Effect of Rooting Promoters on the Rooting and Growth of Cuttings in Several Flowering Shrubs

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ABSTRACT

This study was conducted to investigate the effects of rooting promoters on rooting and seedling quality in *Buddleja davidii* 'Empire Blue', *Hydrangea paniculata* 'Magical Candle', *Hydrangea arborescence* 'Annabelle', *Stephanandra incisa* semi-hardwood cuttings. IAA and IBA (500, 1000, or 1500 mg·L⁻¹ soaking for 30 minutes and 3,000 mg·L⁻¹ dipping for 10 seconds) or Rootone™ were used as rooting promoter. In *B. davidii* 'Empire Blue', IBA 1,500 mg·L⁻¹ soaking reduced rooting percentage than control, but the effect of rooting promoters was generally insignificant. Number of leaves and shoot length were reduced in Rootone™ and IBA 1,500, 3,000 mg·L⁻¹ treatments. IAA 1,000~3,000 mg·L⁻¹ and IBA 500 mg·L⁻¹ treatments showed better mat formation than control. The rooting ratio of *H. paniculata* 'Magical Candle' increased to 66.7% in IBA 1,500 mg·L⁻¹ soaking treatment compared with 26.4% in the control. The mat formation was higher in Rootone™, IAA and IBA treatments compared to control, and root length showed longer tendency in IAA and IBA except Rootone™. The rooting ratio of *H. arborescence* 'Annabelle' was highest at 70.8% in the control and auxin treatments showed negative effect on the rooting percentage except IAA 1,000 mg·L⁻¹ soaking treatment. The mat formation was very poor in IBA 1,000 and 1,500 mg·L⁻¹ soaking at 1.1 and 1.3, respectively. *S. incisa* showed high rooting percentage at Rootone™ (80%) and IAA 1,500 mg·L⁻¹ (80%) treatments compared to control (51.7%). Root length and dry weight were high in IAA 1,500 mg·L⁻¹ soaking treatment. As a result, *B. davidii* 'Empire Blue' and *H. arborescence* 'Annabelle' did not need rooting promoter for stem cuttings, and IBA 1,500 mg·L⁻¹, IAA 1,500 mg·L⁻¹ soaking treatments could be used to improve rooting and seedling quality of *H. paniculata* 'Magical Candle' and *S. incisa* semi-hardwood cuttings, respectively.

Keywords: butterfly bush, lace shrub, panicle hydrangea, smooth hydrangea

Introduction

As the culture of gardening has expanded recently, the demand for flowering shrubs for gardens has also continued to increase. Various types of flowering shrubs for gardens are distributed, but most species have been traded on a small scale, except those that have been widely used for landscaping such as *Rhododendron* spp, *Ligustrum obtusifolium*, *Spireae* spp. and *Sasa borealis* (Park, 2013). This is attributable to the facts that the awareness of plants that can be used for gardening is low, and that technologies to mass-produce and cultivate potential plants for stable production and supply have not been established.

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Buddleja davidii, commonly called butterfly bush, continues to bloom colorful flowers throughout summer. It can pass the winter well in the central region of Korea because of cold tolerance. It is also resistant to high temperature and dry conditions, and various varieties have been developed. Thanks to its high usability for gardening, it is widely used for potting and cuttings overseas. It is propagated mostly through the tissue culture of leaf explants (Dai and Castillo, 2007) and softwood cutting (Montgomery et al., 1995).

Hydrangea including *Hydrangea macrophylla*, *Hydrangea serrata*, *H. paniculata* and *H. arborescence*, is widely used for gardening, potting and cutting, and the size of cultivation has continued to increase (RDA, 2003). *H. arborescence* was first introduced to Korea as an alternative for gardening to *Hydrangea macrophylla*, a less cold-resistant plant, and it has been also used for cutting. The demand for *Hydrangea* plants has increased, and various varieties with different colors and shapes have been developed. However, earlier studies on mass-production focused on the softwood cuttings of *Hydrangea macrophylla* (Ruffoni et al., 2012; Ku and Cho, 2014) and *Hydrangea serrata* (Lee et al., 2009; Ryu et al., 2010), but only few studies were conducted on *H. paniculata* and *H. arborescence*.

