



Effect of Priming Treatments on Germination Performance of Medicinal Sage (*Salvia officinalis* L.) Seeds

Safinaz ELMASULU^{1*}

¹ Akdeniz University, Faculty of Agriculture, Department of Crop Fields, Antalya

*Corresponding author: hselmasulu@akdeniz.edu.tr

Abstract

Medicinal and aromatic plants constitute a significant and increasingly important sector of crop production in Turkey and worldwide. The initial propagation material for these species is frequently sourced from the natural flora, usually as seeds or cuttings. However, seeds collected from wild populations frequently exhibit low germination rates, which constitutes a major constraint limiting successful cultivation. To overcome seed dormancy and improve germination, pre-sowing treatments known as "priming" are applied. These treatments are highly species-specific and can even vary at the cultivar level, underscoring the critical importance of determining the optimal priming protocol for each taxon. In this study conducted at Akdeniz University, Faculty of Agriculture, Field Crops Department, *Salvia officinalis* (medicinal sage) seeds, which are widely used for medicinal purposes, were subjected to 13 different priming treatments together with a control group, and their germination performance was evaluated. The results indicated that the treatments exerted a statistically significant impact ($p < 0.01$) on both the final germination percentage (FGP) and the germination rate. The FGP values ranged from 0% to 25%, but the germination rate values varied from 0 to 5. In comparison, the control group recorded values of 10% and 2 for FGP and germination rate, respectively. Eight of the applied priming treatments yielded higher mean values than the control. According to the findings, the most effective priming treatments for improving *Salvia officinalis* seed germination were mechanical scarification using sandpaper (25.0% FGP) and hydropriming with distilled water at 4°C for 72 hours (23.3% FGP). In contrast, the results for osmopriming applications were generally lower than those of the control group.

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1. Introduction

Today, humans widely harvest and employ medicinal and aromatic herbs from indigenous flora for their therapeutic benefits. This group of plants comprises a diverse array of species exhibiting markedly distinct biological properties. Medicinal aromatic plants are grown on a limited global scale (Sonmez et al., 2019; Chrysargyris et al., 2022). The advancement of medicinal cultivation is a phenomenon that will result in both expanded acreage and heightened productivity. It is imperative to prioritize the distribution of healthcare planting areas within current agriculture, along with the yield per unit area, necessitating considerable focus. For this purpose, determining appropriate plant propagation methods for cultivating medicinal plants is crucial. The seed or planting material is crucial for reproduction in industrial conditions. The most important stage in propagation from seed is germination. There are many factors that affect germination. One of the factors affecting germination that is very common in the genera and species of the Lamiaceae family, which are rich in essential oils, is endogenous inhibitors. Endogenous inhibitors, organic compounds found in various parts of the plant seed, including the pericarp, seed coat, endosperm, and embryo, significantly influence seed dormancy and germination in plants. Endogenous inhibitors can be classified into various categories, such as organic acids, volatile aromatic essential oils, esters, olefins, phenols, quinones, ketones, ethers, and gaseous substances. Although these substances exist in negligible quantities in seeds, they can influence physiological processes, inhibiting cell division, differentiation, elongation, and development, thereby obstructing seed germination (Chenyin et al., 2023; Luo et al., 2025). Seed priming through pre-sowing treatments is a recommended approach to breaking dormancy and improving germination (Dalil, 2014). Due to the difficulty of germinating seeds collected from plants, different priming methods are used. Priming techniques, including seed coat removal, hormonal priming, stratification, hydro

