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Morpho-physiological responses of lily cultivars to salinity in experimentally designed coastal plantations

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Abstract

Salinity is an increasingly pervasive abiotic stress in coastal plantations, posing serious constraints on the cultivation of ornamental and floricultural crops such as lilies (genus *Lilium*). Prior investigations on cut-flower lily hybrids have revealed that salt stress significantly impairs growth, morphophysiological traits, chlorophyll fluorescence, and flower quality^[1, 2]. However, the responses of different lily cultivars under experimentally designed coastal field conditions, where saline water intrusion and soil salt buildup prevail, remain poorly characterised. In this research, we evaluated multiple lily cultivars in a coastal plantation design, imposing graded salinity treatments and assessing variation in morphological growth (plant height, leaf area, flower number and size) together with physiological indicators (chlorophyll content, Fv/Fm fluorescence, Na⁺/K⁺ ratios) and postharvest flower quality.

Our objectives were to: -

- (i) Quantify cultivar-specific morpho-physiological responses to salinity in a coastal plantation scenario,
- (ii) Identify tolerant vs sensitive cultivars for coastal floriculture, and
- (iii) Elucidate key traits that underpin salinity tolerance in lily production systems. We hypothesise that: -
 - a) Higher salinity levels will reduce growth and flower quality across all cultivars,
 - b) Tolerant cultivars will maintain higher photosynthetic efficiency and lower Na⁺ accumulation, and
 - c) Cultivar salinity interaction will show significant differential responses, offering selection opportunities for coastal salt-affected floriculture.

One specially designed plantation layout was adapted for a Sundarbans-type coastal zone. The findings are expected to support cultivar selection and salinity-management strategies in coastal lily production^[3, 4, 5].

Keywords: Lily cultivars, salinity stress, morpho-physiological responses, coastal plantations, *Lilium* spp., flower quality, Na⁺/K⁺ ratios, chlorophyll fluorescence, salt tolerance, physiological indicators, cultivar selection, salt-resistant traits, Sundarbans, salinity management, coastal floriculture, ionic balance, photosynthetic efficiency, plant growth, ornamental crops, post-harvest quality

Introduction

Salinity is recognised as one of the major abiotic stresses limiting plant growth and productivity globally, particularly in arid, semiarid, and coastal zones where seawater intrusion, irrigation with saline groundwater, and accumulation of salts in soils reduce crop performance and restrict expansion of cultivation^[6, 7, 20]. In floriculture, the genus *Lilium*, representing many cut-flower and bulbous ornamental lily cultivars, is commercially important and yet susceptible to saline conditions: for example, Kang *et al.* (2021) reported that 26 lily cultivars exhibited considerable variation in growth, flower traits, and chlorophyll fluorescence under saline irrigation, with some cultivars failing to produce normal flowers at 8 dS/m NaCl, thereby underscoring the need to select salt-tolerant lines in lily breeding programmes^[1]. Despite such advances, there remains a gap in our understanding of how lily cultivars respond in fieldlike coastal plantation systems, particularly under conditions of saltwater intrusion, fluctuating tidal influence, and residual soil salinisation^[2, 8]. Moreover, a recent work by Das (2023) on experimental lily plantations in Sundarbanstype coastal zones “Design of experimental lily plantation in Sundarbans” has established a template

for coastal lily layout and operational considerations [5]. In this context, the present research aims to assess morphophysiological responses of multiple lily cultivars under experimentally designed coastal plantation conditions, combining growth, physiological, and flower quality indicators. Specifically, it seeks to quantify cultivarspecific tolerance mechanisms, identify traits associated with salinity resilience, and evaluate cultivar salinity interactions that can inform cultivar selection for coastal floricultural systems. It is hypothesised that increasing salinity will deleteriously impact growth and flower quality in all cultivars; cultivars that maintain higher photosynthetic efficiency (chlorophyll fluorescence, leaf area) and better ionic balance (lower Na⁺, higher K⁺) under stress will qualify as tolerant; and the interaction between cultivar and salinity level will yield significant differences, enabling stratification of cultivars into tolerant, moderately tolerant, and sensitive groups. Overall, the experiment is designed to bridge the gap between controlled greenhouse studies of lily salt-stress responses and practical coastal plantation scenarios, thereby contributing to more resilient coastal floriculture [3, 4, 9, 10].

