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RESEARCH PAPER

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RESPONSE OF ROOTING STEM CUTTINGS OF SAGE (*Salvia officinalis* L.) FOR EXOGENOUS HORMONE APPLICATIONS IN DIFFERENT GROWTH MEDIA

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ABSTRACT

The objective of this study was to investigate the effects of different growth media and IBA doses on the growth parameters of *Salvia officinalis* L. plant. The study was conducted according to a factorial experimental design in randomized plots within the climate cabin, which has fully controlled conditions, located in the Department of Horticulture at Van Yüzüncü Yıl University. A total of 360 cuttings were used, with 10 cuttings representing each application. In the study, which was conducted with three replications, plants were grown in 200 mL pots. The cuttings used in the rooting study were obtained from medicinal sage (*S. officinalis*) plants in the Medicinal and Aromatic Plants Garden of Van Yüzüncü Yıl University, Faculty of Agriculture, in June 2023. The cuttings were brought to the laboratory, planted in 3 different media: perlite (100%); perlite + peat (1 : 1); peat (100%), and applying four different concentrations of hormones: 0 ppm; 250 ppm; 500 ppm; 1000 ppm IBA (indole-3-butyric acid). The trial ended 50 days following planting, and the necessary measurements were made. In this study, the highest growth performance were obtained in the perlite + peat growth medium, except for root length. Considering the hormone × growth media interactions, the highest fresh plant weight, dry plant weight, fresh root weight, and dry root weight were obtained as 3.549 g, 0.976 g, 4.351 g, and 0.644 g, respectively, in perlite + peat growth medium applied with 1000 mg kg^{-1} IBA. The highest plant length (17.617 cm) and rooting rate (80%) were also obtained with 1000 mg kg^{-1} IBA application in peat (100%) and perlite (100%) growth media, respectively.

Key words: rooting, stem cuttings, indole-3-butyric acid, peat, perlite, substrate

INTRODUCTION

Salvia officinalis L., also known as sage, is a member of the *Lamiaceae* family and is recognized for its wide-ranging medicinal properties. Recent studies highlight the clinical efficacy of *S. officinalis* extracts. Sage leaves contain valuable bioactive compounds such as flavonoids, phenolics, rosmarinic acid, and diterpenes that contribute positively to human health and well-being [Agatonović-Kustrin et al. 2022, Aljuboori et al. 2024]. The content of bioactive compounds supports its application in various fields, including pain management, reducing inflammation, cancer treatment, cognitive enhancement, and antimicrobial action [Rodrigues et al. 2012, Erhan 2020, Aljuboori et al. 2024]. It has also been reported that it has the potential to enhance cognitive function and may play a preventive role against age-related diseases, such as Alzheimer's [Pop et al. 2016]. Furthermore, in addition to health benefits, *S. officinalis* is also recognized for its nutritional value and its use as a culinary herb, as well as a source of essential oil. Although crude essential oils may exhibit limited efficacy, their antibacterial properties

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can be enhanced through extraction, making *S. officinalis* particularly useful in food preservation and health applications [Xu 2022]. In addition, its effectiveness in managing premenstrual syndrome has been confirmed by clinical studies, indicating that it has broader implications for women's health management [Abdnezhad et al. 2019, Heydarpour et al. 2023].

