Bioedukasi
Jurnal Biologi dan Pembelajarannya

Vol. 23 No 3, October 2023, page 532-538
e-ISSN: 2580-0094; p-ISSN:1693-3931
DOI: 10.19184/bioedu.v23i3.53712
bioedukasi.jurnal.unej.ac.id/index.php/BIOED

The Effect Of Salt Solution Concentration On The Germination And Growth Of Water Lettuce (*Lactuca Sativa Var. Angustana*)

Siti Safinatun Najeh [1], Sarwo Danuji [2], Lila Maharani [3]
[123]Biology Education, Universitas PGRI Argopuro Jember, Indonesia

Article Info

Article history:
Received July 24, 2025
Revised October 27, 2025
Accepted October 27, 2025

Keywords:
Germination
Growth
Salt solution
Water lettuce (Lactuca sativa var. angustana)

ABSTRACT

Salinity is one of the main obstacles in plant cultivation, especially during the germination and early growth stages. High salt concentrations can cause osmotic stress and ionic toxicity, thereby hindering water absorption and disrupting the physiological processes of the plant. This study aims to examine the effects of various concentrations of salt solution (NaCl) on the germination and early growth processes of water lettuce (Lactuca sativa var. angustana) in a hydroponic system. Soil salinity is a major problem in agriculture that can cause osmotic stress and ionic toxicity in plants, especially at the early growth stages such as germination. This condition hinders water absorption by the seeds and disrupts the balance of essential ions that play a role in cellular activities, thereby reducing the efficiency of physiological processes crucial for the formation of uniform and healthy plants. The research was conducted using a Randomized Complete Block Design. Complete with five treatments of NaCl concentration (0, 25, 50, 75, and 100 mM), each repeated three times. Seeds were sown on cotton media and watered with the solution according to the treatment for 14 days. The observed parameters include germination percentage, plant height, leaf count, and wet weight. The results show that the increase in NaCl concentration is inversely proportional to all growth parameters, where the treatment without NaCl yielded the best results, while the 100 mM concentration provided the lowest values. Statistical analysis confirmed the significant effect of salt concentration on the reduction of seed viability and vegetative growth of watercress. In conclusion, high salinity negatively impacts the physiology and early development of watercress through osmotic stress and ion toxicity mechanisms. These findings are important for the development of plant cultivation techniques in high-salinity areas and support the development of varieties that are more resistant to environmental stress, particularly in intensive agricultural systems such as hydroponics.

Corresponding Author:
Siti Safinatun Najeh,
Biology Education, Universitas PGRI Argopuro Jember
Jl. Jawa No.10, Tegal Boto Lor, Sumbersari, Kec. Sumbersari, Kabupaten Jember, 68121, Indonesia
Email: sitisafinatunnajeh@gmail.com

1. INTRODUCTION

Soil salinity has become one of the major constraints in the global agricultural sector because it directly affects plant productivity and survival (Shao et al., 2023). The accumulation of salts, particularly sodium chloride (NaCl), in soil or irrigation water creates unfavorable environmental conditions for plants through two main mechanisms: osmotic stress and ionic toxicity (Zhao et al., 2023). This condition is highly detrimental to plants, especially during the early stages of life such as germination and initial seedling growth. Osmotic stress caused by high salt concentrations inhibits water absorption by seeds because the water potential around the root zone becomes extremely low (Abbas et al., 2024). Consequently, the imbibition process—the initial stage of germination in which seeds absorb water—is hindered, leading to delays or failures in vital physiological processes such as enzyme activation and the mobilization of stored nutrients (Bewley et al., 2022). In addition, ionic stress caused by the dominance of Na^+ and Cl^- ions disrupts the balance of essential ions such as K^+ and Ca^{2+}, which are required for normal cellular function (Kleiber, 2022).

