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ORIGINAL ARTICLE

Optimizing germination performance of Lamiaceae family seeds: insights from research

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Abstract
The Lamiaceae family comprises herbaceous to woody plants that can thrive in a wide range of habitats and are cosmopolitan in distribution. In Turkey, there are 45 genera and 586 species belonging to the Lamiaceae family. Among these species, 239 taxa are endemic, making it the third-largest family in Turkey in terms of endemic individuals. In this study, seeds of three species from the Lamiaceae family, Izmir oregano (*Origanum onites* L.), French lavender (*Lavandula stoechas* L.), and basil (*Ocimum basilicum* L.), were used as test materials. The research aimed to overcome heterogeneous and low germination issues observed in these seeds, which were determined to be seed-related through preliminary studies, and to achieve the highest germination percentage and average germination time. Various pre-sowing treatments were applied to improve the germination performance and quality of Izmir oregano, French lavender, and basil seeds. For this purpose, the effects of treatments including control, KNO3, GA3, polymer coating, priming, priming + polymer coating, priming + polymer coating + KNO3, and priming + polymer coating + GA3 on seed germination rate and average germination days were investigated in comparison to the control. Prior to the treatments, molecular analyses were conducted on all seed samples to detect viral agents. As a result of the research, the highest germination percentage of 94% was found in Izmir oregano with the priming + polymer coating + KNO3 treatment. In contrast, for French lavender and basil seeds, the germination performance with a 92% and 94% germination rate, respectively, was achieved with the priming + polymer coating + GA3 treatment. Molecular analyses conducted on seed samples did not detect any viral agents.

Keywords Lamiaceae · Priming · Seed treatments · Germination · Virus · qPCR

Introduction

The interaction between humans and plants has been a fundamental part of human existence since the dawn of time, and this relationship continues to evolve to this day. Throughout this process, the importance of plants has shifted, but it has never diminished entirely. In recent years, there has been a significant increase in demand for plant-based products, leading to a growing recognition of the importance of plants in various aspects of human life.

Medicinal and aromatic plants have been used for various purposes in different regions of the world since ancient times. They play a crucial role in the treatment and prevention of specific diseases. While these plants are generally harvested from the wild, they are also extensively cultivated for use. However, obtaining a consistent level of quality in harvested plants is challenging (Oztekin and Martinov 2014). Incorrect harvesting techniques in the collection of medicinal and aromatic plants pose a threat to the survival of plant species. Additionally, the irregular supply of plant volumes required to meet market demand further complicates wild harvesting. The cultivation of these plants is essential both for conserving biodiversity and for meeting the demand for consumption.

Turkey, with its rich plant diversity, vast land area, and diverse climate conditions, holds significant potential for natural and cultivated medicinal and aromatic plants. While these plants are generally collected from the wild, ensuring standardized quality in harvested plants is challenging. The increasing demand for medicinal and aromatic plants has heightened the importance of their cultivation.

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Consequently, research on new cultivars and addressing production issues in existing genotypes has gained significance.

Globally, 95% of cultivated plants are propagated through seeds. Despite all other agricultural conditions being optimal, if seed quality is subpar, productive cultivation is not feasible. Seed quality encompasses the excellence of genetic or physical attributes of the seed, its storability, and its potential performance after planting. The choice of high-quality seeds is a fundamental factor in increasing yield per unit area. Quality problems arise due to genetic and environmental factors. To address these problems and achieve the desired quality, corrective measures are applied to seeds. The choice of high-quality seeds is a fundamental factor in increasing yield per unit area. Seeds with low vigor, challenging germination, and heterogeneous germination characteristics are more susceptible to adverse environmental conditions, resulting in lower germination performance. This issue is commonly observed in cultivated plants, leading to an increase in research efforts aimed at solving germination problems and enhancing seed quality in recent years.

Seed priming is a widely used technique that is both effective and economical for enhancing germination rates in seeds. Several factors influence seed germination, and when these factors are optimized, the expected seedling emergence occurs. Among these fundamental factors are soil temperature, seed viability, soil moisture, soil-borne pests, and planting method and timing.