priming, and chemical priming, are effective ways that vary by species to enhance germination rates, timing, and quality. There are many different priming methods used for medicinal and aromatic plants. *Salvia* species are among the most valuable members of the Lamiaceae family (Davis, 1982). Numerous research examines the germination behavior of various *Salvia* species (Bahadırli, 2024). Investigations into germination factors, including light, chemicals, and priming, on *S. officinalis*, *S. fruticosa*, *S. pomifera*, and *S. tomentosa* revealed varied germination responses, even within the same genus and clade (Ozcan et al., 2014). *Salvia officinalis* L., often known as "Sage", is a member of the Mint family Lamiaceae, and is indigenous to Europe surrounding the Mediterranean Sea, Southeast Asia, and Central and South America (Sharma et al., 2019). It possesses woody stems, grayish foliage, and blue to violet blossoms. Flowers are aggregated in groups of 4 to 8 at the terminal ends of the stems. Common sage possesses a longstanding history of medical and culinary applications. Over 90 species of sage (*Salvia* sp.) are present in the flora of Anatolia, Turkey. *Salvia officinalis*, despite not indigenous to Turkey, has successfully acclimatized to the climatic conditions of Central Anatolia (Karaca et al., 2015). Previous research examined the effects of storage temperatures on *S. officinalis* (Kretschmer, 1989), various light regimes (Liu et al., 2006), and hydro priming (Dastanpoor et al., 2013). Common sage is a thermophilic species, with seed germination commencing at temperatures between 8-10 °C and also at elevated temperatures of 25-28 °C, germinating within 6 days (Sharifi-Rad et al., 2018) or within 10–15 days (Farooqi et al., 2005), exhibiting enhanced seedling growth under continuous light conditions (Paiva et al., 2016). Seed dormancy significantly hinders the cultivation of *Salvia officinalis* L. seedlings. Local environmental variables influencing seeds till maturation may significantly affect germination behavior. Limited information regarding the germination of *Salvia* seeds utilizing priming methods is accessible (Sonmez et al., 2019; Stoian et al.,

2024). This study is to evaluate seed priming techniques to alleviate the dormancy of sage seeds under controlled settings.

2. Material and Methods

2.1. Material

The research was carried out in the laboratory of the Field Crops Department at the Faculty of Agriculture, Akdeniz University, utilizing seeds with low germination capacity supplied by a commercial medicinal sage producer in Antalya province.

2.2. Methods

The experiment was designed using a randomized plot. Petri dishes measuring 9 cm were used for germination. Twenty seeds of equal size were placed in petri dishes with double-layered germination paper for the applications. Germination investigations were conducted under regulated settings (70% humidity, 20 °C temperature), using six distinct salt concentrations and drought levels, including a control group.

2.2.1. Germination rate (%)

Daily observations were conducted throughout the germination period. Seeds were considered to have germinated when the radicle length exceeded 2 mm. At the end of the 15-day experimental period, the total number of germinated seeds was recorded, and the germination percentage was calculated according to the procedure described by Scott et al. (1984).

2.2.2. Germination day numbers

The period between the day the study was started and the day the first germinated seed was observed.

2.2.3. Germination index

It was calculated with the help of the equation below, reported by Wang et al. (2004). G_i is the germination percentage at the i th day, and T_t is the number of days of the germination test duration.

$$GI = \Sigma(G_i/T_t)$$

2.2.4. Germination energy

It was calculated with the help of the equation below, reported by Li et al. (2020). In the equation, T_1 represents the number of seeds germinated on the first day, and N represents the total number of seeds.

$$GE = (T_1/N) \times 100$$

2.2.5. Treatments

For each treatment, 60 seeds of equal size were counted and placed in capped tubes. After the following treatments were performed, the seeds in the tubes were rinsed with distilled water and placed on blotting paper. Three replicate experiments were set up with 20 seeds placed in each petri dish. Control: Seeds were rinsed in distilled water before use. Soaking in distilled water at room temperature for 24h: 25 ml of distilled water was added to the tube and soaked for 24 hours. The filtered seeds were rinsed in distilled water before use. Heat shock treatment in hot water at 60 °C followed by rapid cooling: A tube with 25 ml of distilled water was placed in a water bath. Once the temperature reached 60 °C, the seeds were added to the tube and then removed. After cooling to room temperature, the seeds were rinsed with distilled water before use. Soaking in distilled water at 4 °C for 72h: 25 ml of distilled water was added to the tube and soaked for 72 hours. The filtered seeds were rinsed in distilled water before use. Mechanical scarification using sandpaper: Seeds were subjected to abrasion between two layers of sandpaper and then washed with distilled water prior to use. Soaking in 100 ppm GA_3 solution for 24h: Seeds were soaked in 25 ml of a 100 ppm GA_3 solution in the dark for 24 hours, followed by rinsing with distilled water before use. Soaking in 100 ppm IBA solution for 24 h: Seeds were soaked in 25 ml of a 100 ppm IBA solution in the dark for 24 hours, then rinsed with distilled water before use. Soaking in 100 ppm kinetin solution for 24h: Seeds were soaked in 25 ml of a 100 ppm kinetin solution in the dark for 24 hours, after which they were rinsed with distilled water before use. Soaking in 10% PEG-6000 solution for 24h: Seeds were soaked in 25 ml of 10% PEG-6000 solution for 24 hours and then rinsed with

