Turkish Journal of Agriculture - Food Science and Technology, 14(2): 493-501, 2026
DOI: https://doi.org/10.24925/turjaf.v14i2.493-501.8578

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

The Effect of Seed Pretreatments on the Germination Performance of Seeds of Some Wild Mountain Tea Species Collected from Nature

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ARTICLE INFO

Research Article

Received : 02.12.2025
Accepted : 24.01.2026

Keywords:
Sideritis spp.
Hydro priming
Hormon priming
Scarification
Environmental conditions

ABSTRACT

The genus *Sideritis* L., a member of the Lamiaceae family, includes over 150 species worldwide. The genus, which is distributed in the Mediterranean basin, is widespread in the Western and Southern Anatolia regions of Türkiye. In Türkiye, this genus is represented by 44 species (55 taxa), 41 of which are endemic. In this study, priming treatments were conducted on seeds collected from nature, belonging to four endemic *Sideritis* species: *Sideritis argyrea*, *Sideritis brevibracteata*, *Sideritis erythrantha* var. *cedretorum*, and *Sideritis psidica*. Twelve distinct seed pretreatments were conducted on these species. The experiment employed a randomized plot design, with each treatment consisting of 3 replicates and was performed under controlled environmental conditions. The results indicate that the differences between species and treatments, along with the species×treatment interaction, were statistically significant at the 1% significance level. Among the treatments, "Soaking in distilled water at room temperature for 24 h" and "Mechanical scarification using sandpaper" resulted in a high germination rate and increased the number of germinated seeds. Conversely, "Heat shock treatment in hot water at 60°C followed by rapid cooling," as well as "Soaking in 100 ppm GA_3 solution for 24 h + germination in 1% KNO_3," failed to induce germination. The highest germination values were recorded for *Sideritis erythrantha* var. *cedretorum*, whereas the lowest values were observed in *Sideritis psidica*. The evaluation of the application results indicated that the highest germination rate was achieved by soaking the seeds of *Sideritis erythrantha* var. *cedretorum* in distilled water for 24 hours at room temperature, leading to a germination rate of 26.67% and a total of 5.33seeds germinated.

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Introduction

The genus name *Sideritis* L. originates from the Greek term "sideros," meaning iron, reflecting the historical use of these plants for treating wounds inflicted by iron weapons. *Sideritis* species have been utilized for centuries due to their vulnerary, anti-inflammatory, anti-ulcerogenic, digestive, and antimicrobial properties (González-Burgos et al., 2011). *Sideritis* L. belongs to the Lamiaceae family, one of the richest families in the plant kingdom. The genus *Sideritis* L. includes over 150 species, which are distributed from the Bahamas to Western China and from Germany to Morocco, with a primary presence in the Mediterranean basin (Kaparakou et al., 2023; Güvenç et al., 2005).

One of the world's two major gene centers is located in the Macaronesian (Mesut) Islands, while the other is concentrated in Türkiye, particularly in the Mediterranean basin. Türkiye is home to approximately one-third (46 species) of the globally distributed *Sideritis* species. In particular, 42 species belonging to the Empedoclia section, whose gene center is in Türkiye, have been identified, and approximately 80% of these species are endemic (Kirimer et al., 2004; Çarıkçı et al., 2023).

Türkiye ranks as the second country with the highest biodiversity, following Spain. Türkiye is home to 44 species (55 taxa) of *Sideritis* spp. (Lamiaceae), of which 41 taxa are endemic in Türkiye (González-Burgos et al., 2011). *Sideritis* spp. are commonly referred to as "adacayi" or "dagcayi" and are extensively utilized as herbal tea in traditional medicine in Türkiye (Duman et al., 2005; Çarıkçı et al., 2023; Kirimeret al., 2004). Infusions of certain *Sideritis* species are commonly used to treat gastrointestinal disorders and the common cold and as diuretics (Tadić et al. 2012). They are also consumed as herbal tea in traditional Turkish medicine (Baytop, 1999). The dried leaves and spikes, or heads, of *Sideritis* species are prepared as tea by simply dipping one or two spikes into a cup of hot water and letting them steep for about half a minute to release their pleasant aroma (Baser, 1995).

The sustainable conservation of medicinal plants in their natural habitats, which are predominantly wild-harvested, necessitates domestication efforts to alleviate the anthropogenic harvesting pressure on these commercially valuable species (Hamilton, 2004; Chen et

al., 2016). For their cultivation, both vegetative and generative propagation methods should be employed. However, generative propagation material, specifically seeds, is often the preferred choice for plants typically collected from the wild (Fay, 1992). A significant challenge in domesticating wild plants using seeds is the frequent presence of physiological, ecological, or genetically inherent dormancy mechanisms that inhibit germination, the critical first stage of propagation (Baskin&Baskin, 2014; Bewley et al., 2013). Consequently, identifying suitable pre-germination priming protocols is essential for breaking dormancy and enhancing germination uniformity and rate (Paparella et al., 2015; Ibrahim, 2021). In both agricultural and ecological restoration contexts, seed priming techniques play a crucial role in enhancing seed germination, seedling growth and development, nutrient use efficiency in plants, soil fertility, essential enzymes, microbial communities, and the ability to adapt to stress. These techniques help alleviate the effects of abiotic stresses on plants. Priming maximizes crop yields, reduces the likelihood of crop failure, and promotes environmentally friendly farming practices (Jarrar et al., 2024).

This study aimed to determine the optimal seed germination protocol for four *Sideritis* species by evaluating 12 different seed pretreatment methods.

