Effects of Salinity and Water Stress on Seeds Germination of *Origanum majorana* cultivated in Morocco

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Abstract. This study investigates the effect of salt and water stress on the germination performance of *Origanum majorana* seeds. Salinity was applied using 0, 50, 100, and 150 mM NaCl, while water stress was simulated, using PEG 6000, at values of 0, -0.1, -0.7, and -1 MPa. In all treatments, germination percentage and rate of germination were measured. Results showed that germination decreased with increasing salt and water stress. However, at 50 mM NaCl (moderate salinity) or -0.1 MPa (moderate water stress), germination remained high (about 82-85%) and comparable to the control. High salinity (>100 mM NaCl) or intense water stress (-0.7 MPa and above) reduced germination to below 40-45%. Germination curves exhibited a typical sigmoid shape due to their longer lag times and lower germination rates under salt and water conditions. The results obtained suggest that *Origanum majorana* shows moderate tolerance to salinity and is highly sensitive to intense environmental stress. Hence, the current experiment indicates that *Origanum majorana* is moderately tolerant to salt stress and highly sensitive to stronger stress conditions, confirming that appropriate management is needed if this plant is cultivated in arid and semi-arid conditions.

1 Introduction

Origanum majorana L. (marjoram) is a perennial aromatic herb of the Lamiaceae family, widely cultivated in the Mediterranean regions due to its culinary, medicinal, and aromatic properties [1]. *O. majorana* is native to Greece, Turkey and Cyprus; however, it has also been cultivated in different countries such as Morocco, Algeria, Tunisia and Egypt [2-3].

O. majorana is highly valued for its essential oils rich in bioactive compounds such as terpenes and phenolics, which have antioxidant, antimicrobial, and anti-inflammatory activities [4]. In addition to its economic and ecological importance, another major aspect of *O. majorana* is its contribution to soil consolidation and biodiversity in arid agroecosystems. However, germination, essential for crop establishment, is highly sensitive to salinity and water stress in Mediterranean and semi-arid regions [5], where osmotic effects and ion

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toxicity limit water uptake and enzymatic activity. Water stress or drought conditions also hinder imbibition and emergence of the radicle and hence germination [6].

Despite the widespread cultivation of *O. majorana*, information about its tolerance to abiotic stresses during germination remains limited. Knowledge on the resistance of the seeds to salinity and water stress is important for optimizing the breeding process or crop establishment on suitable sites, especially where abiotic stresses are prevalent.

In this regard, this study aimed to determine the impact of salinity and water stress conditions on the germination rate and kinetics of *O. majorana* seed germination. This information will give key insights into the stress tolerance threshold for the species and thus help in its effective growth.

2 . Material and Methods

2.1. Seed Material and Experimental Design

Seeds of *O. majorana* were collected in September 2023, from plants cultivated in the Regional Center for Agricultural Research of Oujda, (Morocco) and stored at room temperature until use. The experiments were performed with the aim of determining the influence of salinity and water deficit on the process of seed germination, and this was possible in a laboratory setting. A total of 25 seeds was used for each treatment, and this was repeated thrice, and thus a total of 75 seeds was used for every single treatment. The petri dishes and filters were disinfected with a solution of sodium hypochlorite and then dried with distilled water.

2.2. Salinity stress Treatments

Salinity stress was imposed using NaCl solutions at concentrations of 0 mM (control, T0), 50 mM (T1), 100 mM (T2), and 150 mM (T3). Seeds were incubated in a growth chamber at 25 °C, 75% relative humidity, and a 16 h light / 8 h dark photoperiod. Germination was recorded daily and the final germination percentage as well as germination kinetics were evaluated.

2.3. Water Stress Treatments

Water stress was simulated using polyethylene glycol (PEG 6000) to achieve osmotic potentials of 0 MPa (control, T0), -0.1 MPa (T1), -0.7 MPa (T2) and -1 MPa (T3). Seeds were incubated under the same conditions as for the salinity treatments, and germination was monitored daily.

2.4. Statistical analyses

Data was analyzed using descriptive statistics and one-way and two-way ANOVA with the SPSS software. Mean comparisons were performed using Tukey's test, with a significance level set at 0.05.