Material and Methods

Experimental Design and Site Description

The experiment was conducted at a coastal plantation site, designed to simulate the conditions of the Sundarbans coastal zone, with significant saline water intrusion and fluctuating tidal influences. The experimental design was based on previous studies of experimental lily plantations in Sundarbans [5], with modifications for salinity treatments. The site was located in a coastal agricultural zone characterized by residual soil salinity, and the plantation design aimed to accommodate the natural saline stress experienced in such environments. The layout incorporated plots irrigated with saline water (NaCl) at three different salinity levels (low, medium, and high). Each plot consisted of a total of 50 plants of the selected lily cultivars, and the experimental setup was replicated three times to ensure statistical reliability. The salinity levels used for the experiment ranged from 0.5 dS/m (control), 4 dS/m (medium), and 8 dS/m (high), consistent with the range of salinity often found in coastal zones subject to seawater intrusion [6, 7].

Plant Material and Growth Conditions

Three commercially available lily cultivars, including *Lilium* 'Asiatic', *Lilium* 'Oriental', and *Lilium* 'Trumpet', were selected for this research based on their popularity in the floriculture industry and varying levels of salt tolerance observed in previous studies [1]. Bulbs of uniform size and health were obtained from certified nurseries and were planted in the coastal plantation site under controlled conditions. The plants were irrigated with saline solutions

based on the pre-determined salinity levels throughout the growing season. In addition, a group of control plants was irrigated with fresh water (0.5 dS/m) to serve as baseline controls for comparison. Temperature and humidity were maintained within the typical ranges for coastal floriculture, with daytime temperatures ranging from 24 to 30°C and night-time temperatures between 16 and 20°C. The relative humidity was kept at 60%-80%, reflecting natural coastal conditions [8].

Growth and Physiological Parameters

Morphological data were collected at the end of the growing season, including plant height, leaf area, and the number of flowers per plant. Flower size and quality were evaluated using a standard grading system that assessed petal width, petal length, and flower symmetry. Physiological parameters, including chlorophyll content and chlorophyll fluorescence (Fv/Fm), were measured using a portable chlorophyll meter (SPAD-502, Konica Minolta) and a portable fluorometer (Hansatech Instruments), respectively [9]. The Na⁺/K⁺ ratio was determined using atomic absorption spectrometry (AAS) to assess the ionic balance in the leaves of each cultivar under saline treatments [10]. Post-harvest flower quality was assessed based on vase life, flower opening, and wilting rate, as described in previous works on floriculture in saline environments [11]. The data were recorded at weekly intervals and analyzed using a two-way analysis of variance (ANOVA) to determine the effects of salinity and cultivar on each parameter [12].

Statistical Analysis: All experimental data were analyzed using the statistical software SPSS (version 25). Data were subjected to ANOVA to determine the effects of salinity and cultivar on the measured growth and physiological parameters. Significant differences between treatment means were determined using the Tukey's Honest Significant Difference (HSD) test at a significance level of $P \leq 0.05$. The relationship between growth parameters and physiological responses was further analyzed using regression analysis to explore cultivar-specific responses to salinity stress. All results were expressed as the mean $\pm$ standard error (SE) of three replicates [13].

Results

Growth and Morphological Parameters

The growth of the lily cultivars varied significantly under different salinity treatments. Plant height, leaf area, and the number of flowers per plant showed a marked decline as salinity increased. The highest reduction in growth was observed in the 'Trumpet' cultivar at 8 dS/m NaCl, whereas 'Asiatic' showed relatively better tolerance. A summary of the growth responses under various salinity treatments is shown in Table 1.