Stephanandra incisa is an indigenous species found in the mountains and fields of Korea. As its small but simple flowers cover trees and have high ornamental values, it is often planted as a boundary tree in landscape projects, and the demand for *Stephanandra incisa* has increased as well. Those of similar names in Korea such as *Physocarpus intermedius* and *Physocarpus opulifolius* have been planted widely in gardens (Kim, 2007). *Stephanandra incisa* is known to be propagated using softwood cutting or root cutting techniques, but there was no official report on them.

For the propagation of shrubs, cutting techniques are mostly used to maintain the characteristics of shrubs and reduce the time that it takes to start to flower. The rooting and the quality of seedlings when using cutting techniques are affected by various factors such as the timing of cutting (Ko et al., 2007; Lee et al., 2002, 2007), the size and the number of leaves of cuttings (Kil, 2014; Lee et al., 2009), soil for cuttings (Lee et al., 2009), plant growth regulators (Yoo and Kim, 1996; Lee et al., 2007), etc.

Auxin plant growth regulators such as IAA (indole acetic acid), IBA (indole butyric acid) and NAA (naphtalene acetic acid) increase the rooting ratio and the number of roots of plants that cannot be easily propagated by cutting, reduce the time that it takes to start to root, and also improve the quality of seedlings, thus being widely used for commercial plants (Hartmann et al., 2002; Blythe et al., 2007). The effects of rooting promoters differ depending on the type of auxins (Ryu et al., 2010), the concentration level and treatment methods of auxins (Blythe et al., 2007), the type of plants (Chadwick and Kiplinger, 1938), etc. and thus it is necessary to find the right type of auxin and the proper concentration level and treatment method for each plant in order to improve the efficiency of cutting propagation.

In this regard, this study aimed to examine the effects of different auxins and concentration levels on the rooting and the quality of seedlings when propagating those that can be used widely including *B. davidii* 'Empire Blue,' *H. paniculata* 'Magical Candle,' *H. arborescence* 'Annabelle,' and *S. incisa* using cutting techniques, and to develop fundamental technologies for the stable mass-production of these flowering shrubs.

Methods

Plant materials and experimental environment

The following four shrub species that were planted on open grounds in the National Institute of Horticultural and Herbal Science located in Wanju-gun, Jeonbuk, Korea were selected as a plant material in this study: *B. davidii* 'Empire Blue,' *H. paniculata* 'Magical Candle,' *H. arborescence* 'Annabelle,' and *S. incisa*. semi-hardwood branches after growing shoots were collected before 9 a.m. on June 28, 2016, and were dipped in water for an hour. After that, two leaves were attached

and the length of each plant was prepared as follows: *S. incisa* (10 cm), *B. davidii* 'Empire Blue' (12 cm), *H. paniculata* 'Magical Candle' (15 cm), and *H. arborescence* 'Annabelle' (15 cm).

To reduce the dryness of leaves caused by transpiration, two thirds of the length of the leaves of *H. paniculata* 'Magical Candle' and *H. arborescence* 'Annabelle,' and one half of the length of the leaves of *B. davidii* 'Empire Blue' were cut, but the leaves of *S. incisa* were not cut since their length was not long enough.

This study was conducted in a greenhouse in the National Institute of Horticultural and Herbal Science for three months from June 28 to September 28, 2016. To prevent any damage by direct sunlight, the cutting bed in the green house was covered with 70% black shade net, and the average temperature of the cutting bed was maintained at $25 \pm 2^\circ\text{C}$. In addition, the relative humidity of the greenhouse was maintained at over 80% using an automatic mist sprayer to prevent the dryness of leaves caused by excessive transpiration, and the greenhouse was ventilated two to three times per day to prevent any damage by excessive moisture.

The effects of rooting promoters

To examine the effects of different auxins, used as a rooting promoter, and their different concentration levels on rooting and seedling quality, Rootone (1-naphthylacetamide 0.4%, Dongbu Hitek, Korea), IAA (Duchefa, Netherlands), and IBA (Duchefa, Netherlands) were used as a rooting promoter. The bottom of the prepared cuttings for control and Rootone treatment was soaked in water for 30 minutes and their cut section was coated with Rootone. The bottom of the prepared cuttings in the groups treated with IBA and IAA was soaked in 500, 1,000 or 1,500 $\text{mg} \cdot \text{L}^{-1}$ IBA or IAA respectively for 30 minutes, and in 3,000 $\text{mg} \cdot \text{L}^{-1}$ for 10 seconds, and the cuttings were planted in a 72-cell tray filled with the soil mixed with vermiculite (Verminuri, GFC Co., Korea) and perlite (Paraso, Samson Co., Korea) at the ratio of 2:1 (v:v). Each treatment (24 units per treatment) was repeated three times. This experiment was conducted using a completely randomized design.

