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Improving Aerial and Root Quality Traits of Two Landscaping Shrubs Stem Cuttings by Applying a Commercial Brown Seaweed Extract

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Abstract: The availability of quality planting material is one of the most important requirements for increasing the productivity of any ornamental crop. Horticulturists make use of auxins and apply them exogenously to cuttings to generate adventitious roots and balanced shoots. Many studies have illustrated the influence of seaweed extracts on the growth of ornamental crops; their use in vegetative cutting propagation, to our knowledge, has been little investigated. Moreover, there is a lack of information on the influence of IBA and seaweed extract concentration on the carbohydrate content. This research aimed to compare the effects of the commercial seaweed extract, called Goteo®, with that of the phytohormone IBA, on the aerial and root quality traits of stem cutting in two Mediterranean landscaping shrubs: *Lantana camara* (S1) and *Abelia* × *grandiflora* (S2). The treatments applied to semi-hardwood stem cuttings were as follows: C0: untreated control; IBA concentration: 1250 mg L^{-1}; Goteo® concentrations at 1, 2, and 3 mL L^{-1}. In *L. camara*, the greatest values of rooting percentage were obtained under IBA and Goteo® treatments when compared to the control; in *A.* × *grandiflora*, there were no effects among treatments. The presented study shows that Goteo® stimulated adventitious rooting and provided a better rooting quality and shoot development of stem cuttings in Lantana and Abelia. In S1, cuttings treated with Goteo®, at the dose of 3 mL L^{-1}, were greater in the number of roots, growth traits, root morphology and carbohydrate content, than those treated with IBA. In S2, 1 mL L^{-1} Goteo® concentration could be recommended to obtain high-quality rooted stem cuttings.

Keywords: *Abelia* × *grandiflora*; biostimulants; carbohydrate contents; Goteo®; *Lantana camara*; vegetative propagation

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1. Introduction

Stem cuttings and micropropagation have been identified as the most important approaches for the production of large quantities of homogeneous and clonal plants in ornamentals, due the species diversity of this group [1]. As regards cutting propagation, two key issues are, on one hand, how to increase adventitious root percentage in recalcitrant species [2] and, on the other, how to increase the quality of rooted cuttings. The recalcitrance of cuttings to adventitious root development, in some economically valuable woody species, imposes treatments with exogenous auxins [3].

The quality of a rooted cutting is considered based on the morphological characteristics of the aerial parts and adventitious roots, which will determine their vigor, health, uniformity, and plant fast establishment [4,5]. Their capacity can vary greatly according to the following factors: the species [6], the carbohydrate content of the cutting [7], the rooting environment [8], the level of endogenous phytohormones such as auxins [9,10] and the application of biostimulators [11]. Indole-3-butyric acid (IBA) has been identified as an auxin precursor, therefore as an endogenous constituent in several plants that is

converted to 3-indoleacetic acid (IAA), the main hormone of the auxins group, in a peroxisomal β-oxidation process [12]. In species low in auxins in their leaves and shoots, exogenous auxins can be applied for the prevention of root death and improvement in the development and quality of adventitious roots [13–16], thereby ensuring greater success. In fact, over 30 commercial IBA-based products are registered by United States Environmental Protection Agency for use on fruit, ornamental and vegetable crops, classified as biochemical pesticides [17]; among these products, IBA is frequently used by ornamental farmers as a rooting promoter [18–21], to improve adventitious root quality [22] and to enhance transplant success [23]. Nowadays, there is an emerging market for alternative substances that improve the adventitious root quality, such as biostimulants. According to EU Regulation 2019/1009 [24]: "'Plant biostimulant' means a product stimulating plant nutrition processes, independently of the product's nutrient content, with the sole aim of improving one or more of the following characteristics of the plant or the plant rhizosphere: (a) nutrient use efficiency; (b) tolerance to abiotic stress; (c) quality traits; (d) availability of confined nutrients in soil or rhizosphere". What exactly is a biostimulant? It can consist of a blend of extracts, obtained from different natural raw materials, chosen according to many criteria, including the abundance of poly- and oligosaccharides, amino acids, minerals, vitamins, chitin, chitosan, or humic substances [25–28]. Biostimulants that are produced from seaweed extracts [29], especially from the brown alga *Ascophyllum nodosum* (L.) Le Jolis [30,31], have often proven to be useful due to the substantial content of molecules active in cell signaling, such as polysaccharides [32–35], polyphenols, peptides, and carotenoids [36], betaines, macro and micronutrients. Seaweed extracts also contain some essential phytohormones (e.g., auxins, gibberellins and cytokinins), accelerating metabolism and development [37,38], as well as other hormone-like substances [39–41]. While many studies have illustrated the value of seaweed extracts in promoting the growth, quality and yield when applied to the plant or to the rhizosphere of cereals, fruits, vegetables and ornamentals [42–44], their use in vegetative cutting propagation, to our knowledge, has been little investigated [45–48]. Moreover, there is a lack of information on the influence of IBA and seaweed extract concentrations on carbohydrate content.