distilled water before use. Soaking in 1% KNO₃ solution for 24h: Seeds were soaked in 25 ml of a 1% KNO₃ solution for 24 hours, then rinsed with distilled water and used. Soaking at 4°C for 24h + soaking at room temperature for 24h + germination in 1% KNO₃: 25 ml of distilled water was added to the tube and kept in the refrigerator at 4 °C for 24 hours. After being removed from the refrigerator and kept at room temperature for 24 hours, the seeds were rinsed in distilled water and germinated in petri dishes in a 1% KNO₃ solution. Soaking in 100 ppm GA₃ solution for 24h + germination in 1% KNO₃: Seeds were soaked in 25 ml of a 100 ppm GA₃ solution in the dark for 24 hours, rinsed with distilled water, and subsequently germinated in petri dishes using a 1% KNO₃ solution. Soaking in 100 ppm GA₃ solution at 4 °C for 72h: The seeds were kept in 25 ml of 100 ppm GA₃ solution for 72 hours at 4°C in the dark and were used after being rinsed with pure water. Utilized solutions: To prepare a 1% KNO₃ solution, 2.5 g of KNO₃ was weighed and dissolved in 200 ml of distilled water using a magnetic stirrer. The final volume was adjusted to 250 ml for use. To prepare a 100 ppm IBA solution with a total volume of 100 ml, 0.01 g of IBA was weighed and dissolved in 1 ml of NaOH, followed by dilution to a final volume of 100 ml. To prepare a 100 ml solution of 100 ppm kinetin, 0.01 g of kinetin was weighed and dissolved in 1 ml of NaOH, with the final volume adjusted to 100 ml. To prepare a 10% PEG-6000 solution, 5 g of PEG-6000 was weighed and dissolved in 40 ml of distilled water with a magnetic stirrer, and the

final volume was adjusted to 50 ml for usage. To make a 1% KNO₃ solution, 2.5 g of KNO₃ was measured and dissolved in 200 ml of distilled water using a magnetic stirrer, and the final volume was adjusted to 250 ml for usage.

2.3. The statistical analysis

The experiment was conducted with a randomized complete block design with three replications. The values subjected to statistical analysis were analyzed in three replications. The collected data were analyzed using the JUMP 10.0 statistical software package (Yurtsever, 1984).

3. Findings and Discussion

This study aimed to determine the most effective priming method for achieving high germination rates in medicinal sage seeds. A total of 13 different treatments were tested in three replicates, and the resulting number of germinated seeds, along with germination rates, germination day, germination index, and germination energy, were evaluated statistically. Observations were made over a period of 15 days following the establishment of the experiment. The effect of the treatments on the number of germinated seeds, germination day, germination index, germination energy, and germination rates was determined to be statistically significant at the 1% significance level (Table 1) and mean comparison of main effects of different priming treatments given below, (Table 2).

Table 1. ANOVA on mean of squares of measured traits in *S. officinalis* seeds under different priming treatments

Source of variation	DF	Number of germinated seeds		Germination rate (%)		Germination index (GI)		Germination energy (GE)	
		Mean square	F	Mean square	F	Mean square	F	Mean square	F
Treatments	12	9.02	5.10**	225.75	5.10**	120.04	5,63**	2623.08	5.88**
Error	26	1.77		44.23		1.78		37.18	
Total	38								