Various studies have revealed the influence of growth media composition, including organic additives and basal media formulations, on the physiological traits and overall performance of plants. *Salvia officinalis* is typically cultivated using specific growth media that can significantly impact its growth, development, and essential oil production. Among the various substrates, peat and perlite mixtures have been widely studied due to their favorable physical and chemical properties. The integration of these materials affects moisture retention, aeration, and root development, all of which are important aspects to optimize for sage cultivation. Peat is consistently favored for sage germination and seedling vigor. Peat media yielding the highest germination percentages and robust seedling growth metrics for S. *officinalis*, with peat outperforming 100% soil, perlite, and sand in their trials [Aytekin et al. 2021]. This aligns with the general observation that peat-based substrates provide favorable physical properties and nutrient reservoir capacity critical for sage seedling establishment [Yoo et al. 2017, Aytekin et al. 2021]. Ferrarezi et al. [2016] determined that peat media yielded the highest germination percentage and robust seedling metrics for sage Vista Red compared with alternative substrates, reinforcing peat's suitability for *Salvia* propagation and early growth stages. Perlite is renowned for its lightweight nature and ability to improve aeration in potting mixes. Incorporating perlite into growth media can enhance aeration, but may reduce moisture retention if used in excessive amounts. The balance of perlite and other organic materials, particularly peat, is critical, with research indicating that optimal ratios significantly improve the physical and chemical properties of the medium, resulting in enhanced seedling growth [Maghdouri et al. 2021]. Care must be taken regarding excessive peat substitution with inert materials, as salinity and EC dynamics can negatively affect growth. Moderate incorporation of perlite in peat-based systems is advisable, with genotype- and system-specific validation recommended [Do and Scherer 2013]. The interaction between peat and perlite is particularly beneficial for sage propagation. Yoo et al. [2017] reported that traditional potting mixes containing combinations of soil, sand, perlite, and peat moss provided significantly better growth parameters for *Salvia* plants compared to mixes lacking these components, and peat plays a vital role in maintaining moisture, which is crucial for sage germination and early growth stages. Common peat–perlite baselines [for example, roughly 50–70% peat with 30–50% perlite] are advisable starting points, with adjustments based on irrigation and nutrient management [Ferrarezi et al. 2016, Yoo et al. 2017]. Currey et al. [2019] reported that peat and perlite mixtures play a crucial role in controlling moisture availability, which is essential for the successful cultivation of culinary herbs, including *S. officinalis*. It has been reported that the combined application of nitrogenous fertilization and peat can improve growth parameters in *S. officinalis* and optimize plant development, with the substrate playing a crucial role. Additionally, the moisture-retaining properties of peat contribute to the overall vitality of sagebrush, particularly in environments where water levels fluctuate [Sonmez and Bayram 2017]. The media having less than 25% of compost+ perlite were recommended by Do and Scherer [2013] for Salvia, underscoring the importance of substrate composition in promoting healthy growth of *S. officinalis* plants.

The application of exogenous hormones has a significant impact on physiological responses in *Salvia* species, enhancing their ability to cope with stress and promoting growth. These treatments primarily interact with the plant's endogenous hormone levels to shape responses related to stress tolerance, growth regulation, and secondary metabolite production. Application of exogenous indole-3-butyric acid (IBA), a synthetic auxin, has been extensively studied for its effects on root development and growth responses in various *Salvia* and other plant species. An optimal IBA concentration is essential, as determined in various studies involving different plant species, which have shown that too low or too high concentrations of IBA can inhibit rooting performance [Li et al. 2019]. Therefore, it has been reported that a balanced IBA application can lead to improved rooting, and consequently, increased biomass. Studies have shown that IBA application can affect secondary metabolism by increasing the stress tolerance of *Salvia* in saline conditions, thereby improving growth performance [Tan 2025]. It has been reported that IBA application can improve the rooting percentage and growth behavior of seedlings obtained from *S. officinalis* cuttings, thus effectively assisting vegetative expansion and propagation efforts [Gur et al. 2021]. In micropropagation and ex vitro rooting contexts, growth regulator regimes interacting with peat–perlite substrates influence rooting success and subsequent acclimatization. Papafotiou et al. [2023] reported that *Salvia* spp. microshoots root effectively on half-strength MS medium with low to moderate IBA (e.g., 0.0–0.5 mg L^{-1}) and acclimate successfully on peat–perlite substrates at a 1 : 1 ratio, illustrating a compatible pipeline from *in vitro* culture to peat–perlite-based *ex vitro* production. The general implication is that IBA enhances rooting in sage cuttings, and when used with peat–perlite media, rooting efficiency and acclimatization can be optimized. Although the cited study focuses on Greece-native *Salvia* species, the principle of combining IBA-treated cuttings with peat–perlite rooting substrates is broadly applicable to *Salvia* propagation [Papafotiou et al. 2023].

This study aimed to investigate the effects of different growth media and IBA doses on the growth parameters of *S. officinalis* cuttings.

MATERIALS AND METHODS

The research was conducted according to a factorial experimental design in randomized plots within the climate cabin, which has fully controlled chamber maintained at 23 °C, 65% relative humidity, with an 8/16 h dark/light photoperiod, located in the Department of Horticulture at Van Yüzüncü Yıl University. The cuttings used in the rooting study were obtained from medicinal sage (*S. officinalis*) plants from the Medicinal and Aromatic Plants Garden of Van Yüzüncü Yıl University, Faculty of Agriculture, in June 2023. Mean temperature of the month was 21.4 °C, total precipitation 7.2 mm and mean humidity was 45.4%. Cuttings of 10–12 cm length were selected from the fresh shoots of that yea, cut into cross-sections, and placed in pure water. Then, the cuttings were brought to the laboratory, and planted in 3 different media (M1 – perlite100%; M2 – perlite and peat (1 : 1); M3 – peat 100%) with applying four different levels of hormones (H0 – ethyl alcohol (99.9%) with distilled water (1 : 1) as control; H1 – 250 ppm; H2 – 500 ppm; H4 – 1000 ppm IBA. Hormone applications were done by a quick dipping method for 5 econd [Çiçek and Ozel 2021]. Some properties of materials used in growing media are given in Table 1.

