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# Vegetative Propagation of Wild *Prometheum sempervivoides* (Fischer ex M. Bieb.) H. Ohba by Leaf Cutting: Effects of Auxin and Some Substances

## Yabani *Prometheum sempervivoides* (Fischer Ex M. Bieb.) H. Ohba'nın Yaprak Çeliği Yoluyla Vejetatif Çoğaltılması: Oksin ve Bazı Maddelerin Etkileri

Fazilet PARLAKOVA KARAGÖZ [1]
Atilla DURSUN [2]
Kadir YILDIRIM [1]

[1]: Department of Horticulture, Faculty of Agriculture, Atatürk University, Erzurum, Türkiye
[2]: Department of Horticulture and Agronomy, Faculty of Agriculture, Kyrgyz – Turkish Manas University, Bishkek, Kyrgyzstan

**ABSTRACT**

The aim of the research is to determine the effects of different rooting contents [control (water), plant growth regulator-rooting hormone ($H_1$: 0.25 g $l^{-1}$, $H_2$: 0.50 g $l^{-1}$ and $H_3$: 1.0 g $l^{-1}$), cinnamon powder (T) and *Aloe vera* gel (AV)] and two different planting times on the rooting of leaf cuttings prepared from the stock mother plants of wild *Prometheum sempervivoides* (Fisch. ex M. Bieb.) H. Ohba taxon. Observations and measurements of vitality rate (%), number of rooted cuttings (NR), number of callusing cuttings (NC), maximum root length (MRL), rooting rate (%) and rooting scale (1-5) were made on cuttings whose rooting was completed. The results were evaluated statistically. The most positive rooting effect was determined in the $H_3$ application, which is the highest dose of the commercial rooting hormone tested in the study. Cinnamon powder application was determined as a more effective natural extract for rooting leaf cuttings of *P. sempervivoides* when compared to *Aloe vera* gel application. At the end of our study, in which the effects of different planting times were also examined, it was determined that planting the leaf cuttings of *P. sempervivoides* as soon as they were taken from the stock mother plant had a positive effect on rooting. The very good quality roots were observed in $H_1$(0 h), $H_2$ (0 h), $H_3$ (0 h) and $H_3$ (24 h) applications. These applications can be recommended for rooting the leaf cuttings of *P. sempervivoides* succulent plant. It was also concluded that *P. sempervivoides* can be reproduced by vegetative propagation method using leaf cuttings.

**Keywords:** *P. sempervivoides,* rooting, *Aleo vera,* wild flower, ornamental plants, hormone

**ÖZ**

Doğal olarak yetişen *Prometheum sempervivoides* (Fisch. ex M. Bieb.) H. Ohba, taksonuna ait anaç bitkilerden hazırlanan yaprak çeliklerinin köklenmesinde, farklı köklendirme içeriklerinin [kontrol (su), bitki gelişim düzenleyici-köklendirme hormonunun üç farklı dozu ($H_1$: 0.25 g $l^{-1}$, $H_2$: 0.50 g $l^{-1}$ ve $H_3$: 1.0 g $l^{-1}$), tarçın tozu ve *Aleo vera* jeli] ve iki farklı dikim zamanının uygulanmasının etkilerini saptamak araştırmanın amacını oluşturmaktadır. Canlılık oranı (%), köklü çelik sayısı (NR), kallus oluşturan çelik sayısı (NC), maksimum kök uzunluğu (MRL), köklenme oranı (%) ve köklenme ölçeği (1-5) parametreleri köklenmesi tamamlanan çelikler için yapılmıştır. Sonuçlar istatistiksel olarak değerlendirilmiştir. En olumlu köklenme etkisi, araştırmada kullanılan ticari köklendirme hormonunun en yüksek dozu olan $H_3$ uygulamasında belirlenmiştir. *P. sempervivoides* yaprak çeliklerinin köklenmesinde toz tarçın uygulamasının *Aloe vera* jel uygulamasına göre daha etkili bir doğal ekstrakt olduğu belirlenmiştir. Farklı dikim zamanlarının etkilerinin de incelendiği çalışmamız sonunda, *P. sempervivoides* yaprak çeliklerinin ana bitkiden alınır alınmaz dikilmesinin köklenme üzerine olumlu etkisi olduğu belirlenmiştir. $H_1$(0 h), $H_2$ (0 h), $H_3$ (0 h) ve $H_3$ (24 h) uygulamalarında çok kaliteli kökler gözlenmiştir. Bu uygulamalar *P. sempervivoides* sukulent bitkisinin yaprak çeliklerinin köklendirilmesi için önerilebilir. Ayrıca *P. sempervivoides*'in yaprak çelikleri kullanılarak vejetatif çoğaltma yöntemiyle çoğaltılabileceği sonucuna varılmıştır.