Growth measurement and statistical analysis

After three months of planting cuttings, the rooting ratio, mat formation, root length, the number of shoots, the number of leaves, shoot length, and the fresh and dry weight of roots and shoots were measured. Mat formation was divided into five stages (1: very poor, 5: very good), and the longest root was measured as root length. The dry weight of roots and shoots was measured after drying them in a dryer (80°C) for two days.

Data were analyzed using SAS Package (statistical analysis system, ver Enterprise Guide 7.1, SAS Institute Inc.), and significance between the groups was verified using ANOVA (analysis of variance) and Duncan's multiple range test (5% significance level).

Results and discussion

The effect of rooting promoters on the rooting ratio of *B. davidii* 'Empire Blue' was low overall, and the rooting ratio of the group treated with IBA 1,500 $\text{mg} \cdot \text{L}^{-1}$ (soaked for 30 minutes) was lower than that of the control group (Table 1). The number of leaves and the length of shoots of the groups treated with Rootone, IBA 1,500 $\text{mg} \cdot \text{L}^{-1}$ (soaked for 30 minutes) and 3,000 $\text{mg} \cdot \text{L}^{-1}$ (dipped for 10 seconds) were low, indicating that the growth of shoots was suppressed. The number of shoots and roots differed depending on the type and concentration level of auxins, but the length of shoots, and the fresh and dry weight of shoots were affected only by the concentration level of auxins, not their type.

Table 1. Effect of auxin treatments on the rooting and shoot growth according to semi-hardwood cuttings in *Buddleja davidii* ‘Empire Blue’.

Treatment (mg·L ⁻¹)	Rooting ratio (%)	Mat formation ^z	Root length (cm)	No. of shoots (ea)	No. of leaves. (ea)	Shoot length (cm)	Root weight		Shoot weight		
							F.W. (g)	D.W. (mg)	F.W. (g)	D.W. (mg)	
Control	91.7 a ^z	3.2 c	7.9 a-c	1.8 a	14.4 ab	10.8 a	145.3 b	32.3 de	473.0 ab	188.8 a-c	
Rootone	86.7 ab	3.9 a-c	6.7 bc	1.9 a	10.5 cd	5.3 cd	241.0 ab	38.7 de	316.7 ab	111.1 bc	
IAA	500	95.0 a	3.8 a-c	8.5 ab	1.8 a	17.7 a	9.0 ab	140.0 b	25.2 e	383.7 ab	137.6 a-c
	1,000	88.3 ab	4.2 ab	9.2 a	1.9 a	17.6 a	7.7 a-c	238.3 ab	41.2 c-d	462.3 ab	150.6 a-c
	1,500	98.0 a	4.4 ab	7.9 a-c	1.9 a	13.7 bc	8.1 a-c	313.0 a	51.0 a-d	564.7 a	170.2 a-c
	3,000	88.3 ab	4.1 ab	8.5 ab	1.9 a	16.1 ab	7.7 a-c	220.0 ab	35.5 de	420.9 ab	137.7 a-c
IBA	500	85.0 ab	4.6 a	8.5 ab	1.9 a	15.1 ab	9.6 a	139.0 b	70.4 a	497.7 ab	207.3 ab
	1,000	83.3 ab	3.6 bc	8.4 ab	2.0 a	14.3 ab	6.0 b-d	147.3 b	45.7 b-e	206.0 b	103.2 c
	1,500	71.7 b	3.8 bc	6.1 c	1.6 b	8.8 d	3.9 d	232.7 ab	62.0 a-c	219.3 b	107.2 c
	3,000	90.0 ab	3.8 bc	6.1 c	1.6 b	8.6 d	3.8 d	303.3 a	67.7 ab	555.3 a	221.9 a
Source of variation ^x											
Auxin type (A)	ns ^w	ns	ns	*	**	ns	ns	ns	ns	*	
Concentration (B)	ns	ns	ns	**	**	**	*	*	**	**	
A*B	**	ns	ns	ns	ns	ns	ns	ns	*	*	

^z1 (very poor), 2 (poor), 3 (normal), 4 (good), 5 (very good).^yMean separation within columns by Duncan's multiple range test at 5% level.^xAnalysis of variation was performed only between IBA and IAA treatments.^wns, *, ** non-significant, significant at $P < 0.05$ or $P < 0.01$ respectively.