Thus, this research aimed to compare the effects of the commercial seaweed extract, called Goteo®, with that of the phytohormone IBA, on the stem cutting quality traits of the aerial parts and roots of two Mediterranean landscaping shrubs, wild sage (*Lantana camara*) and glossy abelia (*Abelia* × *grandiflora*).

2. Materials and Methods

2.1. Rooting Environment

The experiment was conducted from 17 February to 8 April 2021 in a commercial propagation greenhouse situated in southern Italy (40°54′19.1″ N, 17°18′21.4″ E; 66 m a.s.l.). The cover material was an ethylene–vinyl acetate film with a net providing 50% shading. Throughout the experiment, the greenhouse environmental parameters imposed and measured were: air temperature ranging from a minimum (night) of 12 °C to a maximum (day) of 20 °C; seedbeds (bottom heating) at the temperature of 18 ± 1 °C and misting: 60 s at 20 min intervals, daily from 8 a.m. to 3 p.m.

2.2. Stock Mother Plants and Cuttings

Two landscaping shrubs were utilized: *Lantana camara* 'Little Lucky' (Fam. *Verbenaceae*, S1) and *Abelia* × *grandiflora* 'Edward Goucher' (Fam. *Caprifoliaceae*, S2). Fifteen mother plants were randomly selected per species, grown in 30 cm diameter pots in greenhouse conditions and regularly pruned to prevent flowering. Twenty-seven median and semi-hardwood stem tissue cuttings were taken from each mother plant (n = 405 cuttings per species). Each cutting was checked for uniformity, vigor, absence of disease, trueness to type, and a length of 5–6 cm, with three nodes, removing the basal leaves and maintaining six leaves per cutting.

2.3. Rooting Promoters and Cutting Propagation

Two types of rooting promoters were used: (i) a commercial phytohormone IBA (Rhizopon AA—Sigma, St. Louis, MO, USA); (ii) a commercial seaweed-based biostimulant: Goteo® (Goteo—Goactiv, UPL, Cesena, Italy), marked as G, which is a liquid preparation containing GA142, a biologically active filtrate from the seaweed *A. nodosum*, used as a source of auxins and cytokinins, polysaccharides and vitamins [49,50]. GA142 is complemented with organo-mineral fertilizers by the company (*w*/*v*): 13% P_2O_5, 5% K_2O, and 1.3–2.4% organic substances. Regarding the concentration, the company recommends 0.1% solution (1 mL L^{-1}) on vegetable crops, and does not provide a dosage for ornamentals. On the other hand, Gajc-Wolska [51] and Matysiak [52] recommended the dosage for hastening the rooting system regeneration as being equal to three to four treatments with a 0.2% solution (2 mL L^{-1}) every 2 weeks. On 17 February 2021, plastic trays (104 holes and 3.5 cm in diameter) were sanitized with a fresh chlorine solution: one part bleach (5.25% sodium hypochlorite) to nine parts water, giving a final strength of 0.5%. They were filled with paper cylinders containing a commercial growing medium consisting of a mixture of brown and blond *Sphagnum* peat and perlite (*v*:*v* = 80:20; pH 5.0–6.0; organic carbon, 35%; organic nitrogen, 0.8%; organic matter, 85%) and watered to saturation.

2.4. Experimental Design

For both species: S1 = *L. camara* 'Little Lucky' and S2 = *A.* × *grandiflora* 'Edward Goucher', the treatments applied were different concentrations (C) of bio root stimulators:

- ✓ C0, untreated control (distilled water);
- ✓ IBA: 1250 mg L^{-1};
- ✓ GC1: 1 mL L^{-1};
- ✓ GC2: 2 mL L^{-1};
- ✓ GC3: 3 mL L^{-1}

The basal end of the stem cutting (10 mm) was dipped into IBA solution and immediately planted into prepared seedling trays. A coated controlled-release fertilizer (Plantacote® Pluss NPK 14-9-15 with microelements, 2 months, Westdorpe, The Netherlands) at dose of 1 kg m^{-3} substrate, was applied to control and IBA treatments.

Starting from 17 February, Goteo® solutions were applied, using a hand sprayer until they run off the cutting' leaves, at two-week intervals, totaling three applications.

Treatments were laid out in a randomized complete block design of 15 experimental units (5 concentrations × 3 replicates) for each species. Each experimental unit was conducted using 27 cuttings (n = 405 cuttings per species).

