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Use of Compost Based on Invasive Algae *Rugulopteryx okamurae* as a Peat Alternative in Nursery Growing Media

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Abstract: The invasion of the macroalgae *Rugulopteryx okamurae* is causing several environmental and economic problems along Spanish Mediterranean coasts. The use of composts based on *R. okamurae* as a peat alternative in nursery production could be a valid alternative for the exploitation of this organic material. The present study evaluated three different composts as peat substitutes in potting media to grow tomato seedlings: compost of *R. okamurae*, compost of green horticultural residues (two-thirds) and *R. okamurae* (one-third), compost of garden pruning residues (two-thirds) and *R. okamurae* (one-third). Each compost was used to formulate two different substrates to reduce the use of peat (40% compost, 40% peat, 20% perlite) or entirely substitute it (80% compost, 20% perlite), using a control treatment with 80% peat and 20% perlite. Only the control treatment received mineral fertigation during the trial. The results showed that the high initial electrical conductivity and ion concentration were remarkably reduced thanks to the fast leaching of salt that occurred with customary irrigation. Generally, compost-based treatments allowed us to obtain tomato seedlings with satisfactory morphological parameters. The substrates that contained 40% compost of *R. okamurae* or a compost of garden pruning residues and *R. okamurae* led to the best results in term of seedling parameters. It is therefore concluded that composts based on *R. okamuare* could be used as a seedling growing medium for the valorization of algae.

Keywords: substrate; seedlings; tomato; organic residues; circular horticulture

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1. Introduction

Since 2015, the invasive brown macroalgae *Rugulopteryx okamurae* has colonized the Western Mediterranean Sea [1], with devastating impacts on marine ecosystems, fishing, and the tourism sector [2]. Tons of *R. okamurae* algal biomass are collected every year from the Spanish Mediterranean coastline [3], resulting in high costs for municipalities and several environmental problems [4,5]. In addition to the importance of mapping and controlling the expansion of the invasive seaweeds, to alleviate the economic costs derived from their recollection and disposal, the analysis of the potential applications of algae is a useful approach [2,6]. With this purpose, different authors have evaluated the use of the algae *R. okamurae* for the generation of biogas [7], as an ingredient of aquafeeds for fish farms [8], as a raw material for the development of bioplastics [9], or in composting processes [2]. Composting is an economic and easy way to elaborate organic wastes, allowing to obtain a stable product, namely compost, that can be applied as a fertilizer, soil amendment, or potting medium ingredient in agriculture [10–12]. The quality of compost depends on the starting materials, and to overcome the possible limitations of composting algae alone, such as its low C/N ratio [2,13], co-composting with agricultural or green local waste could be considered [2,5].

In the horticultural system, transplant production in nurseries is an essential component, since it allows one to obtain uniform and high-quality seedlings with efficient management of resources [14,15]. In nursery production, the quality of the growing media is one of the most influencing factors for obtaining high-quality seedlings [15,16], with peat being the most widely used potting medium in nurseries [10] thanks to its excellent physical, chemical, and biological properties for plant development [17]. Nevertheless, awareness of the high environmental impact associated with its use [10,18] and increases in its price [19] have encouraged the horticultural sector to look for eco-friendly and low-cost peat alternatives [10,19,20], and compost has been the most investigated one [16,18,21–24].

Numerous studies have reported that compost can reduce the use of peat in potting media by a proportion of 20–50% by volume in horticultural and forest nursery production [17,22,25]. The high pH, high electrical conductivity (EC), and high concentration of potential phytotoxic elements in compost may limit the feasibility of using it as a potting medium [10]. Nevertheless, some studies have obtained horticultural transplant seedlings of good quality with growing media with a high EC [21–23] thanks to the rapid leaching of elements with an irrigation program [26,27]. Compost is rich in nutrients and organic matter, and it can be used to improve the physical and chemical properties of substrates [10]. However, the effects of compost used as growing medium on plants development depend on the specific characteristics of each compost and need to be monitored for every substrate. To our knowledge, there are no studies that have investigated the use of compost made with *R. okamurae* as an ingredient of the substrates. In an area with an intensive horticultural system (the south of Spain), the exploitation of composted invasive seaweeds such as *R. okamurae* with agricultural or garden pruning residues, could result in a win–win paradigm [28], since it allows for alleviating the costs of organic waste disposal, and, used as substrate medium, it offers a low-cost and more sustainable alternative to peat. For this, the effects of compost and the proportions on the chemical characteristics of the substrates and on the morphological parameters of tomato seedlings were studied.

