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Research Article
(Araştırma Makalesi)

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Effects of growing media and IBA concentrations on rooting characteristics of *Satureja thymbra* L. cuttings*

Satureja thymbra L. çeliklerinin köklenme özellikleri üzerine yetiştirme ortamı ve IBA konsantrasyonlarının etkileri

* This article has been summarized from the Master's thesis of the second author, supervised by the first author.

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ABSTRACT

Objective: This study was conducted to determine the effects of a variety of growing media [Perlite + Peat (2:1 v/v), Peat + Sand (1:1 v/v), and Perlite + Sand (1:1 v/v)] and indole-3-butyric acid (IBA) concentrations [0 (control), 3000 ppm, and 6000 ppm] on the rooting characteristics of semi-hardwood cuttings of *S. thymbra*.

Materials and Method: The experiment was conducted within a single season, with the rooting media forming the main plots and different IBA concentrations forming the subplots, which were arranged in a split-plot design with three replications, using 25 cuttings per replication, totaling 675 cuttings. At the end of the rooting period, rooting percentage, number of roots, root length, fresh and dry root weight, number of shoots, shoot length, shoot diameter, fresh and dry shoot weights were all measured.

Results: The highest rooting percentage (58.66%) and root number (6.28) were obtained from the cuttings treated with 3000 ppm IBA and rooted in the Perlite + Peat medium. The effect of growing media on rooting characteristics was found to be statistically more dominant compared to IBA treatments (p<0.05 and p<0.01).

Conclusion: The results suggest that proper medium and hormone combination can significantly enhance rooting in *S. thymbra*, an important Mediterranean medicinal plant.

Keywords: Lemon savory, medicinal plant, propagation, rooting hormone, rooting media

ÖZ

Amaç: Bu çalışma, *S. thymbra* yarı odunsu çeliklerinin köklenme özellikleri üzerine farklı yetiştirme ortamları [Perlit + Torf (2:1 hacimsel), Torf + Kum (1:1 hacimsel) ve Perlit + Kum (1:1 hacimsel)] ve indol-3-butirik asit (IBA) konsantrasyonlarının [0 (kontrol), 3000 ppm ve 6000 ppm] etkilerini belirlemek amacıyla yürütülmüştür.

Materyal ve Metot: Deneme tek dönemde gerçekleştirilmiş olup, köklendirme ortamları ana parselleri; farklı konsantrasyonlardaki IBA uygulamaları alt parselleri oluşturacak şekilde bölünmüş parseller deneme desenine göre 3 tekerrürlü olarak oluşturulmuş ve her tekerrürde 25 adet olmak üzere toplam 675 adet çelik kullanılmıştır. Köklenme dönemi sonunda köklenme oranı, kök sayısı, kök uzunluğu, yaş ve kuru kök ağırlığı, sürgün sayısı, sürgün uzunluğu, sürgün çapı, yaş ve kuru sürgün ağırlıkları ölçülmüştür.

Bulgular: En yüksek köklenme oranı (58,66 %) ve kök sayısı (6,28 adet), 3000 ppm IBA ile muamele edilen ve Perlit + Torf ortamında köklendirilen çeliklerde elde edilmiştir. Büyüme ortamlarının köklenme özellikleri üzerindeki etkisi, IBA uygulamalarına kıyasla istatistiksel olarak daha baskın bulunmuştur (p<0.05 ve p<0.01).

Sonuç: Sonuçlar, uygun ortam ve hormon kombinasyonunun, önemli bir Akdeniz tıbbi bitkisi olan *S. thymbra*'da köklenmeyi önemli ölçüde artırabileceğini göstermektedir.

Anahtar sözcükler: Limon kekiği, tıbbi bitki, çoğaltım, köklendirme hormonu, köklenme ortamı

INTRODUCTION

With global climate change and the depletion of water resources, the importance of water conservation has increased, a condition highlighting landscape design approaches that utilize water efficiently. The use of species with groundcover or small shrub potential, naturally found in native vegetation, in landscape design not only enables the creation of ecological landscapes but also reduces the threat to biodiversity caused by the overharvesting of these species from the wild for various purposes.

The cultivation of medicinal plants is important and necessary not only due to their bioactive properties and traditional medicinal uses (Verpoorte et al., 2002; Ranya et al., 2024) but also for their use as ornamental plants in landscape design. Medicinal and aromatic plants contribute to landscape design by functioning as groundcovers that help retain soil, prevent erosion and water loss, as well as creating surface layers through their color, form, scale, and texture characteristics. Moreover, due to their therapeutic effects—particularly the significance of scent, sight, and touch in healing garden designs—these plants often stand out more prominently than other groundcover species (Kösa, 2021). The primary applications of medicinal and aromatic plants include collection gardens, healing therapy gardens, botanical gardens, rock gardens, rooftop and terrace gardens, dry stone walls, parterres, pots, sloped areas, and pathways (Arslan et al., 2018; Kösa, 2021).