**Anahtar Kelimeler:** *P. sempervivoides,* köklenme, *Aloe vera*, yabani çiçek, süs bitkileri, hormon

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**Corresponding author**/Sorumlu Yazar: Fazilet PARLAKOVA KARAGÖZ
**E-mail:** f.parlakova@atauni.edu.tr

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## Introduction

Succulent plants, which have an important place among ornamental plants, have been known and used by people since ancient times. In recent years, especially after the changing living conditions with the COVID-19 pandemic (Khayru, 2021), the popularity of succulent plants as ornamental plants has increased. In this increase, succulent plants' unique geometric shapes that form rosettes and their ability to hold high humidity levels play a major role (Cabahug et al., 2018). In addition, when many succulent plants grown in their natural environment are examined, it can be observed that they can withstand extreme conditions and have low irrigation requirements (Sarı, 2021).

Due to the global climate change and the intense drought expected (Bhattacharya, 2019) to be experienced due to this, practices are carried out to reduce water consumption all over the world (Hatfield & Dold, 2019; Zhao et al., 2020; Tahat et al., 2020). Prioritizing the use of natural species in landscape areas due to the decreasing rainfall in recent years is a sustainable method in terms of rational use of water. *Prometheum sempervivoides*, which has eye-catching red flowers, stays in flower for 3 months and during the flowering period, the star-shaped flowers formed by pollen dusts of yellow on red make the flowers of this species even more remarkable. In addition, the color of the flowers of this species turning to burgundy in the seed period after flowering (Fig. 1a, b) and the fact that the plant can attract attention in this color for a long time are among the features that can have a long-lasting effect on designs (Parlakova Karagöz et al., 2020). In this context, it is important to increase in the cultivation studies of *P. sempervivoides*, one of the natural succulent plant species. According to our literature review results, no study was found on the germination or propagation of *P. sempervivoides* species. In addition, it is necessary to increase in the production of these plants by introducing them to the ornamental plants sector, in the shortest possible time and at the highest rate, by revealing the reproduction techniques, transferring them to applications or carrying out breeding studies.

Propagation by cuttings is a method frequently used in vegetative propagation of succulent plants (Anton & Cristescu, 2009; Cabahug et al., 2018). Factors such as rooting medium, plant part to be used as cutting, rooting stimulants, drying time are affected rooting success in the propagation of succulent plants by leaves (Paterson & Rost, 1978; Jeong, 1999; Mihaela et al., 2011; Cabahug et al., 2016a; Khalid & Ahmed, 2022). The use of hormones as rooting stimulants in order to prevent the drying and death of the prepared cuttings, to encourage rapid rooting (Khalid & Ahmed, 2022) and to obtain from rooted-cutting seedlings in series has an important place in horticultural crops. Auxins are the most commonly used of these hormones (Ibrahim et al., 2015; Chaudhari et al., 2018). Synthetic auxin applications are widely used in cutting rooting (Khalid & Ahmed, 2022). It has been reported that synthetic rooting hormones such as indole-3-butyric acid (IBA) and other synthetic growth regulators can affect the environment and people, pollute the environment and cause harmful effects on living things through the food chain (El-Sherif et al., 2017; Sezgina & Kâhya, 2018).

Several studies have reported that biostimulants that can promote physiological processes in plant cells can be a good alternative to the important and widely used synthetic rooting hormones (Hasan et al., 2019; Hamza & AL-Taey, 2020; Al-Khafajy et al., 2020; Khalid & Ahmed, 2022). It has been reported that biostimulants such as coconut water, honey, willow tea (Shield, 2012), *Aloe vera* gel (Hamouda et al., 2012; Uddin et al., 2020), cinnamon powder (Xing et al., 2010), humic acid, seaweed extract (Rajan & Singh, 2021) can be an alternative to widely used synthetic rooting hormones. Comparison of the effects of both synthetic and biological rooting stimulants on the rooting of the leaf cutting of *P. sempervivoides* is important in revealing the propagation techniques, transferring them to applications and culturing this species in the shortest possible time and at the highest rate.

In this context, the aim of the study is to determine the rooting of leaf cuttings of naturally grown *P. sempervivoides* and the effects of different rooting contents on the root formation and rooting performance of the leaf cuttings. With the results of the study, it is aimed to provide information to the literature about the propagation method of *P. sempervivoides*, which has the potential to be an ornamental plant (Dilaver, 2001; Arslan, 2010; Erduran et al., 2010; Gülbağ, 2016; Dilaver et al., 2020; Parlakova Karagöz et al., 2020), to provide data to the cultivation studies and breeding studies and to contribute to the proposal of landscape use opportunities.