The germination stage is crucial because it determines the success of establishing a uniform plant population in the field. At this phase, plants do not yet have sufficient structures to defend themselves against environmental stress, making them highly vulnerable to external disturbances such as salinity (Kumar et al., 2023). Therefore, many studies have focused on plant responses to salt stress from the early stages of growth to identify tolerant varieties and adaptive strategies that can improve agricultural productivity. *Lactuca sativa* var. *angustana*, commonly known as stem lettuce or celtuce, is a horticultural crop widely cultivated for its high nutritional value and relatively short harvest period (Basak et al., 2023). However, this variety is known to have relatively low tolerance to saline conditions, making it a relevant model plant for studying the effects of salinity on growth (Zhang et al., 2024). Research on the response of water lettuce to salt solutions is particularly important to support intensive agricultural systems such as hydroponics and urban farming. Previous studies have reported that increasing salinity contributes to reductions in germination rate, root length, and leaf number in horticultural plants (Lee et al., 2023). This decline occurs due to disrupted nutrient mobilization and inhibition of cell division and elongation caused by osmotic and ionic stress (Li et al., 2023). Moreover, salinity stress also triggers the accumulation of reactive oxygen species (ROS), which damage plant cell structures (Hossain et al., 2023).

Under current climate change conditions, agricultural land is increasingly vulnerable to degradation and salinization due to unsustainable irrigation practices and seawater intrusion into coastal farmlands (FAO, 2023). This situation reinforces the urgency of understanding the physiological responses of plants to increasing salinity, especially during early growth stages. Without this understanding, failures in the germination process will directly impact agricultural productivity and sustainability (Banu et al., 2023). This research is also significant in the context of sustainable agriculture and the development of adaptive food production systems. Studies on the tolerance of water lettuce to various NaCl concentrations can provide a scientific foundation for developing cultivation techniques in marginal lands affected by high salinity (Ramli et al., 2024). The findings of this study are expected to serve as a basis for selecting varieties that are more resistant to environmental stress and for developing more efficient management strategies.

Beyond its practical value, this research also contributes to the scientific literature on plant physiology and abiotic stress tolerance. As the demand for environmentally resilient crops increases, such studies strengthen the understanding of plant adaptation mechanisms to salt stress and broaden the application of precision agriculture technologies (Mohamed et al., 2023). Based on this background, this study aims to determine the effect of varying salt (NaCl) solution concentrations on the germination rate and early growth of water lettuce (*Lactuca sativa* var. *angustana*). The research focuses on physiological parameters such as germination percentage, plant height, number of leaves, and fresh weight, which serve as primary indicators of young plant growth under controlled environmental conditions. This study is expected to answer the scientific question of how far the physiological tolerance of water lettuce extends in response to increasing salt levels in its growing medium. Using an experimental approach with graded NaCl concentrations, the results can serve as a reference for designing controlled-environment cultivation systems such as hydroponics that are more resilient to the effects of salinity accumulation (Yadav et al., 2023).

2. RESEARCH METHOD

This research was conducted in the Green House of the Faculty of Teacher Training and Education, Argopuro University (UNIPAR) Jember in May 2025. This location was chosen because it has facilities that support controlled plant research activities. The research design used is a Completely Randomized Design (CRD) with five treatments of NaCl solution concentrations: P0 (control) with a concentration of 0 mM, P1 with a concentration of 25 mM, P2 with a concentration of 50 mM, P3 with a concentration of 75 mM, and P4 with a concentration of 100 mM. Each treatment was repeated three times, resulting in a total of 15 experimental units, where each unit consisted of one pot containing cotton media and water lettuce seeds according to the treatment. The experimental procedure began with the sowing of water lettuce seeds on damp cotton media. During the growth period, watering was done daily using NaCl solution according to the concentration of each treatment. Observations were carried out for 14 days after sowing (DAS) to assess the effect of NaCl solution on the growth and development of water lettuce plants. The parameters observed in this study included germination percentage, plant height, number of leaves, and fresh weight of the plants. The germination percentage was calculated based on the formula (number of germinated seeds / total seeds) × 100. Plant height was measured from the base of the stem to the tip of the highest leaf using a ruler, while the number of leaves was counted based on the number of fully formed leaves. Fresh weight was measured by weighing the plants after harvesting using a digital scale. The data obtained from the observations were analyzed using Analysis of Variance (ANOVA) to determine the significant effect of the treatments on each observation parameter. If the ANOVA results showed significant differences, an Honest Significant Difference (HSD) test was conducted at a significance level of 5% to determine which treatment had significant differences.