The aim of this study was to evaluate if composts based on *R. okamurae* and vegetal wastes can be used in mixtures of growing media as a peat alternative and as source of nutrients in tomato seedling production to turn the disposal of algae biomass and vegetable debris from an environmental problem into an opportunity.

2. Materials and Methods

2.1. Experimental Design

The experiment was performed during the summer season of 2021 at the commercial nursery El Plantel Semilleros in El Ejido (Almería, Spain) in a polyethylene greenhouse with passive climate control and natural daylight.

Tomato (*Solanum lycopersicum* L.) cv. Obelix (CapGen Seeds) was chosen for the trial and cultivated in 14 polystyrene trays with 96 cells measuring 4.5 $\times$ 5.5 cm.

The experimental design was fully randomized, using two trays per treatment, with four replicates each and 48 plants per replicate.

The treatments described in Table 1 comprised different potting media. Three composts were used to formulate the substrates to replace 50% and 100% of the peat. The volume of perlite was kept constant in all treatments at 20% (% volume) to improve aeration. A standard growing medium comprising 80% peat with a medium fertilizer content (Pindstrup Mosebrug SAE, Burgos, Spain) and 20% perlite (Knauf, Spain) was used as a control (Table 1).

Table 1. Composition of the substrates for each treatment.

Treatment	Substrate Composition (% Volume)					% of Peat Substituted
	Peat	CA	CHA	CPA	Perlite	
Control	80	-	-	-	20	0
40CA	40	40	-	-	20	50
80CA	-	80	-	-	20	100
40CHA	40	-	40	-	20	50
80CHA	-	-	80	-	20	100
40CPA	40	-	-	40	20	50
80CPA	-	-	-	80	20	100

CA: compost of *R. okamurae* algae (100%); CHA: compost of horticultural green residues (two-thirds) and *R. okamurae* algae (one-third); CPA: compost of garden pruning residues (two-thirds) and *R. okamurae* algae (one-third). - corresponds to 0.

The seeds were sown on 1 July 2021. The trays were filled with the substrate, and then the seeds were sown automatically, at one seed per cell, covered with vermiculite, and irrigated with water (0.07 mmol L^{-1} NO_3^-, 0.14 mmol L^{-1} K^+, 0.53 mmol L^{-1} SO_4^{2-}, 7.75 mmol L^{-1} Cl^-, 1.65 mmol L^{-1} Ca^{2+}, 1.43 mmol L^{-1} Mg^{2+}, 5.06 mmol L^{-1} Na^+, 0.11 mg L^{-1} Cu, 0.25 mg L^{-1} B, pH 8.01, and 1.13 dS m^{-1} EC).

After sowing, the trays were placed in a germination chamber programmed at 25 °C and 95% humidity with recirculating air for 3 days. Then the trays were set on rails inside the polyethylene greenhouse with natural daylight and passive climate control.

During the trial, the plants were irrigated daily according to the irrigation management of the commercial nursery, with an automatic sprinkler system. The treatments (substrates) containing compost were irrigated with water during the whole trial period, and no external mineral fertilizers were supplied. Only the control treatment was fertigated with a mineral nutrient solution (14.47 mmol L^{-1} NO_3^-, 1.4 mmol L^{-1} P, 7.15 mmol L^{-1} K^+, 0.94 mmol L^{-1} NH_4^-, 0.77 mmol L^{-1} SO_4^{2-}, 5.08 mmol L^{-1} Ca^{2+}, 1.46 mmol L^{-1} Mg^{2+}, 5.41 mmol L^{-1} Na^+, 8 mmol L^{-1} Cl^-, 0.15 mg L^{-1} Zn, 2.08 mg L^{-1} Fe, 0.8 mg L^{-1} Mn, 0.39 mg L^{-1} Cu, 0.4 mg L^{-1} B, pH 7.01, 2.87 dS m^{-1} EC), following the fertilization program of the commercial nursery.

2.2. Composts Used as Ingredients of Growing Media

The three composts (CA, CHA, and CPA) were tested as ingredients of the growing media (Table 2). The CA was prepared with biomass of the algae *R. okamurae* (100%), the CAH was prepared as two-thirds horticultural green residues mixed with one-third *R. okamurae*, and CPA was prepared as two-thirds garden pruning residues (leaves and branch of ficus and palm tree leaves) mixed with one-third *R. okamurae* (weight/weight). The *R. okamurae* algae were collected from the Tarifa coast (Spain) and transported to the IFAPA experimental center of La Cañada (Almeria, Spain), where the composting process was carried out. Before starting the composting process, the algae were washed in tap water for 48 h to reduce the initial high electrical conductivity (EC) (84 dS m^{-1}) and then dried in fresh air [29].