The genus *Satureja* belongs to the Lamiaceae family and comprises more than 200 species (Khalil et al., 2020; Öz, 2022). *Satureja* species exhibit considerable variation in both morphological traits and essential oil yield. In recent years, the intense harvesting of *Satureja* plants during their flowering period for commercial purposes may not have appeared to cause immediate harm; however, it has affected seed production (Satil et al., 2002). Katar & Katar (2016) reported that 15 species of this genus are found in Türkiye. Yet, *Satureja thymbra* L., an endemic aromatic-medicinal plant of the Mediterranean region, is currently facing the risk of extinction.

S. thymbra is an endemic woody shrub of the Mediterranean region, characterized by a thyme-like aroma, and grows in typical Mediterranean maquis vegetation in dry and rocky habitats, ranging from sea level up to 1500 meters in elevation. *(*Skoula et al., 2005). *S. thymbra* is a shrub-like plant reaching a height of 20-40 cm. Its stems are covered with curved hairs; the leaves vary in shape from linear to obovate-spatulate. Its inflorescence is dense and irregular, with flowers ranging between 4 and 12 cm in size. The flowering period occurs between April and June (Aktaş, 2001).

Due to its remarkable botanical characteristics, *S. thymbra* possesses significant potential for use with aesthetic, ecological, functional, economic, social, and psychological purposes. In recent years, efforts aimed at the utilization and conservation of *S. thymbra* have increased. This plant is of great importance not only because of its environmental benefits but also due to its economic value and traditional uses. Native to the Mediterranean climate, *S. thymbra* has become a preferred species in landscape planning and ecological conservation strategies. Varela-Stasinopoulou et al. (2023) conducted a study demonstrating that certain native and endemic Mediterranean (Greek) plant species, including *Satureja thymbra*, are capable of thriving on urban green roofs. This finding represents a significant step toward enhancing biodiversity and strengthening green infrastructure in urban areas. Plants used on rooftops provide not only ecological benefits but also contribute to the improvement of urban air quality. Bariotakis et al. (2023), on the other hand, emphasized that climate change is expected to reduce the natural habitat range of *S. thymbra* on the island of Crete and underline the need for ex situ conservation measures. Their study highlighted the urgency of mitigating the negative impacts of climate change, such as habitat loss and the decline of biodiversity.

Ecological approaches in planting design prioritize the use of native plant species in landscapes, aiming to minimize environmental damage and promote the sustainable use of natural resources. In this context, many plant species can be used in combination with others for pest management purposes. A recent study by Stathakis et al. (2023) investigated the potential of four medicinal and aromatic plants, including *S. thymbra*, to support natural enemies of citrus pests when used as hedge plants in orange orchards. The results indicated that *S. thymbra* had a positive effect on increasing the abundance of parasitic wasps and arachnid predators such as spiders. The use of such plants can help reduce reliance on chemical pesticides and contribute to maintaining ecological balance. Satil et al. (2008) reported that in Türkiye, *Satureja* species are often collected intensively from the wild by local people, and destructive harvesting methods—such as uprooting the entire plant—have led to habitat loss and a decline in genetic diversity. This situation poses a risk of extinction for these species, indicating the importance of cultivating them for long-term conservation. The protection of natural habitats and the promotion of sustainable agricultural practices are critical steps for ensuring the future of these valuable plants.

Despite its ecological, medicinal, and landscape-related significance, comprehensive research on the optimized vegetative propagation of *S. thymbra* remains insufficient. A review of the existing literature reveals that only a few studies (Thanos et al., 1995; Çatav et al., 2012; Öz, 2022) have focused on seed germination. While research specifically addressing the propagation of this species through cuttings is particularly scarce, existing studies on both *S. thymbra* and related Lamiaceae species (Ayanoğlu et al., 2002; Ünal et al., 2004; Iapichino et al., 2006; Bhat et al., 2008; Bahadori & Sharifi Ashorabadi, 2017; Kösa, 2021; Ranya et al., 2024) confirm that IBA treatment is a common practice. However, since the response of cuttings can vary significantly depending on the specific environment and hormonal balance, there is a further need to evaluate a broader range of hormone doses and diverse growing media. Establishing how *S. thymbra* responds to different substrate-hormone combinations will provide a more comprehensive understanding of its propagation requirements. Therefore, this study aims to contribute to the existing literature by testing various media and IBA concentrations to develop a more versatile and efficient protocol for the species.The propagation of woody shrub species through cuttings offers a significant advantage in terms of enabling rapid production for commercial sale and reducing cultivation costs. Different from previous studies on propagation by cuttings, the present study aims to obtain high-quality *S. thymbra* plants by testing different cutting characteristics and treatments.