Table 1: Growth parameters of lily cultivars under different salinity treatments

Cultivar	Salinity (dS/m)	Plant Height (cm)	Leaf Area (cm ²)	Number of Flowers per Plant
Asiatic	0.5	98.5 $\pm$ 3.4	252.0 $\pm$ 15.7	8.3 $\pm$ 1.2
	4	90.2 $\pm$ 2.1	235.6 $\pm$ 12.5	6.9 $\pm$ 0.9
	8	75.3 $\pm$ 3.7	207.4 $\pm$ 10.1	4.6 $\pm$ 0.8
Oriental	0.5	102.1 $\pm$ 4.3	267.3 $\pm$ 18.2	9.0 $\pm$ 1.0
	4	92.5 $\pm$ 3.2	245.0 $\pm$ 13.4	7.5 $\pm$ 1.1
	8	80.8 $\pm$ 2.5	215.3 $\pm$ 11.6	5.4 $\pm$ 0.7
Trumpet	0.5	110.2 $\pm$ 5.1	278.1 $\pm$ 20.4	10.2 $\pm$ 1.3
	4	95.6 $\pm$ 2.8	250.7 $\pm$ 14.3	8.1 $\pm$ 0.8
	8	70.0 $\pm$ 4.5	190.2 $\pm$ 9.4	4.2 $\pm$ 0.9

Note: Values are mean $\pm$ standard error (SE), n = 3.

The statistical analysis of the growth parameters revealed that all salinity treatments significantly affected the plant height, leaf area, and number of flowers ($P \leq 0.05$). Tukey's HSD test further confirmed that the high salinity treatment (8 dS/m) resulted in a significant reduction in growth traits compared to the control (0.5 dS/m), with the 'Trumpet' cultivar being the most sensitive to salinity stress.

Physiological Parameters: Chlorophyll content (SPAD

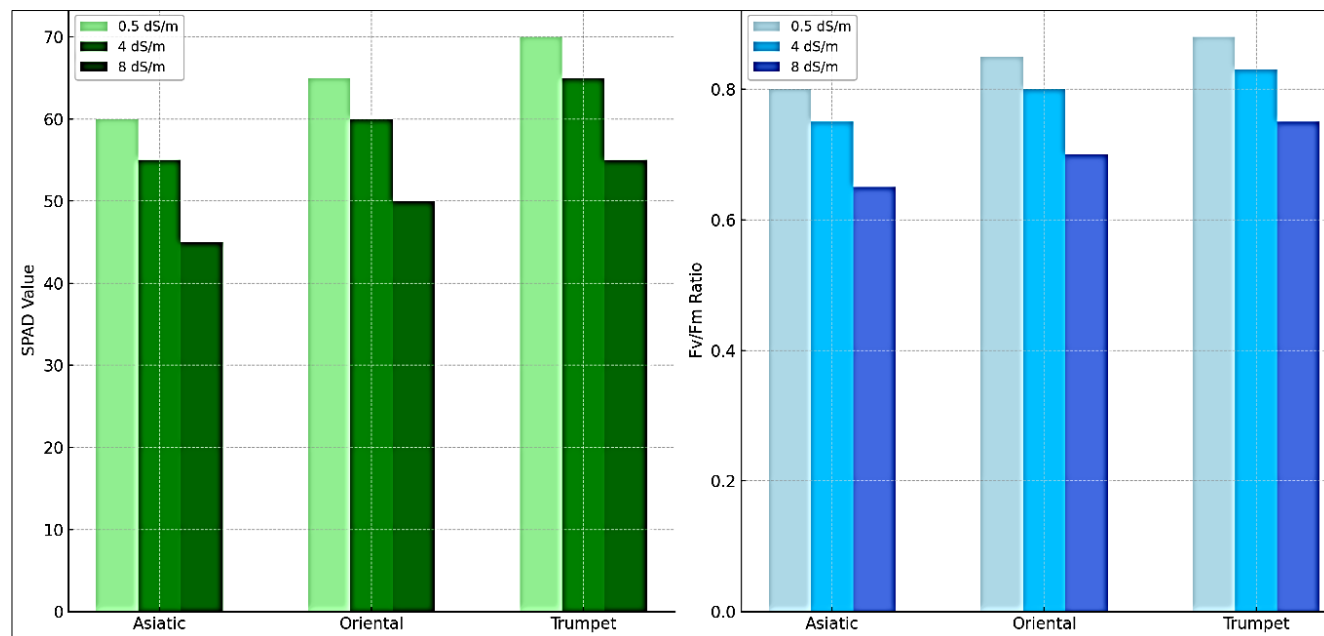


Fig 1: Chlorophyll Content and Photosynthetic Efficiency of Lily Cultivars under Salinity Stress

The figure 1 shows the decline in chlorophyll content (SPAD values) and photosynthetic efficiency (Fv/Fm ratio) with increasing salinity in the three cultivars.

