Effects of Seasons and Indole-3-buteric Acid Doses on the Propagation of Some Native *Rhododendron* Species by Air Layering Technique in their Natural Habitats

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This research was conducted to determine to the effects of indole-3-butyric acid (IBA) doses and propagation season on rooting rates and some root parameters of *Rhododendron* species, *R. ponticum* L., *R. luteum* Sweet, *R. ungernii* Trautv, and *R. caucasicum* Pallas. Air layering technique and IBA doses (0, 500 ppm, and 1,500 ppm) were applied to each *Rhododendron* species in their natural habitat in autumn and spring. In the present investigation, dry root weight (mg), root length (cm), root volume (cm^3), and root diameter (mm) were investigated as root quality parameters. The highest rooting efficiency (100%) was obtained from *R. caucasicum* and *R. ungernii* species. The rooting efficiencies of *R. ponticum* (between 6.67% to 66.67%) and *R. luteum* (between 0% to 53.33%) species were lower than the other two species. The heaviest dry root (266.10 mg), the largest root volume (1.49 cm^3), and the thickest root diameter (0.05 cm) were obtained in autumn and 1,500 ppm IBA dose from *R. caucasicum* species. The longest roots, 349.21 cm, were formed in the *R. ungernii* species in the spring, during the air layering, in which 500 ppm IBA dose was applied.

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INTRODUCTION

The *Rhododendron* genus contributes to the rich plant diversity of Türkiye. In Türkiye, nine taxa *Rhododendron* species have naturally spread, of which five are species level and four are natural hybrids (Avcı 2004; Altun 2011). Although rhododendrons that naturally spread in Türkiye are flamboyant ornamental plants, they are not used as ornamental plants in urban landscape applications because the native species have not yet been cultivated. One of the main reasons for not being able to be cultured is that these plants cannot be propagated easily like many other ornamental plants, and the plants related to this genus generally grow very slowly (Altun *et al*. 2017; Vipasha *et al.* 2017; Yazıcı and Altun 2021).

Rhododendrons can be propagated by generative or vegetative methods, as in many other cultivated plants. Today, the current techniques in propagation of rhododendrons have been grafting, cutting, air layering, and tissue culture (Elmongy *et al*. 2018). Air layering is a method that is simple to apply, requires little material, and relatively large rooted plants are obtained (Brennan and Mudge 1998). It is based on the creation of roots from adventitious buds on the stem while the cuttings are still attached to the plant. Today, it is a reliable method used in clonal propagation for the production of some rootstocks and especially for plants that are difficult to become rooted with cuttings of valuable species. Its biggest advantage is that seedlings can be obtained without any damage to the main plant, which saves the producer considerable time. This method allows for obtaining rooted seedlings of maturity and size (for example 1 m long and 8 years old), which can be planted in the garden if rooting occurs, because the branch of the plant applied air layering is of a certain age.

Indole-3-butyric acid (IBA) is an auxin frequently used for rooting vegetative components such as cutting and leaves. It is used to accelerate the root formation of cuttings and increase the number and quality of roots per cutting, especially in hard rooting species. IBA promotes rooting as it is slowly broken down by enzyme systems that degrade Auxin and its effect is continuous and quite high (Zenginbal *et al*. 2006). The possible effects of IBA doses may differ depending on plant species and their propagation periods. Application time may also differ depending on the dosage and plant species. It can be said that IBA gives different reactions according to propagation season and plant species as well as the method of applications in rooting plants. However, there has been no sufficient study with air layering method on the effects of IBA and propagation season on different *Rhododendron* species.

To the best of the author's knowledge, there has been limited studies on ornamental plants by air layering (Gamlath *et al*. 2010; Morsink and Hilgerdenaar 2010; Pratiksha *et al*. 2017), and no study on the present *Rhododendron* species. In contrast, there have been many studies on air layering propagation of fruit species, such as *Eusideroxylon zwageri* Teijsm. & Binn. (Irawan *et al*. 2019), *Mangifera indica* L. (Fumuro 2019), *Litchi chinensis* Sonn (Paixão *et al*. 2020), *Moringa oleifera* Lam. (Coles and Toit 2020), and *Plinia cauliflora* (Mart.) Kausel (Silva *et al*. 2019). However, in the propagation of rhododendrons by cuttings, the rooting success is quite low, although it varies according to the species (Czekalski 1998; Altun *et al*. 2017; Pacholczak *et al*. 2020).