Table 1. Some properties of materials used in growing media

Material	Brand	Structure	pH	Content
Peat	Klasmann TS1 Fine (white peat)	0–5 mm (extra fine)	6	Fertiliser level 1 g L^{-1} Nutrients added: 140 mg N L^{-1}, 160 mg P_2O_5 L^{-1}, 180 mg K_2O L^{-1}, 100 mg Mg L^{-1}, with necessary trace elements, Iron as EDTA chelate
Perlit	Ultraper	20–200 micron	6.8	Silicon 33.8%; Aluminium 7.2%; Potassium 3.5%; Sodium 3.4%

A total of 360 cuttings were used, with 10 cuttings representing each application. Plants were grown in 200 mL pots, and the experiment was conducted in three replications. After planting, the pots were watered with distilled water as needed. The trial ended 50 days following planting, and the necessary measurements were made. Plant height was determined by measuring the distance from the soil surface to the tip of the plant using a ruler and expressed in centimeters (cm). Plant roots were removed from the pots, and carefully cleaned by washing under water without damaging the roots. Their lengths were then determined by measuring the distance from the root collar to the tip of the root, and expressed in centimeters. Rooting rate was determined as a percentage by dividing the number of rooted cuttings by the number of planted cuttings for each application. While the fresh plant weight was determined by weighing the harvested above-ground parts immediately, the dry weight was determined after drying the plant samples in an oven at 40 °C for 24 hours. The root fresh weight was determined by weighing the roots, cleaned of soil and excess water with a napkin. The root dry weight was determined after drying the fresh root samples in an oven at 40 °C for 24 hours. The SPSS computer analysis program was used for statistical analysis of the obtained data, and the Duncan multiple comparison test was used to evaluate the differences between the means.

RESULTS AND DISCUSSION

The results of the variance analysis for plant growth parameters are given in Table 2. Plant length, fresh shoot weight, and dry shoot weight were significantly influenced ($p < 0.01$) by hormone concentration, and by the interaction between hormone level and growth medium. Growth medium alone also exerted a significant effect on plant length and fresh shoot weight ($p < 0.01$); however, no significant differences were observed in dry shoot weight among the tested media. Root length, rooting rate, and fresh root weight differed significantly ($p < 0.01$) in response to both, hormone levels and growth media. Moreover, the interaction between hormone level and growth medium significantly affected root length and fresh root weight ($p < 0.01$), as well as rooting rate ($p < 0.05$), whereas dry root weight remained statistically unchanged across all treatments (Table 2).

Table 2. The results of the analyses of variance for the plant growth parameters

Source of variation	Plant length	Fresh shoot weight	Dry shoot weight	Root length	Rooting rate	Fresh root weight	Dry root weight
Hormone (H)	109.63**	71.95**	38.73**	44.110**	13.500**	67.813 **	0.99^{ns}
Growth Media (M)	14.01**	85.48**	7.09	211.730**	67.170**	109.346**	1.05^{ns}
H × M	27.60**	28.01**	13.94**	59.440**	6.500*	23.789**	0.99^{ns}
CV	3.365	6.038	8.561	4.622	15.151	13.090	11.626

* significant at $p < 0.05$; ** significant at $p < 0.01$; ns – not significant

Mean values of plant growth parameters and the interactions between hormone concentration and growth medium are presented in Table 3. In the present study, the highest mean values for plant length, fresh shoot weight, and root length were recorded in the pure peat growth medium, reaching 15.018 cm, 2.645 g, and 15.018 cm, respectively. The greatest rooting rate, fresh root weight, and dry root weight were observed in the perlite + peat growth medium, with mean values of 66.7%, 2.569 g, and 0.344 g, respectively. In contrast, the highest dry shoot weight was recorded in perlite (0.789 g) and perlite + peat (0.762 g), which were classified within the same statistical group. Shoot growth parameters generally increased with rising hormone concentrations up to 1000 mg kg^{-1} IBA. However, the highest mean values for plant height, fresh shoot weight, and dry shoot weight were obtained at the 500 mg kg^{-1} IBA level, amounting to 15.727 cm, 2.817 g, and 0.870 g, respectively. Root growth parameters exhibited a consistent increase with increasing hormone doses, with the highest root length, rooting rate, fresh root weight, and dry root weight observed at 1000 mg kg^{-1} IBA, reaching 14.165 cm, 62.2%, 2.542 g, and 0.430 g, respectively.