## Materials and Methods

### Description of the Study Area

The research was carried out in a heated glass construction research greenhouse between November 2022 and January 2023. The glass greenhouse where the experiment was conducted has a composite roof, ventilation from the side and the roof, and a steel construction. Temperatures inside the greenhouse are between 17.6 °C and 33.1 °C. Humidity rates in the greenhouse showed values varying between 10% and 46%.

### Experimental Materials

In the study, seeds of *Prometheum sempervivoides* (Fischer ex M.Bieb.) H.Ohba, grown naturally in Erzurum city and its

surroundings (Türkiye), were collected (Fig. 1 b), and new plants were grown by germinating in the research greenhouse. These plants grown from seed were used as stock mother plants from which leaf cuttings were taken (Figure 1c). Leaf cuttings taken from stock mother plants in appropriate sizes were used as the main plant material of the study (Fig. 2 a, b).

For the rooting of leaf cuttings, the active ingredient of the commercial plant growth regulator-rooting hormone product is 0.52% 1-Naphtaleneacitic Acid (NAA) + 0.51% 3-Indole Butyric Acid (IBA). This product was obtained from a private company. Three different doses of this commercial product were prepared and applied in the relevant experimental group. Cinnamon powder (Fig. 1d) was obtained from any market, while *Aloe vera* gel was obtained from plants grown in the greenhouse as potted plants at the time of use (Fig. 1e).

The viols in which the leaf cuttings are planted are 24-cell plug trays (viol), 320x500x82 mm in size, the lower diameter of each cell is 55 mm and the upper diameter is 75 mm. Ornamental peat with a pH of 5.06 was used as the rooting medium used in the viols. The cuttings were kept under observation in viols until the experiment was completed.


**Figure 1.**
*Naturally grown wild Prometheum sempervivoides (Fischer ex M.Bieb.) H.Oh. (a); Stage in which the seeds used in the propagation of stock mother plants are collected (b); view from greenhouse grown stock mother plants (c); cinnamon powder application (d), Aloe vera gel application (e)*

**Table 1.**
*The details of the applications in the experiment*

| Application code | Definition | Application code | Definition |
|---|---|---|---|
| Control (0 h) | Control (As soon as the leaf cutting was prepared, it was dipped in tap water and planted.) | Control (24 h) | Control (Leaf cuttings were prepared and kept in room conditions for 24 hours, then dipped in tap water and planted.) |
| H1 (0.25 g $l^{-1}$) (0 h) | Leaf cuttings were prepared and planted immediately without waiting and the solution prepared with 0.25 g $l^{-1}$ plant growth regulator-rooting hormone was applied as life water. | H1 (0.25 g $l^{-1}$) (24 h) | Leaf cuttings were prepared and planted after waiting for 24 hours at room conditions and plant growth regulator-rooting hormone (H1: 0.25 g $l^{-1}$) solution was applied as life water. |
| H2 (0.5 g $l^{-1}$) (0 h) | Leaf cuttings were prepared and planted immediately without waiting and the solution prepared with 0.50 g $l^{-1}$ plant growth regulator-rooting hormone was applied as life water. | H2 (0.5 g $l^{-1}$) (24 h) | Leaf cuttings were prepared and planted after waiting for 24 hours at room conditions and plant growth regulator-rooting hormone (H2: 0.50 g $l^{-1}$) solution was applied as life water. |
| H3 (1.00 g $l^{-1}$) (0 h) | Leaf cuttings were prepared and planted immediately without waiting and the solution prepared with 1.00 g $l^{-1}$ plant growth regulator-rooting hormone was applied as life water. | H3 (1.00 g $l^{-1}$) (24 h) | Leaf cuttings were prepared and planted after waiting for 24 hours at room conditions and plant growth regulator-rooting hormone (H3: 1. 005 g $l^{-1}$) solution was applied as life water. |
| T (0 h) | Leaf cuttings were prepared and the base of the cuttings was soaked, dipped in cinnamon powder and planted immediately without waiting. | T (24 h) | Leaf cuttings were prepared and kept at room conditions for 24 hours, then the base of the cuttings was soaked, dipped in cinnamon powder and planted. |
| AV (0 h) | Leaf cuttings were prepared and the base part of the cuttings was dipped in the gel from the fresh *Aloe vera* leaf and planted immediately without waiting. | AV (24 h) | Leaf cuttings were prepared and kept at room conditions for 24 hours, then the base of the cuttings was soaked, dipped the gel from the fresh *Aloe vera* leaf and planted. |

**Experimental Design**

The research was established according to factorial (different rooting content x 2 planting times) arrangement in a randomized plot design. The experiment was established with 4 replications and a total of 288 leaf cuttings were used, 6 for each replication.