2.5. Rooting Quality Traits

On 24 March (at 35 days after cutting—DAC), the number of roots (longer than 0.5 cm) per cutting was recorded. At the end of the experiment, 50 DAC, the rooted cutting percentage was assessed: i.e., number of rooted cuttings per total number of cuttings × 100. Data, expressed as a percentage, were subjected to arcsine square root transformation before ANOVA analysis. Ground dry weight (g) was measured: samples were dried on a stove at 70 ± 1 °C until constant humidity.

At 35 DAC, nine rooted cuttings per treatment were analyzed for the morphology of the adventitious rooting system. The substrate was gently washed away using a warm bath and then a brush. The roots were scanned at 400 dpi using an Epson v700 Perfection (Japan) scanner. The captured images were then processed using image analysis software (WinRHIZO v. 2005b©, Regent Instruments Inc., Québec, QC, Canada, www.regentinstruments.com accessed on 18 July 2022) for the identification of total root length, root surface area, root average diameter, number of root tips, forks and crossings.

2.6. Aerial Quality Traits

At 35 DAC, nine rooted cuttings per treatment were analyzed for aerial growth traits. Three new and fully opened leaves on the intact top of cutting were sampled for the analysis of chlorophyll index (SPAD) (Konica Minolta Chlorophyll Meter SPAD-502 Plus, Solna, Sweden). The number of leaves per cutting was counted and the total leaf area per rooted cutting was measured with a leaf area meter (Delta-T; Decagon Devices, Pullman, WA, USA). Subsequently, the cuttings were washed and each was separated into leaves, stems and roots. Above-ground dry weight (g) was measured: samples were dried on a stove at 70 ± 1 °C until constant humidity.

2.7. Biochemical Quality: Carbohydrates Content

Recent studies have demonstrated that the use of high-performance anion-exchange chromatography coupled with pulsed amperometric detection (HPAEC-PAD) for carbohydrate analysis results in highly selective and sensitive determination [53–55]. At 35 DAC, 15 samples per genotype (20 g above-ground fresh weight) were analyzed using the HPAEC-PAD method (Thermo Fisher Scientific, Sunnyvale, CA, USA, Thermofisher.com accessed on 18 July 2022). Samples were filtered (0.45 µm) before analysis and injected with an AS40 automated sampler (Dionex, Sunnyvale, CA, USA). An anion exchange CarboPac™ PA1 column (Thermo Fisher Scientific) was used for the separation of glucose, fructose and sucrose. The AOAC 996.11 [56] method was used for the assessment of starch content, determined by the Megazyme Total Starch Assay kit, K-TSTA 05/06 (Megazyme International Ireland Ltd., Bray Business Park, Bray, Co., Wicklow, Ireland), which is based on the amyloglucosidase/α-amylase method. All sugar analyses were performed in triplicate and results are expressed on a mg g^{-1} dry-weight basis.

2.8. Statistical Analysis

We performed a one-way analysis of variance (ANOVA) within each species to test the effects of different concentrations of the rooting promoters on rooting performance and morphology, rooted cutting morphological traits and carbohydrates contents. All the above data analyses were performed using SAS version 9.3 statistical software (SAS, 1999); treatment means were separated by the SNK (Student–Newman–Keuls) test ($p \leq 0.05$).

3. Results

In *L. camara* (S1), the greatest values of rooting percentage (Table 1) were obtained under IBA (91.7%) and Goteo® treatments (in average 87.9%), compared to the control (80.7%). In *A.* × *grandiflora* (S2), ANOVA did not reveal any significant effects in comparison with the different treatments (Table 1). In terms of the number of roots per cuttings, in *L. camara* (Table 1), the highest value (15.7) was found in cuttings treated with GC3, a value that was 51% greater than that achieved with IBA. Conversely, in *A.* × *grandiflora*, the highest values of roots per cutting were obtained with applications of IBA, GC1 and GC2 (9.8, 10.7 and 9.3 respectively), i.e., an average value of 44% greater than the control (Table 1).