Table 2. Physiochemical characteristics of CA (*R. okamurae*), CHA (two-thirds horticultural green residues and one-third *R. okamurae*), and CPA (two-thirds garden pruning residues and one-third *R. okamurae*).

	BD ($g\ cm^{-3}$)	Porosity (%)	Saturation (%)	OM (% dm)	C/N	TN (% dm)	TP (% dm)	TK (% dm)	pH	EC ($dS\ m^{-1}$)
CA	0.17	85.52	330	54.8	8.0	4.0	0.21	0.14	7.5	7.7
CHA	0.24	76.43	220	57.1	9.8	3.4	1.26	1.50	8.4	21.1
CPA	0.31	69.25	180	47.1	10.3	2.7	0.42	0.50	8.1	12.5

BD: bulk density; OM: organic matter; C/N: carbon/nitrogen; TN: total nitrogen; TP: total phosphorous; TK: total potassium; EC: electrical conductivity; dm: dry matter.

The horticultural and garden pruning residues were supplied by the Planta Industrial de Compostaje Servicios Ambientales Las Chozas (El Ejido, Almería-Spain).

Three piles with a volume of 1.6 m^3 were prepared in November 2020. During the composting process, the piles were turned every 7–14 days and irrigated to maintain the humidity between 30% and 60% to facilitate the activity of aerobic microorganisms [29]. The composting process lasted 6 months.

2.3. Analysis of the Growing Media

The chemical characteristics of the growing media (treatments) were evaluated before starting the trial and at the end of it. At the beginning of the trial, once the raw materials had been mixed, three samples of each treatment were randomly collected. At the end of the growth cycle, after the seedlings had been removed from the trays, the substrate of each treatment was mixed, and three samples were collected. For each sample, pH, EC, and the concentrations of soluble elements in the saturated paste extract were measured. The substrates' pH was determined via potentiometry. The EC was determined in a water suspension via electrometry. The ammonium (NH_4^+) was determined via the colorimetric method. The potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^+) were determined via ICP-MS. The nitrate (NO_3^-), phosphate ($H_2PO_4^-$), sulfate (SO_4^{2-}), and chloride (Cl^-) were determined by ionic chromatography.

2.4. Morphological Parameters of Seedlings

The germination rate was determined at 14 days after sowing (DAS), counting the number of germinated plants per tray.

At 40 DAS, the seedlings reached the commercial transplantation size, and 10 plants per repetition were randomly selected to measure the morphological parameters. The number of leaves, plant height, stem diameter, and dry seedling weight were evaluated. The plant height was measured from the base region of the root to the top of the stem. The stem diameter was determined at the cotyledons' height. To determine the dry weight, the seedlings were kept in an oven at 65° for 72 h and then weighed with an electronic balance. The index of seedling quality (I) [30], which is useful for determining the seedlings' performance, was calculated as

$$I = \frac{SD}{SH} \times SDW$$

where SD is the stem diameter, SH is the stem height, and SDW is the seedlings' dry weight.

2.5. Statistical Analysis

For statistical analysis, Statgraphics 19 software was used. An analysis of variance (ANOVA) was carried out, using Fisher's comparison test of the means, with the statistically least significant difference being expressed as $p < 0.05$ (LSD).

3. Results and Discussion

3.1. Effects of Treatments on the Initial and Final Chemical Properties of Growing Media

The main chemical properties of the initial and final substrates' saturated paste extracts are reported in Tables 3 and 4.

Table 3. Effects of different treatments on the initial and final pH, electrical conductivity (EC), and cation concentrations in paste saturated extracts of the substrates (NH_4^+; K^+; Ca^{2+}; Mg^{2+}; Na^+).

