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The Effect of Salt Solution Concentration on the Condition of Red Onion Cells

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ABSTRACT

This study aims to determine the effect of salt solution (NaCl) concentration on the cellular condition of red onions (*Allium ascalonicum* L.), specifically regarding the occurrence of plasmolysis in epidermal cells. The research was conducted using several NaCl concentration treatments (0 – 0,8 M). Observations were carried out macroscopically and microscopically, with parameters including changes in bulb length and width, as well as the percentage of cells undergoing plasmolysis. The results indicated that an increase in salt solution concentration tends to increase the number of plasmolyzed cells. At a concentration of 0.4 M, a plasmolysis percentage of 60% was obtained, while at 0.8 M, it reached 100%. However, Kruskal–Wallis statistical tests showed that the variation in solution concentration did not exert a significant effect on the condition of the red onion cells ($p > 0.05$). This lack of significance is suspected to be influenced by limited sample size, low data variation, and technical factors during microscopic observation. This study demonstrates that salt concentration affects biological osmosis and plasmolysis processes, despite not showing statistically significant differences.

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1. INTRODUCTION

Red onion (*Allium cepa* L.) is a vital commodity used as a spice and a source of bioactive compounds, such as flavonoids and antioxidants (Ratnaningsih et al., 2018). In biology, its epidermal cells are primary objects of observation due to their distinct structure, consisting of the cell wall, cytoplasm, nucleus, and vacuoles that function in nutrient storage (Nikmehr, 2022). Environmental conditions, such as exposure to salt solutions, significantly influence cellular stability through the following processes.

Osmosis is the movement of water across a semipermeable membrane toward a solution with a higher concentration (Nikmehr, 2022). Plasmolysis occurs when cells are placed in a hypertonic solution; water exits the cell, causing the vacuole to shrink and the plasma membrane to detach from the cell wall (Nikmehr, 2022). Conversely, in a hypotonic solution, the cell becomes turgid. An increase in salt concentration is directly proportional to the degree of plasmolysis.

As a salinity-sensitive plant, high salt levels can inhibit the growth and metabolism of red onions (Saleh, 2017). However, technically, salt is utilized in food processing to reduce water activity, thereby inhibiting microbial growth and extending the product's shelf life (Ratnaningsih et al., 2018). Therefore, it is necessary to determine the range of salt concentrations that red onion cells can still tolerate and to evaluate the cellular effects induced by different salt concentrations. This information contributes to a better understanding of the osmotic responses of red onion cells under saline conditions.

2. METHODS

Materials used in this study included red onion plants (*Allium ascalonicum* L.), NaCl at various concentrations (0.2, 0.4, 0.6, and 0.8 M), and distilled water as the control solution. The growth medium consisted of a mixture of soil and manure in a 3:1 ratio, with a total weight of 1 kg per container.

The apparatus used included a ruler to measure plant height and root length, a digital scale to weigh the NaCl powder, and a razor blade for sectioning the onion plants. In addition, microscope slides and cover slips were used for microscopic observation, graduated cylinders for solution preparation, and a microscope to examine the prepared specimens.

The research procedure involved planting the red onions in 25×25 cm polybags filled with 2 kg of the growth medium. NaCl treatments were applied every two days, with each application consisting of 150 ml, for a total of seven applications; each concentration had three replications. Measurements of plant length and width were recorded both prior to planting and following the treatment period.

Anatomical observations of the roots were conducted by preparing transverse sections of the root bulbs using a razor blade. These sections were placed on microscope slides with a drop of distilled water. Subsequently, the cells within the specimens were observed under a microscope. The parameters measured included the plasmolysis state of several cells within the specimen, cortical thickness, and stele diameter (Cavusoglu, 2023). The data obtained were analyzed using the Kruskal–Wallis test to ensure the accuracy and suitability of the final results using SPSS software version 27.

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3. RESULTS AND DISCUSSION

3.1. Macroscopic Observations of Red Onion Bulbs

Based on macroscopic observations of the red onion bulbs, the results indicate variations in morphological values across all treatments, specifically in the parameters of length and width as shown in **Figure 1** and **Table 1**. In general, the control group established initial values that subsequently changed at each treatment concentration, demonstrating that the sample responses were non-uniform. Regarding the length parameter, mean values in several treatments tended to be higher than the control. Conversely, changes in the width parameter were relatively minor, yet they still exhibited trends of increase or decrease at specific concentrations. This pattern indicates that the treatments influenced the morphological characteristics of the samples, though the effects were dependent on the concentration applied. These findings are consistent with Bouaziz and Smith (2023), who stated that the response of a sample to bioactive treatments is not always linear but is influenced by the stability of active compounds, concentration, and the conditions of the observed system.