The propagation of woody shrub species through cuttings offers a significant advantage in terms of enabling rapid production for commercial sale and reducing cultivation costs. Different from previous studies on propagation by cuttings, the present study aims to obtain high-quality *S. thymbra* plants by testing different cutting characteristics and treatments. It is anticipated that the synergy between specific physical properties of the growing media and optimal IBA concentrations will significantly enhance rooting efficiency and quality. Specifically, this study focuses on evaluating whether the combination of perlite-peat mixtures and moderate IBA doses can optimize rooting performance, thereby aiming to provide a standardized and high-efficiency propagation protocol for the species.

The objective of this study is to determine the effects of different growing media and IBA concentrations on the rooting characteristics of semi-hardwood cuttings of *S. thymbra*.

MATERIALS and METHOD

Plant material and experimental site

The rooting experiment was conducted in a glasshouse at the Faculty of Agriculture, Akdeniz University (Antalya, Türkiye), using semi-hardwood cuttings of *S. thymbra* (lemon savory) collected from the natural population located on the university campus in Konyaaltı, Antalya, on October 8, 2023. The cuttings were obtained from healthy, mature mother plants that exhibited uniform physiological growth. To minimize intra-population variation, plants with similar morphological characteristics (height and canopy

spread) and vigorous growth were selected, ensuring that the plant material was representative and homogenous. Temperature in the glasshouse was maintained at 20-25°C during the day and 15-18ºC at night.

Experimental design

The experiment was carried out in a single period using a split-plot design with three replicates. The main plots included three growing media combinations: perlite + peat (2:1), peat + sand (1:1), and perlite + sand (1:1). Sub-plots included three concentrations of IBA: 0 ppm (control), 3000 ppm, and 6000 ppm. These IBA concentrations were determined based on previous successful studies conducted on similar Lamiaceae species, which indicated that moderate-to-high doses are effective for root induction in semi-hardwood cuttings.

A total of 675 semi-hardwood cuttings, each 10 cm long with 3-4 nodes and 0.1 cm in diameter, were used, with 25 cuttings per replicate. The basal 0.5 cm of each cutting was dipped for 5 seconds in the respective IBA solutions, prepared by dissolving crystalline IBA in 95% ethanol and diluting with distilled water to the desired concentrations. Cuttings in the control group were dipped in distilled water using the same method. The treated cuttings were planted in 6×8 cm plastic trays (cell pots) filled with the growing media mixtures and placed on benches in the glasshouse. Regular irrigation was applied to maintain optimal moisture conditions.

Data collection and statistical analysis

After 30 days, cuttings were inspected, and final data collection was carried out after 70 days on the basis of development. The parameters measured included the rooting percentage (%), number of roots (count), root length (cm), number of shoots (count), shoot length (cm), shoot diameter (mm), root dry weight (g), and shoot dry weight (g). Roots and shoots were dried in an incubator at 70ºC for 5 days, and dry weights were measured using a precision scale. Statistical analysis was performed using IBM SPSS v24 software. Data were analyzed according to a Split-plot design, with growing media assigned to the main plots and IBA concentrations to the sub-plots. Analysis of variance (ANOVA) was conducted to determine the significance of the main effects and their interactions. Means were compared using Duncan's multiple range test at the 5% significance level (p<0.05). The results are presented as the mean values followed by their standard errors (±SE). Duncan's test was preferred due to its higher sensitivity in differentiating and grouping treatment means within complex interactions compared to other post-hoc tests.

RESULTS and DISCUSSION

The results demonstrated the presence of significant effects of different growing media and IBA (indole-3-butyric acid) treatments on the rooting percentage of *S. thymbra* cuttings. Statistical analyses revealed that the type of growing medium had a highly significant effect on rooting percentage at the 1% significance level, while the hormone treatments exhibited a significant effect at the 5% level. The highest rooting percentage (58.66%) was recorded in the cuttings treated with 3000 ppm IBA and rooted in a perlite + peat mixture, followed by those treated with 6000 ppm IBA in the same substrate, which achieved a rooting percentage of 49.33% (Table 1). Conversely, the lowest rooting percentage (25.33%) was observed in cuttings treated with 6000 ppm IBA and rooted in a perlite + sand medium. Such findings highlight the critical influence of both substrate composition and hormone concentration on rooting success. Ayanoğlu et al. (2002) similarly reported that IBA treatments significantly enhanced the rooting percentage in *S. thymbra*, achieving a maximum rooting ratio of 92% at a dose of 2000 ppm in the second year of their study. In conformity with these findings, Bhat et al. (2008) demonstrated that the highest rooting percentage in *Lavandula angustifolia* cuttings was achieved with 3000 ppm IBA treatment. Some consistent results were also reported by Sarı & Kaçar (2019), who found that rooting performance in rosemary (*Rosmarinus officinalis*) cuttings was improved in media containing peat and perlite. Likewise, Kösa (2021) reported for *Thymus revolutus* and Özcan et al. (2013) for *Lavandula hybrida* that the

highest rooting percentage were achieved in peat + perlite media. Supporting these outcomes, a study by Iapichino et al. (2006) on softwood cuttings of *Thymus capitatus* L., *T. serpyllum* L., and *T. vulgaris* reported that cuttings treated with 500 ppm IBA exhibited better rooting compared to that of the control group.