Material and Methods

Material

Seeds collected from Antalya's natural flora in 2023 were utilized in the study. Details regarding the collection sites of the species' seeds are presented in Table 1, while the locations on the map are given in Figure 1.

The endemic *Sideritis* species, which are the subject of the study, and their distribution in the natural flora of Antalya are described taxonomically with different characteristic features; *Sideritis argyrea* P. H. Davis: The worldwide distribution of *S. argyrea* is identified in Southern Anatolia, specifically with a confined presence east of Antalya (Güner et al., 2012). The altitude of the seed collecting site for this investigation is 856 m. The species is a woody perennial at its base, reaching a height of 30 to 100 cm. The stem is either simple or little branching, the leaves are densely compressed, white, and silky, and the petals are 12–15 mm in length and are yellow. Flowering occurs in July and August, and its habitat comprises rocky slopes with Pinus nigra and Pinus brutia (Huber-Morath, 1982).

Sideritis brevibracteata P. H. Davis: *S. brevibracteata* is recorded only from Alanya, a district of Antalya (Güner et al., 2012). The elevation of the location where seeds were collected for this study is 1141 m. A woody perennial at its base, the species grows 70–90 cm tall, is simple or slightly branched, and has dense, flat, white felt-like hairs below and sparsely felt-like hairs above, almost glabrous. The petals are 9–10 mm long, yellow and semi-hairy, and they have brown grooves inside. The species blooms in May, June, July, and August, and its habitat is rocky limestone slopes (Huber-Morath, 1982).

Sideritis erythrantha Boiss. et Heldr. Apud Bentham subsp. *cedretorum* P.H. Davis: The species, endemic to Antalya, has two subspecies which are also endemic to Antalya (Güner et al., 2012). The difference between the two subspecies is their flower color. *S. erythrantha* var. *erythrantha* has purple-violet flowers, while *S. erythrantha* var. *cedretorum* has yellow flowers. The elevation at which the seeds of *S. erythrantha* var. *cedretorum* were collected for this study was 1327 m. A woody perennial at the base, the species grows 25–45 cm tall, is generally much branched, and has flat, greenish or white felt-like hairs. The petals are yellow with brown bands inside. The flowering period is July and August. Its habitat is dynamic rocky slopes and *Pinus nigra* and *Cedrus forests* (Huber-Morath, 1982).

Sideritis pisidica Boiss. et Heldr. Apud Bentham: Seeds of the *S. pisidica* species, endemic to Antalya province, were collected from a site at an elevation of 1327 m in Antalya province for this research (Güner et al., 2012). This perennial species, with a woody base, has a stem that is 25–75 cm in height, either simple or sparingly branched, and covered with hair. The petals are vivid yellow (9–13 mm), pubescent, and with dark striations inside. The species flowers in July and August, inhabiting arid, rocky inclines and cork thickets (Huber-Morath, 1982).

Methods

The experiment employed a randomized plot design. Germination assays were conducted in 9 cm Petri dishes, each containing twenty uniformly sized seeds sown on a double layer of filter paper. The study was performed under controlled environmental conditions (20°C; 70% relative humidity). Treatments consisted of 12 seed pretreatments, alongside an untreated control group.

The study was carried out utilizing seeds from four endemic mountain tea species sourced from the natural flora of Antalya. A total of thirteen pretreatments, including a control group, were conducted. The seeds were subsequently planted in petri dishes and monitored in a germination chamber for a period of 28 days. After the trial was concluded, the results were statistically evaluated.

Seed Pretreatments

Sixty seeds of uniform size were counted and placed in capped tubes for each treatment. Subsequent to the treatments, the seeds in the tubes were rinsed with distilled water and positioned on blotting paper. Three replicate experiments were conducted, with 20 seeds allocated to each petri dish.

1. Control: Seeds were rinsed with distilled water prior to initiation of the experiment.

2. Hydropriming: Seeds were immersed in 25 ml of distilled water at ambient temperature for a 24-hour period. Following immersion, seeds were filtered and rinsed with distilled water before use.

3. Heat Shock Treatment: Seeds were subjected to a thermal shock treatment by immersion in 25 ml of distilled water maintained at 60°C for 30 seconds within a controlled water bath. Immediate removal and rapid cooling to ambient temperatures were followed by a rinse with distilled water.

4. Cold Stratification: Seeds underwent stratification by immersing in 25 ml of distilled water at 4°C for 72 hours. Subsequently, seeds were filtered and rinsed with distilled water prior to germination.

Table 1. Location data for species collection areas

Species	Altitute / Date / Location
S. argyrea	856m / 28 July 2023 / Alanya Kuşyuvası
S. brevibracteata	1141m / 28 July 2023 / Alanya Karapınar
S. erythrantha var. *cedretorum*	1327m / 3 August 2023 / Alanya Gökbel
S. psidica	1655m / 4 August 2023 / Korkuteli Kırkpınar

