



# Effects of Bed Soils and Plant Growth Regulators on Root Growth of *Hibiscus syriacus* L.

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## ABSTRACT

**Background and objective:** As the COVID-19 pandemic gripped the entire world and people found themselves spending more time at home, many households began gardening, and purchased various ornamental plants. Many cultivars of *Hibiscus syriacus* are grown for their showy flowers, or used as landscape shrubs. *H. syriacus* is generally known for its high rate of asexual reproduction. However, it is known that the effectiveness of propagation by cuttings can have big differences depending on internal and external factors. This study was conducted to determine the effects of optimal rooting bed soil composition and auxin on the rooting of *H. syriacus* cuttings.

**Methods:** Cuttings used in this study were from 17 cultivars. As types of bed soil for propagation by cutting, gardening bed soil, sand, mixed soil 1, and mixed soil 2 were used, and the plant growth regulators of IBA and NAA were applied at 500, 1000, and 1500 mg · L<sup>-1</sup> concentrations.

**Results:** The rooting rate and number of roots were highest with the combination of perlite and vermiculite. On the other hand, the gardening bed soil showed an extremely low rooting percentage. The root growth was improved in most cultivars when treated by plant growth regulator. The highest rooting rate was verified at IBA 500 mg · L<sup>-1</sup> treatment while the number of roots and root length showed good result in IBA 1500 mg · L<sup>-1</sup> treatment.

**Conclusion:** In many cultivars, it was observed that the rooting rate and number of roots differed depending on the bed soil. The most suitable bed soil for the cuttings was a mixture of peat moss and vermiculite, and it was possible to increase the efficiency through treatment with a growth regulator, and the efficiency of IBA was better than that of NAA. However, it is necessary to identify which detailed growth regulator treatment is suitable for the root development of each cultivar, because plant growth regulator was less effective and even problematic in some cultivars.

**Keywords:** Garden plant, Auxin, IBA, NAA, Propagation, Rooting percentage

## Introduction

As the COVID-19 pandemic gripped the entire world in the early part of 2020, many people found themselves quarantined at home for weeks, or even months. As people spent more time at home, the garden market grew in scale (Gabellini and Scaramuzzi, 2022). The propagation and growing of ornamental plants is one of the most profitable sectors of the garden market (Darras, 2020). This is why it is so important to constantly introduce new species and cultivars, particularly those with a long ornamental season

and different flowering times (Wani et al., 2018).

Unlike most ornamental plants that bloom in spring, *Hibiscus syriacus* L. (Rose of Sharon), an important garden plant representative of summer, has nearly 3 months of flowering time from July to September, and there are more than 350 cultivars of this plant that have been developed worldwide (Lee et al., 2020).

*H. syriacus* is generally known to have high reproductive capacity and can be easily propagated through vegetative methods, such as cutting and grafting (Ha et al., 2013). However, the quality of the plants obtained through vegeta-

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tive propagation techniques can vary greatly. Roots of certain cultivars do not develop sufficiently, thereby demanding additional treatment, such as grafting and sealed cutting (Souza et al., 2015).

Propagation through cuttings is mainly used to secure high quality plants and vegetative propagation of excellent cultivars. The technique is known for producing plants with highly variable quality, depending on internal (age, nutrition status, and hormone content), as well as external factors (temperature, humidity, and soil properties). In this case, soil properties and plant growth regulators can be manipulated to increase production efficiency (Hartmann et al. 2002).

The soil's chemical and physical properties not only influence the rooting percentage and speed of root growth, but also directly mold the shape of roots (Miller and Jones, 1995). Usually, it is necessary to use one or a combination of various bed soils, such as vermiculite, peat moss, perlite, or coconut coir, to successfully stimulate root development. Plant growth regulators, such as auxin, cytokine, gibberellin, ethylene, and abscisic acid (ABA) show diverse effects on plant development, depending on the method of application and concentration used (Campbell et al., 1999). For this reason, it is important to control external factors according to the specific purpose in each case. Plant auxins are known to be involved in cell growth stimulation and promotion of root development through their enhancement of the number of roots and rooting percentage (Overvoorde et al., 2010).