DF: Degrees of freedom; p< 0,01

Table 2. Mean comparison of main effects of different priming treatments

No	Treatments	Number of germinated seed	Germination rate (%)	Germination Index (GI)	Germination Energy (GE)
1	Control	2.00 cde	10.00cde	1.43cd	5.00de
2	Soaking in distilled water at room temperature for 24h	4.00 abc	20.00abc	4.28ab	20.00ab
3	Heat shock treatment in hot water at 60 °C followed by rapid cooling	0 e	0 e	0d	0e
4	Soaking in distilled water at 4 °C for 72h	4.67 a	23.33a	4.05ab	16.67b-d
5	Mechanical scarification using sandpaper	5.00 a	25.00a	5.36a	25.00a
6	Soaking in 100 ppm GA ₃ solution for 24h	4.33 ab	21.67ab	4.64ab	21.67ab
7	Soaking in 100 ppm IBA solution for 2 h	1.33 de	6.67de	1.19cd	5.00de
8	Soaking in 100 ppm kinetin solution for 24h	4.33 ab	21.67ab	4.40ab	20.00ab
9	Soaking in 10% PEG-6000 solution for 24h	1.33 de	6.67de	1.43cd	6.67cde
10	Soaking in 1% KNO ₃ solution for 24h	0.33 de	1.67de	0.36cd	1.67de
11	Soaking at 4°C for 24h + soaking at room temperature for 24h + germination in 1% KNO ₃	2.33 bcd	11.67bcd	2.50bc	11.67bcd
12	Soaking in 100 ppm GA ₃ solution for 24h + germination in 1% KNO ₃	2.33 bcd	11.67bcd	2.50bc	11.67bcd
13	Soaking in 100 ppm GA ₃ solution at 4 °C for 72h	4.33ab	21.67ab	4.64ab	21.67ab

In their review on priming, Pawar and Laware (2018) noted that priming applications lead to uniform and faster germination rates in seeds exposed to abiotic stress conditions. They reported that these applications not only enhance the germination rate and break dormancy but also improve the plant's resistance. The mean number of germinated seeds in the applications ranged from 0 to 5, (Figure 1), while the mean germination rate varied from 0% to 25%, (Figure 2). The highest germination rate was obtained from treatment number 5 (25%), which used mechanical abrasion, and treatment number 4 (23.33%), which used hydropriming by keeping the seeds in distilled water at 4°C for 72 hours. These two treatments were statistically in the same group. Following this,

treatment number 6 (soaking in 100 ppm GA₃ solution for 24 hours), treatment number 8 (soaking in 100 ppm kinetin solution for 24 hours), and treatment number 13 (soaking in 100 ppm GA₃ solution for 72 hours at 4°C) were found in the next statistical group, which included hormone treatments. Another hormone application, application number 7 (soaking in 100 ppm IBA solution for 24 hours), showed lower germination success compared to the control, while applications number 9 (soaking in 10% PEG-6000 solution for 24 hours) and number 10 (soaking in 1% KNO₃ solution for 24 hours) were also in the same statistical group. No seeds germinated as a result of the "Shocking and Cooling in Hot Water at 60°C" (number 3) application.

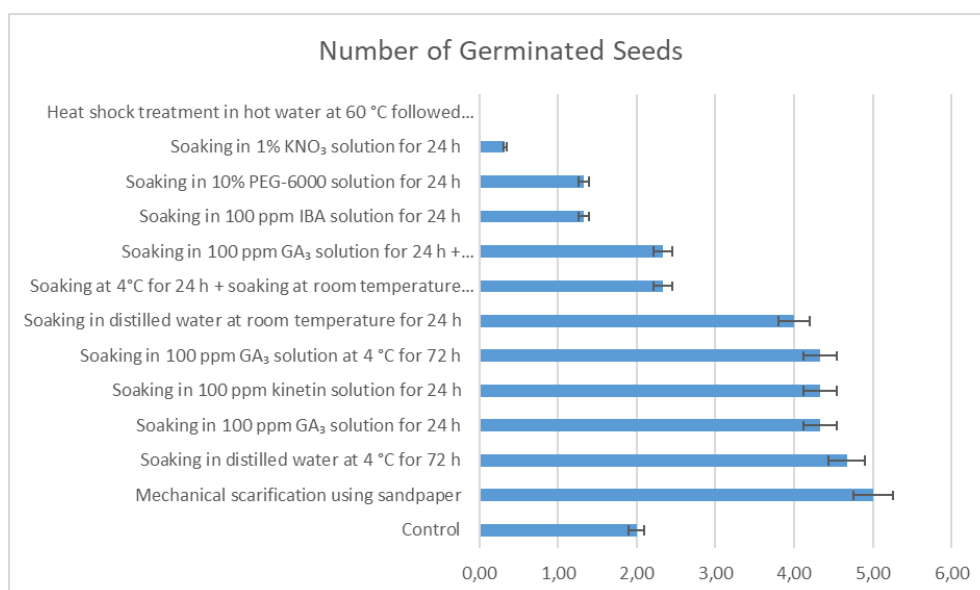


Figure 1. Graphical representation of germinated seed numbers in priming applications of *Salvia officinalis* L.