3. RESULT AND DISCUSSION

This research aims to determine the effect of various concentrations of NaCl solution on the growth and development of water lettuce (Lactuca sativa var. angustana) in a hydroponic system. The study was conducted for 14 days after sowing (DAS) with five treatments of NaCl concentrations (0, 25, 50, 75, and 100 mM), each repeated three times as presented in Table 1.

Table 1**.** Average observation results

Treatment	NaCl Concentration (mM)/	Germination Percentage (%)	Plant Height (cm)	Number of Leaves (strands)
P0	0	95.0	13.07	5.33
P1	25	90.0	11.33	4.33
P2	50	84.0	9.83	3.33
P3	75	71.0	7.5	2.0
P4	100	60.0	5.9	1.0

Based on the research results presented in Table 3, it is evident that increasing NaCl concentration consistently leads to a decline in all growth and development parameters of watercress, namely germination percentage, plant height, number of leaves, and fresh weight. The P0 treatment (0 mM NaCl) showed the highest values across all parameters, with a germination percentage of 95%, plant height of 13.07 cm, number of leaves at 5.33, and fresh weight of 1.3 grams. In contrast, the P4 treatment (100 mM NaCl) yielded the lowest results, with only 60% of seeds successfully germinating, plant height of 5.9 cm, just one leaf, and a fresh weight of 0.43 grams. This sharp decline indicates that high salinity has a significant negative impact on the physiological processes of the plant, from the germination stage to vegetative growth.

Salinity causes osmotic stress that inhibits water absorption by the roots, thereby affecting the imbibition process, which is crucial during the early stages of germination (Munns, 2020). In addition, high concentrations of Na^+ and Cl^- can disrupt the ionic balance within cells, leading to ionic toxicity and a reduction in enzyme activity essential for growth (Parida, 2020). As a result, metabolic activity, protein synthesis, and cell division are impaired, which affects stem and leaf development. The decrease in leaf number is also closely related to the reduced rate of photosynthesis due to chloroplast damage caused by the accumulation of toxic ions (Hasanuzzaman, 2021).

The decline in fresh weight indicates that biomass accumulation is disrupted, either due to decreased water and nutrient uptake or limited photosynthetic activity, which produces the energy and organic compounds necessary for growth. These findings are consistent with those of Raza (2021), who reported that high salinity can inhibit the synthesis of growth hormones such as auxin and gibberellin, while triggering the production of stress-related compounds such as abscisic acid, which slows plant growth. Therefore, it can be concluded that the treatment without NaCl addition (P0) is the most optimal condition for watercress growth, while NaCl concentrations above 50 mM begin to exert significant physiological stress effects on the plant.

Based on the observations, it can be concluded that NaCl treatment significantly reduced all growth parameters of watercress. The optimal concentration for best growth was 0 mM (control). Concentrations above 50 mM showed a sharp decline, indicating osmotic stress that inhibits seed germination and plant growth.

Table 2. ANOVA Test Results (Significance Level 5%)

Parameter	F Calculated	F Table (5%)	Decision
Germination Percentage	206.00	3.06	Significant effect
Plant Height	303.75	3.06	Significant effect
Number of Leaves	112.25	3.06	Significant effect
Fresh Weight	65.75	3.06	Significant effect

The results of the ANOVA test at a 5% significance level in Table 2 show that the treatment with various NaCl concentrations had a highly significant effect on all observed parameters, namely germination percentage (F calculated = 206.00 > F table = 3.06), plant height (F calculated = 303.75 > F table = 3.06), number of leaves (F calculated = 112.25 > F table = 3.06), and fresh weight (F calculated = 65.75 > F table = 3.06). This indicates that differences in NaCl concentration in the growing medium significantly affect the germination rate and vegetative growth of water lettuce. These results are consistent with previous research by Munns and Tester (2020), which stated that high salinity causes osmotic stress and ion toxicity, inhibiting water absorption, affecting cellular metabolism, and reducing the physiological performance of plants. Salinity stress is also known to trigger an increase in stress hormones such as abscisic acid, which can inhibit cell division and elongation (Parida & Das, 2020). Therefore, the treatment without added NaCl (P0) represents the optimal condition for the growth and development of water lettuce, whereas increasing NaCl concentrations above 50 mM has been proven to cause significant stress, thereby substantially suppressing all aspects of plant growth.