The 'Creation and Management of Forest Resources Act' was amended in 2017 as social interest in *H. syriacus* rapidly increased, therefore many local governments and public organizations are planting *H. syriacus* pursuant to this Act (Kwon et al., 2017). Thus, it has become a priority to develop production technologies that can guarantee the stable distribution of high-quality cultivars of interest.

Previous studies on *H. syriacus* cutting propagation have focused on the environment required for the propagation of cuttings to increase the rooting percentage and the physiological characteristics for cuttings (Kwon et al., 2011). Some researchers have compared the root development and growth characteristics of various *H. syriacus* cultivars, and classified some cultivars that are difficult to propagate by cutting methods (Lee et al., 1998). However, there is little

information about improving the production efficiency of such cultivars, which are not easily propagated through cuttings.

The present study compared the growth and development of cuttings cultured in soils with different properties and treated with plant growth regulators. The purpose of the study was to identify the optimal conditions for the stable propagation of *H. syriacus* cultivars, and thus solve the current problems associated with field-grown cuttings.

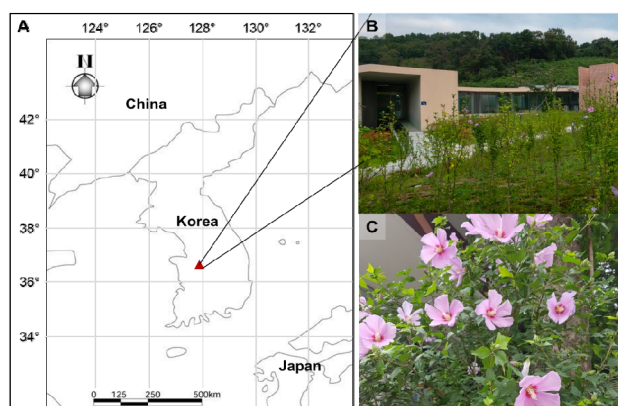
## Research Methods

### Plant materials

*H. syriacus* cuttings (Semi-hard wood, 10cm in length, 5 mm in diameter) collected from Jeon-wol mountain Rose of Sharon park (36°30'N, 127°17'E) in South Korea were provided by the City of Sejong in mid-March (Fig. 1). Cuttings in this study were of 17 domestic and foreign cultivars, including 'Kojumong' and 'Coelestis,' which recorded rooting percentages of under 40% in field cutting propagation surveys examined in 2021 (Table 1).

### Methods and measurements

Thirty cuttings of every cultivar were planted on a cutting bed (52 × 31 × 10 cm) at 3 cm intervals. Cuttings were irrigated in a greenhouse at 60% humidity and an



**Fig. 1.** *H. syriacus* cutting collection site in South Korea. **A.** A map of the *H. syriacus* cutting collection site. The red triangle indicates Jeon-wol mountain Rose of Sharon park. **B.** *H. syriacus* plants in Rose of Sharon park. **C.** *H. syriacus* flower.

**Table 1.** Cultivar name and rooting rate of *H. syriacus* cultivars examined in this study. The cultivars used in this study had a low rooting rate of less than 40% in the field cutting propagation experiment in 2021

Cultivar name	Rooting rate in 2021 (%)	Cultivar name	Rooting rate in 2021 (%)
Kojumong	20.4	Hanso	38.9
Samchulri	30.0	Hwahong	25.6
Sowol	20.0	Elegantissimus	26.0
Hanmaum	36.7	Hongsun	30.0
Hamabo	9.0	Hwarang	18.0
Woodbridge	1.3	Pyonghwa	25.6
Chungmu	30.0	Saehan	31.0
Coelestis	12.0	Soltanshim	6.7
Pink giant	3.3	-	-

ambient temperature of 20 to 25°C. Two months later, we recorded rooting percentage, number of roots, root length, leaf length and width, and new twig length. The number of > 1 mm diameter roots was recorded to represent the number of roots; the length of the longest root was measured to represent root length; the longest and widest leaves were representative of leaf length and leaf width; and the longest twigs represented new twig length.