The number of roots was also influenced by both the growing medium and IBA treatments. The highest mean root number (6.28) was recorded in cuttings treated with 3000 ppm IBA and rooted in a perlite + sand mixture, whereas the lowest mean root number (2.38) was observed in the control group rooted in the same substrate (Table 1). This finding suggests that the synergistic effect of IBA treatments and perlite-based media is effective in enhancing the number of roots**.** Consistent with this result, Ayanoğlu et al. (2002) reported that IBA applications increased the number of roots in *S. thymbra*, with the most favorable outcomes obtained at 2000 ppm IBA. Iapichino et al. (2006) also reported that the highest number of roots in cuttings of *Thymus capitatus* L., *T. serpyllum* L., and *T. vulgaris* was observed in those treated with 500 ppm IBA. In addition, Yeşil & Özcan (2021) similarly concluded that substrates containing perlite enhanced root number in *Mentha piperita* cuttings.

With respect to root length, the growing media exhibited statistically significant effects at the 5% level. The longest roots (2.12 cm) were observed in the group treated with 6000 ppm IBA and rooted in a peat + sand mixture (Table 1). However, neither the IBA treatments nor the interactions between factors had a statistically significant effect on root length. The shortest roots (1.38 cm) were recorded in the control group rooted in a perlite + sand substrate. In line with these findings, Ayanoğlu et al. (2002) reported that IBA treatments also increased root length in *S. thymbra*, with the most favorable results obtained at 2000 ppm IBA. Similar outcomes were reported by Özcan et al. (2013), who found that all IBA concentrations tested significantly increased both the length and number of roots in *Lavandula hybrida* cuttings compared to those in the control group.

Given the results of this study, when root length values were evaluated according to the mean IBA concentrations, an increasing trend in root length was observed with higher IBA doses (Table 1). In contrast, Kösa (2021) reported that in *Thymus revolutus* cuttings, root length decreased with increasing IBA concentrations. Similarly, Bahadori & Sharifi Ashorabadi (2017) found that in *Thymus kotschyanus* cuttings, higher root lengths were obtained at lower IBA concentrations (100 and 300 ppm). Furthermore, the findings of the present study underscore the significant role of substrate composition in influencing root elongation.

The impact of growing medium, hormone treatments, and their interactions on the number of shoots were found to be statistically non-significant (Table 1). The highest mean number of shoots (2.95) was in the control group rooted in a perlite + peat substrate. Similarly, Kösa (2021) reported that in *Thymus revolutus* cuttings, the highest number of shoots was recorded in control cuttings rooted in a perlite + peat medium. The lowest number of shoots (1.81), on the other hand, was determined in cuttings treated with 6000 ppm IBA and rooted in a peat + sand substrate. This finding suggests that shoot production may be less sensitive to variations in substrate type and hormone concentration. When the number of shoots was evaluated based on mean IBA concentrations, a decreasing trend was observed with increasing IBA doses. Conversely, in the study on *Thymus atlanticus* cuttings, Ranya et al. (2024) reported that the number of shoots in the control group was lower compared to those treated with IBA, indicating a different response pattern.

Table 1. Effects of growing media and IBA concentrations on rooting characteristics of *S. thymbra* cuttings
Çizelge 1. *S. thymbra* çeliklerinin köklenme özellikleri üzerine yetiştirme ortamı ve IBA konsantrasyonlarının etkileri