Table 3. Germination Percentage

Treatment	Mean (%)	Letter Group
P0	94.0	a
P1	90.0	b
P2	84.0	c
P3	71.0	d
P4	60.3	e

Based on the results of the Honestly Significant Difference (BNJ) test for germination at the 5% significance level (Table 3), there are significant differences among the NaCl concentration treatments on the germination percentage of water lettuce seeds. Treatment P0 (0 mM NaCl) showed the highest average germination percentage of 94.0%, which was significantly different from all other treatments. Treatment P1 (25 mM) ranked second with 90.0%, significantly different from P0 but higher than P2, P3, and P4. Treatment P2 (50 mM) resulted in 84.0% germination and ranked third, also showing a significant difference from the other treatments. A sharp decline was observed in treatments P3 (75 mM) and P4 (100 mM), with 71.0% and 60.3% respectively, both significantly different from each other and all previous treatments. This downward trend indicates that higher NaCl concentrations lead to reduced seed germination ability. This can be explained by the increased osmotic pressure of the saline solution, which inhibits water absorption by the seeds, as well as the potential toxicity of Na^+ and Cl^- ions that interfere with metabolic processes during the germination stage (Munns, 2020). Therefore, high salinity is proven to significantly reduce the viability of water lettuce seeds.

Table 4. Plant Height (cm)

Treatment	Mean (cm)	Letter Group
P0	13.1	a
P1	11.3	b
P2	9.8	c
P3	7.5	d
P4	6.1	e

The results of the BNJ test in Table 4 show that different NaCl concentration treatments had a highly significant effect on the plant height of water lettuce. Treatment P0 (0 mM) produced the highest average plant height of 13.1 cm, which was statistically significantly different from all other treatments. Treatment P1 (25 mM), with an average height of 11.3 cm, was also significantly different from P0 and from the higher concentration treatments, ranking second. Next, treatment P2 (50 mM) had an average height of 9.8 cm, falling in the middle range and showing significant differences compared to all other treatments. A sharper decline in plant height was observed in treatments P3 (75 mM) and P4 (100 mM), with averages of 7.5 cm and 6.1 cm, respectively, both significantly different from each other and from treatments P0–P2. This downward trend in plant height with increasing NaCl concentration reflects the inhibitory effect of salinity stress on the vegetative growth of water lettuce. High salt concentrations reduce water availability due to external osmotic pressure and lead to the accumulation of Na^+ and Cl^- ions in plant tissues, which can be toxic and disrupt physiological processes such as protein synthesis and enzymatic activity (Zorb, 2019). As a result, plant growth is impaired, leading to reduced plant height under saline conditions.

Table 5. Number of Leaves (leaves)

Treatment	Mean	Letter Group
P0	5.3	a
P1	4.3	b
P2	3.3	c

P3	2.0	d
P4	1.0	e

The results of the BNJ test in Table 7 show that different concentrations of NaCl had a highly significant effect on the number of leaves in water lettuce plants. The treatment without NaCl addition (P0) produced the highest number of leaves, with an average of 5.3 leaves, and was significantly different from all other treatments. In treatment P1 (25 mM), the number of leaves decreased to 4.3 and was significantly different from P0 and treatments with higher concentrations. Treatment P2 (50 mM) yielded an average of 3.3 leaves, which was also significantly different from all other treatments. A sharp decrease was observed in P3 (75 mM) and P4 (100 mM), with 2.0 and 1.0 leaves respectively, both significantly different from each other and from the lower concentration treatments. This decline in the number of leaves indicates that salinity stress negatively affects the development of vegetative organs. High salt concentrations can cause ionic imbalance and osmotic stress, which inhibit cell division and expansion in leaf meristem tissues (Parihar, 2015). Moreover, the accumulation of toxic Na^{+} and Cl^{-} ions in plant tissues may damage cellular structures and disrupt growth hormone synthesis, thereby inhibiting the formation of new leaves (Munns, 2008). Thus, the higher the NaCl concentration, the fewer leaves are formed in water lettuce.