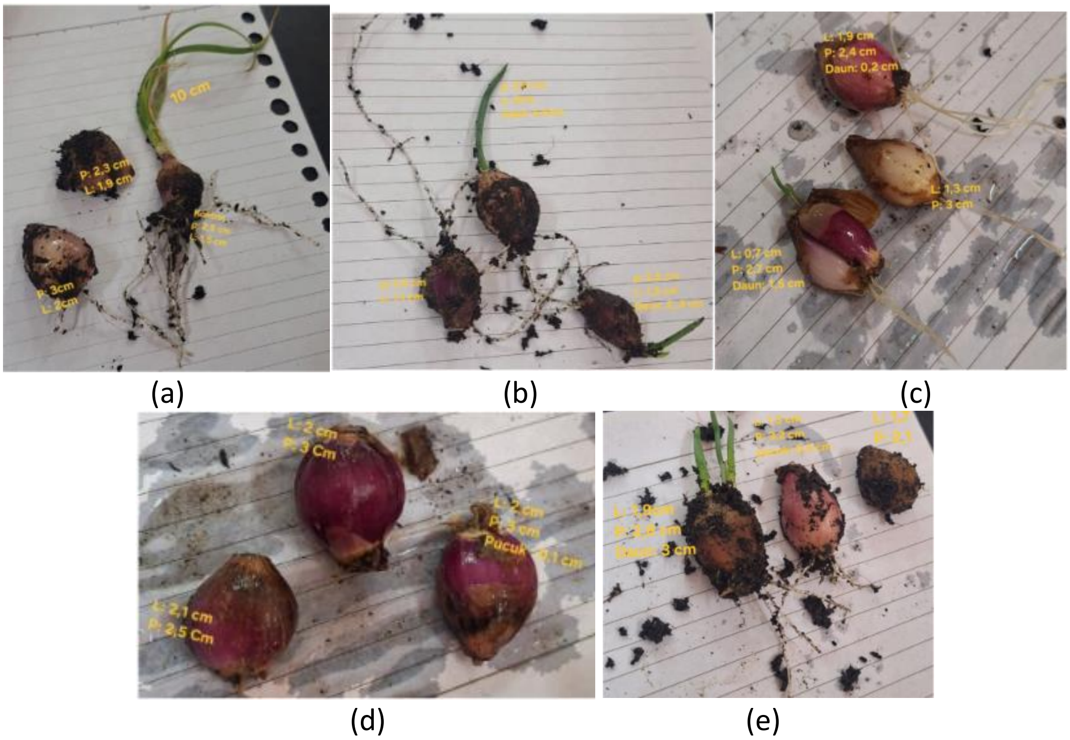

Figure 1. Morphological comparison of red onion bulbs in 0 M (a); 0,2 M (b); 0,4 M (c); 0,6 M (d); and 0,8 M (e) NaCl solutions

Relatively small standard deviations, as shown in **Table 1** values, indicate that the data across replicates tended to be homogeneous, whereas larger standard deviations in other parameters signify a higher variation in response. This is significant for the discussion as it demonstrates that the treatments influenced not only the magnitude of the parameters but also the stability of the observed results. According to Patel and Lee (2021), variations in results within encapsulation systems or bioactive treatments are often influenced by formulation homogeneity, the distribution of active components, and the system's ability to maintain stability during observation.

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Table 1. Macroscopic observation results

Concentrations	Lenght (cm)			Wide		
	Day 0	Day 14	Change	Day 0	Day 14	Change
Control (0 M)	2,8	2,6	-0,2	1,8	1,8	0
0,2 M	2,7	2,5	-0,2	2,4	1,5	-0,9
0,4 M	2,2	2,7	+0,5	1	1,3	+0,3
0,6 M	2,7	2,8	+0,1	2,1	2	-0,1
0,8 M	2,3	2,7	+0,4	1,7	1,6	-0,1
Std dev.	0,27	0,11	0,33	0,52	0,27	0,44

The graphical data in **Figure 2** reveals fluctuations at several concentration points, where one treatment showed a sharp decline before increasing again, while others remained stable or increased gradually. This pattern supports the assumption of an optimum treatment point the concentration at which the produced effect on the observed morphological parameters is most favorable and suggests that treatments at specific concentrations may provide a more effective influence compared to others. This is consistent with Bouaziz and Smith (2023) and Patel and Lee (2021), who emphasized that the effectiveness of a treatment is strictly determined by the balance between dosage, stability, and the system's capacity to respond to the treatment.