Growing media	IBA (ppm)			Means of growing media	Significance		
	0 (Control)	3000 ppm	6000 ppm		G.media (GM)	IBA	GM x IBA
Rooting percentage (%)							
Peat + Sand	*29.33*±1.89 **Ab**[y]	*42.66±4.99***Aa**	41.33±9.98 **Aab**	**37.77 b**[z]	**	*	NS
Perlite + Sand	*36.00*±3.27**ABab**	*44.00±8.64* **Aa**	25.33±1.89 **Bb**	**35.11 b**			
Perlite + Peat	*46.66±9.43 A***a**	*58.66±8.64* **Aa**	49.33±6.80 **Aa**	**51.55 a**			
Means of IBA	**37.30 a**	**49.55 a**	**38.66 a**				
Number of roots (count)							
Peat + Sand	*4.09*±0.87 **Aa**	*4.58±0.11* **Aa**	*4.39*±1.16**Aa**	**4.35 ba**	*	*	NS
Perlite + Sand	*2.38*±1.04 **Aa**	*6.28*±1.92 **Aa**	*5.13*±1.72 **Aa**	**4.60 a**			
Perlite + Peat	*2.43±0.33***Aa**	*3.46*±1.07 **Aa**	*2.62*±0.93**Aa**	**2.84 b**			
Means of IBA	**2.96 b**	**4.77 a**	**4.05 ba**				
Root length (cm)							
Peat + Sand	*1.76*±0.16 **Aab**	*1.78*±0.09 **Aa**	*2.12*±0.45 **Aa**	**1.89 a**	*	NS	NS
Perlite + Sand	*1.38*±0.16 **Ab**	*1.81*±0.31 **Aa**	*1.56±0.03* **Aa**	**1.58 b**			
Perlite + Peat	*1.96*±0.29 A**a**	*1.91*±0.07 **Aa**	*1.83±0.24 A***a**	**1.90 a**			
Means of IBA	**1.73 b**	**1.83 a**	**1.84 ba**				
Number of shoots (count)							
Peat + Sand	*2.09*±0.13 **Aa**	*1.96*±0.07 **Aa**	*1.81±0.32* **Aa**	**1.95 a**	NS	NS	NS
Perlite + Sand	*2.68*±0.28 **Aa**	*2.01*±0.09 **Ba**	*2.10*±0.32 **Aba**	**2.26 a**			
Perlite + Peat	*2.95*±0.76 A**a**	*2.16*±0.29 A**a**	*2.01*±1.16 A**a**	**2.37 a**			
Means of IBA	**2.57 a**	**2.04 ab**	**1.97 b**				
Shoot length (cm)							
Peat + Sand	*0.81*±0.15 **Ba**	*1.2*±0.13 **Aba**	*1.56*±0.07 **Aa**	**1.19 a**	***	***	**
Perlite + Sand	*0.54*±0.09 **Aa**	*0.57*±0.07 **Ab**	*0.53*±0.10 **Ab**	**0.55 b**			
Perlite + Peat	*0.67*±0.07 A**a**	*0.55*±0.08 **Ab**	*0.45*±0.19 **Ab**	**0.56 b**			
Means of IBA	**0.67 a**	**0.77 a**	**0.84 a**				
Shoot diameter (cm)							
Peat + Sand	*0.11*±0.01 **Aa**	*0.10*±0.01 **Aa**	*0.12*±0.02 **Aa**	**0.11 ab**	*	NS	NS
Perlite + Sand	*0.09*±0.01 **Aa**	*0.11*±0.03 **Aa**	*0.15*±0.04**Aa**	**0.12 a**			
Perlite + Peat	*0.10±0.01* **Aa**	*0.08*±0.01**Aa**	*0.08*±0.01**Aa**	**0.09 b**			
Means of IBA	**0.10 a**	**0.09 a**	**0.11 a**				

[y]**:** In the italicized section, capital letters indicate comparisons of means across rows (horizontally), while lowercase letters represent comparisons of means within columns (vertically).

[z]**:** Means followed by different letters are significantly different at the 5% level according to Duncan's multiple range test.

NS, ***,**, *:* Not significant, significant at 0.1%, 1% and 5% alpha levels, respectively.

±: Standard error (SE)

Table 1. (Continued).

Çizelge 1. (Devamı).

Growing media	IBA (ppm)			Means of growing media	Significance		
	0 (Control)	3000 ppm	6000 ppm		G.media (GM)	IBA	GM x IBA
Root diameter (cm)							
Peat + Sand	*0.03±0.01***Aa**	*0.03±0.01* **Aa**	*0.03±0.01* **Aa**	***0.03* a**	**NS**	**NS**	**NS**
Perlite + Sand	*0.02*±0.01 **Ab**	*0.03*±0.00 **Aa**	*0.03*±0.01**Aa**	***0.03* a**			
Perlite + Peat	*0.02*±0.00 **Ab**	*0.02*±0.00 **Ab**	*0.03*±0.02 **Aa**	**0.02 a**			
Means of IBA	**0.02 a**	**0.02 a**	**0.03 a**				
Dry weight of roots (g)							
Peat + Sand	*0.61*±0.33 **Aa**	*0.24*±0.16 **Aa**	*0.12*±0.03 **Aa**	**0.32 a**	**NS**	**NS**	*
Perlite + Sand	*0.06*±0.05 **Ab**	*0.14*±0.03 **Aa**	*0.09*±0.05 **Aa**	**0.10 a**			
Perlite + Peat	*0.08*±0.02 **Ab**	*0.06*±0.03 **Aa**	*0.4*±0.35 **Aa**	**0.18 a**			
Means of IBA	**0.25 a**	**0.15 a**	**0.20 a**				
Fresh weight of roots (g)							
Peat + Sand	*1.01*±1.01 **Aa**	*0.29*±0.06 **Aa**	*1.04*±1.08 **Aa**	**0.78 a**	**NS**	**NS**	**NS**
Perlite + Sand	*0.26*±0.05 **Aa**	*0.36*±0.16 **Aa**	*0.19*±0.04 **Aa**	**0.27 a**			
Perlite + Peat	*0.29±0.15* **Aa**	*0.27*±0.02 **Aa**	*0.31*±0.11 **Aa**	**0.29 a**			
Means of IBA	**0,52 a**	**0,31 a**	**0,51 a**				
Dry weight of shoots (g)							
Peat + Sand	*0.34±0.14* **Aab**	*0.24*±0.10 **Aa**	*0.26*±0.08 **Aa**	**0.28 ab**	*	**NS**	*
Perlite + Sand	*0.18*±0.08 **Ab**	*0.32*±0.10 **Aa**	*0.11*±0.09 **Aa**	**0.20 a**			
Perlite + Peat	*0.63*±0.21 **Aa**	*0.20*±0.10 **Ba**	*0.33*±0.10 **Bba**	**0.39 b**			
Means of IBA	**0.38 a**	**0.25 a**	**0.23 a**				
Fresh weight of shoots (g)							
Peat + Sand	*1.23*±0.25 **Aa**	*0.90*±0.24 **Aa**	*1.52*±1.13 **Aa**	**1.22 a**	**NS**	**NS**	**NS**
Perlite + Sand	*0.78*±0.32 **Aa**	*1.04*±0.05 **Aa**	*0.56*±0.34 **Aa**	**0.79 a**			
Perlite + Peat	*1.19*±0.30 **Aa**	*0.51*±0.34 **Aa**	*0.67*±0.14 **Aa**	**0.79 a**			
Means of IBA	**1.07 a**	**0.81 a**	**0.92 a**				