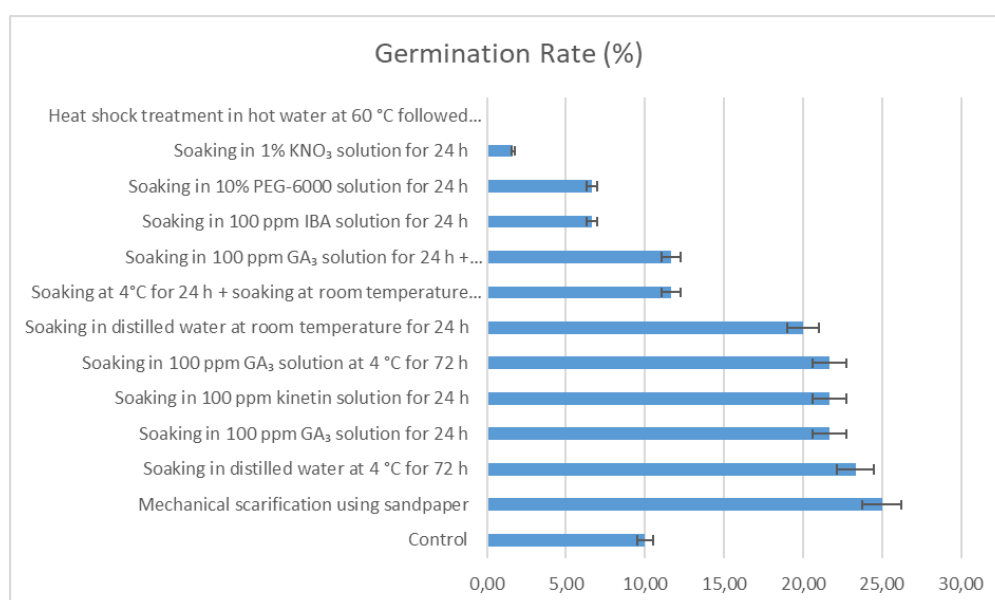


Figure 2. Graphical representation of germination rates in priming applications of *Salvia officinalis* L.

GI values for the treatments ranged from 0 to 5.36, and this value was calculated as 4 for the control group. Treatment number 9 had the same index value as the control, whereas eight treatments had values higher than the control, and three had values lower, (Figure 3). The calculated GE values for the treatments in the

study ranged from 0 to 25, and the calculated GE value for the control was 5. Treatment number 7 had the same value as the control, while nine treatments had values higher than the control, and two treatments had values lower than the control, (Figure 4).

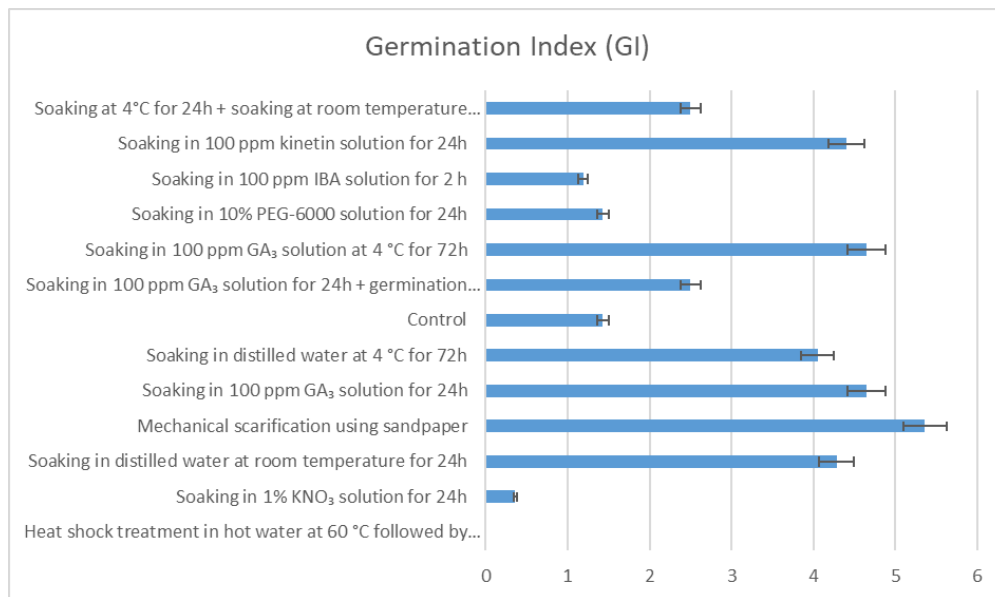


Figure 3. Graphical representation of germination index in priming applications of *Salvia officinalis* L.