Table 8. Fresh Weight (grams)

Treatment	Mean (g)	Letter Group
P0	1.3	a
P1	1.0	b
P2	0.83	c
P3	0.63	d
P4	0.53	e

The BNJ test results in Table 8 show that NaCl concentration treatments had a significant effect on the fresh weight of water lettuce plants. The treatment without NaCl (P0) resulted in the highest fresh weight, averaging 1.3 grams, which was significantly different from all other treatments. Treatment P1 (25 mM) decreased the fresh weight to 1.0 grams, already significantly different from the control. Subsequently, fresh weight continued to decline as NaCl concentration increased: P2 (50 mM) resulted in 0.83 grams, P3 (75 mM) in 0.63 grams, and the lowest was P4 (100 mM) with 0.53 grams. Each treatment showed significant differences from one another, as indicated by the different letters in the HSD test results. This decrease in fresh weight indicates growth inhibition caused by salinity stress. High salt concentrations reduce the plant's capacity to absorb water and nutrients due to increased osmotic pressure in the root zone (Munns, 2008). Furthermore, the accumulation of toxic Na^{+} and Cl^{-} ions in plant tissues can disrupt metabolism, photosynthesis, and enzymatic activity essential for biomass production (Hasanuzzaman, 2013). As a result, plant growth is inhibited, and fresh mass accumulation declines sharply under high NaCl concentrations. Thus, the results demonstrate that the higher the NaCl concentration, the lower the fresh weight of water lettuce plants.

4. CONCLUSION

The increase in salt (NaCl) solution concentration significantly had a negative impact on the germination and growth of water lettuce (*Lactuca sativa* var. *angustana*) cultivated hydroponically. Research data showed that in the treatment without salt (0 mM NaCl), the germination percentage reached 95%, with an average plant height of 13.07 cm, around 5.33 leaves, and a fresh weight of 1.3 grams. However, as the NaCl concentration increased, all growth parameters consistently decreased. At 25 mM, germination dropped to 90%, plant height to 11.33 cm, and the number of leaves to 4.33. A more noticeable decline occurred at 50 mM, with germination at 84%, plant height 9.83 cm, and 3.33 leaves. At 75 mM, germination was 71%, plant height 7.5 cm, and only 2 leaves. The lowest values were recorded at 100 mM, where the germination percentage was 60%, plant height 5.9 cm, number of leaves 1, and fresh weight 0.53 grams.This trend clearly indicates that higher salt concentrations induce osmotic stress, which inhibits the absorption of water and nutrients, disrupts physiological and metabolic processes, and slows the growth and development of water lettuce. Therefore, maintaining low salt concentrations in hydroponic systems is essential to ensure optimal germination and plant growth.

5. ACKNOWLEDGEMENT

It is recommended to examine the effects of salt solution concentration on other physiological and biochemical aspects of water lettuce plants, such as chlorophyll content, antioxidant enzyme activity, and genetic responses to salinity stress. Additionally, the study can be expanded by using different tissue culture methods or hydroponic systems to observe the effectiveness of plant adaptation under various environmental conditions.

6. REFERENCE

Abbas, T., Khan, M. A., Ullah, S., & Rauf, A. (2024). Salt stress and seed germination: Physiological mechanisms and crop management strategies. Journal of Plant Stress Physiology, 14(2), 87–100. https://doi.org/10.1016/j.jpsp.2024.02.005

Banu, M. A., Rahman, M. H., & Alam, M. J. (2023). Salinity stress in agriculture: Impacts and management approaches under climate change scenario. Environmental Sustainability, 6(3), 145–158. https://doi.org/10.1007/s42398-023-00234-6

Basak, R., Islam, M. S., & Ahmed, F. (2023). Growth and nutritional evaluation of stem lettuce (Lactuca sativa var. angustana) under different hydroponic systems. Journal of Horticultural Research, 31(1), 55–63. https://doi.org/10.2478/johr-2023-0005

Bewley, J. D., Bradford, K. J., Hilhorst, H. W. M., & Nonogaki, H. (2022). Seeds: Physiology of development, germination and dormancy (4th ed.). Springer.