[y]: In the italicized section, capital letters indicate comparisons of means across rows (horizontally), while lowercase letters represent comparisons of means within columns (vertically).

[z]: Means followed by different letters are significantly different at the 5% level according to Duncan's multiple range test.

NS, ***, **, *:* Not significant, significant at 0.1%, 1% and 5% alpha levels, respectively.

±: Standard error (SE)

In terms of shoot length, both the growing media and IBA treatments exhibited statistically significant effects, and the interaction between these two factors was also found to be significant at the 1% level (Table 1). The longest shoots (1.56 cm) were observed in cuttings treated with 6000 ppm IBA and rooted in a peat + sand medium, while the shortest shoots (0.45 cm) were recorded in cuttings treated with the same IBA concentration but rooted in a perlite + peat mixture. These results indicate that both hormone concentration and substrate composition play a critical role in shoot development.

Moreover, when shoot length was evaluated based on mean IBA concentrations, a positive correlation was observed, with shoot length increasing as IBA concentration increased. However, this trend contrasts with the findings of Kösa (2021), who reported a decrease in shoot length with increasing IBA concentrations in *Thymus revolutus* cuttings. Nonetheless, the results align with those of Ranya et al. (2024), who found that in *Thymus atlanticus* cuttings, shoot lengths were higher at all IBA concentrations compared to the control group.

The effect of growing medium on shoot diameter was found to be statistically significant at the 5% level. The highest shoot diameter value (0.15 cm) was observed in cuttings treated with 6000 ppm IBA and rooted in a perlite + sand medium. In contrast, the lowest shoot diameter (0.08 cm) was recorded in cuttings treated with 3000 and 6000 ppm IBA and rooted in a perlite + peat substrate. When shoot diameter was evaluated according to mean IBA concentrations, the highest value was associated with the highest IBA dose (6000 ppm). However, this finding contrasts with that of Kösa (2021), who reported that in *Thymus revolutus* cuttings, shoot diameter was lower at the highest tested concentration (1000 ppm). Collectively, these results suggest that both the growing medium and hormone treatments interactively influence shoot diameter development in cuttings.

Various degrees of effects were also observed in other morphological parameters such as root diameter, root dry weight, root fresh weight, shoot dry weight, and shoot fresh weight (Figure 1). The interaction between growing medium and hormone treatments was found to be statistically significant at the 5% level for root dry weight, with the highest value (0.61 g) recorded in the control group rooted in a peat + sand medium. When root dry weight and root fresh weight were evaluated based on the mean values of the growing media, the highest values for both parameters were also found in the peat + sand medium. In contrast, when shoot dry weight and shoot fresh weight were assessed by the growing media averages, the highest values for both were obtained in the perlite + peat medium. While the effects of the growing medium and the interaction were statistically significant for shoot dry weight, the effect of hormone treatment alone was not found to be significant. When the dry and fresh weights of both roots and shoots were examined according to the mean IBA concentrations, it was observed that all values were higher in the control group. However, this finding contrasts with that of Ranya et al. (2024), who reported that in *Thymus atlanticus* cuttings, both root and shoot dry and fresh weights were higher in the IBA-treated groups compared to those of the control group. Similarly, Bahadori & Sharifi Ashorabadi (2017) reported that the highest root dry weights in *Thymus kotschyanus* cuttings were obtained at lower IBA concentrations (100 and 300 ppm). A related observation was made by Kösa (2021), who found that root and shoot dry weights were higher at 500 ppm IBA in *Thymus revolutus* cuttings, when compared to other tested concentrations (0 and 1000 ppm). These findings collectively highlight the importance of carefully selecting both the appropriate growing medium and the optimal hormone concentration to achieve favorable root and shoot development. Tüzel et al. (2020) emphasized that the effects of different growing media change according to ingredients of growing medium, their rates, physical and chemical properties of medium, crop species, growing period and crop management including irrigation, fertigation, and the use of beneficial microorganisms.