The main purpose of the research is to investigate the applicability of the air layering method in present *Rhododendron* species, which are difficult to reproduce with cuttings. The specific goals are (1) to compare the effects of three different IBA concentrations and 2 different propagation seasons on rooting, and (2) to determine the appropriate IBA dose and propagation season that will increase the rooting efficiency in air layering.

Fig. 1. *Rhododendron* species (*R. ponticum* (a), *R. luteum* (b), *R. ungernii* (c), and *R. caucasicum* (d)) used in the study

EXPERIMENTAL

Material

In the research, four native *Rhododendron* species of Türkiye were used as plant material *in-situ* conditions (Fig. 1).

Study sites

The experimental trials on natural *Rhododendron* species (*R. luteum*, *R. ponticum*, *R. ungernii*, and *R. caucasicum*) were completed at forests in Artvin (Türkiye) province and district boundaries. Coordinate information of the species used in the study and their habitat are given in Table 1. Artvin center receives an average annual rainfall (between 1949 and 2021) of 690.4 mm. The average highest temperature of the area between 1949 to 2021 was 43 °C and the lowest temperature was -16.1 °C. The average temperature value is 12.1 °C (Turkish State Meteorological Service (MGM) 2022). The soil structure of the experimental areas is generally acidic (average of pH value 4.82) and brown forest soil (Altun 2011).

Table 1. Location Information of *Rhododendron* Species Applied Air Layering

Species	Altitude	Coordinate	Application Place
R. ponticum L.	1652 m	41°08' 914" N, 41°46' 205" E	Artvin
R. luteum Sweet	1671 m	41°10' 424" N, 42°18' 943" E	Şavşat
R. ungernii Trautv.	1249 m	41°18' 870" N, 41°53' 495" E	Borçka
R. caucasicum Pallas	2289 m	41°43' 450" N, 42°28' 376" E	Şavşat

Methods

Air layering and IBA treatment

The air layering experiments were completed in four different forest locations during fall (end of the October) and spring (end of the May), using prepared root promoting hormone IBA (Merck, Darmstadt, Germany) at different concentrations of 0 ppm (as a control), 500 ppm, and 1,500 ppm. Experiments were set up separately for each species, according to the randomized blocks design, with 3 replications and 15 plants in each replication. For the air layering process, approximately 10 years old and 50 cm length shoots were selected. The area to apply air layering on the branch was cleaned from leaves and on the three sides of the stem diameter axis. To reach wood tissue on the bark part, approximately 2 cm scratches in length were perpendicularly created with a sharp knife. These regions were sprayed with 0 ppm, 500 ppm, and 1,500 ppm prepared IBA solution. The scratches on the branch were covered with a sterile acidic sphagnum moss and black polythene strip was wrapped in this area and tied with paper tape and rope (Fig. 2a).

Rooting efficiency and root quality

One year after, the air layering applied sections were cut 5 cm above and below the branch and separated from the mother plant. Then, black polythene strips were opened and rooting efficiencies and root qualities were determined. Rooting efficiencies were obtained by calculating the number of roots branches as a percentage. It was determined that the roots on the branches were thin and sensitive and completely cover the sphagnum moss (Fig. 2b). Therefore, the ruptures occur while trying to separate the roots.

To determine root dry weight (mg), root materials were dried in a forced-air oven until the roots reached constant weight for 3 days at 60 °C. The root length, volume, and root diameter of the plants were determined using the special software program WinRHIZO (Win/Mac RHIZO Pro V. 2002c Regent Instruments Inc., Quebec City, Canada) (Fig. 2c).

Fig. 2. Air layering applied branch in *R. ponticum* (a), rooted branch (b), and (c) root analysis

Data analysis

The statistical analyses were performed by SPSS Software Programme (IBM Corp., Armonk, NY, USA). One-way analysis of variance was used to test the significance and the Duncan Multiple Comparison tests.

RESULTS AND DISCUSSION

The obtained data were evaluated separately based on species, as described below.