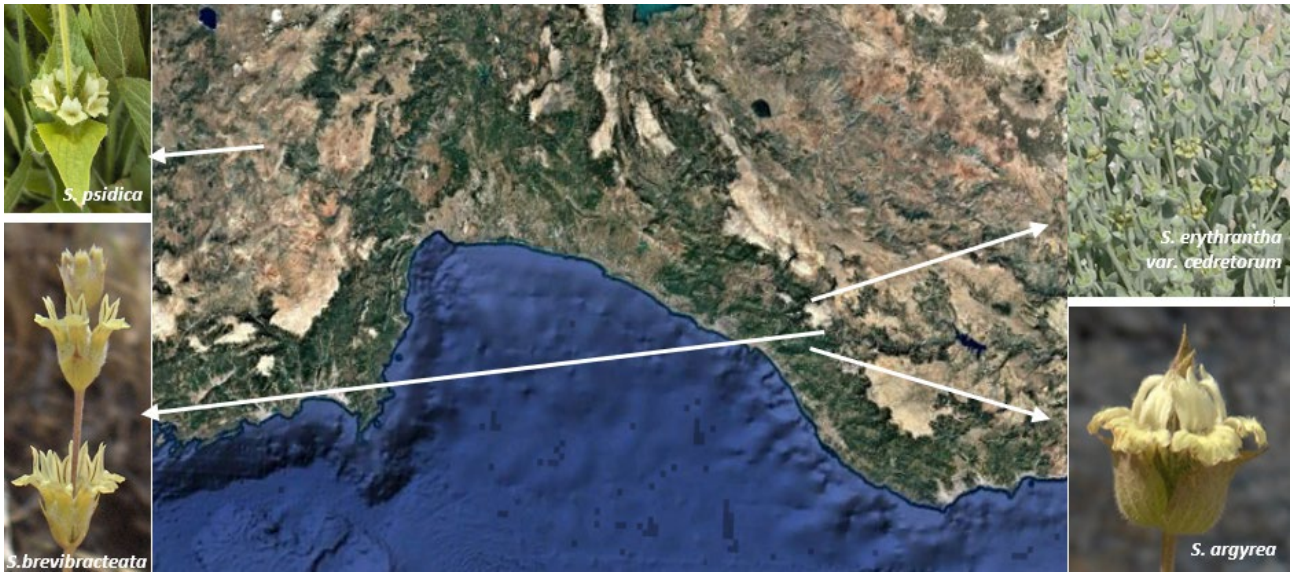


Figure 1. Map indicating the locations of collecting places

5. Mechanical Scarification: The seed coat was mechanically abraded by hand rubbing seeds between two layers of coarse sandpaper for 10 seconds. Scarified seeds were then washed with distilled water to remove debris.

6. Gibberellic Acid (GA_3) Treatment: Seeds were treated with a 100 ppm gibberellic acid (GA_3) solution. Soaking was conducted in 25 ml of solution under dark conditions for 24 hours, after which seeds were rinsed with distilled water.

7. Indole-3-butyric Acid (IBA) Treatment: Seeds were soaked in 25 ml of a 100 ppm indole-3-butyric acid (IBA) solution and maintained in darkness for 24 hours. Treated seeds were then rinsed with distilled water.

8. Kinetin Treatment: Seeds were exposed to a 100 ppm kinetin solution by soaking in 25 ml of solution in the dark for 24 hours. A final rinse with distilled water was performed before use.

9. Polyethylene Glycol (PEG-6000) Osmopriming: Seeds were osmoprimed by soaking in 25 ml of a 10% (w/v) polyethylene glycol (PEG-6000) solution for 24 hours, followed by rinsing with distilled water.

10. Potassium Nitrate (KNO_3) Treatment: Seeds were soaked in 25 ml of a 1% (w/v) potassium nitrate (KNO_3) solution for 24 hours and subsequently rinsed with distilled water.

11. Combined Stratification and KNO_3 Germination: Seeds were first stratified in 25 ml of distilled water at 4 °C for 24 hours. They were then transferred to ambient temperature for an additional 24-hour soaking period. After rinsing, germination was carried out in petri dishes containing a 1% KNO_3 solution.

12. Combined GA_3 and KNO_3 Treatment: Seeds were initially soaked in 25 ml of a 100 ppm GA_3 solution in darkness for 24 hours. Following a distilled water rinse, the seeds were germinated in petri dishes on a substrate of 1% KNO_3 solution.

13. Cold Stratification with GA_3: Seeds were subjected to a combined treatment of cold stratification and phytohormone application by soaking in 25 ml of a 100 ppm GA_3 solution. The treatment was performed at 4 °C under dark conditions for 72 hours, after which seeds were rinsed with distilled water.

Seed Germination (%)

Daily evaluations were conducted during the germination phase. Seeds were classified as germinated when the radicle length surpassed 2 mm. Upon conclusion of the 15-day experimental period, the total count of germinated seeds was documented, and the germination percentage was calculated according to the methodology outlined by Scott et al. (1984).

Statistical Analysis

The data obtained in the study were analyzed using the JUMP 10.0 statistical program. Statistical analyses of the parameters were performed according to a randomized plot experimental design (Yurtsever, 1984). The values subjected to statistical analysis were analyzed with 3 replications.

Results and Discussion

The effects of pre-treatments on the number of germinated seeds and germination rate of *Sideritis argyrea, Sideritis brevibracteata, Sideritis erythrantha* var. *cedretorum*, and *Sideritis psidica* species were found to be statistically significant at the 1% significance level for species, treatments, and species*treatment interaction (Table 2).