### Bed soils

We investigated root and shoot growth of *H. syriacus* cuttings in various prepared mixtures of soils for propagation by cutting, including gardening bed soil (Hanareum, Shinsung, Korea), sand, mixed soil 1 (peat moss: vermiculite: granite, 1 : 1 : 1, v/v/v), and mixed soil 2 (perlite: vermiculite, 1 : 1, v/v).

### Plant growth regulators

The mixed soil 2, which promoted the highest rooting rate, was used as the basic culture medium for investigating reproduction differences according to the type and concentration of plant growth regulators. IBA (57310-25G-F, Sigma, USA) and NAA (N0640-25G, Sigma, USA) were diluted to 500, 1000, and 1500 mg · L<sup>-1</sup>, and the base of each cutting was dipped into an aqueous solution of auxins with corresponding concentrations for 10 mins.

### Statistical analysis

SPSS (Statistical Package for Social Sciences) 18.0 was used for the analysis of the experimental data. One-way analysis of variance (One-way ANOVA) and Duncan's multiple range test were conducted at 5% significance level to detect treatment differences.

## Results and Discussion

### The effects of bed soil on the growth of cuttings

In many cultivars, differences in rooting rate and number of roots depending on the bed soils were observed. However, leaf length and width and the length of new twigs and roots did not exhibit any significant difference in most cultivars. The rooting rate according to bed soil was highest in mixed soil 2. On the other hand, the gardening bed soil showed an extremely low rooting percentage. Even when roots emerged, the tips of the roots were rotten or showed poor growth. This soil type was thus considered unsuitable for the propagation of *H. syriacus* cuttings. Soffer and Burger (1988) and Yoshida et al. (1992) reported that the root growth of cuttings was affected by the physicochemical properties of the bed soil. In addition, the physical properties of the bed soil directly affect the growth of the root (Marin et al., 2022). Therefore, it is considered that the good root growth in a mixed soil 2 in this experiment is due to it having better water retention and air permeability compared to other soils.

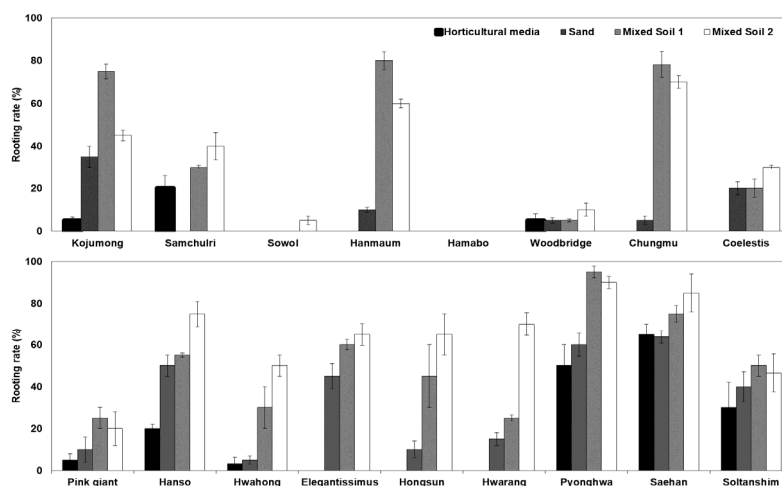
The number of roots was also higher in mixed soil 2.

The rooting rate and root growth of the *H. syriacus* cultivars being studied varied with the type of bed soil; however, most of the cultivars showed high rooting rates in the mixed soil. Some cultivars, including 'Hanmaum' and 'Chungmu,' showed considerable differences in rooting percentage depending on the bed soil. For this reason, it is highly important to choose a suitable bed soil for the successful propagation of cuttings. Conversely, neither 'Sowol,' 'Hamabo' or 'Woodbridge' germinated well in any bed soil, and showed a low rooting percentage (under 10%). These cultivars will require additional treatment for propagation by cutting (Fig. 2).

