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Review Article

Effect of salt stress on seed germination and early seedling growth of chamomile plant

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Abstract

Chamomile is a widely cultivated plant used for its medicinal value and aroma. It's cultivated successfully with reliable seed germination. Soil salinity is a global problem for plant growth, as it reduces seed germination rate and plant productivity. This review shows the salt stress on chamomile and studies its physiology and biochemistry. Saline environment affects chamomile growth and early seedling germination by restricting the water uptake and disrupting the hormonal and enzymatic balance, and also affects physiologically and biochemically. To overcome this problem, there are mitigation strategies such as seed priming, including hydro-, osmo-, hormonal-, and biostimulant-based methods, and bio priming, which improve the early development and ion exchange with the help of Plant Growth Promoting Rhizobacteria (PGPR). Future research should focus on integrating physiological, biochemical, and molecular analyses with advanced priming technologies and eco-friendly nanomaterial-based coatings to strengthen germination under salinity and other abiotic stresses.

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Introduction

Chamomile *(Matricaria chamomilla* L.) is a very important medicinal plant species (Ghanavati et al., 2011). It is from the Asteraceae family that the plant has been extensively used for its anti- inflammatory, antioxidant, antimicrobial, sedative, and gastrointestinal protective effects. The chemical constituents identified in chamomile as secondary metabolites include 28 terpenoids, 36 flavonoids, and 52 additional compounds (Ghanavati et al., 2011). It is utilized in many forms, such as essential oil, tea, and ointment. Chamomile is used in both traditional and modern medicine. Seed germination represents a vital phase in the plant life cycle, as it significantly influences later stages of growth and overall crop productivity. A comprehensive understanding of the various environmental and physiological factors governing germination is essential for optimizing crop management and enhancing cultivation practices. (Kheloufi et al., 2025). Germination is a complex physiological process that begins with water uptake by the seed (imbibition) and culminates in the emergence of the embryonic root (radicle). This process is regulated by a delicate balance of internal factors such as hormonal signaling, enzyme activity, and seed metabolic status, along with external factors including temperature, light, salinity, and moisture availability. Many abiotic stresses reduce seed germination, mainly the salt and drought stresses, which reduce water intake and increase ion toxicity, ultimately leading to reducing seed germination rate and seed vigor. Salinity and drought stress are among the major abiotic factors that negatively affect the growth and productivity of crops. Soil salinity, which may arise naturally or as a consequence of irrigation using saline water, poses a

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serious challenge to sustainable crop production. This problem is particularly prevalent in arid and semi-arid regions of the world, where limited rainfall and high evaporation rates intensify salt accumulation in the soil (Rajmzoo et al., 2008). Salinity impacts nearly 50% (approximately 45 million hectares) of the world's irrigated agricultural land. It adversely influences plant growth, physiological processes, and yield potential (Khorasgani et al., 2017). The salt stress or saline environment reduces the seed germination and its water uptake due to ion toxicity, which leads to low germination rate and seed vigor. Salt stress affects the chamomile essential oil production and its seed germination. This Review helps to understand the effect of salt stress on chamomile seed germination and its vigor, as well as strategies to enhance seed performance and improve plant establishment under saline conditions.

Mechanism of salt stress and its effect on chamomile seed germination

The presence of high concentrations of soluble salt in soil is referred to as soil salinity. It reduces the water intake, which leads to stunted growth of the plant. There are many types of soil salinity, including NaCl, Na_2SO_4, etc. NaCl is common salt, which accumulates in soil and is found in arid and semi-arid areas. A high concentration of sodium chloride increases the electrical conductivity of soil and reduces the ability of plants to absorb water. Na^+ and Cl^- enter seed tissue and cells due to prolonged exposure to toxic saline conditions. These ions disturb ion homeostasis, displacing essential nutrients such as K^+ and Ca^{2+}, which interfere with enzymatic reactions crucial for energy metabolism and germination. This ion toxicity also disrupts cellular metabolism by disturbing protein synthesis, enzyme activity, and membrane function (Pandit et al., 2024). Na_2SO_4 is another type of soil salinity that also accumulates in soil and increases electrical conductivity and reduces plant growth. Salt stress impairs the overall photosynthetic efficiency of plants by damaging pigment synthesis, disrupting chloroplast function, and limiting the diffusion of CO_2 into the leaves. Excessive salt uptake disrupts the plant's internal nutrient balance, causing toxic ion accumulation and deficiency of essential minerals, which ultimately interferes with normal metabolic and physiological functions (Arif et al., 2020). Na^+ in excess disrupts membrane stability and compete with essential nutrients like calcium and potassium, and SO_4^{2-} excess affects ionic balance more than chloride, which leads to deeper inhibition of germination (Hadjadj et al., 2023). In chamomile, certain genotypes exhibit better germination performance under saline conditions compared to more sensitive ones (Table 1). Salt-tolerant chamomile accessions generally show higher germination percentages and faster germination rates than salt- sensitive types, indicating inherent physiological differences in stress tolerance mechanisms. Recent research indicates that salt stress markedly influences the phytochemical composition and biological activity of chamomile. For example, treatment with NaCl concentrations between 0 and 150 mM has been shown to modify its chemical constituents and antioxidant potential, thereby altering its overall medicinal quality and effectiveness (Shakir et al., 2024). However, higher concentrations of salt in the growth medium progressively inhibit chamomile seed germination by creating osmotic stress and ion toxicity, which interfere with water absorption, enzyme activity, and the overall metabolic processes required for seed emergence (Afzali et al., 2011).