The first group of the experiment consisted of control, plant growth regulator-rooting hormone, 3 different doses (0.25 g /L, 0.50 g /L and 1.00 g /L), cinnamon powder and Aloe vera gel applications. The second group of the experiment is the different planting times: The rooting ingredients are applied as soon as the cuttings are taken (0h) and the different rooting contents are applied after the cuttings are taken and kept at room conditions for 24 hours (24 h). The details of the applications were created as in Table 1.

**Establishment of the Experiment**

Preparation of leaf cuttings: The branches which it was decided to take cuttings from the stock mother plants are determined and the stems are separated from the stock mother plants. The dried, wilted leaves on the stem were cleaned and the leaves were carefully plucked from their bases. Care was taken to leave the bottom parts on the leaf cuttings (Fig. 2 a, b). For the application groups belonging to the 24 h planting time, the leaves were carefully plucked one by one from the stock mother plants and kept on blotting paper at room conditions for 24 hours (Hodzic 2020; Jeong 1999; URL-1). At the other planting time (0 h), the leaf cuttings in the experiment group were planted without waiting.

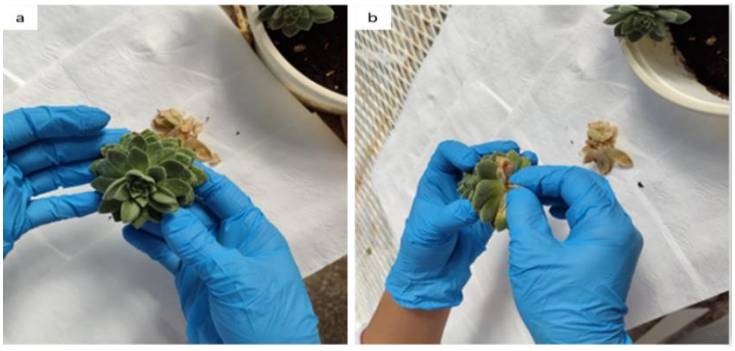


**Figure 2.**
*Preparation of cuttings by carefully separating the leaves from the stock mother plants (a, b)*

**Preparation of plant growth regulator-rooting hormone doses:** 0.25 g, 0.50 g and 1.00 g of the hormone were weighed separately and each was dissolved in 1 liter of water.

**Planting of leaf cuttings by making applications:** Leaf cuttings belonging to the control application were dipped in tap water (controls at two different planting times) and planted in the medium. Cuttings were planted in viols to be applied at different doses of plant growth regulator-rooting hormone, and certain doses of hormone solutions were given as life water (Fig. 3 a). For T (0h / 24 h) application, the base parts of the leaf cuttings were dipped in cinnamon powder and planted in peat medium (Fig. 1d). For the AV (0h / 24 h) application, the base of the cuttings was dipped into the gel extracted from the leaves of the *Aloe vera* plant, planted in the environment and the experiment setup was carried out (Fig. 1e) (Table 1).

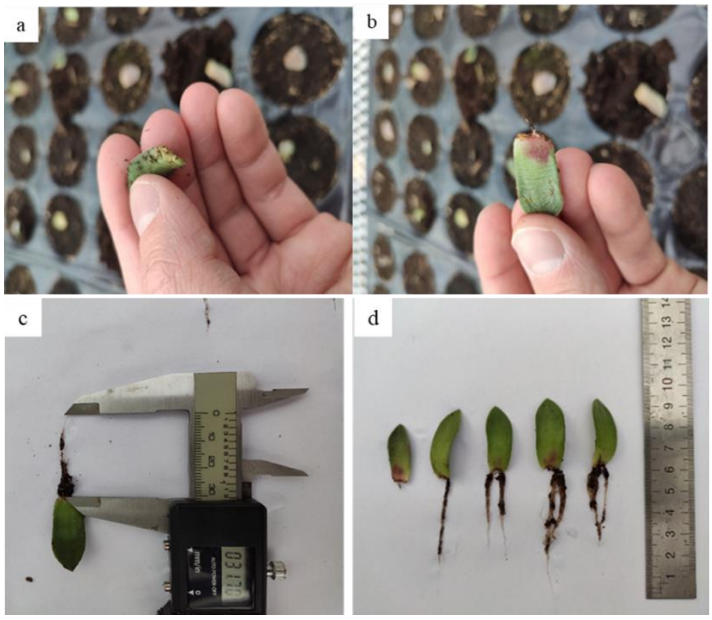


**Figure 3.**
*Callus formation (a), callus and first adventitious root (b) in P. sempervivoides leaf cuttings; measurement of maximum root length (c); the scale prepared with the rooting status of the cuttings in the experiment (d)*

Viols were filled with moist peat, and a leaf cutting was planted in each viol cell. Under greenhouse conditions, plant leaf cuttings were rooted in viols at natural day length and light intensity. As the most important maintenance process, water was sprayed on the leaf cuttings twice a day. This application was made in order to prevent moisture loss. Irrigation is done in a way that does not make any difference between applications in case of need.

