DOI: 10.29050/harranziraat.1397407
Harran Tarım ve Gıda Bilimleri Derg. 2024, 28(1):11-18

Research Article/Araştırma Makalesi

Effect of two different base cuts and indole-3-butyric acid (IBA) doses on rooting of stem cuttings of wild *Silene compacta* Fischer

Doğal Silene compacta Fischer'in gövde çeliklerinin köklenmesi üzerine iki farklı çelik tabanı kesimi ve indol-3-bütirik asit (IBA) dozlarının etkisi

Muharrem ARSLAN[1*]

[1]Aydın Adnan Menderes University, Koçarlı Vocational School, Department of Park and Horticulture, Aydın, Türkiye

[1]https://orcid.org/0000-0002-9543-560X

To cite this article:
Arslan, M. (2024). Effect of two different base cuts and indole-3-butyric acid (IBA) doses on rooting of stem cuttings of wild silene compacta fischer . Harran Tarım ve Gıda Bilimleri Dergisi, 28(1): 11-18
DOI: 10.29050/harranziraat.1397407

Address for Correspondence:
Muharrem ARSLAN
e-mail:
arslanmuharrem07@gmail.com

Received Date:
28.11.2023
Accepted Date:
26.02.2024

ABSTRACT

Silene compacta Fisch. ex Hornem., which grows naturally, is a plant species with high ornamental plant potential in the *Silene* L. genus of the *Caryophyllaceae* family. Vegetative propagation is one of the important ways to preserve naturally growing and cultivated plant species. In this study, the effect of two different cutting areas of the cutting base (above the node-below the node) and five different indole-3-butyric acid (IBA) doses (control, 500, 1000, 2000 and 4000 ppm) on the rooting of stem cuttings taken from individuals of the natural *S. compacta* species were investigated. IBA was applied to the cuttings' bases in a commercial rooting powder. Perlite+peat mixture at a ratio of 1:1 (v/v) was used in the rooting medium. Survival rate, rooting percentage, blooming rate, root number, root length, seedling height, seedling stem diameter, side shoot number, shoot length and shoot stem diameter were evaluated. The evaluation was made one month after the start of the experiment. As a result, the highest survival rate in cuttings was obtained from above-node control group (100%) and under-node 2000 ppm IBA (95%) application, and the highest rooting percentage was obtained from under-node 2000 ppm IBA (68%) and above-node control group (65%), respectively. Based on the results, it can be concluded that different cuttings of the cutting base and IBA concentrations have different effects on the rooting success of the *S. compacta* species with stem cuttings.

Key Words: *Silene compacta,* Ornamental plant, IBA, Rooting, Vegetative propagation

ÖZ

Doğal olarak yetişen *Silene compacta* Fisch. ex Hornem., karanfilgiller (*Caryophyllaceae)* familyasının *Silene* L. cinsi içerisinde süs bitkisi potansiyeli yüksek olan bir bitki türüdür. Doğal olarak yetişen ve kültürü yapılan bitki türlerinin korunmasındaki önemli yollardan biri de vejetatif çoğaltmadır. Bu çalışmada, doğal *S. compacta* türünün bireylerinden alınan gövde çeliklerinin köklenmesi üzerine çelik tabanının iki farklı kesim yerinin (boğum üstü-boğum altı) ve beş farklı indol-3-bütirik asit dozunun (kontrol, 500, 1000, 2000 ve 4000 ppm) etkisi araştırılmıştır. IBA, çeliklerin tabanlarına ticari bir köklendirme tozu içinde toz olarak uygulanmıştır. Köklendirme ortamı olarak 1:1 (v/v) oranında perlit+torf karışımı kullanılmıştır. Canlılık oranı, köklenme yüzdesi, çiçeklenme oranı, kök sayısı, kök uzunluğu, fide yüksekliği, fide gövde çapı, yan sürgün sayısı, sürgün uzunluğu ve sürgün gövde çapı yönünden değerlendirme yapılmıştır. Deney, bir ay sonra sonlandırılmıştır. Sonuç olarak, çeliklerde sırasıyla en yüksek canlılık oranı boğum üstü kontrol grubu (%100) ve boğum altı 2000 ppm IBA (%95) uygulamasından, en yüksek köklenme yüzdesi ise boğum altı 2000 ppm IBA (%68) ve boğum üstü kontrol grubu (%65) uygulamasından elde edilmiştir. Sonuçlara dayanarak, çelik tabanının farklı kesimi ve IBA konsantrasyonlarının *S. compacta* türünün gövde çelikleriyle köklendirme başarısı üzerinde farklı etkiye sahip olduğu sonucuna varılabilir.