Eleven cultivars, including 'Kojumong', showed significant differences in the number of roots depending on the bed soil. However, other than these cultivars there were no significant differences. Outstanding root growth was observed in most cultivars in mixed soil, with the exception of 'Coelestis.' Notably, 'Kojumong,' 'Hanmaum' and 'Pyonghwa' developed

the greatest number of roots in the peat moss: vermiculite: granite mixed soil. The remaining 8 cultivars produced the most roots in the perlite: vermiculite mixed soil (Table 2).

Some studies have examined the effects of soil type and composition on the root growth of horticultural plants, including rose and *Hydrangea serrata*. Similar to our find-



**Fig. 2.** Effect of bed soils on the rooting rate of the 17 *H. syriacus* cultivars. Mixed Soil 1 (peat moss : vermiculite : granite, 1 : 1 : 1, v/v/v); Mixed Soil 2 (perlite : vermiculite, 1 : 1, v/v).

**Table 2.** Effect of bed soils on the number of roots of the 17 *H. syriacus* cultivars

Cultivar name	Horticultural media	Sand	Mixed soil 1 <sup>z</sup>	Mixed soil 2 <sup>y</sup>
Kojumong	1 <sup>c*</sup>	2.3 <sup>bc</sup>	6.9 <sup>a</sup>	4.8 <sup>ab</sup>
Samchulri	1	0	2.3	3
Sowol	0	0	0	1
Hanmaum	0 <sup>c</sup>	1 <sup>bc</sup>	3.8 <sup>a</sup>	2.7 <sup>ab</sup>
Hamabo	0	0	0	0
Woodbridge	1 <sup>b</sup>	2 <sup>b</sup>	1 <sup>b</sup>	7.5 <sup>a</sup>
Chungmu	0 <sup>b</sup>	1 <sup>ab</sup>	2.8 <sup>ab</sup>	4.6 <sup>a</sup>
Coelestis	0 <sup>b</sup>	2.3 <sup>a</sup>	1.3 <sup>b</sup>	2.0 <sup>a</sup>
Pink giant	3	1	3	4.5
Hanso	1.5 <sup>b</sup>	2.5 <sup>b</sup>	2.2 <sup>b</sup>	5.1 <sup>a</sup>
Hwahong	1 <sup>b</sup>	1 <sup>b</sup>	1.3 <sup>b</sup>	4.6 <sup>a</sup>
Elegantissimus	0 <sup>c</sup>	2.2 <sup>bc</sup>	2.8 <sup>ab</sup>	4.8 <sup>a</sup>
Hongsun	0 <sup>b</sup>	2.5 <sup>ab</sup>	3 <sup>ab</sup>	6.2 <sup>a</sup>
Hwarang	0 <sup>b</sup>	2.3 <sup>b</sup>	3.6 <sup>ab</sup>	7.3 <sup>a</sup>
Pyonghwa	1.9 <sup>b</sup>	5.7 <sup>ab</sup>	8.6 <sup>a</sup>	7.8 <sup>a</sup>
Saehan	3	3	3.9	3.7
Soltanshim	1.2	2	3.4	2.8

Note. <sup>z</sup>Peat moss : vermiculite : granite (1 : 1 : 1, v/v/v) mixed soil.

<sup>y</sup>Perlite : vermiculite (1 : 1, v/v) mixed soil.

\*Means in each row followed by different letters show statistical differences using Duncan's test ( $p < .05$ ).

ings, the observed rooting percentage was high in mixed soils, while relatively shorter and thicker roots were observed in the unmixed soil (Choi et al., 2000; Lee et al., 2009).

Bed soils consist of a solid, a gas, and an aqueous phase. A variety of substances can be combined in varying proportions to control aeration and water retention. When large particles are mixed together, soil porosity increases, allowing better aeration, while water retention decreases (Miller and Jones, 1995; Whitcomb, 2003). The gardening bed soil used in our experiments had a large water retention capacity. However, it is expected that the rooting percentage will be reduced due to poor aeration and high humidity, as the soil particles were small.