R. ponticum L.

The experiments were completed during the autumn and spring with an air layering technique. Different concentrations of root promoting hormone (IBA) doses of 0 (as control), 500 ppm, and 1,500 ppm were used for propagation. The experiments with air layering and different IBA doses produced roots at all doses in this species. However, it has been determined that rooting efficiencies and root quality are affected by seasons and applied IBA doses.

The highest rooting efficiency was obtained from the trial performed in autumn with an efficiency of 66.7% when 500 ppm IBA was applied. The lowest rooting efficiency (6.67%) was obtained from the subject applied 500 ppm IBA dose in spring (Fig. 3). When the effects of the IBA applications on root weight were investigated, it was determined that the heaviest root group was in control roots reproduced by air layering in spring (35.31 mg).

In autumn, the heaviest roots were obtained from 500 ppm IBA application with the best rooting efficiency with 29.75 mg (Table 2). The longest (195.08 cm) root and the largest root volume (0.12 cm^3) were obtained from the air layering applied in the spring and from the control group. The effects of seasons and applied IBA doses on root diameters were statistically insignificant (Table 2).

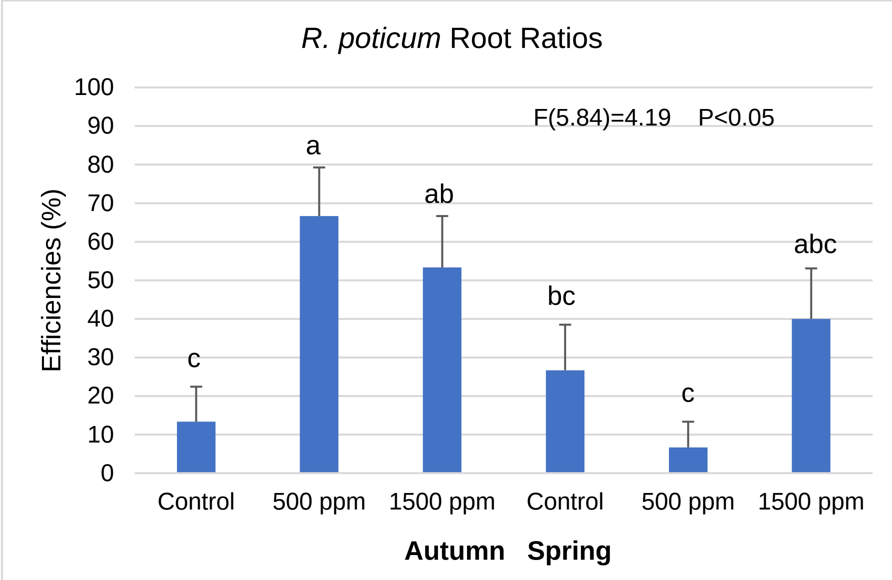

Fig. 3. Effect of IBA doses and seasons on the rooting efficiency of *R. ponticum* L.

Table 2. Effect of IBA Doses and Seasons on Root Parameters of *R. ponticum* L.

Seasons	Doses	Dry Root Weight (mg)	Root Length (cm)	Root Mass (cm^3)	Root Diameter (mm)
Autumn	Control	10.09 ± 6.88 bc*	78.40 ± 53.42 ab	0.03 ± 0.02 b	0.02 ± 0.01 a
	500 ppm	29.75 ± 5.62 ab	187.46 ± 35.43 a	0.11 ± 0.02 a	0.02 ± 0.00 a
	1,500 ppm	2.76 ± 0.69 c	13.81 ± 3.45 b	0.00 ± 0.00 b	0.01 ± 0.00 a
Spring	Control	35.31 ± 15.65 a	195.08 ± 86.46 a	0.12 ± 0.05 a	0.02 ± 0.01 a
	500 ppm	0.73 ± 0.73 c	3.33 ± 3.33 b	0.00 ± 0.00 b	0.02 ± 0.02 a
	1,500 ppm	19.26 ± 6.30 abc	105.87 ± 34.65 ab	0.05 ± 0.02 ab	0.02 ± 0.01 a
		$F(5.84) = 3.34$ $p < 0.05$	$F(5.84) = 3.18$ $p < 0.05$	$F(5.84) = 4.04$ $p < 0.05$	$F(5.84) = 0.05$ $p > 0.05$

*means with the same letter are not significantly different

R. luteum Sweet

In this section, the effects of seasons and IBA treatments on the rooting efficiency and root parameters at propagation with air layering of *R. luteum* species were investigated. Among the four studied species, the lowest rooting efficiencies were observed in this species. In fact, rooting did not occur in the air layering application made by applying 1,500 ppm IBA dose in autumn. It was determined that the effect of propagation season on rooting efficiencies of *R. luteum* species was significant ($P < 0.05$) with no effect of IBA doses ($P > 0.05$).