	Initial Characteristics							Final Characteristics						
	pH	**EC dS m^{-1}**	**NH_4^+ mmol L^{-1}**	**K^+ mmol L^{-1}**	**Ca^{2+} mmol L^{-1}**	**Mg^{2+} mmol L^{-1}**	**Na^+ mmol L^{-1}**	**pH**	**EC dS m^{-1}**	**NH_4^+ mmol L^{-1}**	**K^+ mmol L^{-1}**	**Ca^{2+} mmol L^{-1}**	**Mg^{2+} mmol L^{-1}**	**Na^+ mmol L^{-1}**
Control	6.60 Aa	1.32 Aa	4.06 Be	2.82 Ba	1.93 Aa	0.58 Aa	2.56 Aa	8.30 Bc	2.51 Ba	0.82 Aa	2.37 Ab	2.65 Ba	2.59 Ba	11.49 Ba
40CA	6.75 Ab	4.27 Bb	2.63 Bb	3.85 Bb	5.05 Bb	4.65 Bb	23.56 Bb	7.77 Ba	3.14 Ab	0.93 Aa	1.16 Aa	3.60 Ab	3.59 Ab	14.99 Ab
80CA	7.62 Ad	7.97 Bd	2.36 Ba	4.39 Bb	5.44 Bb	13.73 Be	56.41 Bd	8.01 Bb	3.26 Abc	1.22 Aa	0.89 Aa	3.41 Ab	4.61 Ac	15.17 Abc
40CHA	7.78 Ae	8.68 Be	2.85 Bcd	23.95 Bd	11.40 Be	9.56 Bd	26.63 Bc	8.25 Bc	4.34 Ad	1.45 Aa	3.52 Ad	5.24 Ad	5.73 Ad	18.97 Ad
80CHA	8.12 Af	18.05 Bg	5.52 Bf	55.15 Be	12.41 Bf	23.53 Bf	70.20 Bf	8.23 Ac	4.32 Ad	1.34 Aa	3.48 Acd	6.42 Ae	7.01 Ae	17.81 Abcd
40CPA	7.49 Ac	5.63 Bc	2.69 Bbc	10.77 Bc	6.44 Bc	5.74 Bc	24.43 Bb	8.09 Bb	3.81 Acd	0.92 Aa	2.49 Abc	4.57 Ac	4.32 Abc	17.96 Acd
80CPA	8.08 Af	11.07 Bf	2.94 Bd	23.57 Bd	7.82 Bd	9.34 Bd	64.30 Be	8.09 Ab	4.22 Ad	1.00 Aa	2.42 Ab	5.19 Acd	5.87 Ad	20.52 Ad

Control: 80% peat and 20% perlite; 40CA: 40% compost of *R. okamurae* algae, 40% peat, and 20% perlite; 80CA: 80% compost of *R. okamurae* algae and 20% perlite; 40CHA: 40% compost of horticultural residues and *R. okamurae* algae, 40% peat, and 20% perlite; 80CHA: 80% compost of horticultural residues and *R. okamurae* algae, and 20% perlite; 40CPA: 40% compost of garden pruning residues and *R. okamurae* algae, 40% peat, and 20% perlite; 80CPA: 80% compost of garden pruning residues and *R. okamurae* algae, and 20% perlite. Different capital letters indicate differences between the initial and final values of each parameter within the same treatment; different lowercase letters in the same column indicate significant differences among treatments, according to the LSD test ($p < 0.05$). Identical letters indicate no significant differences.

The pH of the initial growing media was influenced by the treatment (Table 3). All the treatments presented pH values outside the optimal range for potting media (5.3–6.5), as proposed by Abad et al. [31]. The control treatment resulted in the lowest pH, followed by 40CA. As previously reported [16,17], the pH increased with an increase in the ratio of compost, with the 80CHA and 80CPA treatments having the highest values.

The initial electrical conductivity (EC) in all compost-based substrates values ranged between 4.27 (40CA) and 18.05 dS m^{-1} (80CHA), which was significantly higher than that of the control (1.32 dS m^{-1}) (Table 3). It could also be observed that the EC was affected by the percentage of compost, increasing with the ratio of compost in the substrate, which is in line with previous results [17,24,32]. In addition, the EC changed depending on the type of compost incorporated into the potting media, with higher values in the CHA treatment, followed by CPA and CA. The high salinity level was due to the Na^+ concentration and, to a lesser extent, that of K^+ in the treatments based on CHA and CPA, and due to Na^+ followed by Mg^{2+} when CA was incorporated. It has been widely proven that the original material of compost influences its final characteristics [33]. Apart from the control, in all treatments, the EC was higher than 1.99 dS m^{-1}, the admissible maximum value reported by Noguera et al. [34], while Pascual et al. [15] reported an EC of 0.42 dS m^{-1} as the optimum initial average value for an ideal substrate. One of the problems associated with the use of composts as substrates is the high EC, which negatively affects the growth of seedlings and negatively impacts germination [10]. Nevertheless, Herrera et al. [21,22] grew melon and tomato seedlings in compost-based substrates with initial EC values of up to 22 dS m^{-1}, and Díaz and Camacho [23] used potting media with initial EC values up to 16 dS m^{-1} to grow tomato seedlings. Moreover, in studying commercial substrates, Wiberg et al. [35] found that EC values of <12.5 dS m^{-1} were acceptable for growing plants. It is also important to consider that a low EC indicates not only a low concentration of phytotoxic elements, such as Na^+ and Cl^-, but it also suggests a lack of available elements for plant nutrition [10], which necessitates a supply of external fertilizers via fertigation.