3. Results

3.1. Effect of Salt Stress on Germination

3.1.1. Germination Rate

However, salinity significantly reduced the germination rate of *Origanum majorana* seeds, and a marked reduction in germination rate was seen with the increase in concentrations of NaCl (Figure 1). In the control (T0 = 0 mM), the germination rate reached its maximum at 88%. But in 50 mM NaCl (T1), the germination rate remained high at 85%, and it showed no significant difference with that of T0 at $\alpha = 0.05$. However, in higher concentrations (100 mM and 150 mM) of salinity, germination rate dropped significantly to 39% and 38%, respectively, and it showed marked inhibition under saline conditions. Overall, NaCl concentrations equal to or above 100 mM significantly reduced seed germination compared with the control treatments (0 and 50 mM).

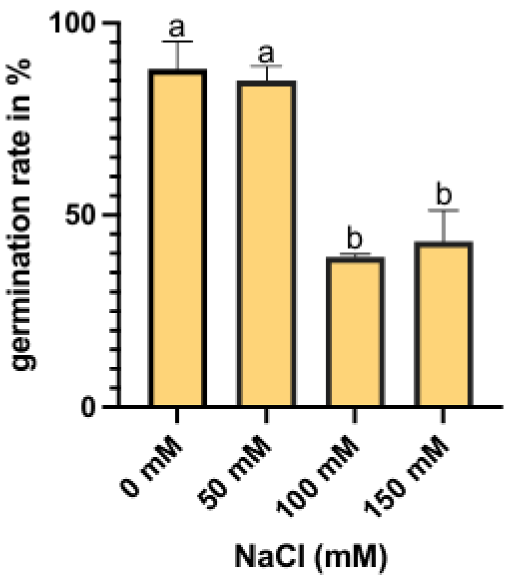

Fig 1. Germination rate of *Origanum majorana* under saline treatments.

3.1.2. Germination Kinetics

The germination kinetics of *O. majorana* under increasing NaCl concentrations followed a typical sigmoidal pattern with three distinct phases: an initial lag phase corresponding to seed imbibition, an exponential phase with accelerated germination, and a final plateau phase marking the completion of the germination process (Figure 2). The lag phase remained short (two days) for all salinity stress treatments. The exponential phase lasted about three days under T0 and T1 but extended to six or seven days under higher salinity levels (T2 and T3), after which germination reaches its maximal rate.

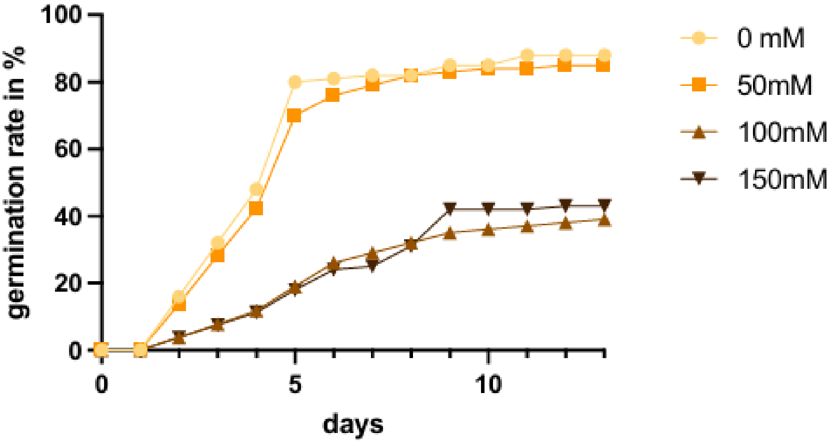

Fig.2. Germination kinetics of *O. majorana* under saline treatments.

3.2. Effect of Water Stress on Germination

3.2.1. Germination Rate

The effect of water stress simulated by PEG 6000 on seed germination is represented in Figure 3. The germinative capacity of *O. majorana* seeds decreased significantly with declining water potential. Germination rates reached 85%, 82%, 64%, and 45% under T0 (0 MPa), T1 (-0.1 MPa), T2 (-0.7 MPa), and T3 (-1 MPa) respectively. At -1 MPa, germination rate decreased by approximately 40% compared to the control ($P < 0.05$), indicating high sensitivity to severe water stress. In contrast, moderate stress levels (-0.1 and -0.7 MPa) did not significantly affect germination compared with the control.

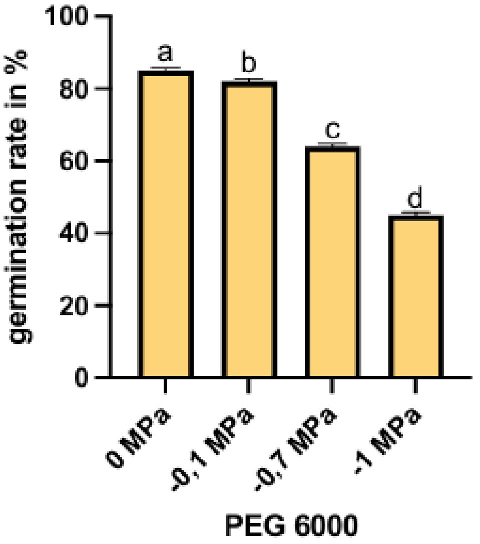

Fig.3. Germination rate of *O. majorana* under water stress induced by PEG 6000.