Table 2. ANOVA on mean of squares of measured traits in *Sideritis* species seeds under different seed pretreatments

Source of Variation	DF	Number of Germinated Seeds		Germination Rate (%)	
		Mean Square	F	Mean Square	F
Species	3	45.77	20.51**	1110.27	20.08**
Treatments	12	102.56	11.49**	2589.42	11.71**
Species*Treatments	36	59.49	2.22**	1510.58	2.28**
Error	104	0.74		18.43	
Total	155				

Table 3. Mean comparison of the number of germinated seeds and germination rate (%) for species

Species	Number of Germinated Seeds	Germination Rate (%)
S. argyrea	0.56^{c}	3.21^{c}
S. brevibracteata	1.00^{b}	5.26^{b}
S. erythrantha var. *cedretorum*	1.72^{a}	8.59^{a}
S. psidica	0.28^{c}	1.41^{c}

Table 4. Mean comparison of main effects of different seed pretreatments on *Sideritis* species seeds

Treatments	Germinated Seeds	Germination Rate (%)
Control	0.83bc	5.00b
Soaking in distilled water at room temperature for 24h	2.58a	12.92a
Heat shock treatment in hot water at 60 °C followed by rapid cooling	0d	0c
Soaking in distilled water at 4 °C for 72h	1.25b	6.25b
Mechanical scarification using sandpaper	2.50a	12.50a
Soaking in 100 ppm GA_3 solution for 24h	1.08b	6.25b
Soaking in 100 ppm IBA solution for 2 h	0.17cd	0.83c
Soaking in 100 ppm kinetin solution for 24h	0.83bc	4.58b
Soaking in 10% PEG-6000 solution for 24h	0.67bcd	3.33bcd
Soaking in 1% KNO_3 solution for 24h	1.00b	5.00b
Soaking at 4°C for 24h + soaking at room temperature for 24h + germination in 1% KNO_3	0.08d	0.42c
Soaking in 100 ppm GA_3 solution for 24h + germination in 1% KNO_3	0d	0c
Soaking in 100 ppm GA_3 solution at 4 °C for 72h	0.58bcd	2.92bc

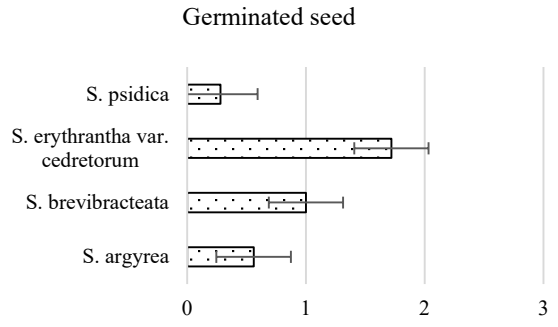


Figure 2. Graphical illustration of the number of germinated seeds in the species

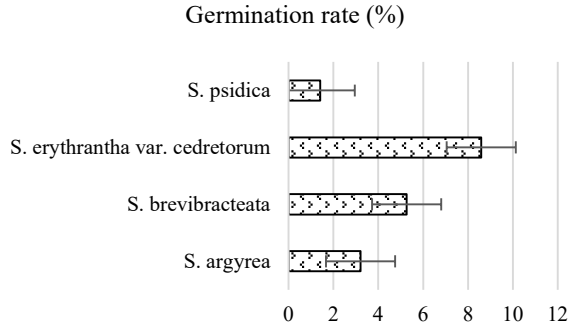


Figure 3. Graphical illustration of germination rates in the species

S. erythrantha var. *cedretorum* exhibited the highest number of germinated seeds and germination rate, while *S. argyrea* and *S. psidica* were categorized within the same statistical group, displaying low numbers of germinated seeds and germination rates (Table 3). Figures 2 and 3 illustrate the number of germinated seeds and the germination rate, respectively.

In evaluating the effects of various seed pretreatments on the quantity of germinated seeds and germination percentages, the highest number of notable findings were statistically obtained from the treatments "Soaking in distilled water at room temperature for 24 hours" and "Mechanical scarification using sandpaper," which are in the same category. However, two treatments, "heat shock treatment in hot water at 60°C followed by rapid cooling" and "soaking in 100 ppm GA_3 solution for 24 hours + germination in 1% KNO_3," fell short of stimulating germination. Five of the seed pretreatments resulted in higher numbers of germinated seeds and germination percentages compared to the control (Table 4). Figures 4 and 5 represent graphical illustrations of the number of germinated seeds and the germination rates for the pretreatments.

The average number of germinated seeds from various treatments applied to the species, along with their statistical grouping results, were presented in Table 5, while the germination rates and their corresponding statistical grouping results were presented in Table 6.

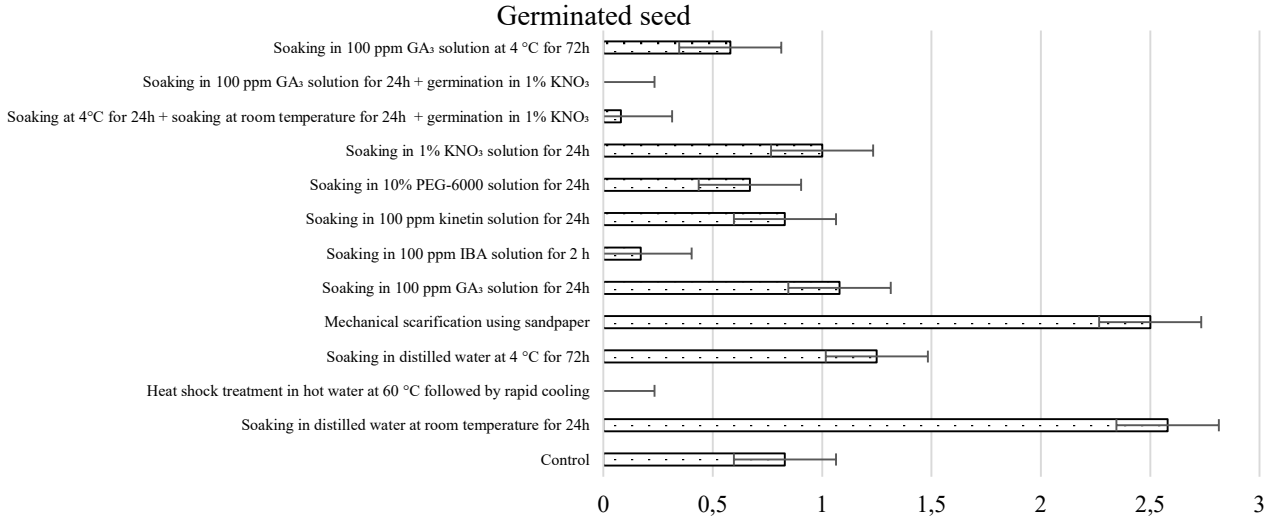


Figure 4. Graphical representation of germinated seed numbers in seed pretreatments of *Sideritis* species