Various priming agents such as water, inorganic salts, sugars, solid media containing water and nutrients, beneficial microbes, micronutrients, hormones, rhizobacteria, and organic substances are used to enhance seed performance. Particularly, drought and temperature stress significantly affect germination, leading to heterogeneous germination. The pre-germination process stimulates metabolic activity in seeds and ensures controlled water uptake at a level that does not result in radical emergence. Priming is not only used to improve plant growth and yield but also to enhance abiotic stress tolerance. (Li and Liu 2023; Noori et al 2022). In particular, priming is an easily applicable solution to increase stress tolerance by modifying antioxidant enzyme activity and organic matter content, aiming to protect and maximize plant yield under abiotic stress conditions, especially drought stress (Sher et al. 2019; Ekren et al 2023).

The use of priming is a common practice to address germination issues in medicinal and aromatic plants, which are gaining increasing importance and demand. In the scope of this research, which focuses on addressing these problems, we have selected seeds from the most important species of the Lamiaceae (Mint) family, namely Izmir Oregano (*Origanum onites* L.), French Lavender (*Lavandula stoechas* L.), and Basil (*Ocimum basilicum* L.). The goal is to improve germination and emergence rates, achieve homogeneity, and ensure early emergence through various applications, including priming, film coating, and their combinations. The research aims to determine the best method for enhancing seed germination and emergence characteristics after these applications.

The significance of these species and their commercial importance underscores the importance of yield per unit area. One way to achieve potential yield increases is by increasing germination percentages and ensuring rapid and homogeneous emergence. The use of high-quality seeds will undoubtedly lead to increased yield. Furthermore, not only the quantity but also the synchronous growth of these plants is essential. This project addresses solutions to the challenges faced in this regard (Panuccio et al. 2018).

Plant viral diseases, with no chemical control options, can be of significant concern, especially in seed transmission cases, as they can be transported internationally. The most common viral diseases in the Lamiaceae family include Cucumber mosaic virus, Tomato yellow leaf curl virus, and Tomato spotted wilt virus. Cucumber mosaic virus is considered one of the most important members of the Cucumovirus genus within the Bromoviridae family. It is non-enveloped, isometric, approximately 29–30 nm in diameter, and possesses a single, three-component (+) ssRNA genome (Palukaitis and Garcia-Arenal 2003). Tomato yellow leaf curl virus belongs to the Begomovirus genus in the Geminiviridae family and has a 2.7–2.8 kb ssDNA genome (Czosnek 2021). Tomato spotted wilt virus, on the other hand, is part of the Tospovirus genus in the Bunyaviridae family. TSWV has spherical particles with lipid membranes, ranging from 80 to 110 nm in diameter (Adkins 2000).

The aim of this study is to enhance the germination performance in seed production of three species belonging to the Lamiaceae family (Izmir Oregano, French Lavender, and Basil), to addresses solutions to the challenges faced in this regard and to identify potential diseases affecting them.

Materials and methods

In this study, seeds of Izmir Oregano (*Origanum onites* L.), French Lavender (*Lavandula stoechas* L.), and Basil (*Ocimum basilicum* L.) were used as research materials. The research was conducted in the laboratories of the Aegean University Seed Technology Application and Research Center (TOTEM). For the research material, 400 seeds in total, with 100 seeds from each of Izmir Oregano, French Lavender, and Basil, were used in four replicates. Film coating application, tetrazolium (ttc) test, pre-soaking (osmopriming) applications, seed coating applications, germination tests, chemical treatments, combined treatments, molecular analyses, and statistical analysis were performed.

The seeds underwent pre-germination treatment using the osmopriming technique. In this process, osmotic conditioning was achieved using the ventilated application container method under controlled conditions (Acikgoz et al. 2004; Bujalski and Nienow 1991; Duman et al. 1998; Duman and İlbi 2001). Osmotic conditioning is achieved using 6000 ppm polyethylene glycol (PEG 6000), as illustrated in Fig. 1.

Film coating application

Another application in the research aimed at improving seed quality is the film coating method. Water-based polymers for seed film coating were obtained from the Incotec company, and three different colored polymers were used for each seed type: Disco AG Blue L-517 (Dark blue), Disco HP Pearl Green 506 (Green), and Disco AG 321 (Red).