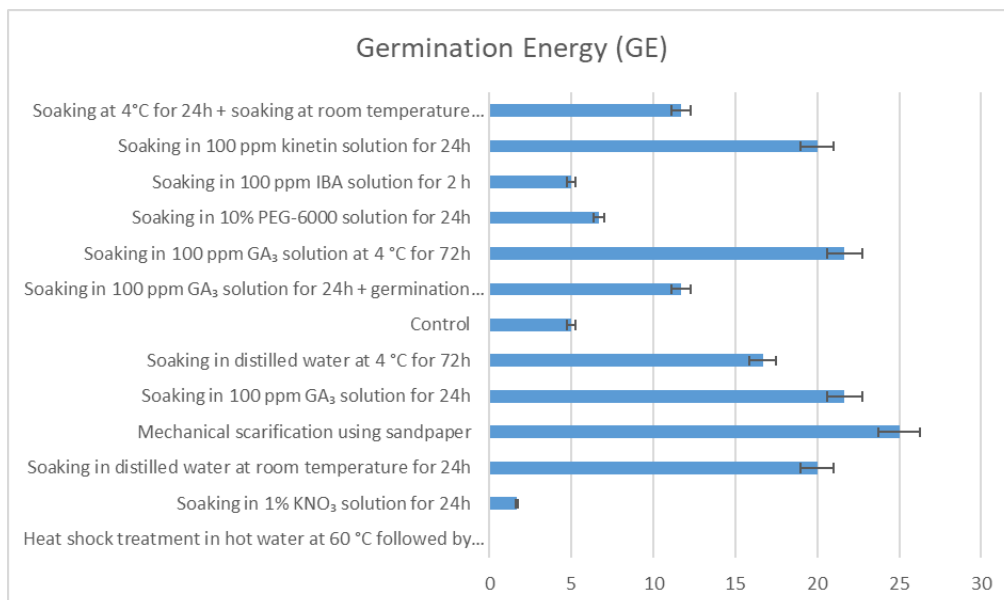


Figure 4. Graphical representation of germination energy in priming applications of *Salvia officinalis* L.

Germination day numbers for the priming treatments varied from 3 to 6 days. The control group was calculated to have a germination time of 6 days, while all other treatments had shorter germination times, except for the "heat shock treatment in hot water at 60°C followed by rapid cooling," which did not result in any germination. Hydro-priming is a pre-treatment technique aimed at improving the germination performance of seeds with low germination potential by reducing dormancy, softening the hard seed coat through controlled hydration to facilitate embryo emergence, and enhancing the seed's water uptake efficiency under

adverse environmental conditions such as drought, (Ceritoğlu et al., 2021). The application of hydro-priming to seeds resulted in an increase in germination rate, Sharma et al. (2018) reported that among the priming techniques they employed, soaking *S. officinalis* seeds in cow dung slurry overnight not only ensured early germination but also significantly increased germination percentage, germination rate, root length, shoot length, and seedling vigor. This method was followed by the application of 5% cow urine for 12 hours. They reported that seed application with hot water and cold water in