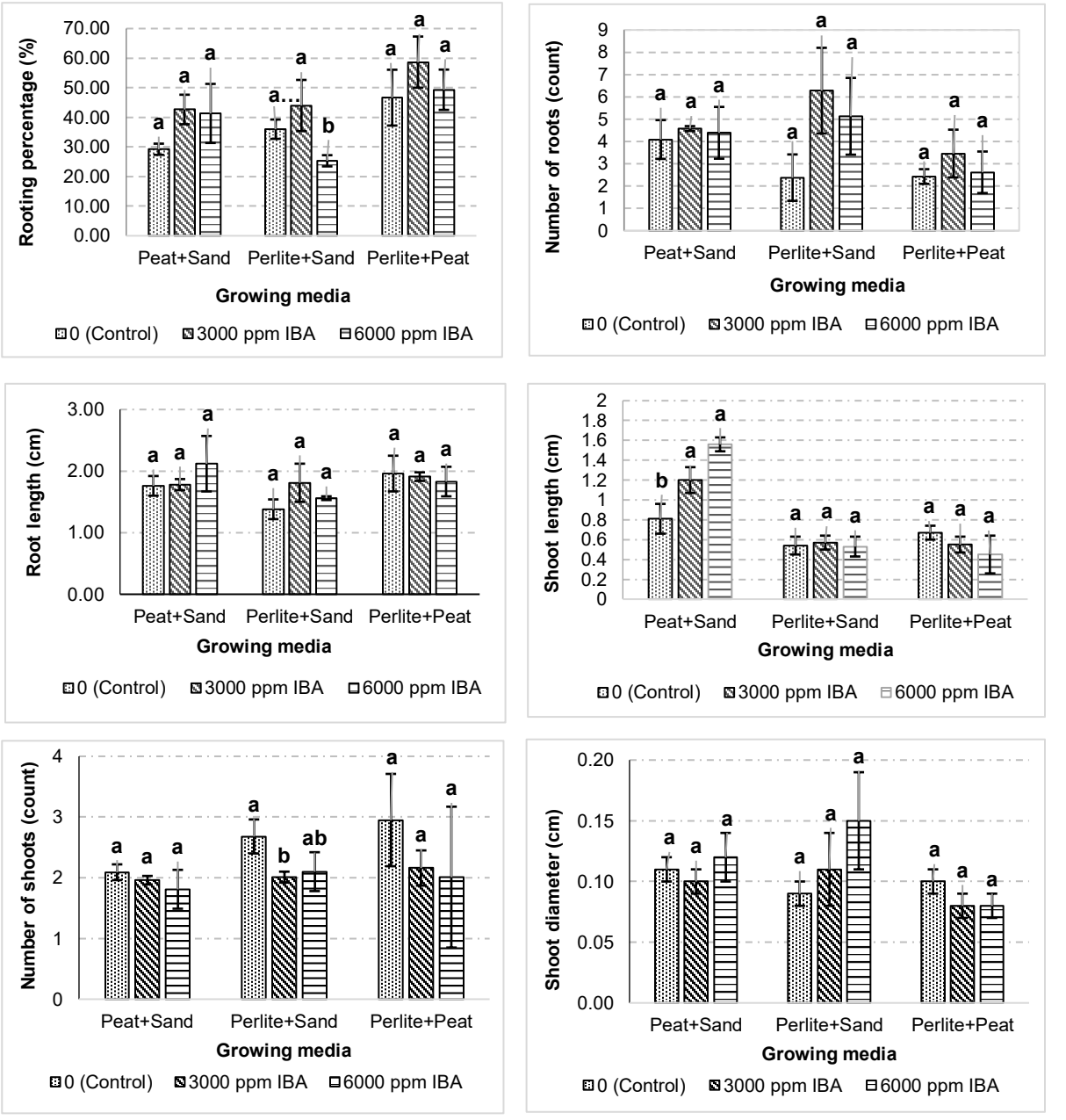


Figure 1. Variations in rooting performance of *S. thymbra* cuttings under different growing media and IBA concentrations. Error bars on the columns indicate the standard error (±SE), and different letters indicate statistical differences between IBA dosages according to Duncan's multiple range test ($p<0.05$).