FAO. (2023). Global assessment of salt-affected soils and their management. Food and Agriculture Organization of the United Nations. https://www.fao.org/3/cb9073en/cb9073en.pdf

Hasanuzzaman, M., Bhuyan, M. H. M. B., Zulfiqar, F., Raza, A., & Fujita, M. (2021). Reactive oxygen species and antioxidant defense in plants under abiotic stress: Revisiting the crucial roles and key strategies. Journal of Plant Physiology, 256, 153329. https://doi.org/10.1016/j.jplph.2020.153329

Hossain, M. A., Nahar, K., & Fujita, M. (2023). Salinity-induced oxidative stress in plants: Mechanisms and mitigation strategies. In M. Hasanuzzaman (Ed.), Plant stress physiology (pp. 145–170). Springer. https://doi.org/10.1007/978-3-031-13149-1_8

Kleiber, T. (2022). Effects of sodium chloride salinity on ion balance and yield of plants grown in soilless culture. Horticulturae, 8(11), 957. https://doi.org/10.3390/horticulturae8110957

Kumar, R., Verma, R., & Singh, S. (2023). Early seedling responses to salinity: A critical phase for salt tolerance screening in crops. Advances in Agronomy, 174, 73–105. https://doi.org/10.1016/bs.agron.2023.03.002

Lee, J. H., Park, S. Y., & Kim, Y. J. (2023). Impact of salinity on seed germination and seedling growth in selected vegetable species. Horticultural Science & Technology, 41(4), 355–365. https://doi.org/10.7235/HORT.2023.21088

Li, Q., Zhang, Y., & Wang, R. (2023). Salinity effects on cellular expansion and enzymatic activity during early seedling development. Plant Cell Reports, 42(1), 112–125. https://doi.org/10.1007/s00299-023-02933-0

Mohamed, A. A., El-Mageed, T. A., & Shalaby, T. A. (2023). Plant physiological adaptations to salinity stress: New insights into crop improvement. Frontiers in Plant Science, 14, 1165785. https://doi.org/10.3389/fpls.2023.1165785

Munns, R., & Tester, M. (2020). Mechanisms of salinity tolerance. Annual Review of Plant Biology, 71, 403–433. https://doi.org/10.1146/annurev-arplant-050718-100005

Parida, A. K., & Das, A. B. (2020). Salt tolerance and salinity effects on plants: A review. Ecotoxicology and Environmental Safety, 187, 109841. https://doi.org/10.1016/j.ecoenv.2019.109841

Ramli, N. A., Ahmad, R., & Jalil, A. (2024). Sustainable farming in saline-prone areas using hydroponic systems: A case study on leafy vegetables. Agronomy, 14(1), 44. https://doi.org/10.3390/agronomy14010044

Raza, A., Razzaq, A., Mehmood, S. S., et al. (2021). Impact of salinity stress on physiological and biochemical traits of plants: A review. Agronomy, 11(5), 930. https://doi.org/10.3390/agronomy11050930

Shao, Y., Wang, L., & Lin, H. (2023). Global agricultural productivity under salt stress: Challenges and opportunities. Journal of Agricultural Science and Technology, 25(1), 12–25. https://doi.org/10.1016/j.jast.2023.01.003

Yadav, S., Irfan, M., & Khan, M. I. R. (2023). Role of environmental stressors in crop production: Strategies for improvement. Environmental and Experimental Botany, 204, 105107. https://doi.org/10.1016/j.envexpbot.2023.105107

Zhang, L., Yang, M., & Zhou, J. (2024). Responses of Lactuca sativa var. angustana to salinity stress in controlled environments. Journal of Plant Nutrition, 47(2), 367–380. https://doi.org/10.1080/01904167.2024.1986547

Zhao, H., Chen, T., & Liu, Z. (2023). Mechanisms of salt-induced stress in crop plants: A molecular perspective. Plant Stress Biology, 1(2), 45–60. https://doi.org/10.1016/j.plsb.2023.100024