45% allowed for the creation of plants similar or superior to the control in terms of development of roots, stem and branches, and leaves. In particular, the replacement of 45% of peat with compost, resulted in a significant increase in FW and DW of the root system (Figures 2D and 3D, respectively). This is an important outcome as the increased root biomass may lead to a reduction in transplant stress when the olive seedlings are transplanted into the open field, ensuring a higher probability of rooting, especially in the presence of water shortage.

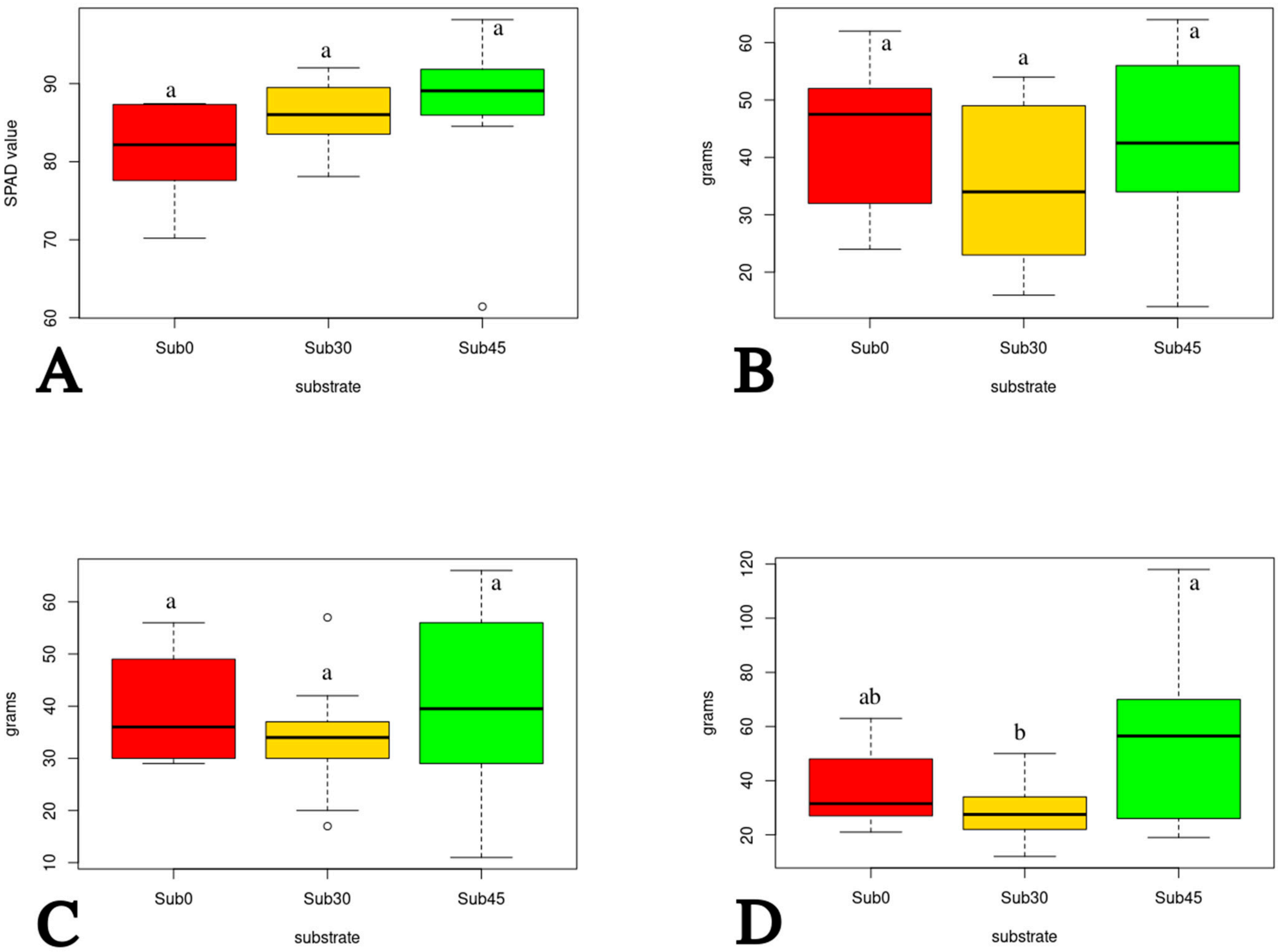

Figure 2. Olive tree pots at the end of the growing season—(**A**): chlorophyll content. (**B**): weight of fresh leaves. (**C**): weight of fresh stem and branches. (**D**): weight of fresh roots. Within each graph, values with different lowercase letters indicate significant differences at post-ANOVA Tukey test ($p < 0.05$).