Table 2 shows the effects of different concentrations of rooting promoters on morpho-biometric parameters: in both species, foliar-spray applications of Goteo® biostimulant increased the number of leaves per cutting when compared to the IBA (S1: 5.0, S2: 12.2) and control treatments (S1: 4.7, S2: 12.3), but there were no differences between the different concentrations: in *L. camara*, high values ranged from 6.7 with GC1 to 8.1 for GC3, with an average increase of 48% compared to IBA; in *A.* × *grandiflora*, this was from 13.8 (GC3) to 15.1 (GC2), with an average increase of 18% when compared to IBA. Table 2 also shows, in *L. camara*, a statistically significant increase in leaf area (62.5%) that was recorded for the cuttings treated with GC3 (11.7 cm^2) over those treated with IBA (7.2 cm^2); in *A.* × *grandiflora*, Goteo® treatments increased the leaf area values when compared to IBA (in average + 14%) and the control (in average + 34%), but there were no significant differences between GC1, GC2 and GC3. ANOVA revealed significant effects

on the chlorophyll index (Table 2): in particular, regarding *L. camara*, the application of GC1, GC2 and GC3 resulted in the highest values of SPAD (352, 336 and 342, respectively) compared to IBA (328) with an average increase of 5%; in *A.* × *grandiflora*, the maximum SPAD values were achieved by the GC1 and GC2 treatments, respectively being 442 and 458, with an average increase of 16% compared to IBA (386).

Table 1. Rooting percentage (%) and roots per cutting (no.) at 50 days after cutting in *Lantana camara* (S1) and *Abelia* × *grandiflora* (S2) influenced by rooting promoters at different concentrations (C).

TMTS	Rooting Percentage (%)		Roots per Cutting (No.)	
	S1	S2	S1	S2
C0	80.7 ± 2.9 b	93.3 ± 2.1 a	9.2 ± 0.6 c	6.9 ± 0.2 c
IBA	91.7 ± 0.9 a	93.9 ± 2.1 a	10.4 ± 0.3 bc	9.8 ± 0.3 a
GC1	89.6 ± 0.7a	92.3 ± 1.5 a	10.8 ± 0.4 bc	10.7 ± 0.4 a
GC2	86.7 ± 3.4 ab	90.7 ± 1.8 a	12.3 ± 0.5 b	9.3 ± 0.4 a
GC3	87.3 ± 1.7 ab	90.1 ± 3.8 a	15.7 ± 0.9 a	7.3 ± 0.5 bc

Different letters mean significant differences within parameters (S.N.K. test, $p \leq 0.05$; mean ± SD, $n = 3$). IBA: Indole-3-Butyric Acid; G: commercial seaweed extract Goteo®; C0, untreated control; IBA: 1250 mg L^{-1}; GC1: 1 mL L^{-1}; GC2: 2 mL L^{-1}; GC3: 3 mL L^{-1}.

Table 2. Aerial morpho-biometric traits: leaves per cutting (no.), leaf area per cutting (cm^2) and chlorophyll index (SPAD) in *Lantana camara* (S1) and *Abelia* × *grandiflora* (S2), influenced by rooting promoters at different concentrations (C).

TMTS	Leaves per Cutting (No.)		Leaf Area per Cutting (cm^2)		Chlorophyll Index (SPAD)	
	S1	S2	S1	S2	S1	S2
C0	4.7 ± 0.3 b	12.3 ± 0.7 b	6.4 ± 0.6 b	13.4 ± 0.7 c	323 ± 15 b	343 ± 20 b
IBA	5.0 ± 0.2 b	12.2 ± 0.3 b	7.2 ± 0.4 b	15.8 ± 0.3 b	328 ± 15 b	386 ± 17 b
GC1	6.7 ± 0.1 a	14.2 ± 0.3 a	6.8 ± 0.5 b	18.4 ± 0.3 a	352 ± 19 a	442 ± 35 a
GC2	7.4 ± 0.1 a	15.1 ± 0.2 a	9.2 ± 0.9 b	18.8 ± 0.3 a	336 ± 12 a	458 ± 7 a
GC3	8.1 ± 0.1 a	13.8 ± 0.3 a	11.7 ± 0.9 a	16.9 ± 1.0 a	342 ± 8 a	420 ± 9 ab

Different letters mean significant differences within parameters (S.N.K. test, $p \leq 0.05$; mean ± SD, $n = 3$). IBA: Indole-3-Butyric Acid; G: commercial seaweed extract Goteo®; C0, untreated control; IBA: 1250 mg L^{-1}; GC1: 1 mL L^{-1}; GC2: 2 mL L^{-1}; GC3: 3 mL L^{-1}.

Table 3 shows the above-ground and ground dry weight per cutting under different concentrations of rooting promoters. The application of the Goteo® biostimulant showed positive effects on the above-ground dry weight of both species: in lantana, a statistically significant value was obtained with the highest Goteo® concentration, GC3 (0.141 g), which resulted in a 75 and 55% increase when compared to the IBA treatment (0.084 g) and control (0.091 g), respectively. A different response was observed in *A.* × *grandiflora* (Table 3): the highest value was found in cuttings treated with GC2 (0.20 g), with an increase of 43% compared to IBA (0.14 g). Similar results were obtained regarding the ground dry weight.