Overall, the lowest values for most plant growth parameters were recorded in the perlite growth medium combined with the 0 mg kg^{-1} IBA treatment, with the exception of dry shoot weight and rooting rate (Table 3). Analysis of the hormone × growth medium interaction revealed that the highest mean values for fresh shoot weight (3.549 g), dry shoot weight (0.976 g), fresh root weight (4.351 g), and dry root weight (0.644 g) were obtained in the perlite + peat growth medium supplemented with 1000 mg kg^{-1} IBA. Furthermore, the maximum plant height (17.617 cm) and rooting rate (80.0%) were recorded in the peat and perlite growth media, respectively, when combined with the highest IBA dose.

When considering hormone dose × growth medium interactions, the lowest growth parameters were found in peat growth medium, without hormone application, except for the plant height and root length. The lowest plant height and root length were observed in perlite growth medium also without applied hormone.

In the present study, the growth media were ranked according to their ameliorative effects on plant growth parameters as follows: perlite + peat > peat > perlite. With respect to hormone treatments, IBA applications at concentrations of 500 and 1000 mg kg^{-1} exerted more pronounced positive effects on plant growth parameters compared with lower doses. Considering the interaction between hormone concentration and growth medium, the combination of 1000 mg kg^{-1} IBA with the perlite + peat substrate was identified as the most effective treatment for achieving optimal plant growth. The cultivation of *Salvia* species, particularly with regard to substrate selection, remains an important area of horticultural research. The physical and chemical properties of the growth media, including pH, drainage, and nutrient content, play a crucial role in establishing conditions favorable for root development and efficient nutrient uptake [Salamat et al. 2019]. Numerous studies have demonstrated that substrate composition, including the proportion of organic components and mineral amendments, significantly influences plant physiological responses and overall performance. In particular, the proportion of perlite in potting substrates has been shown to affect water retention and nutrient availability, both of which are essential for optimal *Salvia* growth.

Table 3. Effects of hormone dose and growth medium on growth parameters of *Salvia officinalis* L. cuttings

Parameter	Growth media	Hormone dose (mg kg^{-1})				
		0	250	500	1000	Mean
Plant length (cm)	Perlite	14.233	14.367	14.733	11.050	13.595 B
	Perlite + Peat	12.219	13.514	14.833	12.958	13.383 B
	Peat	11.400	15.500	17.617	12.833	14.337 A
	Mean	12.618 C	14.461 B	15.727 A	12.281 C	
Fresh shoot weight (g)	Perlite	1.924	1.883	2.338	1.730	1.968 B
	Perlite + Peat	1.713	2.394	2.913	3.549	2.642 A
	Peat	2.017	2.670	3.202	2.693	2.645 A
	Mean	1.884 D	2.315 C	2.817 A	2.315 B	
Dry shoot weight (g)	Perlite	0.735	0.771	0.963	0.689	0.789 A
	Perlite + Peat	0.474	0.674	0.928	0.976	0.762 A
	Peat	0.479	0.816	0.722	0.759	0.694 B
	Mean	0.562 C	0.753 B	0.870 A	0.807 B	
Root lenght (cm)	Perlite	7.600	11.783	11.392	9.850	10.157 C
	Perlite + Peat	11.403	16.764	15.644	16.258	13.725 B
	Peat	14.800	9.167	14.550	16.383	15.018 A
	Mean	11.267 C	12.572 B	13.862 A	14.165 A	
Rooting rate (%)	Perlite	40.0	53.3	80.0	80.0	63.3 A
	Perlite + Peat	66.7	66.7	60.0	73.3	66.7 A
	Peat	13.3	40.0	40.0	33.3	31.7 B
	Mean	40.000 C	53.333 B	60.000 BA	62.222 A	
Fresh root weight (g)	Perlite	0.961	1.422	1.398	1.241	1.255 C
	Perlite + Peat	1.541	1.828	2.559	4.351	2.569 A
	Peat	0.768	1.103	2.060	2.036	1.491 B
	Mean	1.089 D	1.450 C	2.005 B	2.542 A	
Dry root weight (g)	Perlite	0.144	0.192	0.210	0.224	0.192 C
	Perlite + Peat	0.237	0.217	0.280	0.644	0.344 A
	Peat	0.107	0.139	0.260	0.423	0.232 B
	Mean	0.162 C	0.182 C	0.250 B	0.430 A	