### Evaluated Parameters at the End of the Experiment

Vitality rate (%), number of rooted cuttings (NR), number of callusing cuttings (NC) (Fig. 3a, b), maximum root length (MRL) (Fig. 3c), rooting rate (%) and rooting scale (1-5) (Fig. 3d) such as parameters were measured and evaluated in cuttings rooted in rooting medium (approximately 2 months). Based on the studies of Wang et al. (2005) and Cabahug et al. (2016b), the visual assessment scale according to the 1-5 scale was adapted to take into account only the rooting status of the cuttings. This revised scale is "Very weak root quality = 1; Substandard root quality, not sellable = 2; Roots are of good quality, salable = 3; Very good quality roots = 4; Excellent root quality = 5."

### Evaluation of Results

The results were evaluated according to the analysis of variance (ANOVA) in SPSS (Statistical Package for Social Sciences, Version 20.0) statistical program and given in tables after calculating their arithmetic means and standard deviations. Duncan's multiple comparison test (p=0.05 or 0.01) was used to determine the significance of the difference between treatments.

## Results and Discussion

In the study, *Prometheum sempervivoides* (Fischer ex M. Bieb.) H. Ohba seeds that grow naturally in Erzurum city (Türkiye) and its surroundings were collected, new plants were grown by germinating and these grown plants were used as stock mother plant. It was observed that the emergence rate of wild seeds of the related species planted in the peat during the germination stage was very low (about 1%). At the end of the experiment, the effects of our applications on the rooting parameters of *P. sempervivoides* leaf cutting were investigated. The results of the effects on the parameters of cutting viability, number of rooted cuttings and number of cuttings forming callus of using different planting times and different rooting contents in rooting of leaf cuttings belonging to the *P. sempervivoides* taxon were given in Table 2.

In general, it is recommended to wait a few days for planting after the cuttings are prepared in succulents for callus formation (Hodzic 2020; Jeong 1999; URL-1). However, this may vary depending on the plant species. The effects of different planting times on the best rooting in the planting technique of the leaf cuttings of the *P. sempervivoides* succulent plant, which is a natural species and has not been studied in its propagation, were also evaluated in this study. In general, it was concluded that planting the leaf cuttings of *P. sempervivoides* succulent immediately after leaving the stem (0 h) has a positive effect on the rooting of the cuttings and this method is also positive for all rooting parameters examined in the experiment. In a study conducted by Ekici (2020), the effects of different planting times on rooting were investigated, including immediate planting and planting after three days of leaf cuttings of the *Sedum album* L. species. It has been reported that the highest rooting rate and number of rooted

shoots were obtained from cuttings planted by waiting for three days. Again, as a result of the same research, the highest plant height, plant diameter, shoot number, shoot length, root length, fresh weight and dry weight were determined in the immediately planted application groups. The findings of our study show parallelism with the findings of the study reported by Ekici (2020).

With the application of different rooting ingredients to leaf cuttings, the highest viability rate was found in the cinnamon powder (T) application with 66.83%, and the lowest viability rate was determined in the *Aloe vera* gel (AV) application (46.33%). The evaluation made according to different planting times, the viability rate of the cuttings in the experimental group, which were planted without waiting after the leaf cuttings were plucked from the stem (0 h), was determined to be higher than those in the experimental group planted by waiting 24 hours (24 h). The highest viability rate was determined in the $H_3$ application in the cuttings belonging to the 0 h planting time, and it was determined that the viability rate increased in 1.15 times with the $H_3$ application compared to the control (0 h) application. T, AV and control applications were in the same statistical group. When the effects of different rooting contents on cuttings belonging to 24 h planting time were evaluated, the highest viability rate was determined with cinnamon powder application (T). Control (24h) application and AV application are shown with the same letter, and there is no significant difference between these two applications in terms of viability (Çizelge 2). It is known that synthetic auxin applications are widely used (Khalid & Ahmed, 2022) to promote rapid rooting of cuttings and to obtain from effective roots. We believe that the highest viability rate obtained with the $H_3$ application can support the knowledge that the effects of synthetic hormones are high and explain the reason for the widespread use of synthetic hormones. Cinnamon application (T) on leaf cuttings of *P. sempervivoides* belonging to the 24 h planting time caused an increase in the viability rate of the cuttings. Surjushe et al. (2008) stated that some plant extracts such as ginger, licorice and cinnamon are used as alternatives to promote rooting (Hameed et al., 2019). Cinnamon contains cinnamic acid, cinnamyl acidate, cinnamon aldehyde, cinnamyl alcohol, tannin, eugeuol and minerals (Gunjan & Anart, 2009). In addition, cinnamon powder contains salicylic acid, which helps the cuttings to root (Shidiki et al., 2019). The explanation for this increase may be due to the rich content of natural plant substances containing natural antioxidants (Mirihagalla & Fernando, 2020)