Tetrazolium (TTC) test

The TTC test is a method used to distinguish between live and non-live tissues in seeds, determining embryonic viability. The solution used here, 2,3,5 triphenyl tetrazolium chloride, creates color differences in the seeds. Live tissues react and show color, while non-live tissues remain colorless (Gokcol et al. 2010). The prepared 1% tetrazolium solution had a pH of approximately 7.0.

Presoaking (Osmopriming) applications

In osmotic presoaking applications, the ventilated application container technique is commonly used (Duman and İlbi 2001). In the presoaking process, the osmotic pressure created by PEG (polyethylene glycol) with a molecular weight of 6000 ppm controls the emergence of radicals during seed treatment. In the research, presoaking was performed for 16 h under − 0.8 MPa atmospheric pressure. Subsequently, the treated seeds were rinsed in tap water for 4–5 min and then passed through pure water. The drying process for the wet seeds took approximately 2–3 h. Some of the seeds were used in germination trials conducted in four replicates to measure the effects of the applications on germination and emergence rates and speed, while other presoaked seeds were used in combination applications.

Seed coating applications

All seeds used in the study were coated homogeneously in a laboratory-type CC-laboratory (centricoater) Cymbria seed film coating unit. Care was taken to ensure the homogeneous coating of the entire surface. During the coating process, the seeds were placed into the machine through the seed inlet hopper, and a predetermined dose of polymer and pure water was delivered to the system using a syringe. Additionally, to prevent the seeds from adhering to the machine's walls during the coating process, air was introduced into the system from a compressor connected to the machine throughout the process. After the coating process was completed, the seeds were placed on drying papers and left to dry at room temperature until they reached their original weights.

Germination tests

The germination vigor and speed of the seeds were determined according to ISTA criteria. First, the seeds were placed in Petri dishes with drying paper inside. The research was set up in four replicates according to a randomized block design. Each replicate included 100 seeds. Germination tests for each variety were conducted under optimal temperature conditions of 20 °C, following ISTA rules. Counts were made daily during the germination tests, and seeds with a 2 mm radicle were considered "germinated" and removed from the Petri dishes.

The germination vigor (%) value was determined according to Larsen and Andreasen (2004):

$$\text{GV} = \Sigma n/N \times 100$$

n: Number of germinated/emerged seeds, N: Total number of seeds.

The calculation of germination speed was done following Pederson et al. (1993):

Fig. 1 Equipment used in the osmopriming process

Mean Germination Time (MGT) = Σ(gx nx) / Σnx

gx: Number of days from the start of the test, nx: Number of seeds germinated on a given day, Σnx: Total number of germinated seeds.

Chemical treatments

To increase the germination rate of all seeds in the study, a 2000 ppm KNO3 treatment and a 1000 ppm GA3 stock solution were prepared (ISTA 2022).

Combined treatments

Osmotic seed treatments (priming), film coating, and KNO3 and GA3 applications were combined with each other, followed by germination and emergence tests. Seeds were coated not only with the polymer but also separately with a 0.2% KNO3 solution and a 0.1% GA3 solution added to the polymer solution. After coating, the seeds were dried for 24 h. The seed coating process was also applied to the seeds dried after priming. The resulting combinations after the combined treatments were as follows: Control, Polymer coating, Priming, Priming + polymer coating, Priming + polymer coating + KNO3, Priming + polymer coating + GA3.

Molecular analyses

To identify viral agents in the seeds, the qPCR method was employed. The analysis involved RNA isolation (Fig. 2), cDNA synthesis, and qPCR stages for the seed samples. For CMV, the PCR cycling conditions were as follows: initial denaturation at 94 °C for 5 min, followed by 30 cycles of denaturation at 94 °C for 1 min, annealing at 56 °C for 1 min, and extension at 72 °C for 1 min. The final extension was carried out at 72 °C for 10 min. The primers used for CMV were 5′-AGT GAC TTC AGG CAG T-3′ and 5′-GCT TGT TTC GCG CAT TCA-3′ (Atik and Paylan 2023; Bruni et al. 2007; Paylan et al. 2014).