The highest rooting efficiency was obtained with 1,500 ppm IBA application (53.33%) in spring (Fig. 4). In parallel with the rooting efficiency, the heaviest root group (16.60 mg), the longest roots (119.37 cm) and the highest root volume (0.07 cm^3) were obtained from the air layering application in which 1,500 ppm IBA dose was applied in the spring. There was no significant difference in the effect of seasons and applied IBA doses on root diameters (Table 3).

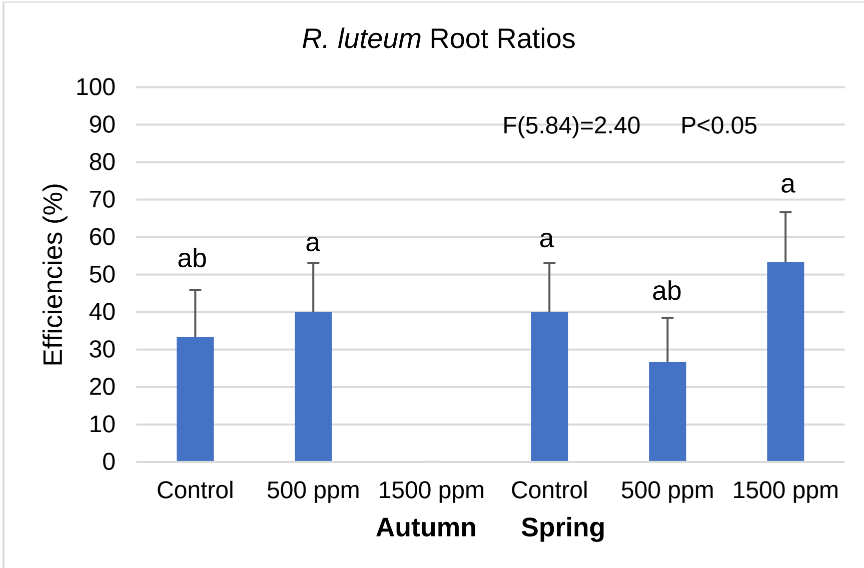

Fig. 4. Effect of IBA doses and seasons on the rooting efficiency of *R. luteum* Sweet

Table 3. Effect of IBA Doses & Seasons on Root Parameters of *R. luteum* Sweet

Seasons	Doses	Dry Root Weight (mg)	Root Length (cm)	Root Mass (cm^3)	Root Diameter (mm)
Autumn	Control	4.00 ± 0.00 bc	16.43 ± 6.21 c	0.01 ± 0.00 b	0.02 ± 0.01 a
	500 ppm	2.30 ± 0.00 c	14.66 ± 4.80 c	0.01 ± 0.00 b	0.01 ± 0.00 ab
	1,500 ppm	0.00 ± 0.00 c	0.00 ± 0.00 c	0.00 ± 0.00 b	0.00 ± 0.00 b
Spring	Control	10.20 ± 0.00 ab	69.95 ± 22.90 b	0.06 ± 0.02 a	0.02 ± 0.01 a
	500 ppm	3.20 ± 0.00 c	18.01 ± 7.98 c	0.01 ± 0.00 b	0.02 ± 0.01 a
	1,500 ppm	16.60 ± 0.00 a	119.37 ± 29.84 a	0.07 ± 0.02 a	0.02 ± 0.00 a
		$F(5.84) = 6.89$ $p < 0.05$	$F(5.84) = 8.16$ $p < 0.05$	$F(5.84) = 7.28$ $p < 0.05$	$F(5.84) = 1.73$ $p > 0.05$

R. ungernii Trautv.

In the *R. ungernii* species, 100% rooting occurred at all IBA doses in the air layering applications in the spring. Another result obtained is that the season significantly affected rooting in the propagation of this species by air layering. The lowest rooting efficiency (80%) was obtained from the air layering application in autumn and 1,500 ppm IBA dose (Fig. 5).