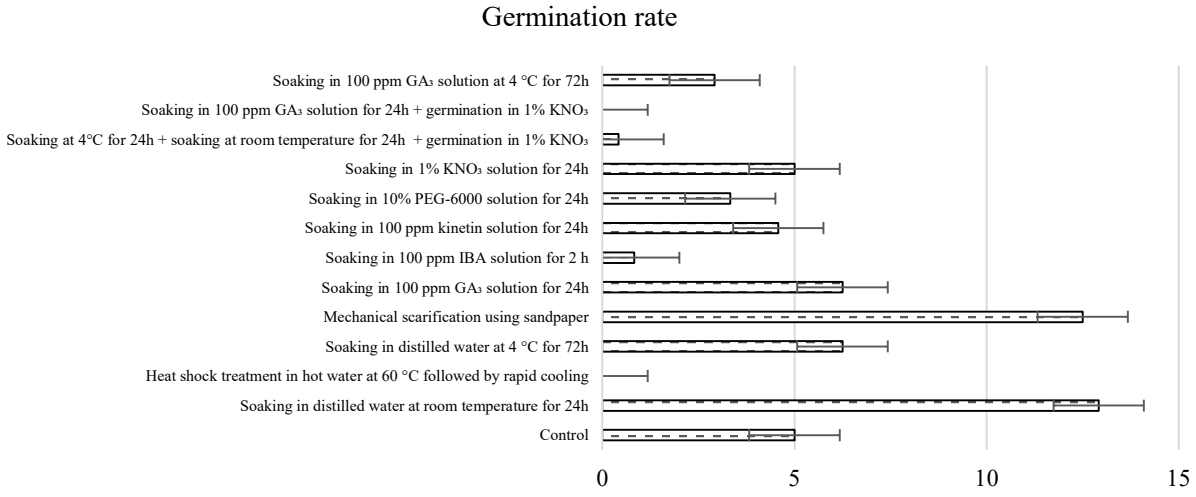


Figure 5. Graphical representation of germination rates in seed pretreatments of *Sideritis* species

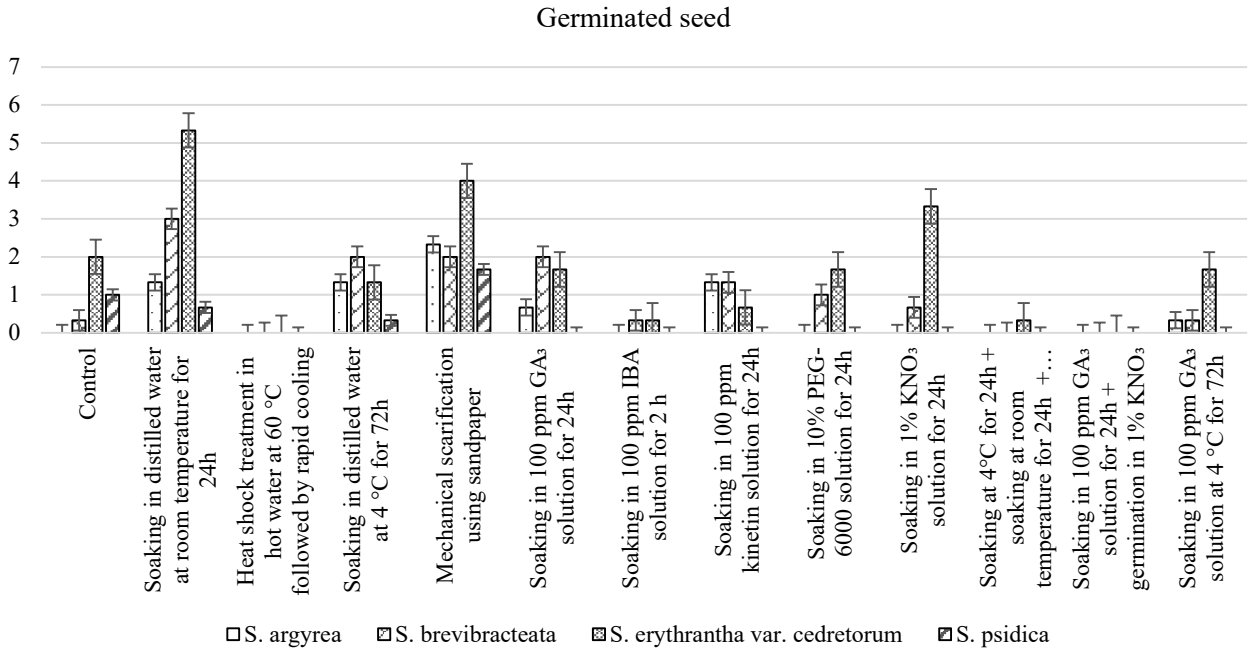


Figure 6. Graphical representation of the number of germinated seeds (n) of species based on pretreatments

Table 5. Mean comparison of main effects of different seed pretreatments on the number of germinated seeds (n)