For TYLCV, the PCR cycling conditions were as follows: initial denaturation at 94 °C for 2 min, followed by 30 cycles of denaturation at 94 °C for 30 s, annealing at 58 °C for 1 min, and extension at 72 °C for 1 min. The final extension was carried out at 72 °C for 10 min. The primers used for TYLCV were 5′-GAG ACT GCA GAA ATG TCG AAG CGA CCA GGC G-3′ and 5′-GAG AGG ATC CIT AAT TIG ATA TIG AAT CAT AGA AAT AG-3′ (Oh et al. 2019).

For TSWV, the PCR cycling conditions were as follows: initial denaturation at 94 °C for 3 min, followed by 30 cycles of denaturation at 94 °C for 1 min, annealing at 58 °C for 45 s, and extension at 72 °C for 1 min. The final extension was carried out at 72 °C for 10 min. The primers used for TSWV were 5′-AGCTTAAATCAATAGTAGCA-3′ and 5′-AGCTTCCTCAAGAATAGGCA-3′ (Poojari and Naidu 2013).

Statistical analysis

The data obtained from the research were subjected to statistical analysis using the Tarist Statistical Package Program. Differences were determined at a significance level of 5% (Açıkgöz et al. 1994). Grouping them using the LSD test allowed us to assess the distinctions that emerged (Stell et al. 1997).

Results and discussion

The TTC test conducted to determine the embryonic viability of the seeds revealed that the viability of all species' seeds was high. These results indicate the suitability of the seeds' viability before the application. Viability rates were determined as follows: 98% for Izmir Thyme (*Origanum onites* L.), 95% for Lavender (*Lavandula stoechas* L.), and 97% for Basil (*Ocimum basilicum* L.).

Findings for Izmir Thyme (*Origanum onites* L.) species

For Izmir Thyme seeds, a classical germination test was conducted according to ISTA rules for control purposes, and the germination rate was found to be 83% (Table 1). It can be observed that there is a statistically significant difference among the applications, and the highest germination power of the seeds was achieved with the Priming + Polymer + GA3 application. The effects of the applications on daily germination values are shown in Fig. 3.

Fig. 2 Nucleic acid extractions of seed samples

Table 1 The impact of applications on germination values for Izmir Thyme seeds

Application	Germination Power (%)		Average germination time (days)	
Control	83,00	cd	7,42	d
Polymer	82,00	d	7,59	d
KNO_3	88,25	bc	5,91	b
GA_3	88,00	bc	6,11	bc
Priming	85,00	cd	5,22	a
Priming + Polymer	86,00	c	6,72	c
Priming + Polymer + KNO_3	94,00	a	4,93	a
Priming + Polymer + GA_3	90,00	b	5,16	a

$p \leq 0,05$ LSD: 3,890 LSD: 0,635

The effect of pre-sowing seed treatments on the average germination time (days) of Izmir Thyme seeds was found to be statistically significant. In terms of average germination time, the treatments in combination with Priming have the shortest germination time statistically, with the Priming + Polymer + KNO3 treatment standing out. On the other hand, the sole Polymer treatment resulted in seeds taking longer (7.59 days) to reach the average germination time compared to the control (Fig. 3).

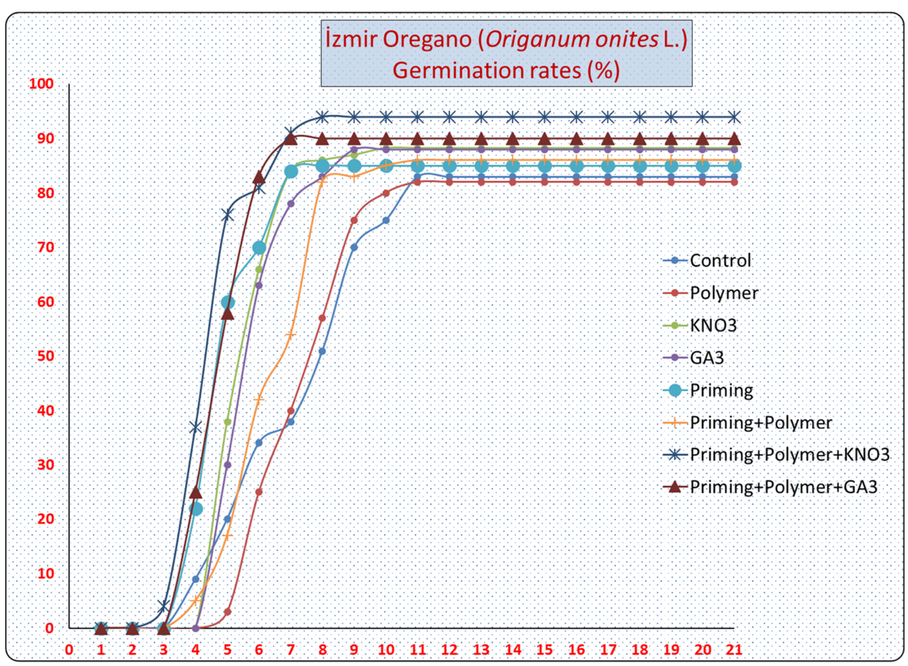
The daily germination values obtained as a result of pre-sowing seed treatments for Izmir Thyme seeds' germination rate are presented in Fig. 1.