Hartmann et al. (2002) indicated that bed soil for propagation by cutting should have good water retention capacity, and thereby be able to provide sufficient moisture to help cuttings maintain their vitality until they develop roots. They also reported that good aeration is important to ensure a sufficient oxygen supply for the development of adventitious roots. Based on these findings, we believe that the mixture of vermiculite featuring high water retention capacity with granite or perlite will increase the

aeration capacity for successful propagation of cuttings.

### The effects of plant growth regulator on the growth of cuttings

Among the surveyed characteristics, neither leaf length, leaf width, or length of new twig showed any difference related to the type or concentration of plant growth regulator treatment. In contrast, most cultivars showed significant differences in root growth characteristics, such as rooting rate, number of roots, and root length.

The average rooting rates for plant growth regulator type and concentration treatment were: NAA 500 mg · L<sup>-1</sup> (45.3%), NAA 1000 mg · L<sup>-1</sup> (46.2%), NAA 1500 mg · L<sup>-1</sup> (55.9%), IBA 500 mg · L<sup>-1</sup> (72.2%), IBA 1000 mg · L<sup>-1</sup> (68.8%), and IBA 1500 mg · L<sup>-1</sup> (60.4%).

A low-concentration treatment of IBA was most effective for stimulating the root growth of cuttings. IBA treatment promoted a higher rooting percentage compared to NAA. The rooting percentage tended to increase with decreasing IBA concentration and increasing NAA concentration (Table 3). These findings are similar to those re-

**Table 3.** Effect of growth regulator treatments on rooting rate of the 17 *H. syriacus* cultivars

Cultivas name	Control (%)	NAA 500 mg · L <sup>-1</sup> (%)	NAA 1000 mg · L <sup>-1</sup> (%)	NAA 1500 mg · L <sup>-1</sup> (%)	IBA 500 mg · L <sup>-1</sup> (%)	IBA 1000 mg · L <sup>-1</sup> (%)	IBA 1500 mg · L <sup>-1</sup> (%)
Kojumong	45	85	70	75	85	75	95
Samchulri	40	40	25	70	70	30	75
Sowol	5	10	0	0	40	30	25
Hanmaum	60	40	40	40	40	40	75
Hamabo	0	5	15	10	75	85	20
Woodbridge	10	5	15	30	50	50	50
Chungmu	70	70	70	75	60	90	40
Coelesis	30	15	20	40	35	15	75
Pink giant	20	0	25	40	40	40	60
Hanso	75	75	50	70	90	65	55
Hwahong	50	20	45	55	90	95	66.7
Elegantissimus	65	65	50	60	90	90	100
Hongsun	65	60	70	70	70	90	20
Hwarang	70	45	40	65	80	95	75
Pyonghwa	90	90	100	85	100	100	55
Saehan	85	80	70	65	95	85	85
Soltanshim	45	65	80	100	100	95	55

ported by Lee and Hong (2003), which showed that IBA was most effective among the auxins to foster the root growth of *H. hamabo* (Hamabo mallow), and that the growth of plants treated with NAA was weaker compared to the controls. Al-Salem and Karam (2001) observed that auxin concentration had the greatest impact on root growth of stem cuttings in several tree species. They also found that neither the type nor the chemical composition of the auxins were significant. However, the *H. syriacus* cultivars used in the present study demonstrated varying degrees of root growth depending on the type of plant growth regulator administered. Therefore, we conclude that the selection of a plant growth regulator is important for effective propagation.