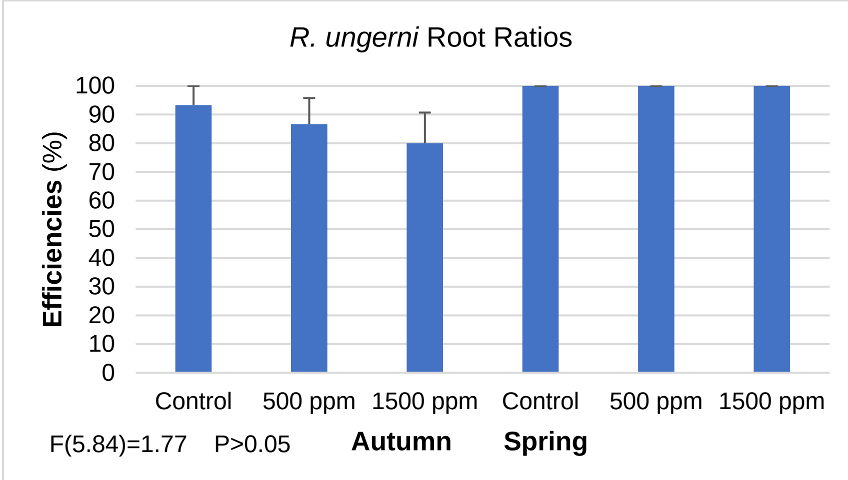

Fig. 5. Effect of IBA doses and seasons on the rooting efficiency of *R. ungernii* Trautv.

The heaviest root bundle (126.70 mg) and the thickest root diameter (0.028 mm) were obtained from the branches that were applied 500 ppm IBA dose in the spring. The longest roots (353.81 cm) and the highest root volume (0.49 cm^3) were obtained from the control group applications in the autumn season (Table 4).

Table 4. Effect of IBA Doses and Seasons on Root Parameters of *R. ungernii* Trautv.

Seasons	Doses	Dry Root Weight (mg)	Root Length (cm)	Root Mass (cm^3)	Root Diameter (mm)
Autumn	Control	119.70 ± 0.01 ab	353.81 ± 25.27 a	0.49 ± 0.04 a	0.02 ±0.00 ab
	500 ppm	68.00 ± 0.01 d	318.82 ± 33.42 a	0.24 ± 0.03 c	0.02 ± 0.00 c
	1,500 ppm	92.10 ± 0.01 c	341.32 ± 45.61 a	0.42 ± 0.06 ab	0.02 ± 0.00 bc
Spring	Control	103,40 ± 0.00 bc	305.85 ± 0.00 a	0.38 ± 0.00 b	0.02 ± 0.00 ab
	500 ppm	126.70 ± 0.00 a	349.21 ± 0.00 a	0.48 ± 0.00 a	0.02 ± 0.00 a
	1,500 ppm	49.00 ± 0.00 d	207.94 ± 0.00 b	0.18 ± 0.00 c	0.02 ± 0.00 bc
		$F(5.84) = 19.70$ $p < 0.05$	$F(5.84) = 4.66$ $p < 0.05$	$F(5.84) = 19.60$ $p < 0.05$	$F(5.84) = 2.86$ $p < 0.05$

R. caucasicum Pallas

A high efficiency of rooting occurred in the branches of *Rhododendron caucasicum*, in which the air layering technique was applied for propagation, in both seasons and at all IBA doses. The highest rooting efficiency (100%) was obtained from the control group and 1,500 ppm IBA applications in the autumn. The lowest rooting efficiency was 93.3% in all other applications (Fig. 6).

The heaviest dry root (266.10 mg), the highest root volume (1.49 cm^3) and the thickest root diameter (0.059 mm) were obtained from the branches that were applied 1,500 ppm IBA dose in the autumn. The longest roots (334.27 cm) were obtained from applied 500 ppm IBA dose applications in the autumn season (Table 5).