Anahtar Kelimeler: *Silene compacta*, Süs bitkisi, IBA, Köklenme, Vejetatif çoğaltma

Introduction

Silene L., which has been an ecologically important plant group since ancient times, is a member of the *Caryophyllaceae* family (Ferreira *et al.,* 2015). *Silene* L., one of the largest genera in the world flora, contains approximately 870 plant species (Eggens *et al.,* 2020; Guner *et al.,* 2012; Jafari *et al.,* 2020; Moiloa *et al.,* 2021).

Silene compacta Fisch. ex Hornem., which grows naturally, is a plant species with high ornamental plant potential in the *Silene* L. genus of the *Caryophyllaceae* family. *S. compacta*, which has phytoremediation potential, has a very important advantage in landscape planning with its ornamental plant feature (Kosa and Karaguzel, 2020; Wei *et al.,* 2021). It has side-branched inflorescences, pink flowers, upright form, very small seeds, striped on the back and flat on the sides (Draghia and Chelariu Zaharia, 2011). It is naturally found in the altitude range of 0-2100 m in the Western, Northern, Eastern, Southern and Central Anatolian regions of Türkiye. It is a single, biennial or perennial herb form, completely hairless (Coode and Cullen, 1967; Kosa and Karaguzel, 2020). It has head-shaped flowers consisting of numerous pink-colored florets. It grows naturally on steep slopes, stream edges, shores, forest clearings, stones and cliffs. When the literature studies on *S. compacta* are examined, it is seen that the research on this species is quite limited, and no data has been found especially for its vegetative propagation.

Natural plant species are in danger of extinction under the influence of many factors such as mines, forest fires, increasing urbanization and climate changes. Therefore, it is necessary to identify natural plant species with economic and ornamental plant potential and to bring them into the ornamental plants sector. Thus, *ex-situ* and *in-situ* conservation of natural plant species will be possible (De Souza and Beckmann-Cavalcante, 2022).

Interest in natural plant species is increasing day by day. Detection and identification of plant species with ornamental plant characteristics and determination of reproduction methods can both reduce the risk of extinction and bring them into the ornamental plants sector. Cuttings are a rapid vegetative propagation method that allows the preservation of traits of interest and promotes *ex-situ* conservation of native species (Villa *et al.,* 2017; Assumpção Bastos *et al.,* 2020).

In plant production, growth regulators (auxins) are widely used as rooting enhancers (Pacholczak and Żatkiewicz, 2022). Auxins are used to stimulate the development of roots (Assumpção Bastos *et al.,* 2020). The most widely used of this auxin group is indole-3-butyric acid (IBA) (Cassol *et al.,* 2017; Azad *et al.,* 2018; Costa Junior *et al.,* 2018; Pêgo *et al.,* 2019; Dias Bezerra *et al.,* 2020; Singh *et al.,* 2021; Adiba *et al.,* 2022; Solgi *et al.,* 2022; Xie *et al.,* 2023).

Nowadays, the emergence of a new breed for commercial flower production is rare. Within a common genus, the introduction of new species is more common, and the dissemination of new varieties from these species is certainly more appropriate. However, it is difficult to develop and launch a taxon that can be commercially successful and profitable. One of the stages of introducing natural plants into the sector as ornamental plants and taking them into culture is to determine the appropriate propagation protocol. Propagation by cuttings, which is one of the vegetative propagation methods, is one of the primary methods that should be taken into consideration in the first attempts (Alp et al., 2020).

The objective of this study was to evaluate the vegetative propagation of stem cuttings of *S. compacta*, which grows naturally in Bolu province and has high ornamental plant potential, using two different base cuttings and five different indole-3-butyric acid (IBA) concentrations.