The mat formation of cuttings in IAA 1,000, 1,500 mg·L⁻¹ (for 30 minutes), and 3,000 mg·L⁻¹ (for 10 seconds) and IBA 500 mg·L⁻¹ (for 30 minutes) was higher than that of the control group. However, since the rooting ratio of the control group was very high (91.7%), and the growth of the cuttings in Rootone and IBA 1,500 mg·L⁻¹ (for 30 minutes) and 3,000 mg·L⁻¹ (for 10 seconds) was suppressed, it can be concluded that rooting promoters are not necessary. Still, IAA 1,000, 1,500 mg·L⁻¹ (for 30 minutes) and 3,000 mg·L⁻¹ (for 10 seconds) and IBA 500 mg·L⁻¹ (for 30 minutes) can be also used depending on the mat formation of cuttings in order to improve the quality of seedlings.

Montgomery et al. (1995) reported that the rooting ratio of *B. davidii* ‘Empire Blue’ planted using green wood cutting techniques can be improved to 94~95% by dipping its cuttings once in a water soluble auxin (K-IBA, 1,500~6,000 mg·L⁻¹), but that the higher the concentration level, the higher the number of roots, and the shorter the length of roots, not affecting the weight of roots. In this study, the length of roots decreased when cuttings were dipped in IBA 1,500 mg·L⁻¹ for 30 minutes and 3,000 mg·L⁻¹ for 10 seconds, showing similar results (Table 1). In terms of the rooting ratio of *B. davidii*, there was no or little significant difference between the control group and the treated groups. The result that the growth of shoots of the groups treated with Rootone (NAA 0.4%) or high concentration levels of IBA was suppressed more than the groups treated with IAA was not found in the study of Montgomery et al. (1995), but one reason behind it is that the cuttings used in this study were not softwood cuttings but semi-hardwood cuttings.

The rooting ratio of cuttings of *H. paniculata* ‘Magical Candle’ dipped in IBA 1,500 mg·L⁻¹ for 30 minutes was 66.7%, up by 40.3% from that of the control group (26.4%) (Table 2). It was found that the rooting ratio of cuttings was affected by the type of auxins and its concentration level respectively, and that the rooting ratio of cuttings dipped in IBA was higher than that of cuttings dipped in IAA. It was also found that the higher the concentration level of IBA, the higher the rooting ratio of cuttings, but that the rooting ratio of cuttings dipped in a high concentration (IBA 3,000 mg·L⁻¹, for 10

Table 2. Effect of auxin treatments on the rooting and shoot growth according to semi-hardwood cuttings in *Hydrangea paniculata* 'Magical Candle'.