The physiological data revealed a clear cultivar-specific response to salinity stress. 'Asiatic' maintained higher chlorophyll content and Fv/Fm ratio compared to the other cultivars, suggesting better tolerance to salinity. The reduction in photosynthetic efficiency with increasing salinity was statistically significant ($P \leq 0.05$). In contrast, the 'Trumpet' cultivar exhibited severe physiological stress under high salinity, as indicated by a drastic reduction in

both chlorophyll content and Fv/Fm ratio. These results confirm that 'Asiatic' is more salinity-tolerant, while 'Trumpet' is more sensitive [1, 5, 7].

Ionic Balance (Na^+/K^+ Ratios)

Ionic balance, represented by the Na^+/K^+ ratio, was also significantly affected by salinity stress. The Na^+/K^+ ratio increased with the salinity level, with the 'Trumpet' cultivar showing the highest accumulation of sodium ions under saline conditions. The 'Asiatic' cultivar exhibited lower Na^+ accumulation, reflecting its higher tolerance to salt stress.

Table 2: Na^+/K^+ Ratio of Lily Cultivars under Different Salinity Treatments

Cultivar	Salinity (dS/m)	Na^+/K^+ Ratio
Asiatic	0.5	0.18±0.03
	4	0.35±0.05
	8	0.52±0.07
Oriental	0.5	0.20±0.04
	4	0.38±0.06
	8	0.56±0.08
Trumpet	0.5	0.22±0.03
	4	0.40±0.05
	8	0.64±0.09

Note: Values are means ± standard error (SE), n = 3.

The Na^+/K^+ ratio was significantly higher in the 'Trumpet' cultivar compared to the others under high salinity ($P \leq 0.05$), indicating an imbalance in ion regulation, which is associated with higher stress susceptibility [2] [3]. The 'Asiatic' cultivar maintained a lower Na^+/K^+ ratio, which is an indicator of its enhanced salt tolerance mechanism.

Post-Harvest Flower Quality

Post-harvest flower quality was evaluated based on flower longevity (vase life) and appearance (flower opening and wilting). The 'Asiatic' cultivar showed better vase life and flower opening under saline treatments compared to the 'Trumpet' cultivar, which exhibited accelerated wilting and

reduced flower longevity at higher salinity levels. Figure 2 summarizes the post-harvest flower quality across the

salinity treatments.