Our research findings indicate that priming, GA3, and KNO3 treatments increased germination compared to the control, while the polymer treatment led to a slight decrease compared to the control. It is known that GA3 has a positive effect on germination. However, the polymer, due to its reduced permeability of the cell membrane to water, can delay germination to some extent, which is consistent with the results of our study (Sönmez et al. 2018).

The combined treatments have been shown to enhance germination. In a study examining the effects of different storage conditions, light–dark conditions, GA3 concentrations, and different temperature degrees on Origanum seeds' germination, it was found that 1 and 10 ppm GA3 had a positive effect on germination (Unal et al. 2004). Some Origanum seeds were germinated in different environments (fogging greenhouse, germination cabinet, and in vitro growth chamber) with GA3 doses of 0, 1, 10, and 20 ppm. The study concluded that the highest germination was observed in the control groups in the in vitro growth chamber. In the fogging greenhouse and germination cabinet experiments, the effects of GA3 application varied depending on the species and applications. The optimum application dose was determined to be 10 ppm (Ulukapı et al. 2008).

Previous studies on *Origanum majorana* L. *and Origanum vulgare* L. seeds suggested that germination should be carried out at alternating temperatures of 20–30 °C or at a constant temperature of 20 °C (Şehirali 1989; Candal 1995). Our study also found that combined treatments yielded better results than individual applications, with the positive effect of GA3 on germination confirmed.

Fig. 3 Izmir Oregano seeds' daily germination values after the treatments



The results for *Lavandula stoechas* L. (Lavender) seeds are as follows

The effects of treatments on germination values of *Lavandula stoechas* L. (Lavender) seeds are presented in Table 2, and the daily germination values of Lavender seeds after treatments are shown in Fig. 4. Both germination rate (%) and average germination time (days) were found to be statistically significant. In terms of germination rate, the Priming + Polymer + GA3 treatment yielded the highest result at 92%, followed by the Priming + Polymer + KNO3 treatment at 88%. The control group had a germination rate of 74%.

Regarding germination time, the highest values were statistically similar within the groups defined as Priming + Polymer + GA3 (5.20 days), Priming + Polymer + KNO3 (5.91 days), and GA3 (5.28 days). The control group had a germination time of 7.84 days.

Table 2 The effect of treatments on the germination values of *Lavandula stoechas* L. (Lavender)

Application	Germination power (%)		Average germination time (days)	
Control	74,00	Ef	7,84	c
Polymer	72,00	F	8,44	d
KNO_3	81,00	C	6,41	b
GA_3	86,00	B	5,91	b
Priming	78,00	Cd	5,35	a
Priming + Polymer	77,00	De	6,08	b
Priming + Polymer + KNO_3	88,00	B	5,28	a
Priming + Polymer + GA_3	92,00	A	5,20	a

$p \leq 0{,}05$ LSD: 3,972 LSD: 0,524

The positive effect of GA3 application on germination was also observed in Lavender seeds. Similar to thyme seeds, the polymer application inhibited germination in Lavender seeds compared to the control.

In the study, it was determined that the material used for film and pellet coating should not hinder seed respiration and should not have a negative impact on germination (Robani 1994). *Lavandula angustifolia* Mill. seeds were treated with different concentrations (100, 200, and 300 ppm) of GA3, and it was found that GA3 doses broke seed dormancy and increased germination. It was also observed that as the application dose increased, germination increased positively (Varga et al. 2021).