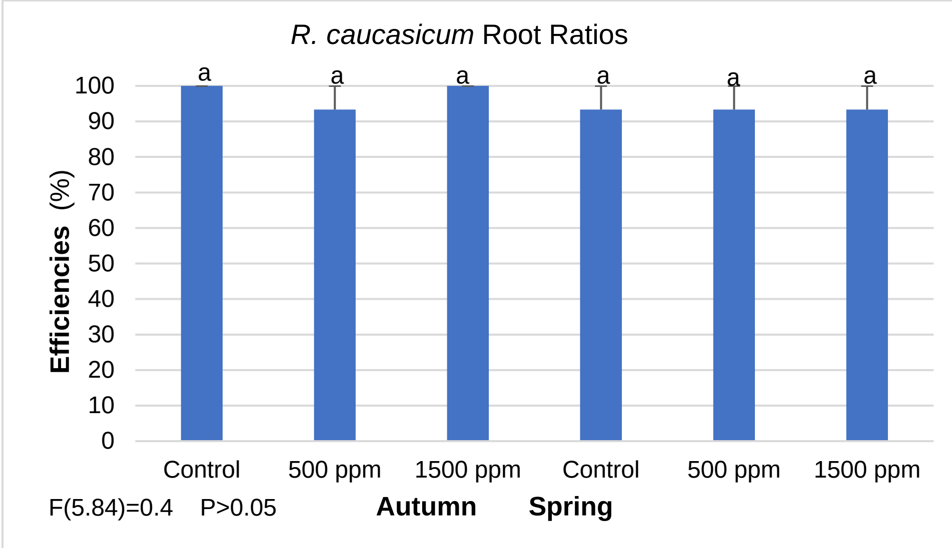

Fig. 6. Effect of IBA doses and seasons on the rooting efficiency of *R. caucasicum* Pallas

Table 5. Effect of IBA Doses and Seasons on Root Parameters of *R. caucasicum* Pallas

Seasons	Doses	Dry Root Weight (mg)	Root Length (cm)	Root Mass (cm^3)	Root Diameter (mm)
Autumn	Control	86.90 ± 0.00 c	321.35 ± 0.00 a	0.42 ± 0.00 c	0.02 ± 0.00 c
	500 ppm	140.60 ± 0.01 b	334.27 ± 23.88 a	0.69 ± 0.04 b	0.03 ± 0.00 b
	1,500 ppm	266.10 ± 0.00 a	235.31± 0.00 b	1.49 ± 0.00 a	0.05 ± 0.00 a
Spring	Control	44.50 ± 0.00 d	188.93 ± 13.49 c	0.12 ± 0.01 e	0.01 ± 0.00 d
	500 ppm	37.80 ± 0.00 d	236.18 ± 16.87 b	0.19 ± 0.01 d	0.02 ± 0.00 d
	1,500 ppm	18.50 ± 0.00 e	127.68 ± 9.12 d	0.07 ± 0.01 e	0.01 ± 0.00 d
		F(5.84) = 429.99 p < 0.05	F(5.84) = 32.96 p < 0.05	F(5.84) = 630.24 p < 0.05	F(5.84) = 126.04 p < 0.05

Rooting of the cuttings and air layering are among the widely used vegetative propagation methods for tree and shrub species. In commercial terms, air layering is used less, while cutting replication is used more. When the air layering technique are applied in field conditions, the plants are exposed to uncontrolled both biotic and abiotic stresses such as fungus, bacterial infection, environmental conditions, temperature, light, and precipitation. For this reason, it was reported that the saplings produced by air layering were more resistant and more harmonious to environmental conditions than those grown in controlled environments (Eganathan *et al.* 2000). Because the air layering method is easy to perform in the field and, also, low cost, it is easily accepted and applicable not only by seedlings businesses, but also by local non-professional producers (Purohit *et al.* 2015).

In the study, it was determined that the rooting efficiencies and root parameters values of *R. ponticum* (between 6.67% and 66.67%) and *R. luteum* (between 0% and 53.33%) species were lower than the other two species. *R. luteum*. One of the species used in the research is deciduous, while the other species are evergreen. The low rooting efficiencies of *R. luteum*, especially in autumn trials, may be related to the absence of leaves in the plant at that time. Rhododendrons are rather slow growing species. Too little water storage in the stems or bark of naturally slow-growing species may adversely affect rooting