Treatment (mg·L ⁻¹)		Rooting ratio (%)	Mat formation ^z	Root length (cm)	No. of shoots (ea)	No. of leaves. (ea)	Shoot length (cm)	Root weight		Shoot weight	
								F.W. (g)	D.W. (mg)	F.W. (g)	D.W. (mg)
Control		26.4 e ^y	3.9 b	6.5 ab	0.2 d	0.9 d	1.0 e	24.6 c	5.7 a-c	17.8 c	3.0 c
Rootone		13.9 f	4.8 a	4.0 b	1.1 b-d	4.0 a-c	6.3 d	31.7 bc	3.9 c	31.4 c	11.8 bc
IAA	500	19.4 f	4.1 ab	7.7 a	0.9 cd	1.9 cd	4.4 de	28.2 bc	5.6 a-c	31.3 c	8.6 bc
	1,000	26.4 e	4.8 a	7.9 a	1.3 a-c	3.0 a-d	8.8 b-d	43.6 a-c	6.7 a-c	63.7 bc	20.1 b
	1,500	44.4 c	5.0 a	7.6 a	2.1 a	4.2 ab	11.8 a-c	62.6 a	9.3 a	63.1 bc	36.8 a
	3,000	26.4 e	4.8 a	8.6 a	1.3 a-c	2.2 b-d	8.1 b-d	50.3 a-c	8.4 ab	49.4 bc	18.9 b
IBA	500	34.7 d	4.8 a	7.7 a	1.6 a-c	2.2 b-d	8.7 b-d	28.2 bc	8.9 a	58.8 bc	20.9 b
	1,000	52.8 b	4.9 a	6.8 ab	1.9 ab	2.4 b-d	12.9 ab	54.6 ab	7.6 ab	100.6 ab	35.7 a
	1,500	66.7 a	5.0 a	7.3 a	2.1 a	2.8 a-d	14.6 a	47.8 a-c	7.3 a-c	117.1 a	43.0 a
	3,000	45.8 c	4.4 ab	7.8 a	1.3 cd	4.8 a	7.2 cd	33.3 bc	8.4 a	60.8 bc	18.4 b
Source of variation ^x											
Auxin type (A)		** ^w	ns	ns	ns	ns	ns	ns	ns	*	*
Concentration (B)		**	ns	ns	*	ns	**	ns	ns	ns	**
A*B		ns	ns	ns	ns	*	ns	ns	**	ns	ns

^z1 (very poor), 2 (poor), 3 (normal), 4 (good), 5 (very good).^yMean separation within columns by Duncan's multiple range test at 5% level.^xAnalysis of variation was performed only between IBA and IAA treatments.^wns, *, ** non-significant, significant at $P < 0.05$ or $P < 0.01$ respectively.

seconds) decreased.

The mat formation of the groups treated with Rootone, IAA and IBA was higher than that of the control group. The root length of the groups treated with IAA and IBA, except Rootone, also tended to be longer than the control group, although there was no statistical significance. The number of shoots and leaves and the length of shoots of the groups treated with Rootone, IAA and IBA were higher than the control group. These tended to continue to increase until the concentration level reached 3,000 mg·L⁻¹ (dipped for 10 seconds) since the groups treated with IAA and IBA were affected by their concentration levels. Therefore, it can be concluded that dipping cuttings of *H. paniculata* 'Magical Candle' in IBA 1,500 mg·L⁻¹ for 30 minutes is effective, but it will be necessary to conduct additional studies in order to increase its rooting ratio.

In the case of *H. arborescence* 'Annabelle,' the rooting ratio of the groups treated with rooting promoters, except IAA 1,000 mg·L⁻¹ (soaked for 30 minutes), was lower than that of cuttings in the control group (70.8%), indicating that they suppressed the rooting of cuttings (Table 3). The mat formation of the cuttings of the groups dipped in IBA 1,000 and 1,500 mg·L⁻¹ for 30 minutes was very low, 1.1 and 1.3 respectively, but that of the other treated groups showed similar results to that of the control group. It was found that the number of shoots and leaves, and the length of shoots are affected by the type of auxins, and that they were higher in the groups treated with IAA, regardless of its concentration level, than in the groups treated with IBA. Therefore, it can be concluded that *H. arborescence* 'Annabelle' shows a relatively high rooting ratio and maintains a high quality of seedlings without rooting promoters. However, since the rooting ratio of the control group was relatively higher than the treated groups, it will be necessary to conduct additional studies on the effects of low concentration levels of auxins below 500 mg·L⁻¹ to improve its rooting ratio.

It was reported that the cuttings of *H. macrophylla* dipped in IBA 500~1,000 mg·L⁻¹ for 30 minutes (Ku and Cho,

Table 3. Effect of auxin treatments on the rooting and shoot growth according to semi-hardwood cuttings in *Hydrangea arborescens* 'Annabelle'.