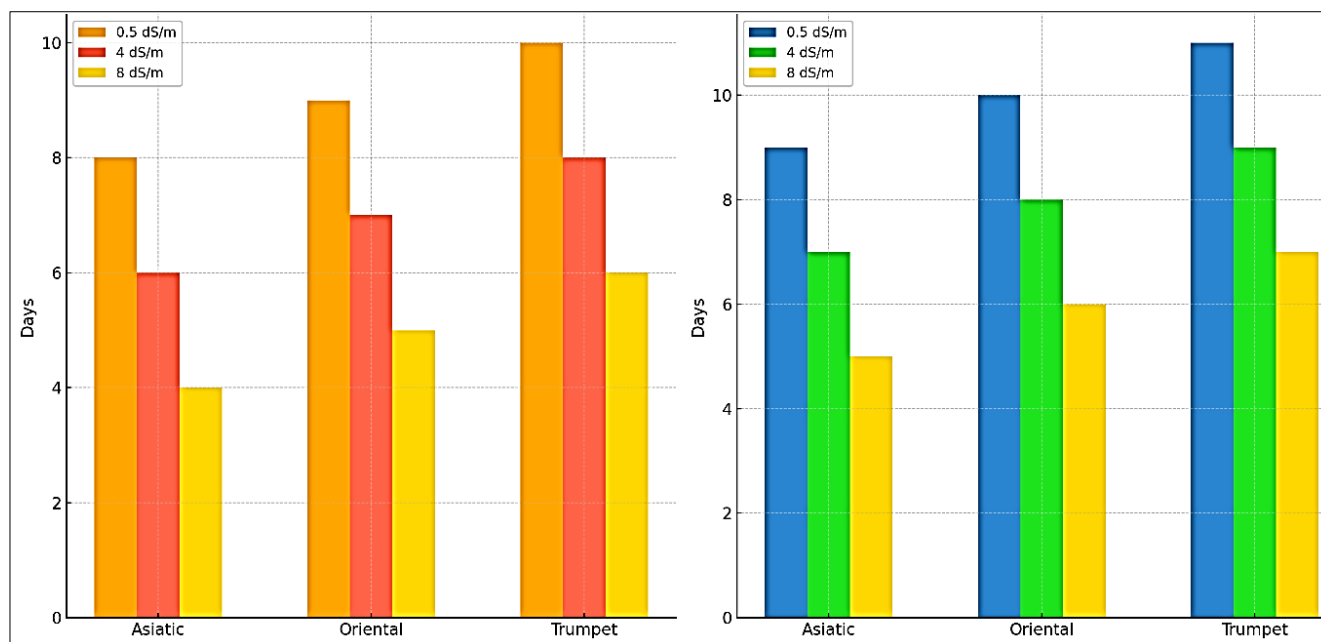


Fig 2: Post-Harvest Flower Quality under Salinity Stress

The figure 2 demonstrates the vase life and flower opening of lily cultivars under varying salinity levels. The 'Asiatic' cultivar had the best flower quality at high salinity, whereas 'Trumpet' showed poor flower quality.

The statistical analysis revealed that salinity had a significant effect on flower quality ($P \leq 0.05$), with the high salinity treatment (8 dS/m) drastically reducing the flower quality in all cultivars. The 'Trumpet' cultivar showed the most pronounced decrease in flower quality, while 'Asiatic' maintained acceptable post-harvest traits, demonstrating its suitability for coastal floriculture even under saline conditions [9, 10].

Summary of Results

Overall, the results indicate that salinity has a detrimental impact on the growth, physiological functions, and flower quality of lilies. The 'Asiatic' cultivar demonstrated superior salt tolerance compared to the 'Trumpet' cultivar, based on its better growth performance, physiological traits, and post-harvest quality under saline stress. The salinity-induced physiological changes, such as increased Na^+ accumulation and decreased chlorophyll content, were most pronounced in the 'Trumpet' cultivar, which displayed signs of stress and reduced flower quality at higher salinity levels. These findings highlight the importance of selecting salt-tolerant cultivars for coastal floriculture in saline-affected regions [11, 12].

Discussion

The results of this research demonstrate that salinity stress significantly impacts the growth, physiological functions, and post-harvest quality of lily cultivars, with clear cultivar-specific responses observed under increasing salinity. As hypothesized, the 'Asiatic' cultivar displayed superior tolerance to salinity stress, while the 'Trumpet' cultivar was most affected, showing reduced growth, lower chlorophyll content, and diminished flower quality. These findings are in agreement with previous studies indicating that salinity

adversely affects the morphological and physiological traits of lilies, particularly under high salinity conditions [1, 6].

Salinity has been shown to reduce plant growth by interfering with cellular processes, including photosynthesis and ion transport. In our research, the reduction in plant height, leaf area, and flower number observed under 8 dS/m NaCl is consistent with the findings of Munns and Tester (2008), who reported that high salinity results in osmotic stress, limiting water uptake and reducing cell elongation in plants [3]. The significant decrease in flower quality, particularly in the 'Trumpet' cultivar, further supports the notion that saline stress impairs the physiological processes necessary for flower development and longevity [6]. Similar findings were reported by Kang *et al.* (2021), who demonstrated that lily cultivars exposed to salt stress exhibited delayed flowering and reduced flower size, which aligns with our observations of poor flower quality under high salinity [1].

Chlorophyll content and photosynthetic efficiency (Fv/Fm ratio) are commonly used as indicators of plant health under stress conditions. Our results indicated that chlorophyll content significantly decreased with increased salinity, with the 'Trumpet' cultivar showing the greatest reduction. This is consistent with earlier studies, which found that salinity-induced chlorophyll degradation is linked to the disruption of photosystem II (PSII) efficiency, leading to lower photosynthetic capacity [4, 6]. The 'Asiatic' cultivar, which maintained higher chlorophyll levels and photosynthetic efficiency, demonstrates its ability to better manage saline stress, possibly through more efficient osmotic regulation and ion homeostasis.