The substitution of peat with compost did not significantly affect the content of leaf chlorophyll in olive tree measured by SPAD. In this way, because olive has a medium resistance to salinity [45,46], the plants could overcome quite rapidly the initial stress. Similar results were obtained by Aleandri et al. [11] with olive trees cultivated in substrates with a reduced percentage of peat (15%, 30%, and 60%) replaced by a compost obtained from pruning residues of woody plants and grass mowing. The olive plants grown in substrate-containing compost showed a regular development of growth parameters (plant height and stem diameter) during the whole cultivation cycle. Varol et al. [47] used compost obtained from two-phase olive-mill pomace, dairy and poultry manure, and straw in different percentages (25, 50, 75, and 100%) in growing media and observed higher values for olive tree biomass compared to control. Regni et al. [15] reported that composted pomace can substitute peat by up to 50% without causing a significant reduction in the final plant growth.

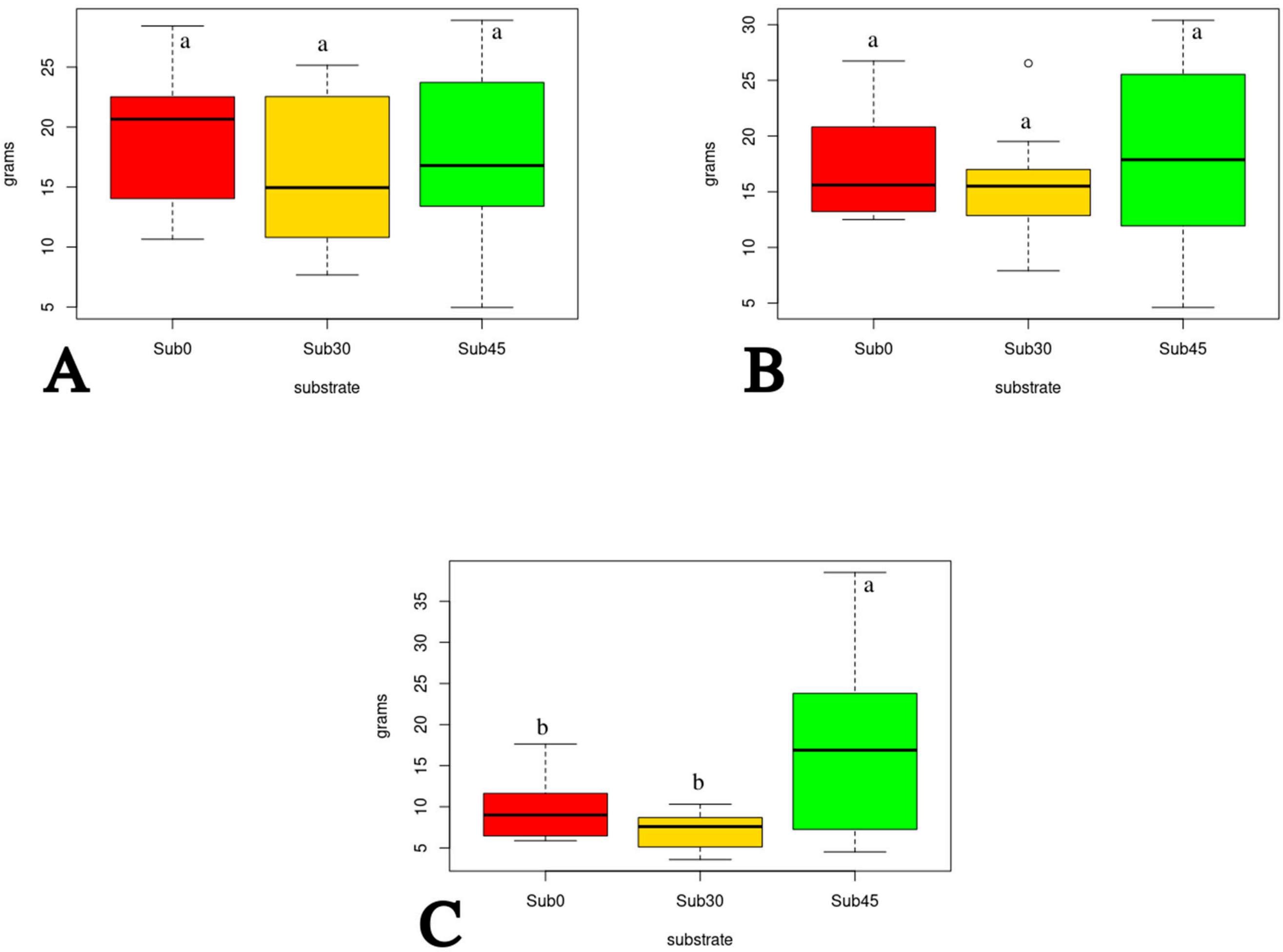

Figure 3. Olive tree pots at the end of the growing season—(**A**): weight of dried leaves. (**B**): weight of dried stem and branches. (**C**): weight of dried roots. Within each graph, values with different lowercase letters indicate significant differences at post-ANOVA Tukey test ($p < 0.05$).

Analyzing in detail the graphs in Figures 2 and 3, some greater variability in the results can be seen in the case of the Sub45 substrate; this could be an indication of a certain inhomogeneity of the substrate induced by the compost, although this inhomogeneity does not invalidate the good results obtained with the addition of compost. This is a very important factor to consider in nurseries, which need very standardized growing substrates to obtain seedlings with very homogeneous characteristics. Strong control of the materials used for composting and of the physico-chemical parameters of composting, therefore, becomes a determining factor in obtaining a compost with standard characteristics that can be easily used as a substitute for peat.

3.3. Hazelnut Tree Growth

As for the hazelnut tree, there was a negative response to the percentages of compost used in the growing medium compared to the control without compost, as plants grown with compost-containing medium showed less vitality than the control. In this case, however, a better response of the species to the lowest percentage (30%) than to the highest (45%) was shown, suggesting that hazelnut could tolerate an addition to the substrate of compost with characteristics similar to those of the compost used in the trials, but adding a small percentage of compost, lower than the 30% used in this study (Figure 4).