Table 4. Effects of different treatments on the initial and final anion concentrations in paste saturated extracts of the substrates (NO_3^-; $H_2PO_4^-$; SO_4^{2-}; Cl^-).

	Initial Characteristics				Final Characteristics			
	NO_3^- mmol L^{-1}	$H_2PO_4^-$ mmol L^{-1}	SO_4^{2-} mmol L^{-1}	Cl^- mmol L^{-1}	NO_3^- mmol L^{-1}	$H_2PO_4^-$ mmol L^{-1}	SO_4^{2-} mmol L^{-1}	Cl^- mmol L^{-1}
Control	0.65 Ba	2.06 Bd	3.16 Ba	2.57 Aa	0.25 Aa	0.34 Ae	1.37 Aa	14.93 Ba
40CA	19.40 Bc	1.34 Bc	6.92 Bb	11.17 Ab	1.07 Ab	0.19 Ab	2.64 Ab	18.40 Babc
80CA	39.48 Bf	0.30 Ba	13.28 Be	25.50 Bc	2.70 Ad	0.14 Aa	3.14 Abc	17.48 Aab
40CHA	23.20 Bd	0.36 Ba	10.41 Bc	42.61 Bd	1.59 Ac	0.24 Acd	3.55 Acd	25.90 Ad
80CHA	51.56 Bg	0.26 Aa	20.84 Bf	100.85 Bf	3.91 Ae	0.24 Acd	3.86 Ad	21.61 Abc
40CPA	15.08 Bb	0.71 Bb	6.48 Bb	25.41 Bc	0.99 Ab	0.25 Ad	3.05 Abc	20.96 Abc
80CPA	31.13 Be	0.31 Ba	11.66 Bd	58.29 Be	1.81 Ac	0.21 Abc	3.27 Abcd	22.47 Acd

Control: 80% peat and 20% perlite; 40CA: 40% compost of *R. okamurae* algae, 40% peat, and 20% perlite; 80CA: 80% compost of *R. okamurae* algae and 20% perlite; 40CHA: 40% compost of horticultural residues and *R. okamurae* algae, 40% peat, and 20% perlite; 80CHA: 80% compost of horticultural residues and *R. okamurae* algae, and 20% perlite; 40CPA: 40% compost of garden pruning residues and *R. okamurae* algae, 40% peat, and 20% perlite; 80CPA: 80% compost of garden pruning residues and *R. okamurae* algae, and 20% perlite. Different capital letters indicate the differences between the initial and final values of each parameter within the same treatment; different lowercase letters in the same column indicate significant differences among treatments, according to the LSD test ($p < 0.05$). Identical letters indicate no significant differences.

Regarding the cations, except for NH_4^+, the control treatment had the lowest initial concentrations (Table 3). NH_4^+ is a fundamental macronutrient in the initial phase of plant growth, and it was highly concentrated in the 80CHA treatment, followed by the control treatment, due to the previous enrichment of peat with mineral elements. The lowest NH_4^+ content was found in the 80CA. The addition of compost contributed to an increase in the concentration of the main cations, such as K^+, Ca^{2+}, and Mg^{2+}. The 80CHA treatment generally presented the highest cation concentrations. In the CHA- and CPA-based treatments, the increase in the compost ratio led to an increase in K^+ and Ca^+, while no statistically significant differences were found between the 40CA and 80CA treatments, probably due to the contribution of peat to the substrates, as it was incorporated at a proportion of 40%. The concentrations of Mg^+ decreased in the substrates with a proportion of compost of 40% with respect to the substrates with the same compost at 80%.