Material and Methods

In this study carried out in May-June 2021, the stem cuttings of *S. compacta* (Figure 1) were used. The cuttings were taken from *S. compacta*, which grows naturally in Bolu, located in the geographical coordinates of 40° 32'-40° 38' N, 32° 10'-32° 20' E and at an altitude of 1300-1600 m. The experiment was carried out in the unheated greenhouse of Aydın Adnan Menderes University Faculty of Agriculture, located at the geographical coordinates of 37° 45' N 27° 45' East and at an altitude of 61 m. The cuttings used in the research were prepared in two different base cuts, 10±2 cm in length, half cut double leaf, straight with a sharp knife, from the main stem, under and above the node. The prepared cuttings were surface sterilized in 1% sodium hypochlorite (NaClO) solution for 5 min. Then, the cuttings were washed thoroughly with distilled water and kept in distilled water for 5 min. Before planting, five different IBA concentrations (control, 500, 1000, 2000 and 4000 ppm) mixed with talcum powder were applied to the cuttings' bases in powder form to stimulate rooting. The humidity and temperature of the greenhouse were recorded daily with a thermo-hygrometer (Figure 2). This study, with 200 cuttings in total, was carried out in a rooting medium in an equal volume white styrofoam foam box with a 1:1 ratio of perlite+peat mixture (v/v). Each application was established according to the random plot design with 4 replications and 10 cuttings in each replication, with a total of 40 cuttings. The medium was sprayed with fungicide (50% Captan) every two weeks. The experiment was terminated after 30 days.

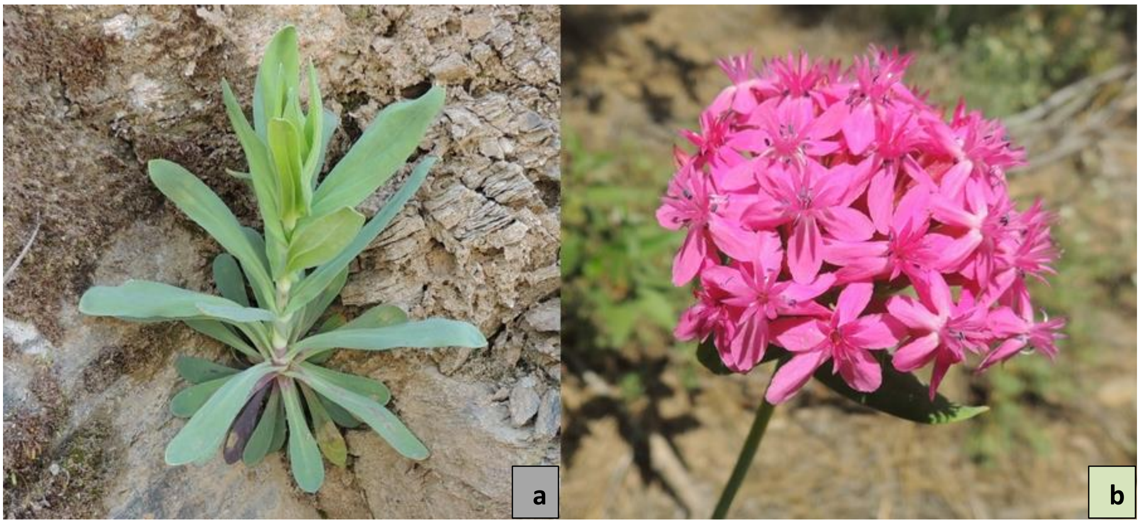

Figure 1. Seedling (a) and flower (b) of wild *S. compacta* species, which constitutes the material of the study.

Survival rate (%), rooting percentage (%), blooming rate (%), root number (piece), root length (mm), seedling height (cm), seedling stem diameter (mm), side shoot number (piece), shoot length (cm) and shoot stem diameter (mm) were evaluated.

Log10 transformation was performed on the obtained variable data (West, 2022). The difference between the treatments was determined by one-way analysis of variance (ANOVA). Means with difference were compared using Tukey's HSD test ($p<0.05$). IBM SPSS Statistics 22.0 software was used for data statistical analysis.

Results and Discussion

At the end of the one-month experiment, the daily average temperature and humidity values of the rooting greenhouse were recorded between 22-33 ºC and 62-87% (Figure 2), respectively.