**Table 2**

*The effects of applications on the viability rate (%), rooted shoot number and callus forming cutting number of P. sempervivoides leaf cuttings*

| Treatments | Viability rate (%) | | | Number of rooted cuttings (NR) | | | Number of callusing cuttings (NC) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 h | 24 h | Mean | 0 h | 24 h | Mean | 0 h | 24 h | Mean |
| Control | 81.33 $^{bcd}$** | 18.00 $^{c}$*** | 49.67 $^{D}$*** | 13.33 $^{ns}$ | 1.67 $^{b}$* | 7.50 $^{BC}$** | 6.00 $^{b}$* | 2.33 $^{b}$*** | 4.17 $^{B}$*** |
| H1 | 83.67 $^{bc}$ | 26.00 $^{b}$ | 54.83 $^{C}$ | 14.67 | 3.00 $^{ab}$ | 8.83 $^{AB}$ | 5.67 $^{b}$ | 3.00 $^{b}$ | 4.33 $^{B}$ |
| H2 | 88.00 $^{ab}$ | 26.00 $^{b}$ | 57.00 $^{BC}$ | 15.33 | 3.00 $^{ab}$ | 9.17 $^{AB}$ | 7.00 $^{ab}$ | 2.00 $^{b}$ | 4.50 $^{B}$ |
| H3 | 93.67 $^{a}$ | 27.33 $^{b}$ | 60.50 $^{B}$ | 16.67 | 3.00 $^{ab}$ | 9.83 $^{A}$ | 8.67 $^{a}$ | 1.67 $^{b}$ | 5.17 $^{B}$ |
| T | 79.67 $^{cd}$ | 54.00 $^{a}$ | 66.83 $^{A}$ | 16.00 | 4.67 $^{a}$ | 10.33 $^{A}$ | 8.00 $^{a}$ | 9.67 $^{a}$ | 8.83 $^{A}$ |
| AV | 74.67 $^{d}$ | 18.00 $^{c}$ | 46.33 $^{D}$ | 11.67 | 2.00 $^{b}$ | 6.83 $^{C}$ | 7.33 $^{ab}$ | 2.33 $^{b}$ | 4.83 $^{B}$ |
| Mean | 83.50 $^{A}$*** | 28.22 $^{B}$ | | 14.61 $^{A}$*** | 2.89 $^{B}$ | | 7.11 $^{A}$*** | 3.50 $^{B}$ | |
| DRCxPT interaction | | $p < .000$ | | | $p < .003$ | | | $p < .001$ | |

ns: NS: insignificant at p>0.05, statistically significant at the * $p < .05$, ** $p < .01$ and ***$p < .001$ probability level. Note: Values followed by the same small or capital letters are not significantly (5%) different within the columns. DRC: Different Rooting Content; PT: Planting Times

When the general average of the effects of different rooting contents on the number of rooted cuttings is examined, the highest number of rooted cuttings was determined in the applications of cinnamon powder (T) with 10.33 and $H_3$ with 9.83. However, in terms of the number of rooted cuttings, T and $H_3$ applications and $H_1$ and $H_2$ applications were in the same statistical group. In the evaluation made according to different planting times, the number of rooted cuttings (14.61) in the experimental group planted without waiting after the leaf cuttings were plucked from the stem (0 h) was determined to be higher than the cuttings in the group planted by waiting 24 hours (24 h) (2.89). The effects of different rooting contents on the number of rooted cuttings in the cuttings belonging to the 0 h planting time were found to be statistically insignificant (p>0.05). The highest number of rooted cuttings in cuttings belonging to 24 h planting time was determined as T application. T application and H1, $H_2$ and $H_3$ applications are indicated with the same letter, and there is no significant difference between these applications in terms of the number of rooted cuttings (Table 2). In the

study of Ekici (2020), it was determined that the effect of different IBA doses on the propagation of *Sedum album* species by cuttings was not statistically significant ($p > .05$) on all parameters examined. As a result of the same research, higher values were obtained from parameters such as plant height, shoot length, plant diameter, rooted shoot number, root length at the control dose (0 ppm), and it was reported that a higher rooting rate was obtained from cuttings with 50 ppm dose compared to other doses. Khalid and Ahmed (2022) compared the effects of some natural substances (*Aloe vera*, cinnamon and honey) and rooting hormone naphthalene acetic acid (NAA) on the rooting of two fig (*Ficus carica*) cuttings. It was reported that the effect of using natural substances and naphthalene acetic acid (NAA) on rooting properties was similar except for the root number parameter. These findings (Khalid & Ahmed, 2022) showed parallelism with our present study results.