In their study on germination methods for plants belonging to the Labiatae family, they reported that germination temperatures for the Labiatae family could be either 15 °C or 20 °C as constant temperatures, or a range of 10 °C–30 °C and 15 °C–25 °C as alternating temperatures (Ellis et al. 1985).

For the seeds of Medicinal Sage (*Salvia officinalis* L.) and Anatolian Sage (*Salvia fruticosa* Mill.), nine different treatments were applied, including KNO3, GA3, Polymer coating, Polymer coating + KNO3, Polymer coating + GA3, Priming, Priming + Polymer coating, Priming + Polymer coating + KNO3, and Priming + Polymer coating + GA3. Compared to the control group, the highest germination percentage (85%) was achieved after the Polymer + GA3 treatment (Sönmez et al. 2018). Our study also found that

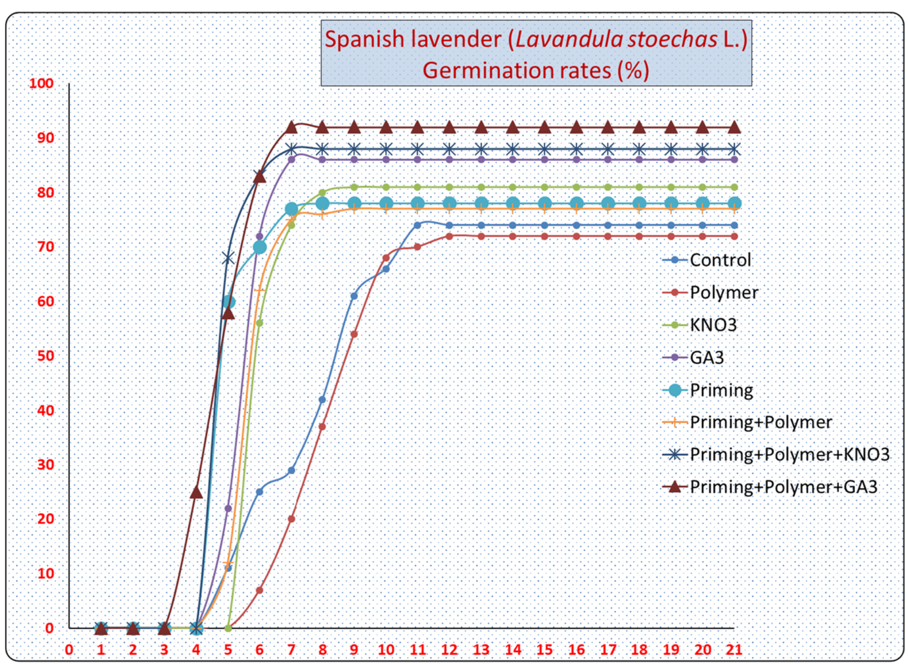


Fig. 4 The daily germination values of *Lavandula stoechas* L. (Lavender) seeds after the treatments

combined treatments yielded better results, consistent with their findings.

The results for *Ocimum basilicum* L. (Basil) seeds are as follows

The statistical analysis applied to the obtained data for germination percentage showed significance at $p < 0.05$ (Table 3). The highest germination percentage, 94%, was achieved through the Priming + Polymer + GA3 application, followed by Priming + Polymer + KNO3 (92%). The control group had a germination rate of 70%.

Table 3 The effect of treatments on the germination values of *Ocimum basilicum* L. (Basil)

Application	Germination power (%)		Average germination time (days)	
Control	70,00	d	4,63	cd
Polymer	68,00	d	5,21	d
KNO_3	86,00	c	4,19	c
GA_3	89,00	bc	4,35	cd
Priming	72,00	d	2,86	a
Priming + Polymer	71,00	d	3,99	bc
Priming + Polymer + KNO_3	92,00	ab	2,66	a
Priming + Polymer + GA_3	94,00	a	3,12	ab

$p \leq 0,05$ LSD: 4,892 LSD: 0,896

Regarding germination time, the results showed that the Priming + Polymer + KNO3 (2.66 days) and Priming (2.86 days) applications had the shortest germination times, followed by Priming + Polymer + GA3 (3.12 days). The control group had a germination time of 4.63 days.