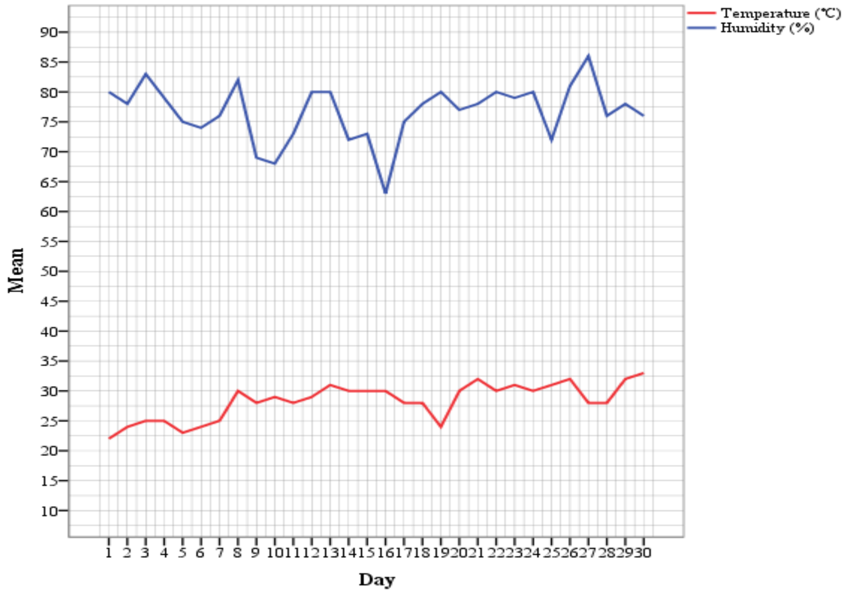

Figure 2. Average temperature (^{0}C) and humidity (%) values measured daily in the trial greenhouse.

Survival rate, rooting percentage, blooming rate, root length, seedling height, seedling stem diameter and side shoot number were affected by different IBA concentrations and the above-under the node cuts of the cutting bases ($p<0.05$). However, for root number, shoot length and shoot stem diameter, there was no significant difference in stem cuttings of wild *S. compacta* in terms of both different IBA concentrations and the above-under the node cuts of the cutting bases ($p>0.05$; Table 1).

In terms of survival rate, the highest effect was obtained from above the node control group (100%), and the lowest effect was obtained from above the node 4000 ppm IBA (55%) application. The survival rate decreased as the IBA dose increased in the above-node cutting of the cutting base compared to the control group. In the under-node cutting of the cutting base, the highest survival rate was obtained from 2000 ppm IBA (95%) application. The highest rooting percentage was obtained from under the node 2000 ppm IBA (68%), and the lowest rooting was obtained from under the node control group and above the node 4000 ppm IBA (20%) applications. The percentage of rooting decreased as the IBA dose increased compared to the control group (65%). The highest blooming rate was obtained from above the node control group (75%), and the lowest blooming was obtained from under the node 4000 ppm IBA (21%) application (Table 1; Figure 3). The high temperatures in the rooting medium can be said to be the reason for the flowering seen in the cuttings (Figure 2).

Table 1. Average rooting and vegetative growth data as a result of two different base cutting IBA concentrations applied to stem cuttings of *S. compacta*.