(Ahmad *et al.* 2021). As a matter of fact, it was determined in the study that rooting efficiencies were higher in *R. ungernii* (between 80% to 100%) species, which produced stronger shoots than other species. Although *R. caucasicum* has high rooting efficiencies (between 93.33% and 100%), it produces smaller plants compared to other species and it is thought that the high rooting efficiency may be related to the growing ecology of the plant. In other words, they have to develop faster than other species, complete their vegetation, and enter winter in a ready condition. Nutrient and hormone activity during this rapid development may have positively affected rooting efficiencies. Compared to many other plant species, rhododendrons have higher phenolic content and diversity (Qiang *et al.* 2011; Ahmad *et al.* 2021). It has been reported that phenolic compounds in plants prevent root initiation and cause various necrosis in the rooting region and reduce rooting efficiencies (Dubravina *et al.* 2005). However, the phenolic content of the species can be very different even if they are in the same genus (Qiang *et al.* 2011). Ahmad *et al.* (2021) did a study on *Rhododendron arboreum* Sm. species for the determination of the effective method in vegetative propagation by testing the root developer hormones IBA, IAA, and NAA with FRI-Wire and air layering techniques. In their study, air layering failed to produce rooting. The better rooting efficiency (66.66%) was obtained by 2.500 ppm IAA application in April and FRI-Wire Technique. They reported that this poorer rooting efficiency in air layering might be attributed to the accumulated phenolic substances in wounded places on branches of *Rhododendron arboreum* Sm. Therefore, the amounts of phenolic substances secreted in the scar tissues opened in the branches in the study may differ according to the species. Accordingly, there may be differences in rooting efficiencies according to species and seasons.

A limited number of studies have been conducted on the propagation of rhododendrons by air layering. With the "Fool's Day air layering method" applied to camellias in early April by Morsink and Hilgerdenaar (2010), they achieved approximately 100% rooting in 6 months. The researchers reported that camellias, gardenias, and evergreen broadleaf rhododendrons can be easily reproduced with this method. Kathiresan and Ravikumar (1995) completed an air layering study in Pichavaram Mangrove forest with two Mangrove species, which are difficult to reproduce with seed and cutting. They reported that roots occur only in monsoon and post-monsoon months and on hormone applied shoots. Auxin applications, especially indole-3-butyric acid (IBA) in rooting cuttings, are one of the most widely used and most effective methods of increasing the rooting efficiency (Zencirkiran and Erken 2012). The IBA from the auxin group was used to stimulate root formation in plants. In general, auxins, while promoting rooting at low concentrations can inhibit at a higher concentration. Brennan and Mudge (1998) examined the air layering method in *Inga feuilleei* DC. for being an alternative clonal propagation method and determined 100% rooting efficiency in 5 weeks with or without IBA. In the present study irrespective to IBA doses and propagation season, 93.3 to 100% rooting efficiencies were obtained in *R. caucasicum*. However, when one looks at the root weights and other root parameters in autumn season, it can be said that the root bundle was increased in dose dependent manner in this species. The heaviest dry root (266.10 mg), the largest root volume (1.49 cm^3) and the thickest root diameter (0.05 cm) were obtained in autumn application and 1,500 ppm IBA dose from *R. caucasicum* species. The longest roots, 349.21 cm, were formed in the *R. ungernii* species in the spring, in the air layering in which 500 ppm IBA dose was applied. In a study with *Rhododendron pulchrum* cv Sweet. (azalea), successful results were obtained for root number and root dry weight of cuttings in combination of IBA and salicylic acid, while higher root number and root length were obtained in combination of IBA and thiamine (Hou *et al*. 2020). In some of the species, obtaining the highest rooting efficiency in the control group without IBA can be interpreted as the high level of natural auxin in the plant at the time of the study. As mentioned above, species may show different reactions to the applications. Purohit *et al*. (2015) also reported that the optimum auxin concentration required for rooting of plant parts, such as cuttings, may vary, depending on the plant type, the living environment of the rootstock plant, the type of auxin used, and the method of application.

Because *Rhododendron* species develop in the form of a bush, it is not possible to complete these studies on a single plant. Therefore, this situation cannot be applied to a single plant. This is because of genotypic differences in plants or environmental conditions (light, temperature, *etc*.) to which the treated branches may be exposed due to being made to a specified population or because of the age of the branch. When evaluated from the perspective of the producer, the highest rooting in the control group seems to be more easily accepted because it does not require IBA cost and application.