3.2.2. Germination Kinetics

Germination kinetics of *O. majorana* under osmotic stress clearly reflected the species sensitivity to reduced water potential (Figure 4). In the normal condition (T0, 0 MPa), the germination life cycle followed the conventional phases, which included a lag phase not exceeding day two, an exponential phase, and an attenuation phase culminating in the highest germination.

Drought stress impacted germination rate and cumulative germination. The rate and cumulative germination at T1 (-0.1 MPa) remained comparable to that of the controls, reaching a final germination rate of about 82%. This confirms that weak drought stress has little impact on germination in *O. majorana*. At a moderately stressing level of -0.7 MPa (T2), the germination rate slowed down to 65%. At the most stressing level of -1 MPa (T3), germination occurred at a highly reduced rate, where the final germination rate did not go beyond 45%. This progressive reduction of germination rate with decreasing osmotic potential confirms the high sensitivity of *O. majorana* seeds to water stress.

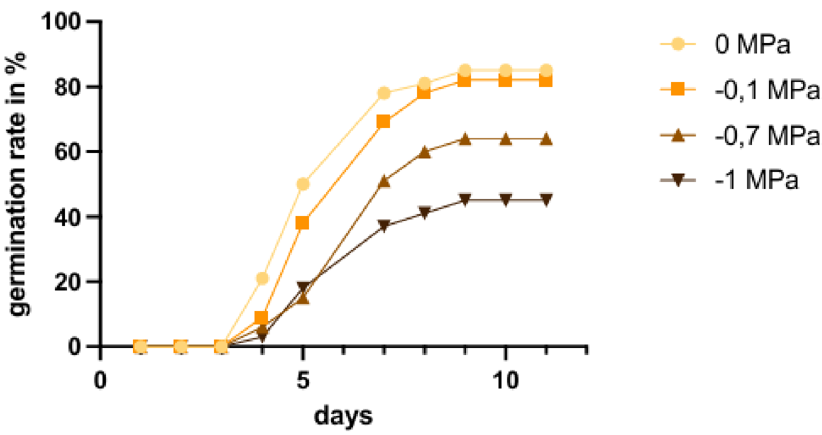

Fig.4. Germination kinetics of *O. majorana* under osmotic treatment.

4. Discussion

The results of this study demonstrated that both salinity and water deficit exerted inhibitory effects on the germination rate and kenetics of *O. majorana*, with the intensity of inhibition depending on the severity of the stress. The germination of seeds remained relatively unaffected by a higher NaCl concentration of 50 mM and higher water stress with osmotic potential values of -0.1 MPa. However, at a higher NaCl concentration above 100 mM and osmotic potential values below -0.7 MPa, the germination percentage and the lag phase significantly increased, showing that higher ionic and water stress inhibits water uptake and germination metabolic processes.

The sigmoidal germination curves for both stress treatments reflect the normal response of Mediterranean aromatic plants to salinity and drought stress: the greater lag phase and lower final values indicate disturbances in metabolism and energy for root emergence. This corroborates previous research indicating stress reduces the capacity for seed germination through disrupted osmoregulation and enzyme function as well as ionic toxicity.

Compared with other Lamiaceae species, the sensitivity of *O. majorana* towards salinity and waterstress is medium, where it can tolerate the stress moderately but will be drastically inhibited by higher levels of the same variables. From the agricultural perspective, the experiment indicates that the best area to grow *O. majorana* would be in soils of lower salinity and with a high supply of water.

5. Conclusion

This study demonstrates that both salinity and water stress significantly affect seed germination of *Origanum majorana*. Germination exhibits moderate levels of stress tolerance, maintaining high germination at 50 mM NaCl and an osmotic potential of −0.1 MPa. However, under high salinity (above 100 mM NaCl) and a very negative water potential (below −0.7 MPa), germination falls drastically and commences later, indicating plant sensitivity to high-intensity ionic and osmotic stress. Therefore, successful cultivation of *O. majorana* in semi-arid regions relies on proper salinity control and sufficient irrigation, and it offers insights into the plant's stress tolerance to support conservation and improved agronomic performance under harsh conditions.

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