All the compost-based treatments presented a concentration of Na^+ that was higher than that of the control and higher than the maximum level allowed for horticultural substrates (Table 3), which is 6 mmol Na^+ L^{-1} [36]. In the treatments that incorporated the composts, the lowest Na^+ values were found in the 40CA (23.56 mmol L^{-1}) and 40CAP treatments (24.43 mmol L^{-1}), while the highest Na^+ level was observed in the 80CHA treatment (70.20 mmol L^{-1}).

Concerning the initial concentrations of anions, except for $H_2PO_4^-$, higher levels were observed in the treatments with compost than in the control (Table 4), with the highest total concentrations found in the 80CHA treatment. NO_3^- and SO_4^{2-} decreased remarkably with a reduction in the compost ratio, with the highest level seen in the 80CHA treatment, and the lowest levels found in the 40CPA treatment (NO_3^-) and in the 40CPA and 40CA treatments (SO_4^{2-}) (Table 4). As already mentioned, the concentration of $H_2PO_4^-$ was higher in the control treatment due to the enriched peat used as an ingredient of the potting media. Composts are generally low in P content [11] and, as a result, in the treatments containing composts, the highest presence of $H_2PO_4^-$ was found in mixtures where peat was incorporated at 40% compared with treatments with 0% peat, with 40CA > 80CA and 40CPA > 80CPA, while no differences were observed between the 40CHA and 80CHA treatments. Compared among compost-based substrates, the highest $H_2PO_4^-$ concentrations were found in CA followed by CPA.

Cl^- constitutes a possibly phytotoxic element, and its recommended concentration in substrates is lower than 28 mmol L^{-1} [36]. Along with the control, which presented the lowest Cl^- concentration, the 40CA, 40CAP, and 80CA treatments had Cl^- values within the suggested limit, while the 80CHA had the highest Cl^- concentrations.

As observed in the initial analysis, the final pH levels of all treatments were above the recommended limits, with the lowest value found in the 40CA treatment, followed by the 80CA, 80CAP, and 40CAP treatments, the pH levels of which were significantly lower than in the control (Table 3). The 40CAH and 80CAH treatments had pH levels similar to the control treatment. If we compare the initial and final pH levels of the same treatment, a general increase in pH during the cultivation of tomato seedlings was observed, except in the 80CHA and 80CPA treatments, which did not experience a change in pH during the trial. The alkalinization of the media may have been due to the slightly alkaline water used for irrigation (8.01 pH).

At the end of the cycle, the compost-based treatments still had EC levels higher than the control, with the final highest salt concentrations observed in the 80CHA, 40CHA, and 80CPA treatments (Table 3). However, the ECs of the saturated paste extracts of the substrates with compost at the end of the trial were significantly lower than the initial values due to the leaching that occurred during the 40-day trial with the standard nursery irrigation plan. Salt leaching in the growing media with the customary irrigation program was previously indicated by Fornes et al. [27] as a successful technique to reduce substrates' salinity. In this context, Herrera et al. [22] registered a decrease in the EC values during the growth of tomato and melon seedlings when applying the standard irrigation program. Hernández-Apaolaza et al. [37] grew ornamental plants in substrates formulated with bark compost, coconut fiber, and composted sewage sludge with initial high EC values (up to 9 dS m^{-1}), reaching EC levels in accordance with the recommended values at the end of the experiment. In the present study, although the EC decreased dramatically, the compost-based treatments still presented final EC values slightly higher than the maximum recommended value (1.99 dS m^{-1}) [34]. With the opposite trend, the EC of the control treatment increased during the trial due to the supply of mineral nutrients via fertigation.

At the end of the trial, no differences were found in the NH_4^+ concentration among the treatments, with a general decrease observed in all substrates during the cultivation of tomato seedlings (Table 3). The 40CA and 80CA treatments had the lowest K^+ values, and only the 40CHA and 80CHA treatments still presented K^+ concentrations higher than that of the control. The Ca^+ and Mg^+ concentrations were lower in the control treatment, although during the trial, an accumulation of Ca^+ and Mg^+ was observed in the control substrate; in contrast, the concentration of these cations in the compost treatments decreased.