According to the general averages of the effects of different rooting contents on the number of callus-forming cuttings, it was determined that the highest number of callused cuttings was in the T application, with an average of 8.83. While numerically the lowest number of callused steel was obtained from the $H_3$ application, all applications except the T application were in the same statistical group as the control application. In the evaluation made according to different planting times, the number of callus-forming cuttings (7.11) in the experimental group planted without waiting after the leaf cuttings were plucked from the stem (0 h) was determined to be higher than the cuttings in the group planted by waiting 24 hours (24 h) (3.50). If the effects of different rooting contents on the number of callus-forming cuttings in the 0 h planting time are evaluated, it was determined that the number of callus-forming cuttings in $H_3$ application was the highest and the number of callus-forming cuttings increased in 1.45 times when compared to the control (0h) application. However, there was no statistically significant difference between the $H_3$ application and the T application. If the effects of different rooting contents on the number of callus-forming cuttings in the 24 h planting time are evaluated, the highest number of callus-forming cuttings was determined with the T application. Except for the T application, all different rooting content applications and the control application were indicated with the same letter, and no significant difference was found between these applications in terms of the number of callus forming cuttings (Table 2).

When the general average of the effects of different rooting ingredients on the maximum root length is examined, the highest maximum root length was determined in the $H_3$ application, while the lowest maximum root length was obtained from the AV application. In the evaluation made according to different planting times, the maximum root length (39.34) of the cuttings in the experimental group, which were planted without waiting after the leaf cuttings were plucked from the stem (0 h), was determined to be higher than those in the group planted by waiting 24 hours (24 h) (19.09). When the effects of different rooting contents on the maximum root length of the cuttings at 0 h planting time are evaluated, it was determined that the maximum root length of the $H_3$ application was higher and the maximum root length increased in 3.06% when compared to the control (0h) application. However, $H_3$ application and H1 and control (0 h) applications were in the same statistical group. In the evaluation made within 24 h planting time, the highest maximum root length was determined with the $H_3$ application. With the $H_3$ application, the maximum root length increased in 146.78% compared to the control (24 h) application. The control (24 h) application and $H_1$, T and AV were denoted with the same letter, and no significant difference was found between these applications in terms of maximum root length (Table 3). As a result of a previous study, *Aloe vera* gel was shown to be more effective than IBA in rooting *Vitex diversifolia* semiwood cuttings (Shidiki et al., 2019). In the current study, the highest maximum root length was obtained from the application of the highest dose ($H_3$) of rooting hormone containing 0.52% 1-Naphtaleneacitic Acid (NAA) + 0.51% 3-Indole Butyric Acid (IBA). The effects of auxin on rooting of cuttings are known in previous studies, and the result obtained from our study is an expected result. In addition, this increase may have been achieved by using two different auxin derivatives together. It was determined that there was no statistically significant difference for the highest maximum root length parameter between the Control, $H_1$, T and AV applications in the group planted by waiting 24 hours (24 h). Uddin et al. (2020) investigated the effect of natural substances on grapevine cuttings by comparing them with synthetic hormones. While the longest root length was observed in *Aloe vera* gel application, it was followed by IBA application and they reported that the lowest root length was measured in the control application. In our study, the maximum root length was determined in the application of the highest dose of auxin hormone. It was determined that there was no significant difference between the other natural substances used in our study and the control application.

When the general average of the effects of different rooting ingredients on the rooting percentage is examined, the highest rooting percentage was determined in T application, while the lowest average rooting percentage was determined in AV and control applications. In the evaluation made according to different planting times, the highest rooting percentage (89.35) was obtained from the cuttings in the experiment group, which were planted without

waiting after being plucked from the stem (0 h). As a result of the evaluation made if it includes 0 h planting time, it was determined that the rooting percentage was higher in $H_3$ and T applications and the rooting percentage increased in 24.13% when compared to the control (0h) application. As a result of the evaluation made in 24 h planting time, the highest rooting percentage was determined with T application. With the T application, the rooting percentage increased in 3.58 times when compared to the control (24 h) application (Table 3). Hameed et al. (2019), in a study examining the effect of cinnamon extract on root formation and vegetative growth of cuttings taken from *Melaleuca viminalis* L., they found that the application with cinnamon extract had a higher rooting rate than the control. In another previous study (Shidiki et al., 2019), *Aloe vera* leaf extract, IBA, coconut water and *Aloe vera* leaf extract + coconut water were used to propagate semiwood cuttings of *Vitex diversifolia* and *Cordia milleneii*. *Aloe vera* + coconut water has been reported to improve rooting with a higher rooting percentage than IBA (Shidiki et al., 2019). In our study, *Aloe vera* gel was used alone. Combining different natural substances can also be tried in future studies.