Treatments	SR*	RP*	BR*	RN**	RL*	SH*	SESD*	SSN*	SL**	SHSD**
Control (above)	100^{a}	65^{ab}	75^{a}	2.0	16.6^{ab}	19.1^{a}	3.7^{a}	1.0^{ab}	11.5	0.8
500 ppm (above)	86^{a}	56^{ab}	44^{ab}	3.2	18.3^{ab}	15.1^{ab}	3.1^{ab}	1.2^{a}	8.5	0.7
1000 ppm (above)	71^{ab}	30^{ab}	30^{ab}	1.8	8.7^{ab}	11.8^{ab}	2.5^{ab}	0.5^{ab}	5.8	0.4
2000 ppm (above)	70^{ab}	40^{ab}	44^{ab}	1.5	13.9^{ab}	15.3^{ab}	2.7^{ab}	0.7^{ab}	9.7	0.6
4000 ppm (above)	55^{b}	20^{b}	25^{ab}	0.7	8.5^{ab}	8.6^{b}	2.0^{b}	0.4^{b}	4.2	0.3
Control (under)	90^{a}	20^{b}	40^{ab}	0.7	4.6^{b}	13.0^{ab}	3.3^{ab}	0.6^{ab}	5.1	0.5
500 ppm (under)	80^{ab}	55^{ab}	65^{ab}	3.6	18.1^{ab}	17.0^{ab}	3.3^{ab}	1.1^{ab}	11.6	0.8
1000 ppm (under)	75^{ab}	51^{ab}	37^{ab}	3.4	21.4^{ab}	13.8^{ab}	2.8^{ab}	0.6^{ab}	7.6	0.5
2000 ppm (under)	95^{a}	68^{a}	34^{ab}	2.9	21.2^{a}	15.1^{ab}	3.5^{ab}	1.0^{ab}	7.8	0.8
4000 ppm (under)	80^{ab}	60^{ab}	21^{b}	2.5	16.7^{ab}	12.2^{ab}	3.0^{ab}	0.7^{ab}	5.9	0.6

*The difference between the values with different letters is significant according to the Tukey's HSD test at $p<0.05$. **The difference between the values with the same letter is not significant according to the Tukey's HSD test at $p>0.05$. SR=survival rate (%), RP=rooting percentage (%), BR=blooming rate (%), RN=root number (piece), RL=root length (mm), SH=seedling height (cm), SESD=seedling stem diameter (mm), SSN=side shoot number (piece), SL=shoot length (cm), SHSD=shoot stem diameter (mm).

The average maximum root length was obtained from under the node 1000 ppm IBA (21.4 mm), while the lowest root length was obtained from under the node control group (4.6 mm) applications. The average longest seedling height and seedling stem diameter was obtained from above the node control group (19.1 cm; 3.7 mm), while the lowest seedling height and seedling stem diameter was obtained from above the node 4000 ppm IBA (8.6 cm; 2.0 mm) applications, respectively. Likewise, the average maximum number of side shoots was obtained from above the node 500 ppm IBA (1.2 piece/cutting) and the least from above the node 4000 ppm IBA (0.4 units/steel) applications (Table 1; Figure 3).

The average maximum number of primary roots was obtained from under the node 500 ppm IBA (3.6 piece/cutting), while the lowest number of primary roots was obtained from under the node control group (0.7 piece/cutting) and above the node 4000 ppm IBA (0.7 piece/cutting) applications. The average longest shoot length and shoot stem diameter was obtained from under the node 500 ppm IBA (11.6 cm; 0.8 mm), while the lowest shoot length and shoot stem diameter was obtained from above the node 4000 ppm IBA (4.2 cm; 0.3 mm) applications, respectively (Table 1; Figure 3).

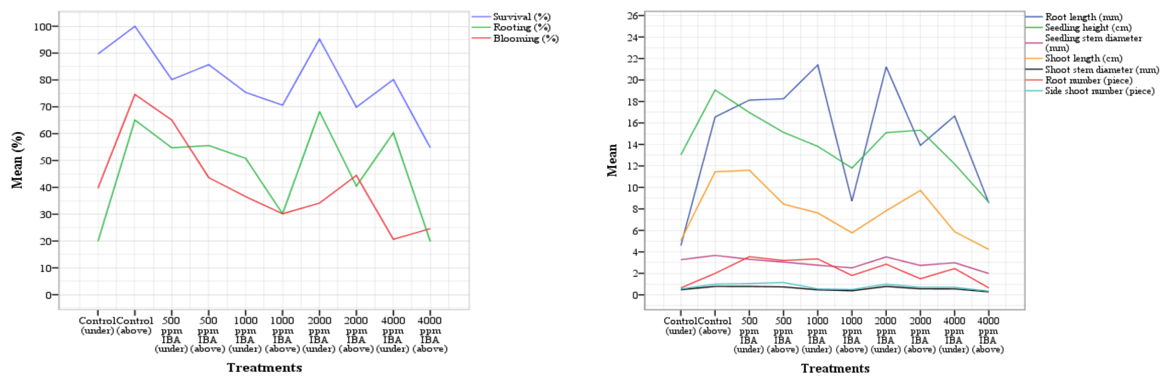

Figure 3. Graphical view of the data obtained from the cuttings at the end of the experiment.