The final NO_3^- levels were statistically lower in the control than in the compost treatments, followed by the 40CPA and 40CA treatments. Nitrates are easily leached from substrates; as a consequence, in all treatments, a reduction in the concentration of more than 90% was experienced. As seen in the first analysis, the $H_2PO_4^-$ was higher in the control treatment, with the lowest concentrations observed in the 80CA treatment. In all treatments, a decrease in $H_2PO_4^-$ was observed during the trial. Along the same lines, the compost treatments presented final concentrations of SO_4^{2-} higher than those of the control, with the highest value seen in the 80CHA treatment. All treatments had final SO_4^{2-} concentrations lower than the initial values. The final Cl^- concentrations in the 40CA and 80CA treatments were similar to those of the control, presenting the lowest Cl^- values. Apart from the treatments that incorporated CPA, the 40CA and 40CHA treatments had higher Cl^- concentrations than the 80CA and 80CHA treatments, respectively. This could have been due to the higher water retention capacity of the peat incorporated into the 40%

peat substrates, which led to an accumulation of Cl^- being found in the water. This could also explain the trend of Cl^- in the control treatment, which increased from 2.57 to 14.93, while in the compost treatments, except for the 40CA treatment, the Cl^- content decreased.

3.2. Morphological Parameters of Seedlings

The effects of the treatments on the morphological parameters of the seedlings are shown in Table 5.

Table 5. Effects of treatments on the morphological characteristics of tomato seedlings (G: germination; LN: leaf number; SH: shoot height; SD: shoot diameter; SDW: seedling dry weight; I: index of seedling quality).

Treatment	G (%)	LN	SH (cm)	SD (mm)	SDW (g plant^{-1})	I
Control	93.75	3.95 c	11.91 b	3.88 c	0.54 b	0.17 bc
40CA	93.75	3.47 a	12.46 b	3.75 bc	0.65 c	0.20 cd
80CA	93.23	3.93 c	11.50 ab	3.58 abc	0.55 b	0.17 bc
40CHA	92.19	3.70 b	12.25 b	3.68 bc	0.50 b	0.15 ab
80CHA	93.75	3.80 bc	10.42 a	3.30 a	0.40 a	0.12 a
40CPA	92.19	3.63 ab	12.35 b	3.73 bc	0.70 c	0.21 d
80CPA	94.27	3.93 c	12.08 b	3.45 ab	0.52 b	0.15 ab

Control: 80% peat and 20% perlite; 40CA: 40% compost of *R. okamurae* algae, 40% peat, and 20% perlite; 80CA: 80% compost of *R. okamurae* algae and 20% perlite; 40CHA: 40% compost of horticultural residues and *R. okamurae* algae, 40% peat, and 20% perlite; 80CHA: 80% compost of horticultural residues and *R. okamurae* algae, and 20% perlite; 40CPA: 40% compost of garden pruning residues and *R. okamurae* algae, 40% peat, and 20% perlite; 80CPA: 80% compost of garden pruning residues and *R. okamurae* algae, and 20% perlite. Different letters in the same column indicate differences among treatments, according to the LSD test ($p < 0.05$). Identical letters indicate no significant differences.

The germination ratios of the seedlings grown in the compost-based treatments were comparable with those of the control. This is in line with the results of a previous study, which reported that the final germination was not affected by the presence of high-salinity compost in the medium due to the fast leaching of salt with the customary irrigation [23,24,38]. However, a delay in seedling emergence is often observed when plants are grown in substrates formulated with compost due to the initial high salinity levels [23,30,31]. In contrast, Tüzel et al. [24] reported a decrease in the tomato germination ratio with an increase in the ratio of compost (olive oil-derived waste) in the growing media.

The effects of the treatments on the morphological parameters were found to be significantly different (Table 5). No significant differences in the number of leaves were found between the control and the treatments with 80% compost, which presented a higher number of leaves compared with treatments with 40% of the corresponding compost treatments, except for the 40CHA treatment, which was not different from the 80CHA treatment.

Regarding the height of the stem, excluding the 80CHA, which reported the lowest value, all the treatments were statistically similar to the control (Table 5). According to Romero-Aranda et al. [39], the stem height is negatively related to an increase in salinity in the growing medium. However, in this study, the EC resulted in a limitation in stem development only in the treatment with the highest EC value (18 dS m^{-1}), since no differences were found in stem height between the control and the other compost-based treatments with initial ECs between 4.27 and 11.07 dS m^{-1}. The stem diameters of the seedlings grown in the 80CA, 40CA, 40CHA, and 40CPA substrates were statistically comparable with those of the control treatment, with the lowest stem diameter observed in the 80CHA treatment. Contrarily, Díaz and Camacho [23] found a greater stem diameter in tomato seedlings cultivated in compost-based growing media compared with the control peat substrate, probably because of the salinity.