Türkiye shows the spread of rhododendrons up to 2800 m above sea level. As natural inhabitants, *Rhododendron ungernii* grows between 1000 and 1800 m altitudes and *R. caucasicum* grows between 1700 and 2800 m altitudes under heavy winter condition such as snow (Ünsal and Altun 2020). For this reason, it is almost impossible to get cutting from these plants in winter. In the observations made in the field conditions within the scope of the researches conducted by the author before, some branches of the plants that are under the snow and lying on the ground are not attached to any branch part after the snow melted, or because of the soil or organic material on it, new roots are formed from the part of the stem that touches the surface (personal observation of author). In the light of this observation, an air layering study was completed in four species of *Rhododendron* as 4 independent trials. It was determined by the present study that 100% rooting efficiency can occur with air layering in species such as *R. ungernii* and *R. caucasicum*, which have very low rooting efficiencies in cutting propagation (Altun *et al*. 2017). There are not many studies on the propagation of the species used in the research. In particular, just north of Türkiye and the Caucasus distributed in a narrow space considering *R ungernii* and *R caucasicum* the number of studies completed is almost non-existent. Therefore, this study is a first in this regard.

In a study on the propagation of Türkiye's *Rhododendron* with summer cutting, it was reported that while rooting efficiency of 46.67% in *R. ponticum* and 38.33% in *R. luteum* were obtained, no rooting occurred in *R. ungernii* and *R. caucasicum* species (Altun *et al*. 2017). Similarly, Czekalski (1998) reported that *R. ungernii* species was difficult to reproduce vegetatively. Pacholczak *et al.* (2020) reported that many *Rhododendron* species or cultivars root poorly with stem cuttings or the rooting period is uneconomically long. Ferus *et al.* (2017) reported that the rooting efficiencies of cuttings ranged between 0% and 100% in their study with eight *Rhododendron* species. Peterson *et al.* (2020) conducted a study on the propagation of sweetgale, rhodora, and catberry species by cuttings. They found that the K-IBA concentration and wounding treatments in *Rhodora* (*Rhododendron canadense* (L.) Torr.) cuttings created inconsistencies on rooting percentages, 60% to 100% in the cuttings taken in June, 80% and 100% in the cuttings taken on the next pick date. However, Li *et al.* (2017) reported that hormone applications in *Rhododendron scabrifolium* Franch species significantly affected root growth rate and number. Similarly, the current findings showed that *Rhododendron* species responded differently to various applications. Each plant species has its propagation ability within its original ecology or within the artificial ambient ecology offered in a suitable way. The important thing is to find a suitable propagation method for the plants. The current study's trials support this hypothesis. This study showed that air layering method was the ideal propagation method for *R. ungernii* and *R. caucasicum* species. In addition, it is a great advantage that seedlings obtained by air layering are quite large (approximately 50 cm) and therefore can be used in landscape applications. In the study, the thinnest and thickest branches were selected for each dose from the shoot parts after taken the roots. The age of the branch was subjected to the age of 8 to 12 years by counting the age rings on them. Therefore, this result means that air layering method brings 8 to 12 years for the producer according to cutting propagation.

The present results are important because the *Rhododendron* species studied in this research are difficult to reproduce by generative and vegetative methods. In addition, this is the first study on this subject with these species. It is an alternative and effective option for these species to be propagated by air layering method and to produce clone plants. These species generally grow very slowly. Therefore, to get a rooted cutting having the size of being used as an ornamental plant in gardens, it needs a very long time of 5 to 7 years. With this method, large seedlings can be obtained in a short time. The method is also cheap and easy to implement. For this reason, it is especially easily accepted by small family businesses. This study has the potential to create an alternative new job for the regional producers all over the world where rhododendrons grow.

CONCLUSIONS

Rhododendrons have never lost the interest of breeders and researchers, thanks to their morphological features such as flowers, leaves, and habitus.

1. In the study, the highest rooting efficiencies (100%) were obtained from *R. caucasicum* and *R. ungernii* species. It was determined that the rooting efficiencies of *R. ponticum* (between 6.67% to 66.67%) and *R. luteum* (between 0% to 53.33%) species were lower than the other two species.
2. When compared with previous studies, it was determined that the air layering method was the most ideal propagation method, especially for *R. caucasicum* and *R. ungernii* species.

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