No study was found on the vegetative propagation of *S. compacta*. In this respect, In rooting *Silene fabaria* subsp *domokina* with cuttings, optimum rooting (100%) was achieved with 20.75 roots of 4.84 cm length with 1000 ppm IBA (Sarropoulou et al., 2018). In rooting *Silene chalcedonica* with cuttings, the highest rooting rate (54.93%) and average number of roots (4,044) were obtained from the application of 1% IBA and 0.5% NAA (Jiang et al., 2016). On the other hand, it has been compared with rooting studies on other species. Different concentrations of IBA applications had different effects on the rooting success of black and white myrtle (*Myrtus communis* L.). The highest rooting percentage (76.67%) in black myrtle was obtained from cuttings applied 1000 mg L^{-1} IBA. In white myrtle, the highest rooting percentage (43.33%), shoot percentage (43.33%), rooted-shooted rates (43.33%) and average root number (1.63 pcs) were obtained from 500 mg L^{-1} IBA dose (Alım and Kaya, 2023). The highest rooting success of *Sterculia foetida* cuttings and the survival rate of rooted cuttings were seen in cuttings treated with 0.8% IBA. The sprouting success of rooted cuttings was obtained from cuttings treated with 0.4% IBA. Also, the cutting type (leaf/leafless) of the cuttings had no effect on rooting and sprouting success and overall survival (Azad *et al.,* 2018). In a study on the rooting of lavender (*Lavandula angustifolia* Mill.), the most suitable cutting type was determined as the semi-woody cutting and the most suitable IBA dose was 8000 ppm (Cicek and Ozel, 2021). IBA concentrations did not affect the rooting percentage of 'Otto' azalea (*Rhododendron simsii* Planch.) cultivars. However, 2000 mg L^{-1} IBA application had a positive effect on root number, mean and total length, dry matter, surface area and volume (Dias Bezerra *et al.,* 2020). In a study on the rooting sandy thyme (*Thymus revolutus* Celak), the highest rooting rate was determined with 88,33% in cuttings that were applied 500 ppm IBA and rooted in torf+perlite (1:1 by volume) (Kosa, 2021). Maximum rooting, root number and root length were obtained from the application of 3000 mg L^{-1} IBA concentration in pomegranate cuttings (Adiba *et al.,* 2022). The highest rooting rate (88.00%) in goji berry was obtained from cuttings applied with 1000 ppm IBA (Celik and Cetin, 2021). According to these studies, the results of our study are similar and even have higher rooting values than some studies.

Figure 4. Stem cuttings planted (a) in rooting medium and cuttings rooted (b) at the end of the experiment.

Conclusion

Above-under the node point of the cutting base cuts and applied IBA doses were effective in the reproduction of *S. compacta* with stem cuttings. The average highest rooting percentage was obtained from the experiment made from above the node of the base cutting of the cuttings and no IBA applied. Likewise, the highest rooting percentage was obtained from the 2000 ppm IBA concentration in the experiment, which was carried out under the node at the base cuts. The highest survival rate in cuttings was obtained from above-node control group (100%) and under-node 2000 ppm IBA (95%) application, and the highest rooting percentage was obtained from under-node 2000 ppm IBA (68%) and above-node control group (65%), respectively. The results of this study showed that *S. compacta* can be easily reproduced vegetatively by stem cuttings.

Conflict of interest: The author declare that he has no conflict of interest.

Author contributions: M.A: Conducting the research and writing the results were done by the author.

References

Adiba, A., Haddioui, A., Outghouliast, H., Hamdani, A., Mekaoui, A., & Charafi, J. (2022). Evaluation of cuttings ability of eighteen pomegranate cultivars from an ex-situ collection under influence of stem age and IBA treatment. *Scientia Horticulturae*, *304*, 111281. https://doi.org/10.1016/j.scienta.2022.111281

Alım, E., & Kaya, A. S. (2023). Effect of different concentrations of IBA and time of taking cutting on propagation of black and white myrtle (*Myrtus communis* L.) cuttings. *Horticultural Studies, 40(1)*, 8-15. http://doi.org/10.16882/HortiS.1233002

Alp, Ş., Zeybekoğlu, E., Salman, A., Özzambak, M. E., (2020). The development and cultivation of wild plants and using as ornamental plant. *Journal of Agricultural Faculty of Bursa Uludag University, 34(Special Issue),* 351-357.