Concerning the accumulation of biomass, the 40CPA treatment, followed by the 40CA treatment, resulted in the highest plant dry weight, while the 40CPA, 80CA, and 80CPA treatments had no differences in seedling dry weight with respect to the control (Table 5). The 80CHA treatment resulted in the lowest accumulation of biomass. One of the main important factors in seedling production is the achievement of a well-developed plant with a high dry biomass that is able to overcome transplantation stress [40,41]. Increased tomato plant biomass with the addition of compost in potting media has also been reported by other authors [19,22,42].

The best seedling quality (seedling quality index) was found in the 40CPA treatment followed by the 40CA treatment. Apart from the 80CHA treatment, which presented the lowest seedling quality index, the rest of the compost-based treatments had no significant differences from the control. The lowest values were observed in the plants grown in the 80CHA substrate. High-quality seedlings grown in substrates with composts were also reported by Meng et al. [19], who obtained seedling quality indexes in plants grown in compost-based substrates that were higher than or comparable with the control treatment.

In this study, the high pH, EC, and salt concentration of the substrates did not negatively affect the tomato seedlings' growth thanks to the fast leaching that occurred during the 40-day trial (Tables 3 and 4), except in the 80CHA treatment, which presented the highest EC and pH levels. The best results for seedlings' growth were obtained when peat was substituted at a 50% rate with compost of garden pruning residues and *R. okamurae* algae (CPA) or compost of *R. okamurae* (CA) (40CPA and 40CA). In fact, among the compost-based substrates, 40CPA and 40CA presented better chemical characteristics, with lower initial levels of EC and phytotoxic elements, and higher concentrations of $H_2PO_4^-$, which is essential for the plants' growth. The results showed that the complete substitution of peat with CA and CPA also seemed possible, since, generally, no differences in the plants' morphological parameters were found among the 80CA, 80CPA, and control treatments. It is crucial to highlight that all compost-based treatments did not receive any external mineral nutrition supply, so the compost alone or mixed with enriched peat provided all the essential nutrients for the first plant growth phase. Moreover, the positive development of plants grown in these treatments was probably also due to the presence of hormone-like substances [16,24], such as fulvic and humic acid in the compost [43] that promoted plant development.

Overall, the results of this study are in line with the previous research [22,23], which obtained high-quality seedlings with the incorporation of compost into the potting media, even with initial EC and pH levels outside the optimal range. Tittarelli et al. [16] used substrates containing green compost and bovine manure compost, which achieved the best performance with the mixtures containing 30–50% compost, with a higher percentage of compost being responsible for a decline in the quality parameters. Along the same lines, Meng et al. [19] recommended 20–50% as the right rate for replacing peat with composted biogas residues and spent mushroom compost in the cultivation of tomato and pepper seedlings in nursery production. Herrera et al. [22] concluded that municipal waste compost can be used as a component of substrates to grow tomato seedlings at a 30% ratio, mixed with peat and perlite, with the initial substrates' EC reaching up to 13 dS m^{-1}, while they experienced adverse effects on seedlings with 60% compost in the substrate (an initial EC of up to 22 dS m^{-1}). If we compare the results of the present study with those of Herrera et al. [22], it seems clear that growing media with EC values up to 13 dS m^{-1}, with a customized irrigation program that allows for fast leaching of salt, are suitable for growing tomato seedlings. In substrates with an initial EC of up to 18 (such as 80CHA), a preliminary leaching treatment could be recommended.

4. Conclusions

It is concluded that the compost of garden pruning residues (two-thirds) and algae *R. okamurae* (one-third) (CPA), and the compost of algae *R. okamurae* (CA) can be used as ingredients of growing media, with satisfactory results in terms of seedlings' growth in substrate mixtures with 40% compost, 40% peat, and 20% perlite. Despite the high initial electrical conductivity (EC) found in these substrates, in nursery, the customary irrigation allowed a fast salt leaching. Only the EC level of 18.05 dS m^{-1} found in the 80CHA treatment (80% compost of horticultural residues and *R. okamurae* and 20% perlite) limited the development of seedlings.

The use of composts based on *R. okamurae* as a substrate medium in the production of tomato seedlings could be a suitable alternative for valorizing the algae biomass, allowing us to reduce the use of peat and mineral fertilizers. Thus, the proposed model could convert the intensive horticultural system to a more circular and sustainable one. However, it is important to mention that before the implementation of peat alternatives, validation by farmers and technicians is important.

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