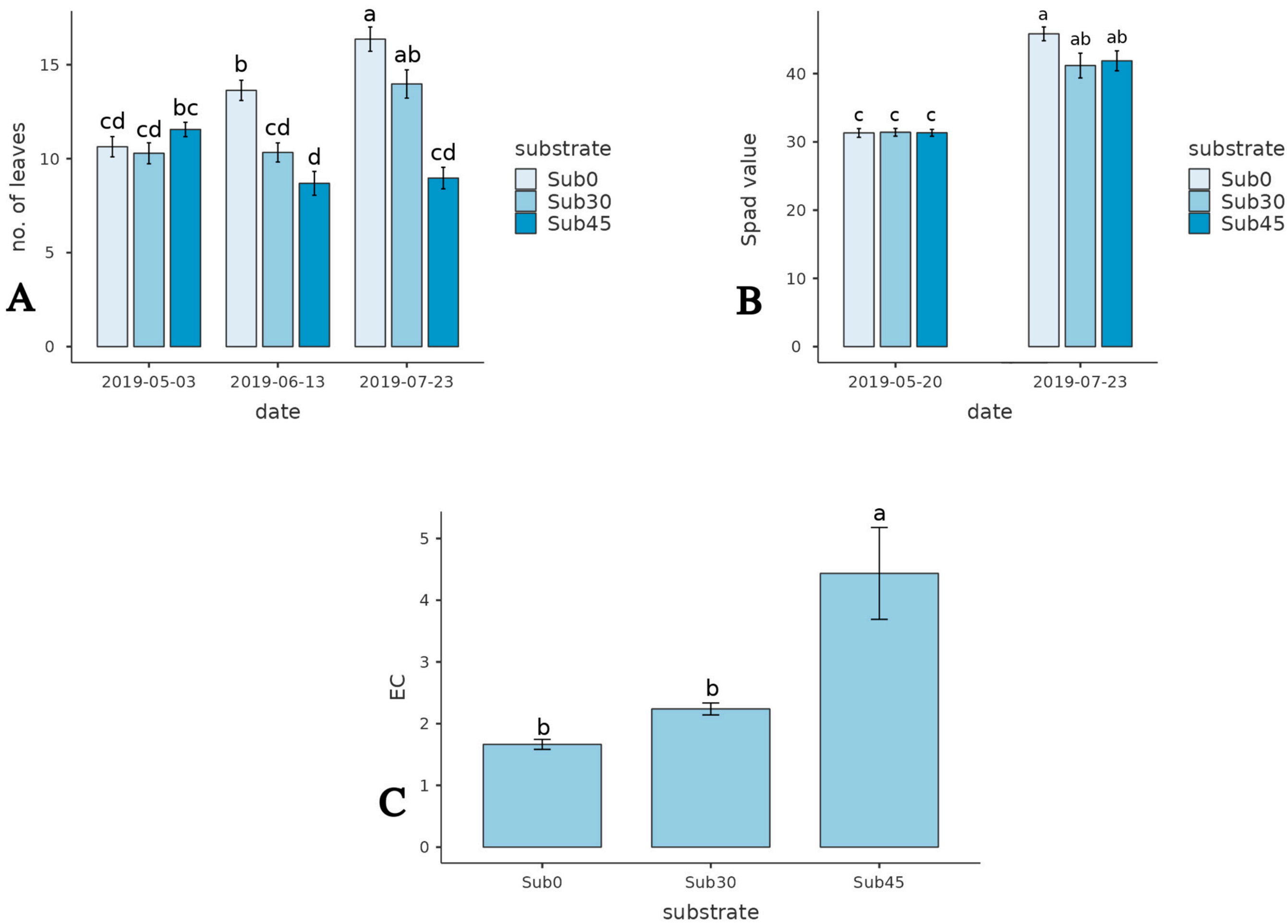

Figure 4. Hazelnut tree pots—(**A**): trend in the number of leaves. (**B**): trend in the leaves' chlorophyll content. (**C**): substrate electrical conductivity (mS cm^{-1}). Within each graph, values with different lowercase letters indicate significant differences at post-ANOVA Tukey test ($p < 0.05$).

Figure 4C shows the differences in electrical conductivity in the three substrates, showing a great increase in salinity, corresponding to the higher percentage of compost. The addition of compost slightly shifts the pH of the substrate towards neutrality and alkalinity for the hazelnut tree pots too.

It is known that hazelnut needs a substrate with a significant calcium content [48,49]. Some research has found a decrease in plant calcium assimilation following the addition of compost; additionally, the higher salinity of the substrate induced by the compost could cause a lower growth of plants [32].

3.4. Hazelnut Tree at the End of the Growing Season

In the hazelnut tree, as in the olive tree, the substitution of peat with compost did not significantly affect the content of leaf chlorophyll measured by SPAD (Figure 5A). On the contrary, the substitution of peat with compost resulted in lower FW and DW of leaves, roots, and stem and branches, as reported in Figures 5 and 6. Looking at Figure 6C, regarding the weight of dried roots, it can be seen that the Sub30 thesis is not significantly different from the Sub0 control, although with greater variability. This could confirm, as mentioned above, that the hazelnut tree could tolerate some amount of compost in the substrate, although less than 30 percent.