**Table 3**

*The effects of applications on the average root length and rooting rate of P. sempervivoides leaf cutting*

| Treatments | Maximum root length (MRL) (mm) | | | Rooting rate (%) | | |
|---|---|---|---|---|---|---|
| | 0 h | 24 h | Mean | 0 h | 24 h | Mean |
| Control | 42.51 $^{ab}$*** | 14.54 $^{c}$*** | 28.53 $^{C}$*** | 80.56 $^{bc}$** | 16.67 $^{c}$*** | 48.61 $^{C}$*** |
| H1 | 41.25 $^{ab}$ | 15.11 $^{c}$ | 28.18 $^{C}$ | 84.72 $^{bc}$ | 25.00 $^{b}$ | 54.86 $^{BC}$ |
| H2 | 39.96 $^{bc}$ | 21.32 $^{b}$ | 30.64 $^{B}$ | 91.67 $^{ab}$ | 20.83 $^{bc}$ | 56.25 $^{B}$ |
| H3 | 43.81 $^{a}$ | 35.88 $^{a}$ | 39.84 $^{A}$ | 100.00 $^{a}$ | 19.44 $^{bc}$ | 59.72 $^{B}$ |
| T | 38.04 $^{c}$ | 14.40 $^{c}$ | 26.22 $^{D}$ | 100.00 $^{a}$ | 59.72 $^{a}$ | 79.86 $^{A}$ |
| AV | 30.45 $^{d}$ | 13.28 $^{c}$ | 21.86 $^{E}$ | 79.17 $^{c}$ | 18.06 $^{bc}$ | 48.61 $^{C}$ |
| Mean | 39.34 $^{A}$*** | 19.09 $^{B}$ | | 89.35 $^{A}$*** | 26.62 $^{B}$ | |
| DRCxPT interaction | | $p < .000$ | | | $p < .000$ | |

ns: NS: insignificant at p>0.05, statistically significant at the * $p < .05$, ** $p < .01$ and *** $p < .001$ probability level. Note: Values followed by the same small or capital letters are not significantly (5%) different within the columns. DRC: Different Rooting Content; PT: Planting Times

**Table 4.**

*Rooting quality scores of cuttings according to applications (1-5)*

| Treatments | 0 h | 24 h |
|---|---|---|
| Control | 5 | 3 |
| H1 | 4 | 3 |
| H2 | 4 | 3 |
| H3 | 4 | 4 |
| T | 3 | 2 |
| AV | 2 | 3 |

As a result of the applications, the quality scores of the cuttings were given according to their rooting status (Table 4).It was observed that the cuttings belonging to the control (0 h) application had very good rooting and rooting quality, and therefore, a rooting quality score of 5 was given to this experimental group. Good quality leaves and roots were observed in $H_1$(0 h), $H_2$ (0 h), $H_3$ (0 h) and $H_3$ (24 h) applications. Considering the rooting quality score scale prepared for control (24 h), $H_1$ (24 h), $H_2$ (24 h), Av (24 h) and T (0 h) applications, the score of these applications was 3. At both planting times, substandard rooting and rooting quality was determined for the cuttings of the T application and were deemed unsaleable. Therefore, the rooting quality score of T application was determined as 2 (Table 4). In summary, very good quality roots were observed in $H_1$(0 h), $H_2$ (0 h), $H_3$ (0 h) and $H_3$ (24 h) applications. These applications can be recommended for rooting the leaf cuttings of *P. sempervivoides* succulent plant.

## Conclusion

As a result, the effects of the application of the highest dose of IBA+NAA, which is frequently used in cuttings, on the average root length and rooted cutting number parameters were found to be statistically significant. At the same time, it was concluded that the reproduction of the species can be done without using synthetic hormones, and it can be promoted with natural substrates. Cinnamon application caused an increase in the viability of the leaf cuttings of *P. sempervivoides*. It was concluded that cinnamon powder applications can be considered as a more effective natural extract for rooting leaf cuttings of *P. sempervivoides* compared to *Aloe vera* gel application. In plant propagation studies, the rooting percentage may vary depending on the plant type and variety, the rooting environment conditions, the rooting medium used, the type of cutting, the type and dose of plant growth regulator used. In general, it has been

suggested in various studies that in propagation of succulents with cuttings, it is necessary to wait for a while after the cuttings are prepared. At the end of our research, in which we examined the effects of different waiting times (immediate planting and planting with 24 hours waiting), it was determined that planting the leaf cuttings of *P. sempervivoides* as soon as they were taken had a positive effect on rooting. Based on these findings, we suggest that *P. sempervivoides* can be propagated with leaf cuttings by vegetative propagation.

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