The number of roots and root length averaged 12.7 and 45 mm in the IBA 1500 mg · L<sup>-1</sup> treatment, respectively. This treatment was identified as optimal for maximum enhancement of root growth in *H. syriacus* cuttings (Tables 4, 5). Treating cuttings with plant growth regulators increases the plant respiration, thereby facilitating the accumulation of amino acids and growth improvement (Strydom and Hartman, 1960). Hartmann et al. (2002) reported IBA

as the best rooting stimulant with fast auxin activity and maximum enduring effect. In the present study, the variables associated with root growth responded positively to IBA treatment. Therefore, IBA is a better plant growth regulator than NAA to ensure the stable growth of cuttings.

'Hamabo,' 'Sowol' and 'Woodbridge' showed low root growth, which in turn caused an increased rooting rate depending on the plant growth regulator used. Considering this finding, the sample cultivars likely had difficulties in sprouting due to the lack of a sufficient auxin supply. Therefore, the problem of weak growth can probably be handled using an adequate plant growth regulator.

'Hamabo,' 'Chungmu,' 'Hongsun' and 'Pyonghwa' showed a remarkable drop in the root growth under the IBA 1500 mg · L<sup>-1</sup> treatment. It is thought that an excessive level of auxin concentration which stimulates plant cell growth induces the synthesis of ethylene, consequently inhibiting growth. Barbez et al. (2017) reported that low auxin concentrations stimulate and high auxin concentrations inhibit root growth. Al-Saqri and Alderson (1996) found that high levels of plant growth regulators can severely damage plants. We

**Table 4.** Effect of plant growth regulator treatments on the number of roots in the 17 *H. syriacus* cultivars

Cultivar name	Control	NAA 500 mg · L <sup>-1</sup>	NAA 1000 mg · L <sup>-1</sup>	NAA 1500 mg · L <sup>-1</sup>	IBA 500 mg · L <sup>-1</sup>	IBA 1000 mg · L <sup>-1</sup>	IBA 1500 mg · L <sup>-1</sup>
Kojumong	4.8 <sup>b*</sup>	2.9 <sup>b</sup>	3.6 <sup>b</sup>	3.9 <sup>b</sup>	3.4 <sup>b</sup>	4.8 <sup>b</sup>	8.0 <sup>a</sup>
Samchulri	3 <sup>b</sup>	4.6 <sup>ab</sup>	4.6 <sup>ab</sup>	2.9 <sup>b</sup>	2.3 <sup>b</sup>	2.7 <sup>b</sup>	7.3 <sup>a</sup>
Sowol	1	1.5	0	0	4.1	5.8	6.4
Hanmaum	2.7 <sup>b</sup>	5 <sup>b</sup>	2.1 <sup>b</sup>	5.9 <sup>ab</sup>	3.9 <sup>b</sup>	4.5 <sup>b</sup>	9.4 <sup>a</sup>
Hamabo	0	5	3	3.5	4.3	4.9	5.5
Woodbridge	7.5 <sup>b</sup>	4 <sup>b</sup>	2.7 <sup>b</sup>	2.7 <sup>b</sup>	5.4 <sup>b</sup>	11.6 <sup>b</sup>	27.3 <sup>a</sup>
Chungmu	4.6	3.7	3.4	2.8	4.8	5.8	3.3
Coelesis	2 <sup>b</sup>	2 <sup>b</sup>	2.8 <sup>b</sup>	1.9 <sup>b</sup>	2.6 <sup>b</sup>	2 <sup>b</sup>	7.6 <sup>a</sup>
Pink giant	4.5 <sup>bc</sup>	0 <sup>c</sup>	3.8 <sup>bc</sup>	3.3 <sup>bc</sup>	4.1 <sup>bc</sup>	8.8 <sup>ab</sup>	14.4 <sup>a</sup>
Hanso	5.1 <sup>ab</sup>	2.9 <sup>b</sup>	2.8 <sup>b</sup>	3.5 <sup>b</sup>	3.8 <sup>b</sup>	6.7 <sup>a</sup>	6.9 <sup>a</sup>
Hwahong	4.6 <sup>b</sup>	3 <sup>b</sup>	2.6 <sup>b</sup>	2.6 <sup>b</sup>	7.1 <sup>b</sup>	9.8 <sup>ab</sup>	17.8 <sup>a</sup>
Elegantissimus	4.8 <sup>bc</sup>	4.1 <sup>bc</sup>	5.7 <sup>bc</sup>	3.6 <sup>c</sup>	7.3 <sup>b</sup>	6.6 <sup>bc</sup>	13.3 <sup>a</sup>
Hongsun	6.2 <sup>c</sup>	6.2 <sup>c</sup>	6.4 <sup>c</sup>	4.1 <sup>c</sup>	8.3 <sup>bc</sup>	11.5 <sup>b</sup>	19.8 <sup>a</sup>
Hwarang	7.3 <sup>bc</sup>	2.8 <sup>d</sup>	4.1 <sup>cd</sup>	4.2 <sup>cd</sup>	5.9 <sup>bcd</sup>	8.5 <sup>b</sup>	17.3 <sup>a</sup>
Pyonghwa	7.8 <sup>bc</sup>	7.7 <sup>bc</sup>	7.3 <sup>c</sup>	6.3 <sup>c</sup>	12.5 <sup>b</sup>	20.0 <sup>a</sup>	22.9 <sup>a</sup>
Saehan	3.7 <sup>d</sup>	7.0 <sup>bc</sup>	6.1 <sup>bcd</sup>	4.4 <sup>cd</sup>	8.2 <sup>b</sup>	8.2 <sup>b</sup>	19.4 <sup>a</sup>
Soltanshim	2.8 <sup>c</sup>	4.9 <sup>bc</sup>	6.2 <sup>b</sup>	5.6 <sup>b</sup>	6.7 <sup>b</sup>	10.2 <sup>a</sup>	9.9 <sup>a</sup>