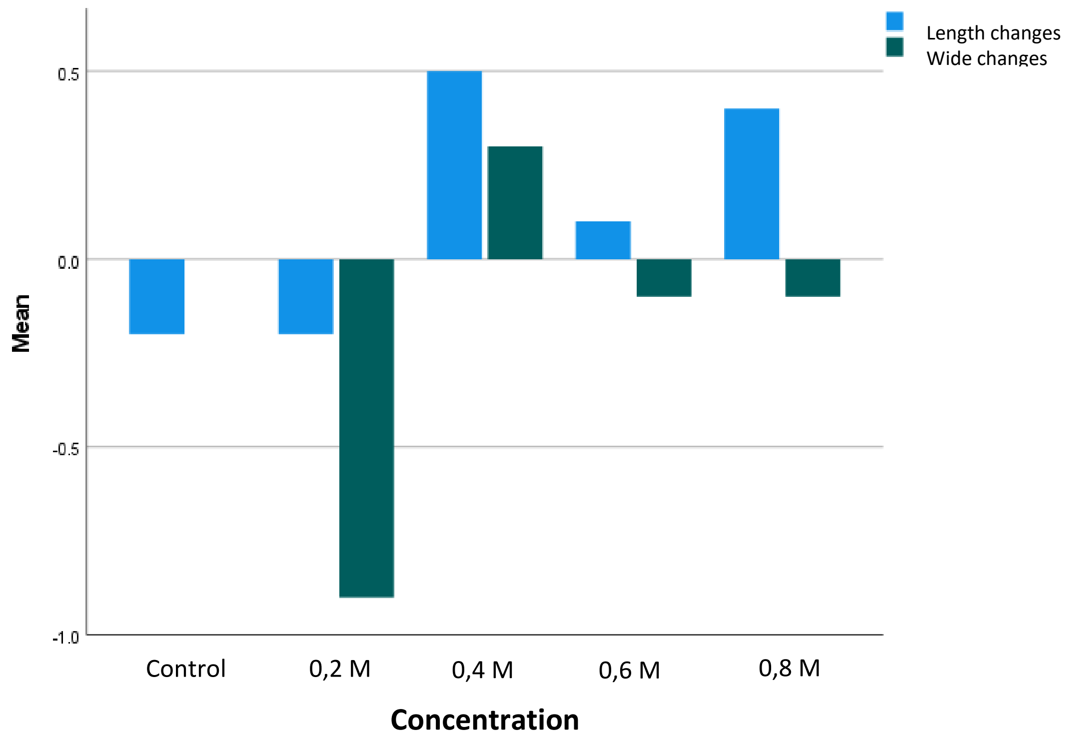

Figure 2. Comparative graph of concentrations and growth differentials in length and width

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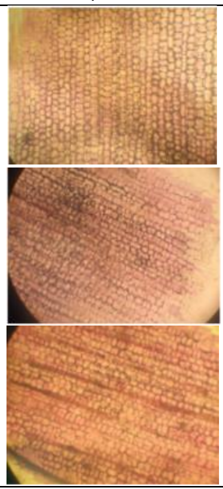
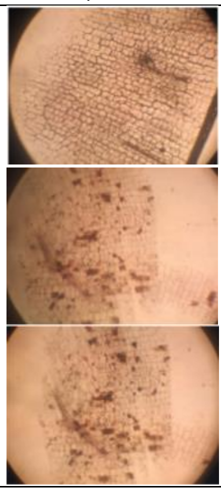
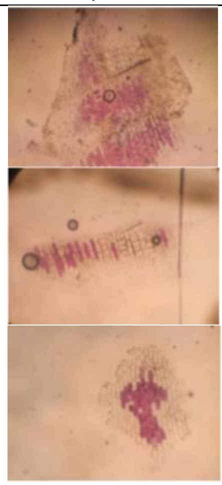
3.2. Microscopic Observation Results of Onion Epidermal Cells

Based on the observational data (**Table 2**), the results demonstrate a directly proportional relationship between the increase in solution concentration (molarity) and the percentage of cells undergoing plasmolysis (**Table 3**). In the control and 0.2 M groups, no plasmolyzed cells were detected (0%), indicating that the 0.2 M solution likely remains isotonic to the cellular fluid. A significant increase was subsequently observed at 0.4 M (60%), reaching a peak of 100% at 0.8 M. Plasmolysis occurs when plant cells are exposed to a hypertonic environment. Water exits the vacuole toward the extracellular space through osmosis, causing the plasma membrane to detach from the cell wall (Sari et al., 2023). Higher concentrations of extracellular solutes result in greater osmotic pressure drawing water out, thereby rapidly increasing the number of plasmolyzed cells. The anomaly observed in the data shown in (at 0.6 M, where the plasmolysis percentage decreased to 32%) may be attributed to data entry errors (human error) and technical inaccuracies, such as inconsistent counting under the microscope, variations in the thickness of the epidermal sections, or non-uniform immersion times (Haryanti & Rahmawati, 2021).