The marked with the same letters were not significantly different based on the Duncan multiple range test (DMRT); significant at $p < 0.01$

Research on culinary herbs, including *S. officinalis*, has shown that substrates composed of sphagnum peat moss combined with perlite improve volumetric water content management and promote balanced shoot and root growth through enhanced moisture regulation [Currey et al. 2019]. This is especially relevant for *Salvia* species, which are sensitive to both excessive and insufficient watering, thereby necessitating a well-aerated and well-drained substrate to ensure healthy root development. Further investigations into substrate ratios and additives have revealed that modifying peat-to-perlite proportions not only alters the physical structure of the growing medium but also influences nutrient dynamics and plant performance. Martini et al. [2022] reported that a balanced peat and perlite mixture (1 : 1, v/v) resulted in high rooting rates and successful acclimatization of *Salvia tomentosa*. Additionally, Londra [2010] highlighted the importance of hydrophobic properties arising from peat–perlite combinations, demonstrating hysteresis effects between drying and wetting cycles that affect water availability to plant roots. The favorable performance of seedlings grown in peat–perlite substrates further underscores the importance of substrate composition in supporting healthy growth of *S. officinalis*. This suggests that substrate composition not only influence early developmental stages, including germination, but also establish good conditions for strong root system formation, which is essential for successful commercial propagation.

Exogenous application of IBA has been widely studied for its role in enhancing root development and growth responses in *Salvia* species and other plants. As a synthetic auxin, IBA promotes adventitious root initiation, improves root quality, and contributes to overall plant vigor. Gur et al. [2021] demonstrated that IBA application increased rooting percentage and improved growth characteristics in *S. officinalis* cuttings, thereby supporting vegetative propagation efforts. The physiological activity of IBA is largely attributed to its conversion to indole--3-acetic acid (IAA), which regulates multiple growth processes, including root initiation [Fattorini et al. 2017]. This interaction between exogenous IBA and endogenous auxin levels highlights the importance of hormonal balance in modulating plant responses.

Previous studies have emphasized that appropriate IBA concentrations enhance rooting and biomass accumulation, whereas excessively low or high doses may inhibit rooting performance [Li et al. 2019]. IBA concentrations ranging from 600 to 2000 ppm have been reported to significantly increase root number and improve growth characteristics under various environmental conditions, including salinity stress [Sari et al. 2014, Tan 2025]. Moreover, synergistic interactions between hormonal treatments and growth media have been shown to further optimize plant growth responses, reinforcing the importance of integrating both factors in horticultural practices [Arthagama et al. 2021].

The incorporation of IBA into effective growth substrates has also been associated with enhanced physiological performance and improved antioxidant responses, facilitating plant adaptation and reinforcing the interdependence between the growth environment, hormonal regulation, and overall plant performance [Logsdon and Sauer 2016, Tan 2025]. In agreement with these findings, the present study demonstrated that the combination of perlite + peat growth medium supplemented with 1000 mg kg^{-1} IBA was the most effective treatment for promoting optimal plant growth. The results obtained are consistent with previously reported literature, confirming the suitability of combined peat–perlite substrates and appropriate IBA concentrations for enhancing growth and propagation of *Salvia* species.

CONCLUSION

The cultivation of *Salvia* species continues to attract considerable interest in horticultural research, particularly with respect to optimizing growth conditions and propagation techniques. In the present study, the highest mean values of most growth parameters were obtained in the perlite + peat growth medium, with the exception of plant height and root length. Overall, increasing IBA concentrations enhanced the growth performance of *S. officinalis* compared with treatments without hormone application. Among the tested hormone doses, 500 mg kg^{-1} IBA was more effective in promoting vegetative growth, whereas 1000 mg kg^{-1} IBA exerted a stronger influence on root development. The results further demonstrated that plant growth parameters were significantly influenced by the interaction between hormone dose and growth medium. Notably, the application of 1000 mg kg^{-1} IBA in a perlite + peat substrate proved to be the most effective treatment for achieving optimal growth of *S. officinalis*. These findings indicate that the combined use of IBA-treated cuttings and peat–perlite rooting substrates represents a practical and efficient approach for the propagation of *Salvia* species and may be broadly applicable in horticultural production systems.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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