\*Means in each row followed by different letters show statistical differences using Duncan's test ( $p < .05$ ).

**Table 5.** Effect of plant growth regulator treatments on root length in the 17 *H. syriacus* cultivars

Cultivar name	Control	NAA	NAA	NAA	IBA	IBA	IBA
		500 mg · L <sup>-1</sup>	1000 mg · L <sup>-1</sup>	1500 mg · L <sup>-1</sup>	500 mg · L <sup>-1</sup>	1000 mg · L <sup>-1</sup>	1500 mg · L <sup>-1</sup>
Kojumong	62.3	48.2	37.4	56.3	41.9	53.0	52.7
Samchulri	38.7	53.1	42.5	47.4	47.0	58.5	65.4
Sowol	7.9 <sup>bc*</sup>	27.4 <sup>ab</sup>	0 <sup>c</sup>	0 <sup>c</sup>	11.4 <sup>bc</sup>	38.2 <sup>a</sup>	43.7 <sup>a</sup>
Hanmaum	12.0 <sup>b</sup>	28.2 <sup>ba</sup>	16.5 <sup>b</sup>	27.7 <sup>ba</sup>	30.2 <sup>ba</sup>	16.5 <sup>b</sup>	43.9 <sup>a</sup>
Hamabo	0	37.7	34.1	35.7	35.4	42.9	30.0
Woodbridge	53.0 <sup>ab</sup>	30.5 <sup>b</sup>	23.9 <sup>b</sup>	28.4 <sup>b</sup>	20.0 <sup>b</sup>	47.4 <sup>ab</sup>	66.6 <sup>a</sup>
Chungmu	30.5	39.1	25.7	18.1	36.2	36.3	29.5
Coelesis	41.7	38.8	60.6	45.9	31.5	38.0	48.8
Pink giant	53.1 <sup>a</sup>	0 <sup>b</sup>	34.1 <sup>a</sup>	36.9 <sup>a</sup>	48.1 <sup>a</sup>	57.0 <sup>a</sup>	55.5 <sup>a</sup>
Hanso	40.5	35.0	31.6	28.8	31.3	28.3	35.5
Hwahong	68.2 <sup>a</sup>	17.6 <sup>c</sup>	43.3 <sup>b</sup>	75.5 <sup>a</sup>	18.3 <sup>c</sup>	42.2 <sup>b</sup>	38.8 <sup>b</sup>
Elegantissimus	43.6	37.1	43.5	53.5	47.2	53.0	45.7
Hongsun	70.0 <sup>a</sup>	31.6 <sup>b</sup>	32.1 <sup>b</sup>	47.9 <sup>ab</sup>	41.4 <sup>b</sup>	45.8 <sup>b</sup>	42.1 <sup>b</sup>
Hwarang	33.0 <sup>a</sup>	24.1 <sup>ab</sup>	16.3 <sup>b</sup>	31.8 <sup>a</sup>	22.9 <sup>ab</sup>	35.0 <sup>a</sup>	34.4 <sup>a</sup>
Pyonghwa	56.0 <sup>ab</sup>	55.8 <sup>ab</sup>	45.4 <sup>b</sup>	67.5 <sup>a</sup>	43.6 <sup>b</sup>	45.8 <sup>b</sup>	39.8 <sup>b</sup>
Saehan	36.7 <sup>bc</sup>	54.3 <sup>a</sup>	31.6 <sup>c</sup>	46.7 <sup>ab</sup>	46.5 <sup>ab</sup>	53.4 <sup>a</sup>	53.1 <sup>a</sup>
Soltanshim	44.6 <sup>ab</sup>	50.8 <sup>ab</sup>	34.3 <sup>b</sup>	63.9 <sup>a</sup>	45.1 <sup>ab</sup>	61.8 <sup>a</sup>	39.7 <sup>b</sup>