Data on root morphological features are provided in Tables 4 and 5. In *L. camara*, applications of Goteo® biostimulant led to improvements in root length and root surface area compared to both IBA treatment and control (Table 4), but with no differences resulting from the different concentrations. In S1, IBA application improved the root length approximately two-fold (649 mm) and the root area by a third (96 mm^2) as compared to the untreated cuttings (370 mm and 60 mm^2). Compared to the IBA treatment, the cuttings treated with Goteo® increased, on average, the root length by 27% and the surface area by 47%. In *A.* × *grandiflora* (Table 4), on the contrary, the applications of IBA and also GC1 and GC2 determined the greatest root length (391, 396 and 336 mm, respectively) and root surface area values (67, 70 and 61 mm^2, respectively). Table 4 also shows that regarding root diameter, in *L. camara* the greatest value (0.60 mm) was achieved in the cuttings treated with

GC2, which was 22.4% higher than the IBA treatment (0.49 mm); while in *A.* × *grandiflora*, the differences from the various treatments showed no statistical significance.

Table 3. Above-ground and ground dry weight (g) in *Lantana camara* (S1) and *Abelia* × *grandiflora* (S2), influenced by rooting promoters at different concentrations (C).

TMTS	Dry Weight per Cutting (g)			
	Above-Ground		Ground	
	S1	S2	S1	S2
C0	0.091 ± 0.007 b	0.145 ± 0.012 b	0.031 ± 0.003 c	0.030 ± 0.001 b
IBA	0.084 ± 0.009 b	0.143 ± 0.012 b	0.041 ± 0.003 bc	0.033 ± 0.003 b
GC1	0.111 ± 0.015 ab	0.180 ± 0.009 ab	0.044 ± 0.003 bc	0.045 ± 0.003 ab
GC2	0.120 ± 0.012 ab	0.201 ± 0.011 a	0.062 ± 0.010 ab	0.053 ± 0.001 a
GC3	0.141 ± 0.014 a	0.174 ± 0.009 b	0.080 ± 0.003 a	0.032 ± 0.003 b

Different letters mean significant differences within parameters (S.N.K. test, $p \leq 0.05$; mean ± SD, $n = 3$). IBA: Indole-3-Butyric Acid; G: commercial seaweed extract Goteo®; C0, untreated control; IBA: 1250 mg L^{-1}; GC1: 1 mL L^{-1}; GC2: 2 mL L^{-1}; GC3: 3 mL L^{-1}.

Table 4. Root morphological traits: root length (mm), root surface area (mm^2) and average root diameter (mm) in *Lantana camara* (S1) and *Abelia* × *grandiflora* (S2), influenced by rooting promoters at different concentrations (C).

TMTS	Root					
	Length (mm)		Surface Area (mm^2)		Diameter (mm)	
	S1	S2	S1	S2	S1	S2
C0	370 ± 23 c	166 ± 16 b	60 ± 5 c	25 ± 3 c	0.52 ± 0.01 b	0.48 ± 0.03 a
IBA	649 ± 38 b	391 ± 5 a	96 ± 6 b	67 ± 5 a	0.49 ± 0.02 b	0.52 ± 0.06 a
GC1	794 ± 53 a	396 ± 5 a	125 ± 10 a	70 ± 3 a	0.51 ± 0.03 b	0.56 ± 0.03 a
GC2	810 ± 41 a	336 ± 24 a	148 ± 9 a	61 ± 3 a	0.60 ± 0.01 a	0.55 ± 0.01 a
GC3	874 ± 29 a	244 ± 38 b	150 ± 7 a	42 ± 2 b	0.56 ± 0.02 ab	0.50 ± 0.02 a

Different letters mean significant differences within parameters (S.N.K. test, $p \leq 0.05$; mean ± SD, $n = 3$). IBA: Indole-3-Butyric Acid; G: commercial seaweed extract Goteo®; C0, untreated control; IBA: 1250 mg L^{-1}; GC1: 1 mL L^{-1}; GC2: 2 mL L^{-1}; GC3: 3 mL L^{-1}.

Table 5. Root morphological traits: root tips (no.), forks (no.) and crossings (no.) in *Lantana camara* (S1) and *Abelia* × *grandiflora* (S2), influenced by rooting promoters at different concentrations (C).