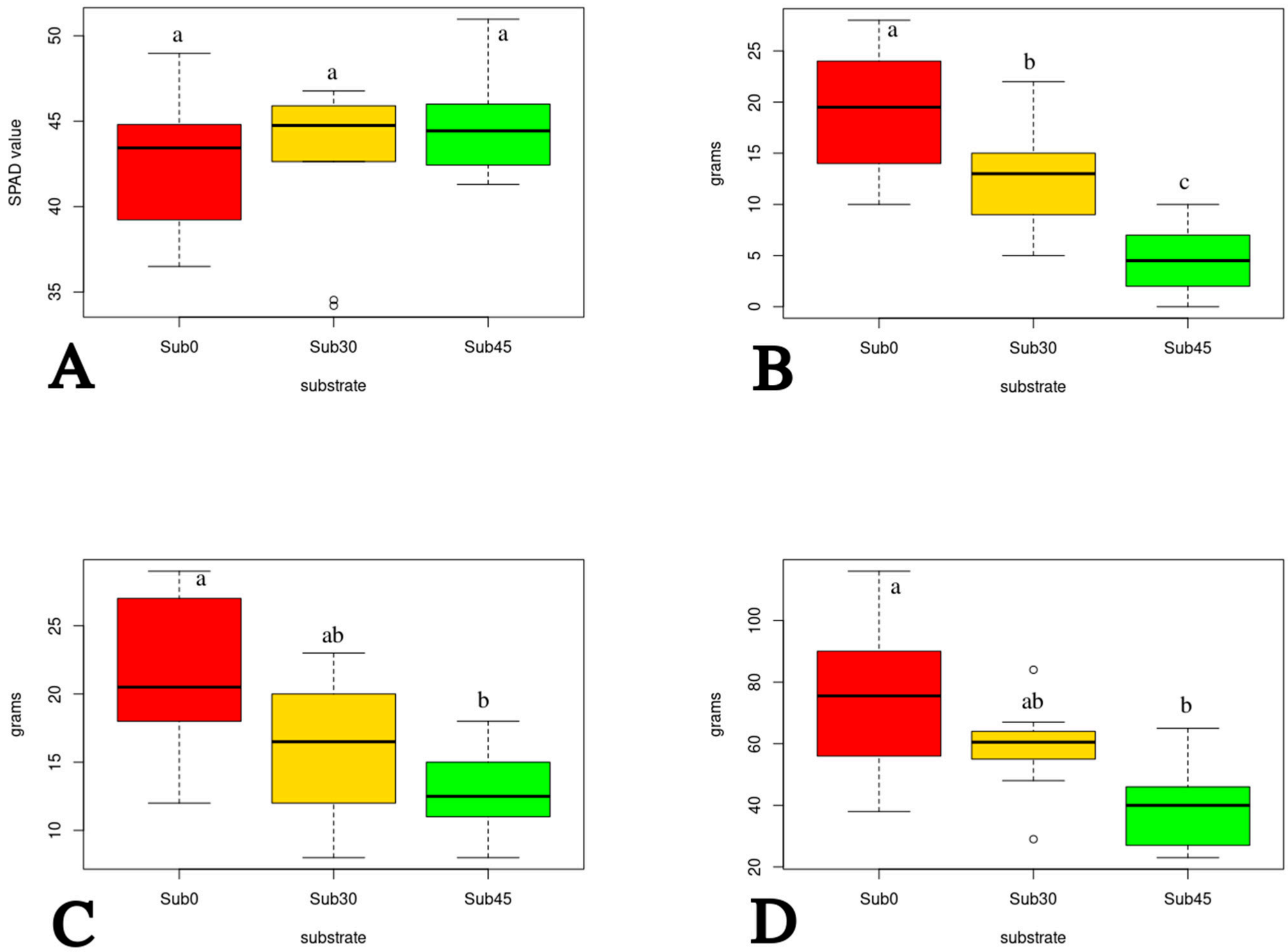

Figure 5. Hazelnut tree pots at the end of the growing season—(**A**): chlorophyll content. (**B**): weight of fresh leaves. (**C**): weight of fresh stem and branches. (**D**): weight of fresh roots. Within each graph, values with different lowercase letters indicate significant differences at post-ANOVA Tukey test ($p < 0.05$).