\*Means in each row followed by different letters show statistical differences using Duncan's test ( $p < .05$ ).

also observed that high concentrations of IBA had negative impacts on the root growth of certain cultivars. Thus, it is most important to control the application of plant growth regulators at suitable concentration levels.

In this study, we collected some useful information concerning cultivars which typically experience difficulties in propagation through cuttings, including 'Hamabo,' 'Sowol,' 'Woodbridge' and 'Pink giant.' We subjected these and other cultivars to various treatment combinations using various bed soils and plant growth regulators. Several cultivars, however, showed poor responses to all of these treatments, and did not perform better than the controls. It is thought that each cultivar requires a different and a specific type of plant growth regulator at a specific concentration to be effective in fostering adequate root and shoot growth of the cuttings. For this reason, further research is required for propagation by cutting from more diverse *H. syriacus* cultivars.

## Conclusion

In this study, the rooting rate and number of roots showed significant differences depending on the bed soil, but in most cultivars the length of the leaf, width of the leaf, length of new branches, and length of the roots did not show significant differences. Perlite: Vermiculite mixed soil was the most suitable bed soil for propagation of cuttings. On the other hand, it was observed that the gardening bed soil had a very low rooting rate and was unsuitable for planting *H. syriacus* due to rotting root tips or poor growth. Therefore, it is considered appropriate to mix vermiculite with granite or perlite, which can increase the air permeability, in order to propagate the sapling of *H. syriacus*.

As a result of this experiment, the rooting rate of 5 cultivars ('Hamabo,' 'Sowol,' 'Coelstis,' 'Pink giant,' and 'Woodbridge') was found to be less than 30% in all bed soils, but could be increased through treatment with plant growth regulators. In most cultivars, IBA treatment was more effective than NAA treatment for root development.

*H. syriacus* is grown mainly as an ornamental landscape or garden plant. It is also cultivated as medicinal plant, because it contains useful substances for antioxidant, anti-cancer, and wound healing. Accordingly, the method of propagating *H. syriacus*, a biological resource with various useful values, is expected to have a wide range of applications.

Through this experiment, useful information was collected to secure *H. syriacus* cultivars that were difficult to propagate through cuttings. However, the treatment effect of growth regulators is observed to be insignificant or lower than that of the controls in some cultivars, so there is a difference among cultivars in the type and treatment concentration of growth regulators suitable for root growth. In the future, it is thought that detailed research on the asexual propagation of various *H. syriacus* cultivars will be needed.

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