Treatment (mg·L ⁻¹)		Rooting ratio (%)	Mat formation ^z	Root length (cm)	No. of shoots (ea)	No. of leaves. (ea)	Shoot length (cm)	Root weight		Shoot weight	
								F.W. (g)	D.W. (mg)	F.W. (g)	D.W. (mg)
Control		70.8 a ^y	3.3 a	8.1 ab	0.9 a-c	3.3 a-c	1.2 a	7.8 bc	4.5 a	11.1 bc	4.9 bc
Rootone		37.5 c	3.4 a	8.5 ab	0.0 d	0.0 c	0.0 c	5.9 bc	4.6 a	0.0 c	0.0 c
IAA	500	54.2 b	2.9 a	6.5 bc	1.1 a-c	5.1 ab	1.4 ab	5.4 bc	3.1 a-c	10.2 bc	5.4 bc
	1,000	66.7 a	3.3 a	7.7 ab	1.3 ab	6.7 a	2.2 a	13.8 a-c	4.6 a	45.2 a	18.0 a
	1,500	20.3 d	3.1 a	7.9 ab	1.1 a-c	6.7 a	1.9 a	17.3 a-c	4.6 a	19.3 bc	8.0 bc
	3,000	21.7 d	3.4 a	9.5 a	1.4 a	7.2 a	2.1 a	26.6 a	5.7 a	33.3 ab	12.5 ab
IBA	500	19.2 d	3.2 a	9.1 ab	0.6 b-d	3.1 a-c	0.8 bc	20.6 ab	3.8 ab	17.2 bc	5.4 bc
	1,000	7.3 e	1.1 b	4.4 cd	0.0 d	0.0 c	0.0 c	3.6 c	0.9 c	0.0 c	0.0 c
	1,500	3.3 e	1.3 b	2.3 d	0.3 cd	2.0 bc	0.7 bc	7.3 bc	1.2 c	3.3 c	1.6 c
	3,000	50.0 b	3.7 a	9.0 ab	1.1 a-c	4.9 ab	2.1 a	25.8 a	5.0 a	33.3 ab	12.5 ab
Source of variation ^x											
Auxin type (A)		** ^w	ns	ns	**	**	**	ns	*	**	**
Concentration (B)		**	*	*	*	ns	ns	*	*	ns	ns
A*B		**	*	*	ns	ns	*	ns	*	*	*

^z1 (very poor), 2 (poor), 3 (normal), 4 (good), 5 (very good).^yMean separation within columns by Duncan's multiple range test at 5% level.^xAnalysis of variation was performed only between IBA and IAA treatments.^wns, *, ** non-significant, significant at $P < 0.05$ or $P < 0.01$ respectively.

2014), and that the green wood cuttings of *H. macrophylla* for. *acuminata* dipped once in IBA 500 mg·L⁻¹ (Lee et al., 2007) or dipped in IBA 50 mg·L⁻¹ for 3 hours (Park and Kim, 1993); and the cuttings of *H. paniculata* dipped in IBA 1,000 mg·L⁻¹ + NAA 500 mg·L⁻¹ for 1 second (Blythe et al., 2003) showed better rooting showed improved rooting ratios. The semi-hardwood cuttings of *H. paniculata* 'Magical Candle' dipped in IBA showed similar rooting ratios to the results of the studies above, but the rooting ratio was relatively low (66.7%). This can be attributable to various factors, including the characteristics of the 'Magical Candle' variety, and using semi-hardwood cuttings.

The rooting ratio of the cuttings of *S. incisa* dipped in Rootone and IAA 1,500 mg·L⁻¹ for 30 minutes was higher (80%) than that of the control group (51.7%) (Table 4). The maximum length and the dry weight of roots of cuttings dipped in IAA 1,500 mg·L⁻¹ for 30 minutes were high (8.1 cm and 25.7 mg respectively), and the number, length and dry weight of shoots were also high. The mat formation of cuttings dipped in 3,000 mg·L⁻¹ for 10 seconds showed a normal level (3.4), and that of cuttings in the other treated groups was very low (all below 2.3). The number of shoots and leaves, and the dry weight of shoots were affected by the type and concentration level of auxins respectively, but the length of shoots, the fresh and dry weight of roots, and the fresh weight of shoots were affected only by the concentration level of auxins regardless of the type of auxins. Therefore, it seems to be more effective to soak *S. incisa* in IAA 1,500 mg·L⁻¹ for 30 minutes in order to improve its rooting ratio and seedling quality, but it will be still necessary to conduct additional studies to improve its mat formation.