Azad, M. S., Alam, M. D., Mollick, A. S., & Islam Khan, M. N. (2018). Rooting of cuttings of the wild Indian almond tree (*Sterculia foetida*) enhanced by the application of indole-3-butyric acid (IBA) under leafy and non-leafy conditions. *Rhizosphere, 5,* 8-15. https://doi.org/10.1016/j.rhisph.2017.11.001

Cassol, D. A., Dotto, M., Pirola, K., & Júnior, M. W. (2017). Behavior of piles and indol butyric or homeopathic prepared acid *Arnica montana* spread of false-erica. *Ornamental Horticulture, 23(2),* 138-143. http://dx.doi.org/10.14295/oh.v23i2.945

Celik, H., & Cetin, F. (2021). Effect of cutting time and IBA application on the rooting of Goji Berry cuttings. *Yuzuncu Yıl University Journal of Agricultural Science, 31(2),* 294-304.

Cicek, E., & Ozel, A. (2021). Determination of suitable cutting type and IBA dose for seedling production in lavender (*Lavandula angustifolia* Mill.). *Harran Journal of Agricultural and Food Science, 25(2),* 254-264. doi:10.29050/harranziraat.827325

Coode, M. J. E., & Cullen, J. (1967). *Silene* L. In: Davis, P. H., Cullen, J. & Coode, M. J. E. (Eds). *Flora of Turkey and the East Aegean Islands, Edinburgh University, Edinburgh*, *UK. 2,* 179-243.

Costa Junior, E. D. S., De Melo Barbosa, M. S., Da Silva, C. M. A., Da Silva, R. C. S., Piedade Kiill, L. H. & Beckmann-Cavalcante, M. Z. (2018). Vegetative propagation of *Rhaphiodon echinus* Schauer (*Lamiaceae*): effects of the period of cutting in rooting, cuttings arrangement and IBA concentrations for seedlings production. *Ornamental Horticulture, 24(3),* 238-247. http://dx.doi.org/10.14295/oh.v24i3.1232

De Souza, R. R., & Beckmann-Cavalcante, M. Z. (2022). Conservation and use of biodiversity. *Ornamental Horticulture, 28(4),* 385-386. https://doi.org/10.1590/2447-536X.v28i3.2561

Dias Bezerra, A. K., Ferraz, M. V., Lopes Pivetta, K. F., Nogueira, M. R., & Mazzini-Guedes, R. B. (2020). Rooting of azalea cuttings of Otto and Terra Nova cultivars treated with auxin and boron. *Ornamental Horticulture, 26(1),* 77-88. https://doi.org/10.1590/2447-536X.v26i1.2041

Draghia, L., & Chelariu Zaharia, E. L. (2011). Aspects regarding the production of planting material at some ornamental species from spontaneous flora. *Bulletin UASVM Agriculture, 68(1),* 332-337.

Eggens, F., Jafari, F., Thollesson, M., Crameri, S., Zarre, S., & Oxelman, B. (2020). Phylogeny and species delimitation in *Silene* sect. *Arenosae* (*Caryophyllaceae*): A new section. *PhytoKeys, 159,* 1-34. https://doi.org/10.3897/phytokeys.159.51500

Ferreira, V., Castro, I., Rocha, J., Crespí, A. L., Pinto-Carnide, O., Amich, F., Almeida, R., & Carnide, V. (2015). Chloroplast and nuclear DNA studies in Iberian Peninsula endemic *Silene scabriflora* subspecies using cpSSR and ISSR markers: Genetic diversity and phylogenetic relationships. *Biochemical Systematics and Ecology, 61*, 312-318. https://doi.org/10.1016/j.bse.2015.06.029

Guner, A., Aslan, S., Ekim, T., Vural, M., & Babac, M. T. (2012). Türkiye Bitkileri Listesi (Damarlı Bitkiler). *Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği, Flora Dizisi*, Istanbul.