Şekil 1. *Farklı yetiştirme ortamları ve IBA konsantrasyonları altında S. thymbra çeliklerinin köklenme performansındaki değişimler. Sütunlar üzerindeki hata çubukları standart hatayı (±SE), farklı harfler ise Duncan çoklu karşılaştırma testine göre IBA dozları arasındaki istatistiksel farkları (p<0.05) ifade etmektedir.*

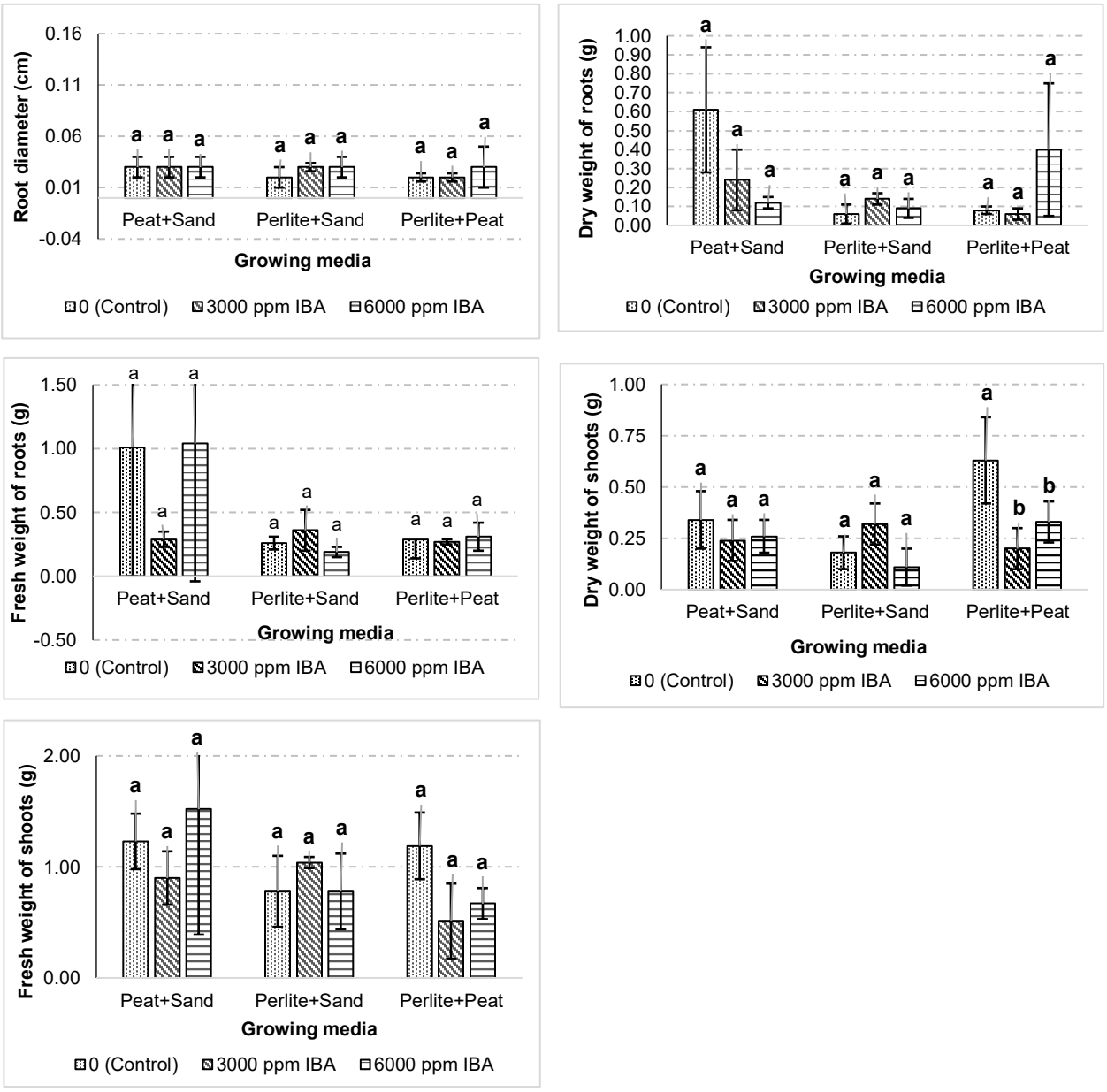


Figure 1. (**Continued**.
Şekil 1. (Devamı).

CONCLUSION

In conclusion, this study demonstrated that the growing medium and IBA hormone play a significant role in the rooting and development of *S. thymbra* cuttings. In particular, the combination of 3000 ppm IBA application with a Perlite+Peat medium yielded the best results. These findings are consistent with previous similar studies and contribute to the identification of optimal conditions that support plant growth. In addition to its rooting capabilities, *S. thymbra* exhibits significant potential for use as a groundcover in diverse landscape applications, including xeriscaping designs, rock gardens, various types of garden designs, and medicinal and aromatic gardens. Integrating such a natural species into landscape architecture applications not only highlights its ecological value but also contributes to the originality and

sustainability of vegetative designs in urban areas. Future research could further investigate the effects of these parameters under different species and environmental conditions in greater detail.

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Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: SK, NK; sample collection: SK, NK; analysis and interpretation of data: SK, NK; statistical analysis: SK, NK; visualization: SK, NK; writing manuscript: SK, NK.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that an ethics committee is not required for this study.

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