The daily germination values obtained for basil seeds due to the pre-sowing seed treatments' effects on seed germination rate are presented in Fig. 5.

In a study conducted on *Ocimum basilicum* L. seeds, it was found that the best germination occurred after hydropriming for 12 h, with a germination rate of 90.66% (Farahani and Maroufi 2011).

Another study on *Ocimum basilicum* L. seeds subjected to salt stress found that as salt stress increased, germination decreased, and consequently, seedling and root lengths decreased. It was determined that *Ocimum basilicum* L. can tolerate up to 200 mM salinity in the cultivation areas (Camlıca and Yaldiz 2017).

In basil seeds, the priming of growth hormones was found to increase germination and emergence percentages and reduce the adverse effects of drought stress on morphological characteristics, 1000-seed weight, volatile oil yield, chlorophyll content, and antioxidant enzymes during vegetation (Gholami et al. 2013).

In a study on *Ocimum basilicum* L. CIM-Saumya variety seed germination, seeds were left in petri dishes at temperatures of 15 °C, 20 °C, 25 °C, 30 °C, 35 °C, and 40 °C for 16 h of light and 8 h of darkness. The results showed that 25 °C was the optimum temperature for germination percentage, while abnormal seedlings were observed at 40 °C.

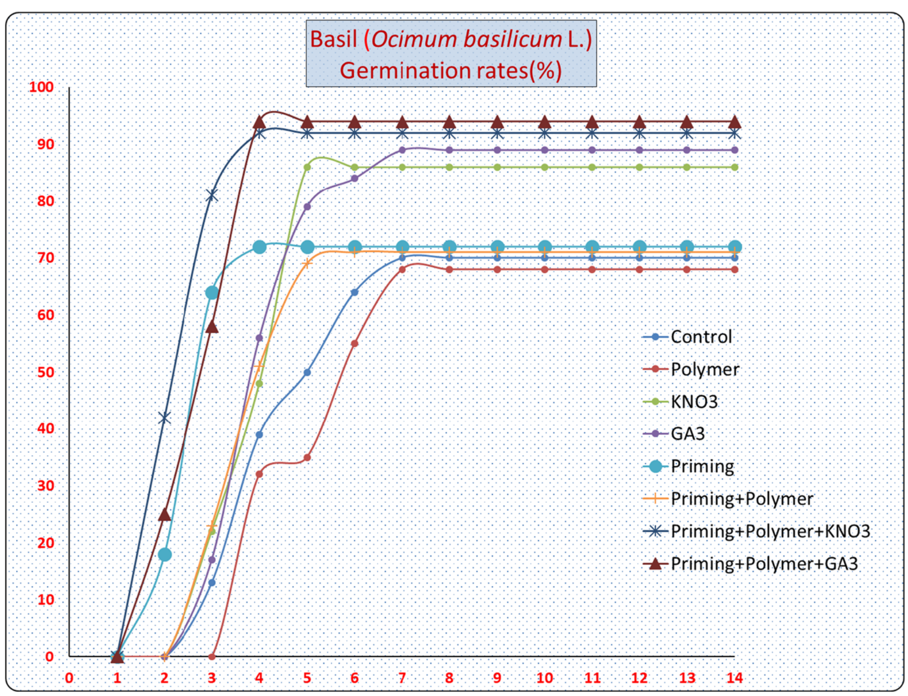
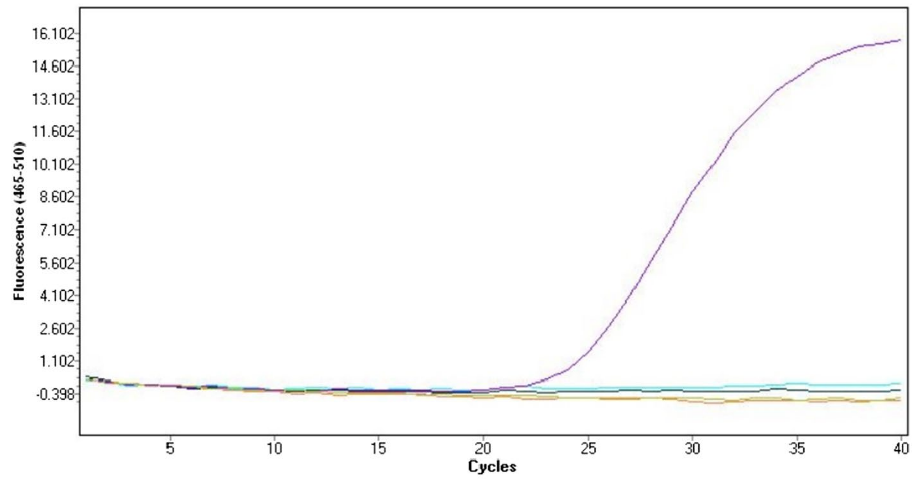