Jafari, F., Zarre, S., Gholipour, A., Eggens, F., Rabeler, R. K., & Oxelman, B. (2020). A new taxonomic backbone for the infrageneric classification of the species-rich genus *Silene (Caryophyllaceae)*. *Taxon, 69(2),* 337-368. https://doi.org/10.1002/tax.12230

Jiang, L., Dunn, B. L., Wang, Y., & Goad, C. L. (2016). Responses to Propagation Substrate and Rooting Hormone Products to Facilitate Asexual Propagation of *Silene chalcedonica* and *Silene coronaria*. *J. Environ. Hort., 34(3),* 80-83.

Kosa, S. (2021). Determination of the effects of growing media and IBA concentrations on rooting of hard wood cuttings of the *Thymus revolutus* Celak. *Journal of Bartin Faculty of Forestry, 23(2),* 595-605. doi:10.24011/barofd.931944

Kosa, S., & Karaguzel, O. (2020). Effects of seed age, germination temperature, gibberellic acid and stratification on germination of *Silene compacta*. *Pakistan Journal of Botany, 52(3),* 901-908. https://doi.org/10.30848/PJB2020-3(18)

Moiloa, N. A., Mesbah, M., Nylinder, S., Manning, J., Forest, F., De Boer, H. J., Bacon, C. D., & Oxelman, B. (2021). Biogeographic origins of southern African *Silene (Caryophyllaceae)*. *Molecular Phylogenetics and Evolution, 162,* 107199. https://doi.org/10.1016/j.ympev.2021.107199

Pacholczak, A., & Żatkiewicz, A. (2022). The interaction of brassinosteroids and indole-3-butyric acid (IBA) in rooting of stem cuttings in ninebark (*Physocarpus opulifolius* (L.) Maxim.). *Propagation of Ornamental Plants, 22(1),* 3-10.

Pêgo, R. G., Andrade Fiorini, C. V., Lopes Machado, A. F., & Silva Gomes, M. V. (2019). Propagation of *Streptosolen jamesonii* (Benth.) Miers by stem cutting treated with IBA in different substrates. *Ornamental Horticulture*, *25(1),* 26-33. http://dx.doi.org/10.14295/oh.v25i1.1184

Sarropoulou, V., Krigas, N., Grigoriadou, K., Tsoktouridis, G., & Maloupa, E. (2018). Vegetative propagation of the range-restricted Greek endemic *Silene fabaria* (L.) Sm. in Sibth. & Sm. subsp. *domokina* Greuter (*Caryophyllaceae*). *International Journal of Botany Studies, 5(3),* 37-40.

Singh, B., Rawat, J. S., Gusain, Y. S., Khanduri, V. P., Riyal, M. K., & Kumar, P. (2021). Shoot position, cutting types and auxin treatments influence rooting response on *Tecoma* stans. *Ornamental Horticulture*, *27(2),* 213-220. https://doi.org/10.1590/2447-536X.v27i2.2262

Solgi, M., Taghizadeh, M., & Bagheri, H., (2022). Response of black mulberry onto white mulberry rootstock to stenting (cutting-grafting) techniques and IBA concentrations. *Ornamental Horticulture, 28(1),* 78-84. https://doi.org/10.1590/2447-536X.v28i1.2413

SPSS. (2013). IBM SPSS Statistics for Windows, Version 22.0. Armonk, N.Y.

Villa, F., Piva, A. L., Mezzalira, E. J., & Santin, A. (2017). Cuttings in propagation of gooseberry. *Magistra, 28(2),* 185-193.

Wei, Z., Van Le, Q., Peng, W., Yang, Y., Yang, H., Gu, H., Lam, S. S., & Sonne, C., (2021). A review on phytoremediation of contaminants in air, water and soil. *Journal of Hazardous Materials, 403,* 123658. https://doi.org/10.1016/j.jhazmat.2020.123658

West, R. M. (2022). Best practice in statistics: The use of log transformation. *Annals of Clinical Biochemistry, 59(3),* 162-165. doi: 10.1177/00045632211050531

Xie, M., Jiang, Y., Xu, K., Guo, W., & Yuan, T. (2023). Strangulation and IBA treatments as an effective method to propagate tree peonies, *Paeonia suffruticosa*. *Scientia Horticulturae, 307,* 111487. https://doi.org/10.1016/j.scienta.2022.111487