TMTS	Root					
	Tips (No.)		Forks (No.)		Crossings (No.)	
	S1	S2	S1	S2	S1	S2
C0	45 ± 2 d	32 ± 3 c	197 ± 4 d	79 ± 3 c	30 ± 3 c	13 ± 1 c
IBA	97 ± 6 c	73 ± 3 a	430 ± 11 c	239 ± 4 a	81 ± 1 b	38 ± 1 a
GC1	114 ± 5 b	68 ± 9 a	477 ± 14 c	242 ± 11 a	83 ± 3 b	38 ± 1 a
GC2	116 ± 6 b	37 ± 3 c	613 ± 35 b	136 ± 3 b	84 ± 4 b	23 ± 2 b
GC3	137 ± 5 a	53 ± 2 b	694 ± 16 a	128 ± 5 b	106 ± 2 a	19 ± 1 b

Different letters mean significant differences within parameters (S.N.K. test, $p \leq 0.05$; mean ± SD, $n = 3$). IBA: Indole-3-Butyric Acid; G: commercial seaweed extract Goteo®; C0, untreated control; IBA: 1250 mg L^{-1}; GC1: 1 mL L^{-1}; GC2: 2 mL L^{-1}; GC3: 3 mL L^{-1}.

In *L. camara*, the application of GC3 resulted in significant increases in the number of tips, forks and crossings (41, 61 and 31%, respectively) compared to results from IBA application (97 tips, 430 forks, 81 crossings); in *A.* × *grandiflora*, the maximum values for the same traits were instead obtained with IBA (73 tips, 239 forks, 38 crossings) and GC1 (68 tips, 242 forks, 38 crossings) (Table 5).

Tables 6 and 7 show the influence of rooting promoters, at different concentrations, on some biochemical parameters related to the carbohydrate contents. When compared to the control, a higher starch content (Table 6) in *L. camara* was recorded in the cuttings rooted

under IBA (3.36 mg g^{-1}d.w.), GC1 (3.03 mg g^{-1}d.w.), GC2 (3.00 mg g^{-1}d.w.) and GC3 (3.13 mg g^{-1}d.w.), without statistical differences between these treatments; conversely, in *A.* × *grandiflora*, the highest increase in starch content was obtained by GC1 (7.30 mg g^{-1}d.w.) and GC2 (7.40 mg g^{-1}d.w.) application, which was on average 18% greater than IBA treatment (6.23 mg g^{-1}d.w.). In terms of glucose content (Table 6), in *L. camara*, treatment with both IBA and GC1 achieved statistically significant increases, with values recorded respectively at 0.231 and 0.216 mg g^{-1}d.w. In *A.* × *grandiflora*, GC2 treatment resulted in an increase of 11% over the lowest value, which was recorded for the treatment with IBA (0.517 mg g^{-1}d.w.). In *L. camara*, the data on fructose content sustained the trend recognized for glucose: IBA and GC1 treatments again resulted in the highest contents (0.176 and 0.180 mg g^{-1}d.w., respectively), without statistically significant difference between the two results, followed by the untreated cuttings and GC2 (0.154 and 0.169 mg g^{-1}d.w., respectively). Cuttings treated with GC3 returned the lowest value (0.137 mg g^{-1}d.w.) In line with this trend, in *A.* × *grandiflora*, GC2 treatment induced a 54% increase in fructose over IBA treatment (Table 6).

Table 6. Biochemical parameters: starch, glucose and fructose (mg g^{-1}d.w.) in *Lantana camara* (S1) and *Abelia* × *grandiflora* (S2), influenced by rooting promoters at different concentrations (C).

TMTS	Starch		Glucose		Fructose	
	(mg g^{-1} Dry Weight—d.w.)					
	S1	S2	S1	S2	S1	S2
C0	2.43 ± 0.26 b	6.93 ± 0.03 b	0.193 ± 0.014 b	0.682 ± 0.031 c	0.154 ± 0.009 b	0.527 ± 0.035 c
IBA	3.36 ± 0.03 a	6.23 ± 0.17 c	0.231 ± 0.002 a	0.517 ± 0.012 d	0.176 ± 0.002 a	0.515 ± 0.021 c
GC1	3.03 ± 0.09 a	7.30 ± 0.06 a	0.216 ± 0.005 a	0.995 ± 0.034 a	0.180 ± 0.005 a	0.753 ± 0.012 a
GC2	3.00 ± 0.11 a	7.40 ± 0.01 a	0.199 ± 0.004 b	1.090 ± 0.030 a	0.169 ± 0.003 b	0.794 ± 0.024 a
GC3	3.13 ± 0.03 a	6.90 ± 0.06 b	0.170 ± 0.002 c	0.913 ± 0.023 b	0.137 ± 0.003 c	0.703 ± 0.013 b

Different letters mean significant differences within parameters (S.N.K. test, $p \leq 0.05$; mean ± SD, $n = 3$). IBA: Indole-3-Butyric Acid; G: commercial seaweed extract Goteo®; C0, untreated control; IBA: 1250 mg L^{-1}; GC1: 1 mL L^{-1}; GC2: 2 mL L^{-1}; GC3: 3 mL L^{-1}.