Treatments/Species	*SA*	*SB*	*SE*	*SP*
Control	0^{h}	0.33^{gh}	2.00^{cdef}	1.00^{efgh}
Soaking in distilled water at room temperature for 24h	1.33^{efgh}	3.00^{bcd}	5.33^{a}	0.67^{fgh}
Heat shock treatment in hot water at 60 °C followed by rapid cooling	0^{h}	0^{h}	0^{h}	0^{h}
Soaking in distilled water at 4 °C for 72h	1.33^{efgh}	2.00^{cdef}	1.33^{efgh}	0.33^{gh}
Mechanical scarification using sandpaper	2.33^{cde}	2.00^{cdef}	4.00^{ab}	1.67^{defg}
Soaking in 100 ppm GA_3 solution for 24h	0.67^{fgh}	2.00^{cdef}	1.67^{defg}	0^{h}
Soaking in 100 ppm IBA solution for 2 h	0^{h}	0.33^{gh}	0.33^{gh}	0^{h}
Soaking in 100 ppm kinetin solution for 24h	1.33^{efgh}	1.33^{efgh}	0.67^{fgh}	0^{h}
Soaking in 10% PEG-6000 solution for 24h	0^{h}	1.00^{efgh}	1.67^{defg}	0^{h}
Soaking in 1% KNO_3 solution for 24h	0^{h}	0.67^{fgh}	3.33^{bc}	0^{h}
Soaking at 4°C for 24h + soaking at room temperature for 24h + germination in 1% KNO_3	0^{h}	0^{h}	0.33^{gh}	0^{h}
Soaking in 100 ppm GA_3 solution for 24h + germination in 1% KNO_3	0^{h}	0^{h}	0^{h}	0^{h}
Soaking in 100 ppm GA_3 solution at 4°C for 72h	0.33^{gh}	0.33^{gh}	1.67^{defg}	0^{h}

SA: *S. argyria; SB: S. brevibracteata; SE: S. erythrantha; SP: S. psidica*

Table 6. Mean comparison of main effects of different seed pretreatments on germination rate (%)

Treatments/Species	SA	SB	SE	SP
Control	0^{g}	5.00^{d-g}	10.00^{cdef}	5.00^{efgh}
Soaking in distilled water at room temperature for 24h	6.67^{efgh}	15.00^{bcd}	26.67^{a}	3.33^{fgh}
Heat shock treatment in hot water at 60 °C followed by rapid cooling	0^{h}	0^{h}	0^{h}	0^{h}
Soaking in distilled water at 4 °C for 72h	6.67^{efgh}	$10.00cd^{ef}$	6.67^{efgh}	1.67^{gh}
Mechanical scarification using sandpaper	11.67^{cde}	10.00^{cdef}	20.00^{ab}	8.33^{defg}
Soaking in 100 ppm GA_3 solution for 24h	6.67^{efgh}	10.00^{cdef}	8.33^{defg}	0^{h}
Soaking in 100 ppm IBA solution for 2 h	0^{h}	1.67^{gh}	1.67^{gh}	0^{h}
Soaking in 100 ppm kinetin solution for 24h	8.33^{defg}	6.67^{efgh}	3.33^{fgh}	0^{h}
Soaking in 10% PEG-6000 solution for 24h	0^{h}	5.00^{efgh}	8.33^{defg}	0^{h}
Soaking in 1% KNO_3 solution for 24h	0^{h}	3.33^{fgh}	16.67^{bc}	0^{h}
Soaking at 4°C for 24h + soaking at room temperature for 24h + germination in 1% KNO_3	0^{h}	0^{h}	1.67^{gh}	0^{h}
Soaking in 100 ppm GA_3 solution for 24h + germination in 1% KNO_3	0^{h}	0^{h}	0^{h}	0^{h}
Soaking in 100 ppm GA_3 solution at 4 °C for 72h	1.67^{gh}	1.67^{gh}	8.33^{defg}	0^{h}

SA: *S. argyria; SB: S. brevibracteata; SE: S. erythrantha; SP: S. psidica*

The graphs comparing the results of the species based on the applications are presented in Figure 6 for the number of germinated seeds and in Figure 7 for the germination rate.

A comparative evaluation of all species and treatments revealed that the highest germination metrics both in terms of seed number and germination rate were achieved in *Sideritis erythrantha* var. *cedretorum*, which underwent a treatment involving 24-hour soaking in distilled water at room temperature. In contrast, no germination was observed for any species under two specific pretreatment conditions: (1) heat shock in water at 60°C followed by rapid cooling, and (2) soaking in a 100 ppm GA_3 solution for 24 hours, followed by germination in 1% KNO_3. Furthermore, the combined treatment of 24-hour cold stratification at 4°C, followed by 24-hour soaking at room temperature and subsequent germination on 1% KNO_3, proved effective only for *S. erythrantha* var. *cedretorum*, with no germination occurring in the other species studied.

In this study, seeds of four endemic mountain tea species were collected from the natural flora of Antalya Province and subjected to 13 different pretreatments, including a control. The statistical analysis revealed that the effects of the treatments on both the mean number of germinated seeds and the final germination percentage were highly significant ($p<0.01$). The four species were statistically separated into three distinct homogenous groups based on their germination performance. The highest germination was achieved in *S. erythrantha* var. *cedretorum*, followed by *S. brevibracteata*. In contrast, *S. argyrea* and *S. psidica*, which clustered in the same statistical group, exhibited significantly lower germination capacity.

Among the treatments, the highest germination values were obtained from "soaking in distilled water at room temperature for 24 hours" and "mechanical scarification using sandpaper," which were statistically grouped together. Conversely, no germination was recorded for any species under the "Heat shock treatment in hot water at 60°C for 30 seconds followed by rapid cooling" or "Soaking in 100 ppm GA_3 solution for 24 h + germination in 1% KNO_3" treatments.