Fig. 5 The daily germination values of *Ocimum basilicum* L. (Basil) seeds after the treatments

Fig. 6 qPCR results of virus tests



It was also noted that germination percentages and seedling vitality indexes I and II significantly decreased at 15 °C, 20 °C, 30 °C, and 35 °C. The study recommended that the 2nd to 3rd days after seed sowing were suitable for the first count, and the 6th to 7th days for the final count (Kumar 2012).

Our research results align with the findings of Kumar (2012), especially regarding the number of days for germination.

Molecular viral analysis results

In the analysis of seed samples using the PCR method, viral infections were not detected (Fig. 6). The tested seeds were found to be clean of viral agents. Studies conducted by June-Pyo Oh & colleagues, S. Poojari and R. A. Naidu, and Renato Bruni, Alberto Bianchi, and Maria Grazia Bellardi have observed the presence of these three viruses in plants of the Lamiaceae family. In the study by Renato Bruni, Alberto Bianchi, and Maria Grazia Bellardi, the CMV density in this family was found to be 88%.

In this research, pre-sowing treatments were applied to seeds of Izmir oregano (*Origanum onites* L.), lavender (*Lavandula stoechas* L.), and basil (*Ocimum basilicum* L.) seeds in order to improve germination and seed quality. To achieve this, nine different methods were applied to the seed, including KNO3 and GA3 application, priming, polymer coating, Priming + Polymer Coating, Priming + Polymer Coating + KNO3 and Priming + Polymer Coating + GA3 coating + GA3, in addition to the control, and the effects of these applications on seed germination rate and average germination days compared to the control. In the evaluation of Izmir Oregano (*Origanum onites* L.), it was found that the seeds with showed the highest germination rates (92% and 88%) in the Priming + Polymer + GA3 and Priming + Polymer + KNO3 treatments, respectively. The positive effect of GA3 application on seed germination has been demonstrated in many studies. Conversely, both polymer and Priming applications have been reported to increase the effectiveness of GA3. The Priming + Polymer + GA3 application statistically gave the shortest average germination time (5.20 days). In contrast, the polymer application alone resulted in longer average germination times compared to the germination times compared to the control.

The results obtained from lavender (*Lavandula stoechas* L.) seeds generally showed similarities to the germination results of Izmir oregano (*Origanum onites* L.). Lavender seeds also exhibited the highest germination rates (94% and 92%) in the Priming + Polymer + GA3 and Priming + Polymer + KNO3 applications, respectively. Similar to Izmir oregano, the Priming + Polymer + GA3 application for lavender seeds allowed them to reach the shortest average germination time (5.20 days). This was followed by the Priming + Polymer + KNO3 application with an average germination time of 5.28 days.

When evaluating basil (*Ocimum basilicum*) seeds in terms of germination rate and average germination time, the results were similar to those of Izmir oregano and lavender seeds. The highest germination rate, 94%, was achieved in the Priming + Polymer + GA3 and Priming + Polymer + KNO3 applications. It was observed that polymer coating resulted in lower germination rates compared to the control. The Priming + Polymer + KNO3 application allowed the seeds to reach the shortest average germination time (2.66 days), followed by the priming application with 2.86 days.

In conclusion, in the Izmir oregano (*Origanum onites* L.), lavender (*Lavandula stoechas* L.), and basil (*Ocimum basilicum*) seeds used as materials in this study, the Priming + Polymer + GA3 and Priming + Polymer + KNO3 applications yielded the best results in terms of germination percentage and average germination time compared to the control group.

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Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Human and animal rights It is not a study involving human participants and/or animals.

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