Table 7. Biochemical parameters: sucrose and total carbohydrates (mg g^{-1}d.w.) in *Lantana camara* (S1) and *Abelia* × *grandiflora* (S2), influenced by rooting promoters at different concentrations (C).

TMTS	Sucrose		Total Carbohydrates	
	(mg g^{-1} Dry Weight—d.w.)			
	S1	S2	S1	S2
C0	0.014 ± 0.001 b	0.088 ± 0.009 c	2.792 ± 0.290 b	8.232 ± 0.033 b
IBA	0.018 ± 0.001 a	0.052 ± 0.001 d	3.785 ± 0.033 a	7.314 ± 0.208 c
GC1	0.019 ± 0.001 a	0.112 ± 0.007 b	3.445 ± 0.066 a	9.201 ± 0.057 a
GC2	0.018 ± 0.001 a	0.130 ± 0.003 b	3.386 ± 0.115 a	9.414 ± 0.057 a
GC3	0.018 ± 0.001 a	0.580 ± 0.015 a	3.455 ± 0.033 a	9.096 ± 0.058 a

Different letters mean significant differences within parameters (S.N.K. test, $p \leq 0.05$; mean ± SD, $n = 3$). IBA: Indole-3-Butyric Acid; G: commercial seaweed extract Goteo®; C0, untreated control; IBA: 1250 mg L^{-1}; GC1: 1 mL L^{-1}; GC2: 2 mL L^{-1}; GC3: 3 mL L^{-1}.

Concerning sucrose (Table 7), in *L. camara* the different treatments did not yield any significant differences in content; in *A.* × *grandiflora*, maximum sucrose values were found with GC3 (0.580 mg g^{-1}d.w.), showing an increase of 559% when compared to untreated samples, and an increase of 1015% when compared to cuttings treated with IBA.

The use of IBA and GC1, GC2 and GC3 enhanced the content of total carbohydrates in *L. camara* without statistically significant differences, resulting in higher values (3.78, 3.44, 3.38 and 3.45 mg g^{-1}d.w., respectively) than the control (2.79 mg g^{-1}d.w.). A different response was observed in *A.* × *grandiflora*: the highest total carbohydrate contents were found in the cuttings treated with GC1, GC2 and GC3, but without any statistically

significant differences; on average they were 28.8% greater than those achieved with IBA (Table 7).

4. Discussion

Efficient adventitious rooting is a key process in the vegetative propagation of woody ornamental species. A well-rooted cutting is essential for optimal growth and high-quality plants. IBA, involved in plant growth and development processes [57] has been identified in a wide variety of plants by gas chromatography mass spectrometry (GC-MS) and high performance liquid chromatography (HPLC). IBA is extracted by using ionic liquid-modified silica gel as a sorbent [58] and used in the formulation of commercial rooting enhancers, such as Rhizopon, in the nursery production of ornamental woody cuttings. The findings presented in this study confirm that the application of IBA-based products improved the rooted cuttings of both species when compared to the untreated control, in line with previous results obtained in many other woody plants [59,60]. The presented study shows that Goteo® stimulated adventitious rooting and provided better rooting quality and shoot development of stem cuttings in Lantana and Abelia: in our experimental conditions, the application of Goteo® gave the same results when compared to IBA in the rooting percentage of wild sage (S1) cuttings (Table 1), which is in agreement with Pacholczak et al. [47] in *Physiocarpus opulifolius* 'Dart's Gold' cuttings. In addition, lantana cuttings treated with Goteo® showed higher rooting percentage values when compared to untreated controls (Table 1); similar results were achieved by Kapczynska et al. [61] in *Pennisetum* 'Vertigo'. The biostimulators that were applied were effective in stimulating the emission of a large number of roots (Table 1): Pacholczak and Nowakowska [48] in ground cover roses, Elfrid 'Kormuse', showed that the application of IBA and Goteo® stimulated the same degree of rooting. Several biological effects of A. nodosum extracts have been reported in different species [62], including the enhancement of aerial quality traits (Table 2): Rayorath et al. [63] showed the increase of leaves in Arabidopsis at a low concentration. Ratore et al. [64] showed that the beneficial effects of improved vegetative growth could be triggered by auxins and cytokinins. The leaf greenness index (SPAD), a measure of the relative chlorophyll content of leaves, also increased in the cuttings of both species when commercial seaweed extract was applied, compared to IBA and control treatments (Table 2); a similar outcome was observed in *Cornus alba* 'Aurea' and 'Elegantissima' [65]. The application of biostimulators, generally, results in an increased concentration of photosynthetic pigments that are closely associated with the plant's photosynthetic activity and carbohydrate levels [66]. Among the exogenous factors involved in rooting there are mineral nutrients, which are involved in many metabolic processes associated with differentiation and root meristem formation, which is essential for root initiation [67]. The increased root and vegetative growth following the Goteo® application could partly be due to generally higher phosphorus levels (a fertilizer response) and not only due to the contribution of the seaweed extract (hormone-like stimulation), as P is known to enhance root growth, in accordance with what Lötze and Hoffman [68] highlighted in the analysis of the nutrient composition and content of the various biological active compounds in three South African-based commercial seaweed biostimulants. In S1, the above-ground and ground dry weight was found to be the highest in GC3 cuttings (Table 3), in line with several research efforts that found a dramatic effect of biostimulants in biomass production [69]. A different behavior was observed in S2 cuttings (Table 3) since the optimal dose of application appears to be a species-specific response [70]. In our study, GC1, GC2 and GC3 positively affected both root length and root surface area in *L. camara* compared to IBA treatments (Table 4). On the contrary, Traversari et al. [71], showed that in the 'Michelangelo' rose, 4000 ppm IBA + NAA was the best treatment to promote root length cuttings when compared to the commercial Phylgreen biostimulant. Our findings showed that the application of IBA and the biostimulant Goteo® increase the concentration of total carbohydrates in S1 cuttings (Table 7). This is in line with previous work on historical roses [72,73]. Potassium (K) is required for stomatal conductance, net photosynthesis, phloem loading of