Table 1. Different varieties of the chamomile plant respond to the salt stress

Variety	Responses to salt stress conditions	References
Germania (German chamomile)	Moderate susceptibility; Under salt treatment, intermediate germination performance	Ebadi et al. (2009)
Bona	More susceptible; lower germination performance under salinity	Ebadi et al. (2009)
Goral	Most tolerant; under salt stress, a higher germination percentage	Ebadi et al. (2009)
Bodgold	Under osmotic stress show a stress response	Ebrahimi et al. (2021)
Soroksari	Under stress shows better physiological and antioxidant responses	Ebrahimi et al. (2021)

Physiological and biochemical response and its mitigation strategies

Chamomile seed shows many physiological and biochemical chemical response it inhibit the water intake and imbibition during germination. Chamomile seeds absorb water rapidly for their metabolic activities, which support embryo development. Water availability is important for seed growth. Saline environment also affects the enzymatic activity, such as amylase, protease, and lipase. These enzymes are necessary for seed germination. They also disrupt the abscisic acid (ABA) and gibberellic acid. This hormone ratio is necessary, as it plays a very Crucial role during chamomile germination. Antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD) are activated by chamomile seed to maintain redox homeostasis during stress conditions (Baily, 2004). The mitigation strategies for the growth of chamomile seed in salt stress are Seed priming, including hydro-, osmo-, hormonal-, and biostimulant-based methods, is used to physiologically pre-adapt seeds before sowing, while bio-priming with plant growth-promoting rhizobacteria (PGPR) enhances early development by regulating ion balance, hormone activity, and antioxidant defenses. Seed priming alleviates salinity stress by activating early metabolic processes and strengthening osmotic and antioxidant mechanisms before germination. Studies on aromatic and medicinal plants indicate that hydro-, osmo-, and hormonal priming—especially with gibberellic acid—enhance germination rate, vigor, and membrane stability through improved enzyme activity and water absorption. Similarly, biostimulant-based priming using seaweed extracts or microbial products boosts antioxidant capacity and osmolyte accumulation, mitigating salt-induced oxidative stress (Lamsaadi et al., 2024). Bio-priming, involving seed treatment with beneficial microbes like PGPR or biofertilizers, has proven effective in mitigating salinity effects in chamomile. Recent studies show that using indigenous PGPR strains or biofertilizers such as Nitroxin and bio-superphosphate enhances germination, chlorophyll content, growth, and nutrient uptake under salt stress by improving root function, ion regulation, and antioxidant activity (Rahmani et al., 2024). Chamomile possesses moderate tolerance to salinity, primarily through maintaining favorable K^+/Na^+ and Ca^{2+}/Na^+ ratios and accumulating proline in shoots. These adaptive responses play a key role in alleviating osmotic stress and reducing ion toxicity during seed germination and initial growth phases (Afzali et al., 2011).

Research gap and future perspectives

There is insufficient quantitative information on the activity of hydrolytic enzymes (α-amylase, protease, lipase) and antioxidant enzymes (SOD, CAT, POD) during seed germination under stress conditions, which are essential for elucidating the mechanisms of metabolic activation and stress tolerance (Tafaroji et al., 2025). The interplay between gibberellic acid (GA_3) and abscisic acid (ABA) during chamomile seed germination under salinity or drought stress remains poorly understood, even though this hormonal balance plays a crucial role in regulating seed dormancy and germination processes (Bewley et al., 2013; Finkelstein et al., 2008). Although seed priming and PGPR bio-priming have demonstrated beneficial impacts, their combined effects, optimal application levels, and underlying molecular mechanisms in chamomile remain insufficiently characterized (Tafaroji et al., 2025). Future research on chamomile seed germination should focus on comprehensive biochemical and molecular analyses, including quantification of metabolic enzyme activities and antioxidant responses under various abiotic stresses to elucidate mechanisms of metabolic adaptation. Detailed studies on hormonal regulation, particularly GA_3–ABA dynamics, hormonal cross-talk, and gene expression during seed activation and radicle emergence, are essential to understand germination control. Additionally, optimization of priming techniques—including hydro-, osmo-, hormonal-, nano-, and bio-priming with PGPR—should be explored to enhance seed vigor and tolerance to salinity. The development of eco-friendly nano- priming agents and biopolymer-based seed coatings offers further potential to improve germination efficiency and protect seeds from abiotic stress.

Conclusion

Salinity poses a major abiotic challenge, hindering germination by limiting water absorption, disrupting enzyme activities, disturbing hormonal balance, and triggering oxidative stress. These effects reduce seedling vigor and may lower essential oil yield, emphasizing the need to understand the plant's physiological and biochemical responses to stress. Key adaptive mechanisms include the activation of hydrolytic enzymes (α-amylase, protease, lipase), enhancement of antioxidant enzymes (SOD, CAT, POD), and regulation of Gibberellic Acid (GA_3) and Abscisic Acid (ABA) levels, which collectively support germination under adverse conditions. Mitigation approaches such as seed priming (hydro-, osmo-, hormonal-, biostimulant, and nano-priming) and bio-priming with plant growth-promoting rhizobacteria (PGPR) have proven effective in improving water uptake, enzyme efficiency, ion regulation, hormonal signaling, and antioxidant defense, thereby enhancing salinity tolerance and early growth. Nevertheless, notable research gaps persist, including insufficient data on enzyme kinetics, antioxidant profiles, GA_3–ABA interactions, and molecular pathways governing priming and microbe-mediated stress responses. Future research should integrate physiological, biochemical, and molecular insights with innovative priming and eco-friendly coating technologies to strengthen germination and establishment under salinity and other abiotic constraints. Bridging these gaps will be crucial for sustainable chamomile production and maximizing its medicinal and economic potential.

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