Regarding the poor performance of the hazelnut tree in substrate-containing compost, a first hypothesis concerns the low tolerance to substrate salinity, which in the case of compost addition was higher than the control, specifically in the Sub45 thesis (Figure 4C). In fact, the literature has shown that composts obtained from digestate often have a higher level of salinity than other types of compost [50,51], levels even higher than what commonly is indicated as maximum thresholds for advantageous use [52]. In addition, a role could be played by the lower availability of calcium [32].

3.5. Comparing Results of the Two Species

In many cases, peat appears difficult to replace in nursery as its characteristics are difficult to find together in alternative substrates. Substitution with compost involves completely rethinking agronomic practices for proper seedling growth since compost has rather different chemical-physical characteristics, as was also found in this study (see Table 5). This characteristics diversity makes it necessary to carefully consider the edaphic needs of the various species for which compost is to be used.

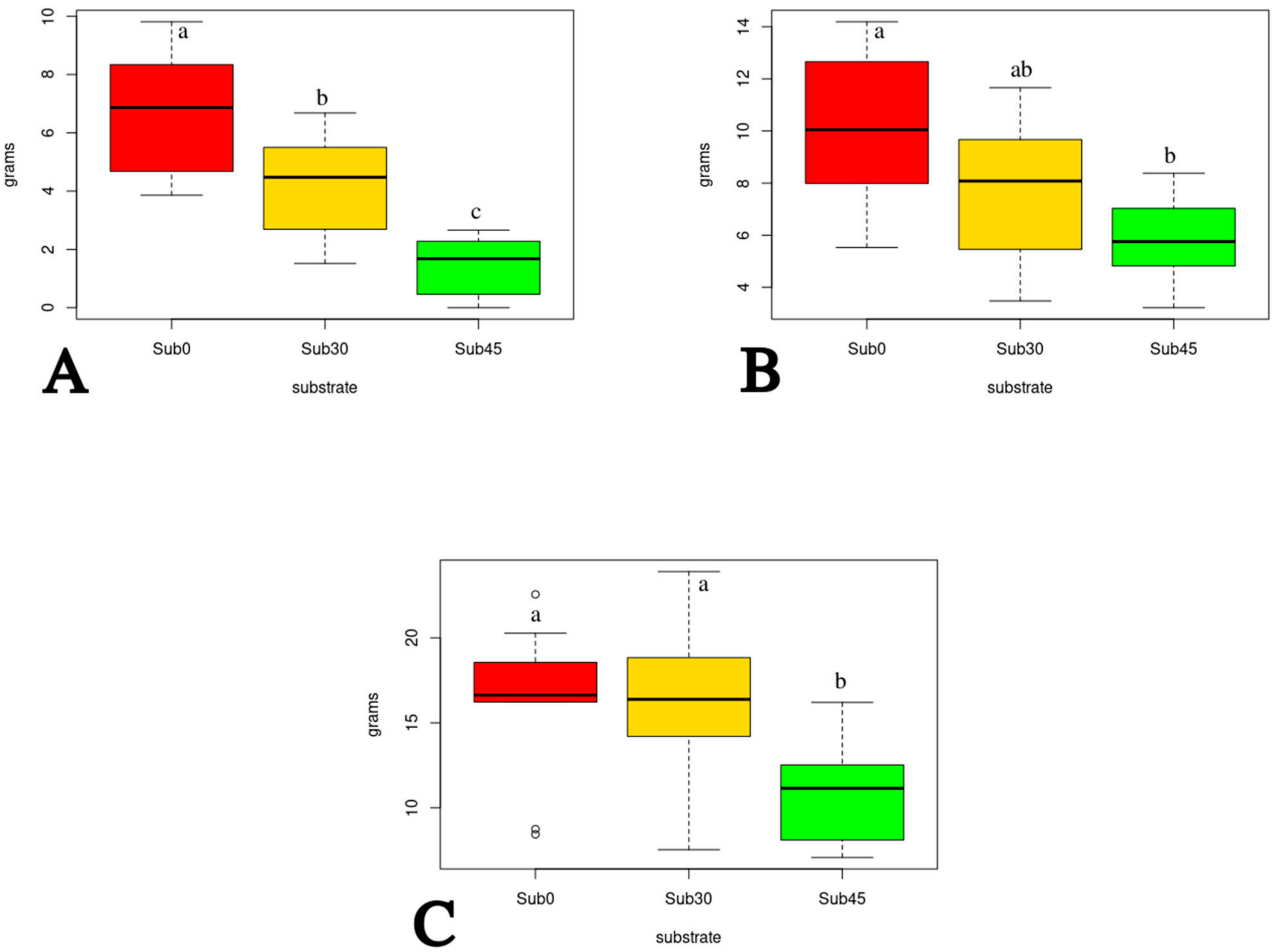

Figure 6. Hazelnut tree pots at the end of the growing season—(**A**): weight of dried leaves. (**B**): weight of dried stem and branches. (**C**): weight of dried roots. Within each graph, values with different lowercase letters indicate significant differences at post-ANOVA Tukey test ($p < 0.05$).

It is evident that the use of this kind of compost from digestate for the nursery growing of olive and hazelnut seedlings gave significantly different results. Olive trees well-tolerated the partial replacement of peat with compost, while hazelnut trees showed considerable intolerance. This leads to the assertion that in nursery, it is not possible to assume a widespread replacement of peat with compost from digestate for all species. This substitution must be calibrated to each species, experimenting with different types of compost and degrees of substitution individually, knowing that the results obtained for one species cannot be immediately transferred to other species. The merit of this study lies precisely in making this issue evident through a direct comparison of the two tested species. This research, moreover, highlighted the need for further study on the use of compost for hazelnut nursery, having highlighted issues related to the type and amount of compost that can be used, salinity tolerance, and influence on calcium absorption.

4. Conclusions

The experimental trials carried out in this study evaluated the response of olive and hazelnut to the addition of a compost from digestate in the potting substrate of nursery seedlings as a partial replacement of peat. Comparing these two tree species, whose edaphic needs are quite different, was an interesting example of how to address the issue of peat replacement. Two different concentrations of compost in the substrate were evaluated: 30 percent and 45 percent (by weight), measuring the effect on some growth parameters during an entire growing season. The trials showed different responses in the two species considered, which were substantially positive for olive tree and substantially negative for hazelnut tree.