photo-assimilates, and as a signaling molecule ands decentralized energy storage [74]. The potassium contained in the Goteo® biostimulator could lead to increased sucrose in the leaves, leading to its loading in the phloem and transport to the roots for storage as starch (Table 6). The importance of carbohydrate reserves in leaves for the rooting performance of ornamental cuttings is well-known: sufficient reserves are indispensable for an balanced development of adventitious roots [7,75,76] and to prevent senescence of leaves during rooting [77]. A considerable portion of sucrose is converted to starch, which probably acts as the major carbon source when the adventitious roots grow [78]. In *Pinus radiata* cuttings, sucrose applied to the propagation substrate leads to higher levels of sugars and starch-enhancing root formation [79]. Traversari et al. [71] compared the total soluble sugars content of control cuttings treated with distilled water with those of cuttings treated with phytohormones: auxins or 22(S), 23(S)—homobrassinolide, or two commercial products based on seaweed extracts: Kelpak® and Phylgreen in 'Michelangelo®' and 'Cosmos®' scented roses. After 16 days of the treatments, the soluble sugar content was lower than the previous days in all treatments and, moreover, it was lower under Phylgreen treatment than for the control cuttings in cv. 'Michelangelo®'. In contrast, Monder and Pacholczak [73] showed that for the 'Duchesse d'Angoulême' rose, a higher concentration of reducing and total carbohydrates in shoots, at the phenological stage in which the flower buds are closed, contributed to a better quality of the root system. In our study, Goteo® increased the level of total carbohydrates in S2 by 12% (Table 7). The improvement of the plant's metabolism was also observed in cuttings of *Physocarpus opulifolius* [47] and *Hydrangea paniculata* [80]. Agricultural use of seaweed extracts such as Goteo® biostimulator is therefore in agreement with the idea of a sustainable and circular economy [81–83].

5. Conclusions

The availability of quality planting material is one of the most important requirements for increasing the productivity of any ornamental crop. Horticulturists make use of auxins and apply them exogenously to cuttings to generate adventitious roots and a balanced shoots. In our research IBA has been successfully used for the rooting of cuttings of woody landscaping species, but currently the panorama of biostimulators has expanded, including algae extracts enriched with organo-mineral fertilizers. As demonstrated in this study, the commercial biostimulator Goteo® improved the aerial and root quality traits of ornamental cuttings. In wild sage (S1), cuttings treated with Goteo®, at the dose of 3 mL L^{-1}, were greater in number of roots, growth traits, root morphologies and carbohydrates content than those treated with IBA. In glossy abelia (S2), a concentration of 1 mL L^{-1} Goteo® could be recommended to obtain high-quality rooted stem cuttings. Based on our knowledge, there is a scarcity of reports focused on the use of seaweed extract, compared to IBA application, in landscape plant cutting propagation. The relation between seaweed-based substances and the quality of ornamental propagation material has yet to be deeply investigated; further studies are needed to evaluate the effect of the biostimulators on the hormonal and nutritional status of plants and, since a biostimulator is a mixture of many compounds, it should be compared with the use of complex chemical treatments, including fertilizers, anti-stressants and trace elements.

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