case of non-availability of cow dung and bovine urine was also effective in increasing germination and growth. Hydropriming is easy to apply and cost-effective, but it has disadvantages, such as uncontrolled water uptake by seeds and varying water uptake rates due to various factors, which result in a heterogeneous germination pattern, (Geisler et al., 2017). Therefore, Ceritoğlu et al. (2021) reported that the sowing time and ambient temperature should be kept under control because the risk of seed germination increases when the hydropriming technique is used. The effect of hydropriming on the germination of *S. officinalis* L. (sage) seeds, applied at three different temperatures (10 °C, 20 °C, and 30 °C) and four different times (0, 12, 24, and 48 hours), Dastanpoor et al. (2013) reported that all treatments increased germination except seeds hydroprimed at 30 °C for 48 hours, and the best result was obtained with 12 hours of hydropriming at 30 °C. In a study evaluating the effects of hydro-priming, magneto-priming, and electro-priming methods on *S. officinalis* seeds, it was determined that hydro-priming was the most effective method, with a germination rate of 70% within 10 days; magnetic and electrical applications were reported to have lower success (Stoian et al., 2024). In the study investigating the effects of hydropriming on seed germination and seedling growth in five different flower seed species: *Antirrhinum*, *Dahlia*, *Impatiens*, *Salvia*, and *Zinnia* plants, Ozden et al. (2017) concluded that hydropriming can enhance seedling quality in flower seeds. The results derived from hydropriming in the studies mentioned above were akin to the findings of this research. In the seeds of two endemic sage plants (*Salvia siirtica* and *Salvia kronenburgii*), applied to treatments of sodium hypochlorite, ethyl alcohol, gibberellic acid, seed cracking, removal of the seed coat, pre-cold treatment, and sulfuric acid, Orcan et al. (2024) investigated their germination performances. Except for sulfuric acid, in all treatments, higher germination rates were obtained compared to the control group for both plants. They remarked that the best germination rate for both plants was obtained

from the treatments where the seed coat was mechanically removed, and GA treatments for *S. siirtica* and cold pre-treatments for *S. kronenburgii* significantly increased germination rates. They stated that the removal of the seed coat, gibberellic acid, and cold pre-treatment effectively broke dormancy in sage seeds and increased germination rates. In this study it was also observed that the treatments of mechanical scarification with sandpaper and soaking in distilled water at 4 °C for 72 hours yielded the highest values for both the number of germinated seeds and the germination rate. The findings obtained in this context are similar to the above studies. Hormone applications were the preferred option for germination treatments due to their significant efficacy, with GA₃ being one of the most commonly employed treatments Bahadırılı (2024). In one study Özcan et al. (2014) on four species (*S. fruticosa*, *S. officinalis*, *S. pomifera*, and *S. tomentosa*) investigated the impact of different germination treatments (ethylene, gibberellin, PEG 8000, salicylic acid, and seaweed) and pretreatments (pre-drying, pre-cooling, and no treatment) under controlled conditions of 25/15°C, with a light cycle of 12 hours and a dark cycle of 12 hours. The evaluation of *Salvia* species regarding their germination potential revealed that all three pretreatments were applicable, and GA₃ application increased the germination rate for all *Salvia* species. Furthermore, the GA₃ application was the most effective treatment with the highest germination rate at 95.1% for *S. officinalis*. Besides, they pointed out that even in the same genus and clade, four *Salvia* species showed different germination behaviors. Sönmez et al. (2019) examined the impact of nine distinct treatments on the germination and emergence rates of seeds, aiming to enhance the performance and quality of medicinal sage (*Salvia officinalis* L.) and Anatolian sage (*Salvia triloba* Mill.). Their findings indicated that the polymer + priming treatment elevated GA₃ activity in both species, while the KNO₃ treatment significantly reduced the average germination time. Research on the seed pretreatment of *Salvia* species indicates that dormancy is

induced by mucilage within the tough seed coat (Khakpoor et al., 2015; Yaman, 2020). Ellis et al. (1985a) reported that the seed coat, immature seeds, and dormancy are the primary factors influencing the success of seed germination, even in viable seeds. On the other hand, they indicated that cold stratification and hormones facilitate the germination of dormant seeds (Ellis et al., 1985b). Priming techniques, including seed coat removal, hormonal priming, stratification, hydro priming, and chemical priming, are effective methods that vary by species to enhance germination rate, time, and quality. Seed dormancy is usually seen in *Salvia* species; however, certain samples from species such as *S. officinalis*, *S. coccinea*, and *S. farinacea* exhibit no dormancy (Ellis et al., 1985b). In one study, Al-Gharaibeh et al. (2017) stated that the collection site, temperature, and salinity affected the salinity tolerance and germination of *S. syriaca* and *S. spinosa* species and remarked that the locations from which seeds were collected significantly influenced germination. Bahadırılı (2024) noted that local environmental conditions that affect seeds until maturation could have a strong impact on germination behavior. In one research Bahadırılı (2024) assessed the impact of priming on the germination characteristics of *Salvia aramiensis* seeds and conducted a total of 34 germination experiments, including a control; however, germination was only successful with the combination of GA₃ (gibberellic acid) and chilling, with the maximum germination rate being from a 30-day chilling period combined with a 2000 ppm GA₃ application. Beken and Özel (2021) conducted a study to evaluate the effects of pre-chilling (stratification) duration (control, 14 days, 28 days, and 42 days at +4°C) and gibberellic acid (GA₃) concentrations (0 ppm, 100 ppm, 200 ppm, 300 ppm, and 400 ppm) on the germination and seedling quality of Anatolian sage (*Salvia fruticosa* Mill.) seeds. Their investigation revealed that 100 ppm GA₃ and a 14-day pre-chilling treatment were effective for seed germination. Costa et al. (2021) conducted a study examining the impact of priming applications on the