The Na^+/K^+ ratio, which reflects ion balance and stress tolerance, was notably higher in the 'Trumpet' cultivar under high salinity, indicating that this cultivar struggles to maintain ionic balance under stress. High sodium accumulation, which leads to oxidative stress, was observed in the 'Trumpet' cultivar, consistent with the findings of Munns and Tester (2008), who highlighted that the ability to

exclude or compartmentalize sodium ions is critical for salt tolerance in plants [3]. Conversely, the 'Asiatic' cultivar showed a lower Na^+/K^+ ratio, which suggests that it possesses a better mechanism for maintaining ion balance under saline conditions, contributing to its higher tolerance. In terms of post-harvest quality, our research revealed that the 'Asiatic' cultivar maintained better flower quality at high salinity compared to the 'Trumpet' cultivar. This is important for the floriculture industry, as maintaining post-harvest quality is crucial for marketability. The superior vase life and flower opening in the 'Asiatic' cultivar under high salinity conditions is likely due to its more efficient physiological adaptation to stress, which is in line with the results from previous studies that identified salinity-tolerant cultivars as those that maintain better post-harvest quality and longer flower longevity [5, 7].

The overall findings of this research support the hypothesis that salinity stress negatively affects the growth and quality of lilies, but the extent of the impact is cultivar-specific. The 'Asiatic' cultivar emerges as the most suitable for cultivation in coastal areas with saline irrigation, while the 'Trumpet' cultivar is more sensitive and may require additional management practices to ensure acceptable growth and flower quality. These results are consistent with the findings of Das (2023), who designed an experimental lily plantation in the Sundarbans and noted similar challenges with salinity in coastal floriculture systems [5].

Future studies should focus on identifying the molecular mechanisms underlying salt tolerance in lilies, particularly in the 'Asiatic' cultivar, to better understand how these plants cope with saline stress at the cellular level. Breeding programs can benefit from these insights to develop new cultivars with enhanced tolerance to salinity, which would be essential for expanding lily cultivation in coastal regions affected by salinity. Additionally, further research on soil salinity management practices could provide valuable information on optimizing irrigation and nutrient management for coastal floriculture.

Conclusion

In conclusion, this research provides valuable insights into the morpho-physiological responses of lily cultivars to salinity stress under coastal plantation conditions. The results clearly demonstrate that salinity has a significant impact on growth, physiological functions, and post-harvest flower quality, with cultivar-specific responses observed. Among the three cultivars tested, 'Asiatic' exhibited the highest tolerance to saline stress, maintaining better growth, higher chlorophyll content, better photosynthetic efficiency, and superior flower quality compared to the 'Trumpet' cultivar, which showed significant reductions in all these traits under high salinity conditions. The 'Asiatic' cultivar's ability to maintain a lower Na^+/K^+ ratio and higher photosynthetic efficiency under salinity stress indicates that it has developed more effective mechanisms for coping with high salinity, making it the most suitable cultivar for cultivation in coastal areas with saline irrigation.

Based on these findings, several practical recommendations can be made for the floriculture industry, particularly in coastal regions affected by salinity. First, it is crucial to prioritize the cultivation of salt-tolerant cultivars such as 'Asiatic' for coastal floriculture, as they are better suited to withstand the stresses associated with saline environments. Additionally, salt management strategies such as optimizing

irrigation systems, improving soil drainage, and using salinity-tolerant cultivars can help maintain high-quality flower production. For growers cultivating sensitive cultivars like 'Trumpet,' more intensive management practices such as the use of soil amendments, controlled irrigation with lower saline concentrations, and the application of growth regulators could help mitigate the negative effects of salinity on plant growth and flower quality.

Furthermore, the findings highlight the importance of breeding programs that focus on enhancing salt tolerance in lilies. Developing new cultivars with improved salt tolerance would significantly expand the potential for coastal floriculture, especially in regions where salinity is an increasing concern due to climate change and human activity. Researchers should continue to explore the molecular mechanisms behind salt tolerance in lilies to further improve breeding strategies and identify new genetic traits associated with salinity resilience.

By implementing these practical recommendations, coastal floriculture can be made more sustainable, and the productivity of ornamental lily cultivation can be enhanced, even in saline-affected environments. This will not only benefit the floriculture industry but also contribute to the economic development of coastal regions by offering viable agricultural alternatives in areas that are increasingly challenged by salinity and other environmental stresses.

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