When species and treatments were evaluated together, the best germination values were obtained with the "soaking in distilled water at room temperature for 24 hours" treatment applied to the seeds of *S. erythranta* var. *cedretorum*. The "mechanical scarification using sandpaper" treatment yielded the highest values for *S. argyrea* and *S. psidica*, and the "soaking in distilled water at room temperature for 24 hours" treatment yielded the highest values for *S. brevibracteata*.

Scarification is a pretreatment technique applied to seeds to break dormancy and encourage uniform germination. This process creates permeable conditions within seeds through various methods, including puncturing, burning, breaking, filing, and scratching, utilizing tools such as knives, needles, and sandpaper, among others (Ardiarini, 2021).

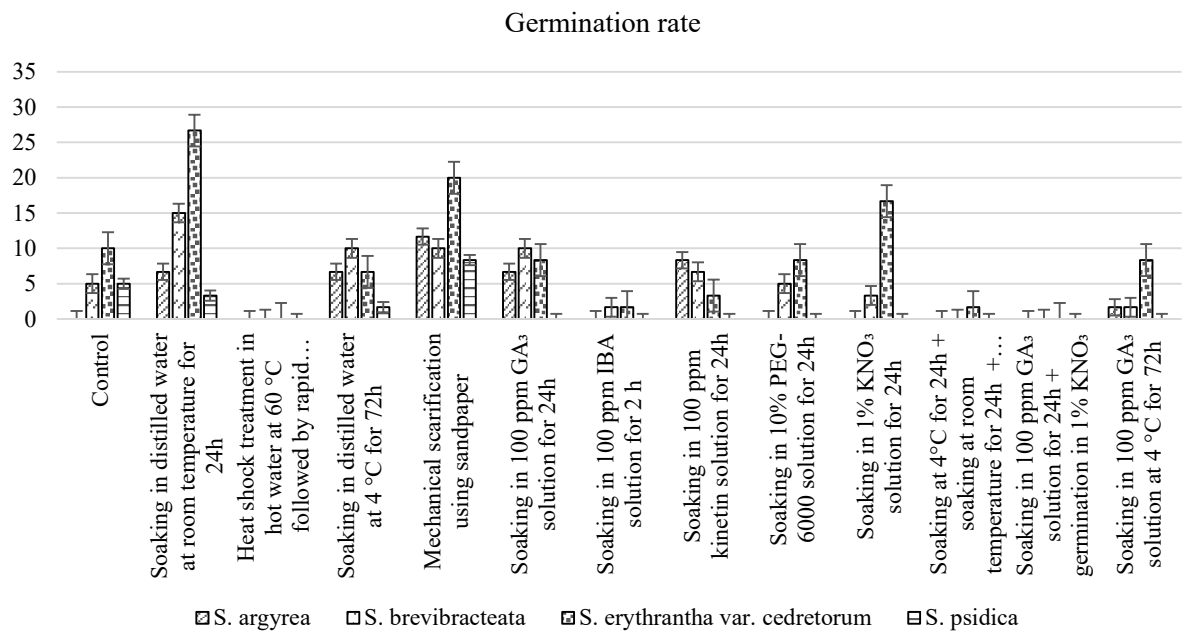


Figure 7. Graphical representation of germination rates of species based on pretreatments

In their study, Vlachou et al. (2019) investigated the effects of seed pretreatment through surface scarification, either mechanical or chemical, on the germination of five Mediterranean sage species: *S. fruticosa, S. officinalis*, *S. pomifera* ssp. *pomifera*, *S. ringens*, and *S. tomentosa*. They found that *S. fruticosa* exhibited higher seed germination percentages following both mechanical and chemical scarification compared to the control group. In contrast, for *S. officinalis*, dipping seeds in H_2SO_4 proved to be the most effective pretreatment. Their conclusion indicated that mechanical or chemical scarification had a more beneficial effect on the seed germination of *S. fruticosa* and *S. officinalis* than on the other three species (*S. pomifera* ssp. *pomifera*, *S. tomentosa*, and *S. ringens*). Similarly, this study also observed that mechanical scarification application was effective.

Hydration-dehydration priming, also known as hydropriming, is a valuable technique for enhancing crop resilience and establishment (Cañizares et al., 2025). The hydropriming method, notable for its simplicity, cost-effectiveness, and practicality, is an effective technology that enhances the vitality of plant seeds by optimizing their physiological metabolism. This process involves pre-soaking the seeds in water at an optimal temperature for a specified duration, followed by a natural drying phase that enables the seeds to revert to their original weight (Fu et al., 2024).

In their study investigating the effects of hydropriming on seed parameters of *Salvia officinalis* L., Dastanpoor et al. (2013) applied hydropriming to sage seeds for 0, 12, 24, and 48 hours at three temperatures: 10, 20, and 30°C. Their results indicated that hydropriming significantly improved final germination percentage (FGP) and mean germination time (MGT) and synchronized the germination of seeds at each of the three temperatures. They stated that 12 hours of hydropriming at 30°C was the most effective method for improving seed germination, with FGP increasing by 25.5% compared to unprimed seeds. They reported that the improvement in seed germination due to hydropriming could be explained by increased water uptake and cell division rate.

Tahaei et al. (2016), in their study, examined the effects of different priming techniques on fennel (*Foeniculum vulgare* Mill). They stated that among the seed dormancy-breaking methods, biopriming and hydropriming were among the most effective, which significantly increased seed germination and removed the seed dormancy barriers. In this study, it was observed that hydropriming application yielded positive results in the Sideritis species studied.