germination of *S. hispanica* seeds subjected to salt stress. Their findings indicated that salt stress negatively affected the germination and growth of *S. hispanica*. However, both gibberellic acid and salicylic acid were found to mitigate the effects of salt stress on *S. hispanica* at an osmotic potential of -0.4 MPa. Additionally, hydropriming application demonstrated a beneficial effect by alleviating the impacts of salt stress on *S. hispanica* seeds at an osmotic potential of -0.3 MPa. Evaluating the hormone treatments and their combinations resulted in higher germination rates compared to the control group; however, the IBA treatment yielded results that were lower than the control. Similarly to the aforementioned studies, this research noticed as well that hormone priming applications positively influenced germination. Kinetin and GA₃ treatments (6-8-13) were included in the same statistical group. When comparing GA₃ treatments 6 and 13, it was observed that keeping them in the cold for longer periods of time did not make a difference in the obtained values. The overall evaluation revealed that eight of the treatments yielded higher values, while four yielded lower values, compared to the control group. This finding suggests that priming treatments have an increasing effect on the germination rate of medicinal sage seeds.

4. Conclusion

Seed germination performance is one of the most critical stages that directly affects success in plant production. Low germination rates, particularly in seeds collected from natural populations or those that are physiologically dormant, constitute a significant limiting factor in cultivation (Bewley et al., 2013). Seeds of most medicinal plants adapt to environmental conditions differently. Therefore, it is necessary to create optimal conditions for the germination of seeds of medicinal plants and determine the ecological/physiological factors affecting dormancy in their production (Khakpoor et al., 2015). Therefore, priming practices have been widely used recently due to their positive effects on the germination rate and speed of seeds in many commercially

important species. Priming is based on the principle of pretreating seeds in specific solutions under controlled conditions, activating metabolic processes and ensuring faster and more uniform germination (Ashraf and Foolad, 2005; Paparella et al., 2015). Priming techniques activate enzymes and antioxidant defense mechanisms that play a role in the germination process, demonstrating positive effects on plant development from germination to maturity and increasing tolerance to environmental stress factors. In addition to being an applicable, economical, and effective method, the technique is considered an important alternative for achieving sustainable agricultural production goals due to its potential to reduce chemical input use (Ceritoğlu et al., 2021). The quality of the seed, which initiates agricultural production, is vital at every developmental stage. From germination to harvest, the seed's ability to germinate and produce strong, healthy seedlings has a direct effect on yield and product quality in later stages. The scenario is similar for medicinal and aromatic plants, which have recently been integrated into agricultural production patterns. The seeds' high germination capacity, along with the healthy development of the resulting seedlings, will provide a significant advantage when initiating production. This study aimed to investigate the effects of priming treatments, a recent research topic, on the germination properties of *S. officinalis* seeds. In this context, seeds were pretreated with solutions containing water, growth regulators, and salt and then germinated under controlled conditions to assess the effectiveness of the treatments. When the results were evaluated, eight out of the thirteen applications tested alongside the control group showed higher germination values. The mechanical abrasion treatment achieved a germination rate of 25%, which was 2.5 times greater than the control group's 10% germination rate. Additionally, soaking seeds in pure water at 4 °C for 24 hours increased the germination rate by 2.33 times, resulting in a final rate of 23.33%. The hormone treatments and their combinations resulted in higher germination rates compared

to the control group; however, the IBA treatment yielded results that were lower than the control. Similarly, the osmopriming treatments, which included a 24-hour soaking in a 10% PEG-6000 solution and a 24-hour soaking in a 1% KNO₃ solution, also produced results below the control level. The results of this study indicate that priming treatments are effective on seed germination in *S. officinalis*, an important medicinal plant. However, further research is needed to determine the most appropriate method for different genera and species.

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