These results indicated that IBA was effective for *H. paniculata* 'Magical Candle' (Table 2), while IAA was more effective for the cuttings of *H. arborescence* 'Annabelle' and *S. incisa* (Table 3, 4). The reason behind it seems to be that different types of auxins are suitable for different types of plants. It was reported that IBA is more effective in general for the rooting and growth of shoots than NAA or IAA (Dirr, 1992; Lee et al., 2007; Ryu et al., 2010), and that IBA is more

Table 4. Effect of auxin treatments on the rooting and shoot growth according to semi-hardwood cuttings in *Stephandra incisa*.

Treatment (mg·L ⁻¹)		Rooting ratio (%)	Mat formation ^z	Root length (cm)	No. of shoots (ea)	No. of leaves. (ea)	Shoot length (cm)	Root weight		Shoot weight	
								F.W. (g)	D.W. (mg)	F.W. (g)	D.W. (mg)
Control		51.7 bc ^y	1.8 ab	6.5 ab	1.0 a	4.5 a	2.1 ab	16.0 c	14.7 bc	55.0 bc	32.3 bc
Rootone		80.0 a	2.3 ab	6.1 ab	0.9 ab	3.0 b-d	1.6 a-c	68.7 ab	20.3 ab	89.0 ab	39.3 ab
IAA	500	55.0 bc	1.7 ab	7.4 a	1.0 a	4.1 a-c	1.5 a-c	40.3 a-c	17.3 a-c	64.0 bc	28.6 b-d
	1,000	50.0 bc	1.0 b	6.6 ab	0.7 bc	2.3 de	1.0 cd	12.0 c	8.5 c	19.3 c	9.2 e
	1,500	80.0 a	2.3 ab	8.1 a	1.0 a	4.3 ab	2.2 a	76.3 a	25.7 a	125.0 a	51.1 a
	3,000	60.0 a-c	2.3 ab	6.6 ab	1.0 a	4.3 ab	1.9 a-c	40.3 a-c	18.4 a-c	88.0 ab	35.7 a-c
IBA	500	50.0 bc	2.0 ab	6.4 ab	0.9 ab	2.6 de	1.3 b-d	56.3 a-c	17.4 a-c	50.0 bc	21.2 b-e
	1,000	66.7 ab	1.9 ab	5.1 b	0.6 c	1.4 e	0.5 d	25.7 bc	11.4 bc	34.6 c	12.4 de
	1,500	36.7 c	1.4 ab	6.6 ab	0.7 bc	2.8 cd	1.9 ab	47.3 a-c	13.4 bc	49.0 bc	17.8 c-e
	3,000	71. ab	3.4 a	6.7 ab	0.9 a	3.3 a-d	1.9 ab	52.3 a-c	19.6 ab	87.3 ab	32.8 bc
Source of variation ^x											
Auxin type (A)		ns ^w	ns	ns	*	**	ns	ns	ns	ns	*
Concentration (B)		ns	ns	ns	**	**	**	*	*	**	**
A*B		**	ns	ns	ns	ns	ns	ns	ns	*	*

^z1 (very poor), 2 (poor), 3 (normal), 4 (good), 5 (very good).^yMean separation within columns by Duncan's multiple range test at 5% level.^xAnalysis of variation was performed only between IBA and IAA treatments.^wns, *, ** non-significant, significant at $P < 0.05$ or $P < 0.01$ respectively.

effective in a low concentration level than IAA (Ludwig-Müller et al., 1993). However, it was also reported that IAA is more effective for green wood cuttings of *Abeliophyllum distichum* (Yoo and Kim, 1996), *Juniperus chinensis* var. *sargentii*, (Song et al., 2010), and *Rosa davurica* (Lee et al., 2000), IAA was more effective, and that NAA is more effective for *Rhododendron brachycarpum* (Hwang et al., 2015) and *Rosa davurica* (Lee et al., 2000) than IBA. Considering these results, it can be concluded that the type and concentration level of auxins suitable for cuttings differ depending on the species or variety of plants.

Conclusions

The results above indicated that rooting promoters are not needed for the mass-production of *B. davidii* 'Empire Blue' and *H. arborescence* 'Annabelle' using cutting techniques. It was found that *S. incisa* and *H. paniculata* 'Magical Candle' need to be soaked in IAA 1,500 mg·L⁻¹ and IBA 1,500 mg·L⁻¹ for 30 minutes respectively in order to improve their rooting ratio and seedling quality. It will be necessary to conduct additional studies on methods to increase the mat formation of *H. arborescence* 'Annabelle' and *S. incisa*.

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