Hormonal priming refers to the external pre-sowing seed treatment of plant growth regulators that utilizes various phytohormones, such as GA_3, salicylic acid (SA), ascorbate, and kinetin, to stimulate seed imbibition and alter seed metabolism and enhance growth and seedling development. According to Rouhi and Sepehri (2020), hormonal priming with GA_3 can alleviate the adverse effects of aging and drought stress (Bryksová et al. 2020; Diya et al., 2024).

The study examines the effects of several pretreatments (ethylene, gibberellin, mannitol, seaweed, and cold pretreatment) on the germination of Sideritis perfoliata L., which naturally grows in western Anatolia. Arabacı et al. (2014) noted significant differences between the applications regarding germination rates and vigor values. According to the results of the different pretreatments on *Sideritis perfoliata* L., the best application was found to be 100 ppm GA_3, which yielded the highest germination power (100%).

A study assessing the germination efficacy of four endemic *Sideritis* species (*Sideritis condensata*, *S. libanotica* ssp. *linearis*, *S. leptoclada*, and *S. tmolea*) examined seeds harvested freshly or stored for one and two years, focusing on germination percentage and mean germination time. Additionally, it evaluated the effectiveness of seed treatments, including hydration, gibberellic acid (GA_3) application, and their combination with pre-chilling, to address germination challenges. Kaya

et al. (2015) reported germination percentages ranging from 28.5% to 77.0%, with *S. libanotica* exhibiting the lowest germination rate and the highest mean germination time of 11.9 days. *S. libanotica*, ssp. *linearis*, exhibited the lowest germination rate and the longest average germination duration (11.9 days) among fresh seeds. They observed that the application of 200 mg/L of GA_3 resulted in enhanced germination and a decreased mean germination time; thus, irrespective of seed age, GA_3 treatment should be employed to improve the germination of endemic *Sideritis* species. Researchers indicated that gibberellic acid positively influenced the germination of the examined endemic *Sideritis* species, with all species attaining a germination rate surpassing 60% when GA_3 treatment was administered either independently or alongside pre-chilling. They stated that seed storage had no impact on the germination of *Sideritis* species; consequently, pre-chilling was unnecessary for germination.

Gümüşçü (2014) investigated the germination of seeds from *Sideritis congesta*, *Sideritis condensata*, *Sideritis leptoclada*, *Sideritis tmolea*, and *Sideritis libanotica* ssp. *linearis*, which are endemic to Türkiye, utilizing varying doses of gibberellic acid (100, 250, 500, 750, and 1000 ppm), stratification (maintaining seeds at +4°C for one week), and hot water treatments (exposing seeds to 60 to 70°C for durations of 30, 60, and 90 seconds) within a germination chamber (maintained at 25°C and 70% humidity), under conditions of 8 hours of light and 16 hours of darkness. The germination ratios observed were as follows: stratification application yielded 12%, 6%, 0%, 10%, and 8%; hot water application resulted in 6%, 6%, 6%, 4%, and 4%; and GA3 application produced 48%, 52%, 54%, 44%, and 36% for *Sideritis congesta*, *S. condensata*, *S. leptoclada*, *S. tmolea*, and *S. libanotica* ssp. *linearis* species, respectively. He indicated that the application of GA_3 was optimal for the germination of *Sideritis* seedlings.

The study involved the application of GA3 to seeds using three distinct approaches. Upon evaluating the results from applications using 100 ppm solutions, germination was noted in the seeds of *S. argyrea, S. brevibracteata*, and *S. erythrantha* var. *cedretorum* species. Seeds stored at room temperature for 24 hours exhibited high or near-control results, whereas seeds maintained at +4°C for 72 hours demonstrated germination, however at a lower rate compared to the control.

In the experiment involving germination in a 1% KNO_3 solution, after being maintained at room temperature for 24 hours, no germination was noted in any of the species tested. In summary, it was noted that GA_3 demonstrates effectiveness in Sideritis species for hormone priming applications, aligning with findings from other studies on the subject.

Conclusion

The genus *Sideritis* is important for our country, both for its biodiversity and for its widespread traditional use as tea. Antalya province is a wealthy region for *Sideritis* species. The promotion of cultivated production of these mountain teas, which are intensively harvested from the wild for commercial markets, is crucial for conserving endemic species against genetic erosion. Medicinal and aromatic plants, particularly recommended for sloped and rocky areas not well-suited to agricultural production, are also important as livelihood sources in rural areas. The transition from wild collection to controlled cultivation is highly dependent on the availability of viable seeds as primary propagation material. However, seeds collected from wild populations often exhibit pronounced germination challenges at the genus or species level. To overcome germination problems, the application of various priming treatments has become an increasingly common practice.

In conclusion, a general evaluation of the results indicates that seed pretreatments applied to wild-collected *Sideritis* seeds had an effect on germination and significantly influenced its success. A key finding of this study is that the efficacy of these treatments is highly species-specific. Therefore, it is imperative to evaluate germination protocols on a species-by-species basis rather than generalizing for the entire genus. These findings provide a critical foundation for developing targeted propagation protocols to support the conservation and sustainable agricultural production of these valuable endemic species.

Declarations

Ethics Statement
No ethical clearance required.

Conflicts of Interest Statement
The author declares no conflict of interest.

AI Disclosure Statement
During the preparation of this article, the author did not use any artificial intelligence tools for [specific purposes, e.g., language editing/formatting]. The author is solely responsible for the content of the article.

Funding Statement
This work received no external funding.

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