In the olive seedlings, the presence of this kind of compost from digestate in the substrate resulted in a good response, substantially similar to that of the control without compost, with a slightly better result in the case of the 45% concentration than in the case of the 30% concentration. At the end of the growing season in plants with 45% compost, an increase in both fresh and dry weight of the root system was observed compared to the control and plants with 30%. From these results, it can be concluded that olive trees respond well to the addition of some composts from digestate at least up to 45% weight content.

In hazelnut seedlings, instead, the addition of this kind of compost from digestate resulted in lower viability than in the control, which was more pronounced with the 45% compost content; in fact, at the end of the growing cycle, replacing peat with that compost resulted in fewer leaves per plant and lower fresh and dry weights of all seedling parts (leaves, roots, stem and branches), with slightly better results in the case of the 30% content than the 45% content, but still worse than the control. This suggests that the hazelnut plant could tolerate percentages of compost similar to that tested, below 30 percent; this could be the subject of future research.

In all substrates, the addition of compost resulted in an increase in salinity, which was more pronounced in the case of the hazelnut tree. This may have led to the negative result for this species, perhaps reducing its ability to assimilate certain elements such as calcium; further research is needed in this regard.

From this study, in addition to the more practical aspects described above regarding the two plant species compared, a general conclusion can be drawn, apparently, quite obvious but almost never highlighted in previous studies: in the nursery sector, compost can be used to replace peat, but the replacement percentage should be calibrated according to the characteristics of the compost and individual crop species, since each species has different edaphic needs and different tolerance capacity to various nutrient concentrations. All this calls for a careful design and experimentation of new nursery substrates, in which compost is unlikely to be used in significant percentages to replace peat, therefore, also having to refer to other substitutes to be identified and experimented.

Lastly, research on hazelnut tree nursery still appears to be very insufficient, given the little literature on this subject. It seems appropriate to increase it, considering the growing worldwide interest for this crop.

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