Table 2. Onion epidermal sections in different concentrations

0 M	0,2 M	0,4 M	0,6 M	0,8 M
				

The external solution concentration determines the water potential within the system. When the external solute concentration exceeds that of the intracellular environment, turgor pressure decreases until it reaches the point where the plasma membrane detaches from the cell wall. This plasmolysis phenomenon is frequently utilized to determine the osmotic potential of plant tissues via the incipient plasmolysis method (where 50% of the cells are plasmolyzed). Based on the observed data trends (60% at 0.4 M), the incipient plasmolysis point likely falls within a concentration range slightly below 0.4 M (Nuraini & Setiawan, 2020).

The high standard deviation values in the plasmolysis data indicate varying levels of sensitivity among individual cell units toward environmental osmotic pressure. Statistically, this broad variance causes the treatment effect patterns to appear inconsistent. This is likely influenced by the non-uniform physiological conditions of the cells within the tissue sections and the limited number of replicates during observation.

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Table 3. Microscopic observation results

Parameters	Concentration					Std. dev
	0 M	0,2 M	0,4 M	0,6 M	0,8 M	
Number of cells observed	25	25	25	25	25	0
Plasmolyzed cells	0	0	15	8	26	10,64
Plasmolysis percentage	0%	0%	60%	32%	100%	42,57

3.3. Results of Statistical Analysis

Data analysis in this study was conducted using Kruskal–Wallis tests to determine the effect of varying solution concentrations on the condition of red onion cells, particularly the percentage of plasmolysis, since the data did not meet the assumptions of normality and homogeneity of variance (Nahm, 2016). The results showed an Asymptotic Significance value of 0.406 ($p > 0.05$); thus, it can be concluded that there were no significant differences between the solution concentration treatments regarding cell plasmolysis. A significance value greater than 0.05 indicates that the alternative hypothesis was rejected, and the treatments did not exert a significant effect on the observed parameters (Van Hecke, 2012).

The lack of significance in these results may be influenced by several factors, such as the limited number of replicates, lack of data variation, precision in specimen observation, and the physiological condition of the cells during microscopic examination. Furthermore, the plasmolysis process is governed by the osmotic pressure exerted by the solution on the plant cells. Higher solution concentrations increase the likelihood of water exiting the cell, causing the plasma membrane to detach from the cell wall. These changes did not demonstrate statistically significant differences between treatments in this study. Overall, the Kruskal–Wallis tests indicate that the variations in solution concentration did not significantly affect the observed condition of the red onion cells; therefore, the research hypothesis could not be accepted (Okeh, 2013).

4. CONCLUSION

Based on the research results, increasing concentrations of salt solution (NaCl) tend to elevate the percentage of red onion cells undergoing plasmolysis. The 0.8 M concentration showed the highest degree of plasmolysis, whereas no plasmolyzed cells were observed in the control and 0.2 M groups. This indicates that hypertonic solutions trigger the efflux of water from the cells via osmosis, leading to plasmolysis. However, according to the Kruskal–Wallis statistical tests, the variations in salt solution concentration did not exert a statistically significant effect on the condition of the red onion cells ($p > 0.05$). Consequently, this study demonstrates a biological trend regarding the influence of salt concentration on red onion cell plasmolysis, despite not showing statistically significant differences.

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6. AUTHORS' NOTE

Future research is encouraged to utilize a reduced volume of soil medium or to adjust the medium quantity relative to the number of planted bulbs to prevent the accumulation of NaCl solution within the soil. This adjustment aims to ensure that the roots can absorb the NaCl solution more effectively, consistent with the administered treatment dosage.

Furthermore, to obtain clearer observations of plasmolysis, it is recommended that the onion epidermal samples be immersed directly in the NaCl solution for a specific duration. This immersion method is considered more effective in clarifying plasmolytic changes and reducing observational bias regarding the physical dimensions of the plant as research variables.

Researchers are also advised to maintain consistent watering schedules and ensure that the NaCl solution is homogenized prior to application, thereby ensuring a more uniform treatment concentration across all samples.

During the treatment period, the growth medium should be stored in an appropriate environment, such as an area with sufficient sunlight exposure that is shielded from rain—both direct rainfall and wind-driven precipitation—to prevent environmental factors from interfering with the treatment.

In the epidermal cell observation stage, the specific tissue section harvested from each sample should be standardized to prevent errors in data counting and processing. This standardization is essential to ensure that the research results are more accurate and can be objectively compared.

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