Effect of ultraviolet radiation (UV) and salinity stress (NaCl) on some vegetative and flowering growth traits of Gypsophila paniculata.

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Abstract

This study investigated the combined effects of Ultraviolet (UV) radiation and salinity(NaCl)stress on the vegetative and floral acclimation of Gypsophila paniculata. A factorial experiment was carried out with four UV exposure durations (0, 5, 10, and 15 minutes per day) and three salinity levels (0, 100, and 150 mM NaCl),key field traits were measured and analyzed using two-way ANOVA and LSD tests ($p < 0.05$). The results demonstrated that both UV radiation and salinity significantly influenced multiple plant traits including plant height, leaf area, flower bud initiation and opening times, number of flowering stalks, and dry flower blossoms percentage. Across all traits, UV exposure exhibited a stronger effect compared to salinity, with significant interaction effects observed between the two factors. Specifically, treatment T7 (10 minutes UV exposure without salinity) consistently produced the most favorable outcomes, increasing plant height by 20.7%, leaf area by 246.8%, and dry flower blossoms percentage by 50.2%, compared to the control. It also accelerated flower bud initiation and opening, while treatments with higher salinity or lower UV exposure delayed these developmental stages and reduced growth performance. Effect size analysis revealed that UV radiation accounted for the largest portion of the variation observed in plant height (49.0%), leaf area (65.7%), and bud initiation (34.6%), underscoring its dominant physiological role. Salinity had a comparatively smaller, yet still significant, impact on these traits. Strong correlations were noted among growth and reproductive parameters, indicating integrated plant responses to combined stresses. These findings suggest that controlled UV exposure can enhance plant acclimation and performance under salinity stress by promoting growth and accelerating reproductive development. Overall, this research provides valuable insights into improving G. paniculata cultivation under adverse environmental conditions and supports the development of stress-resistant ornamental varieties capable of thriving under combined UV and salinity stress.

Keywords: Gypsophila paniculata, UV, salinity stress, growth traits.

Introduction

Gypsophila paniculata L., commonly known as baby's breath, panicled baby's breath, or common gypsophila, belongs to the Caryophyllaceae family. Although it is a perennial plant, it is often grown as an annual in commercial flower production. Native to the temperate regions of Europe and Asia, Among these species, G. paniculata (2n=34) is classified as a herbaceous perennial shrub. [1], The word Gypsophila is derived from the Greek words "Gypso", meaning gypsum, and "philios", meaning loving, referring to flowers

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that thrive in gypsum-rich soils. Gypsophila is highly valued as a cut flower in the art of floral arrangement, commonly used as a filler in bouquets and in dried floral decorations. It is also well-known for its ornamental, medicinal, and industrial applications[2]. this species is widely used in gardens and is considered one of the most valuable filler flowers in floral arrangements and bouquets[3], [4]. It is a highly resilient perennial plant characterized by a deep taproot system. The stems are slender, ranging from upright to spreading, and are swollen at the nodes. The leaves are small, opposite, and narrowly lanceolate, often curved like a sickle, with a bluish-green hue. The plant produces numerous small flowers arranged in large, heavily branched panicles. Each flower is tiny, measuring 10–18 mm in diameter, and features white or pink petals. [5] Environmental stresses that plants experience include various types such as drought, salinity, extreme temperatures (both low and high), and heavy metal levels, all of which negatively affect plant growth, development, and productivity. These abiotic stresses disrupt essential physiological processes like photosynthesis, water and nutrient absorption, flowering, and other aspects of growth and development, making them a major contributor to crop loss worldwide[6]. Environmental stresses that plants experience include various types such as drought, salinity, extreme temperatures (both low and high), and heavy metal levels, all of which negatively affect plant growth, development, and productivity[7]. These abiotic stresses disrupt essential physiological processes like photosynthesis, water and nutrient absorption, flowering, and other aspects of growth and development, making them a major contributor to crop loss worldwide[8]. Recent research has focused on understanding these mechanisms at the genetic and molecular levels, particularly the role of key genes involved in ion transport and signaling pathways that enable plants to cope with saline environments. Biotechnological techniques, including gene-editing tools, are being employed to develop salt-tolerant crop varieties, aiming to ensure agricultural productivity in salt-affected regions [9] . Ultraviolet (UV) radiation poses a significant threat to plant health by causing molecular damage, particularly to DNA, proteins, and lipids. Increased UV exposure, driven by ozone layer depletion and environmental changes, intensifies this stress, leading to reduced photosynthesis, altered growth, and decreased crop yields. UV radiation can also induce cellular damage, triggering oxidative stress in plant cells through the generation of reactive oxygen species (ROS). In response, plants activate various defense mechanisms, including the production of UV-absorbing compounds such as flavonoids, and the enhancement of antioxidant enzyme activity to neutralize and regulate ROS levels[10]. This study aimed to investigate the vegetative and flowering responses of Gypsophila.p plants under combined ultraviolet (UV) radiation and salinity stress, with a focus on the defensive mechanisms adopted by the plant to cope with this stress

Material and Methods

The experiment was carried out during the fall season of 2024–2025 in the greenhouses of the Department of Horticulture and Landscape, College of Agriculture, Tikrit University. The study aimed to evaluate the vegetative and flowering responses of Gypsophila. paniculata to ultraviolet (UV) radiation and salinity stress under controlled environmental conditions.

Plant Material and Growth Conditions:

Seeds of Gypsophila paniculata were sourced from a local company(wadi albudhur) in Iraq.

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On October 28, 2024, the seeds were sown in sterilized seed trays under controlled greenhouse conditions. To ensure optimal moisture levels, irrigation was carried out daily. Germination occurred within seven days, and once the seedlings reached a suitable size, they were transplanted into prepared pots after 45days for the application of experimental treatments.

Soil Preparation and Potting

A loamy soil mixture (1:1, sand:peat soil) was disinfected by exposing it to direct sunlight for 48 hours to eliminate pathogens and weed seeds. After sterilization, the soil was placed into plastic pots with a diameter of 25 cm and arranged according to a randomized complete block design (RCBD). Soil samples were taken for physical and chemical analysis, which was carried out by the Horticulture Division of the Ministry of Agriculture to ensure consistency in soil properties across all treatments.

Fertilization Regime

Four types of fertilizers were applied during the experiment:

Humic acid (Humate International, China) 10 g diluted in 15 L-1 of water, applied in three doses. Balanced NPK fertilizer (SQM) 10 g in 5 L-1 of water, applied in two doses. Amino acids (BOMBARDIER) (Agroindustrial Kimitec S.L.) 20 mL in 10 L-1 of water, applied in three doses. High-phosphorus NPK (Diamond, Egypt) 15 g in 10 L-1 of water, applied once. All fertilizers were applied according to the manufacturers' recommendations.

Experimental Treatments

The experiment was conducted using a factorial design that included two stress factors: salinity and UV radiation.

UV Radiation Treatment

Plants were subjected to UV-C radiation (wavelength range: 250–275 nm) using UV-C lamps installed in a specially designed treatment chamber. The chamber was equipped with four shelves (each measuring 80 × 200 cm and spaced 40 cm apart). The top shelf served as the control and received no UV exposure, while the other three shelves were fitted with UV-C lamps to provide varying durations of daily UV exposure:

V0: 0 minutes (control(

V1: 5 minutes

V2: 10 minutes

V3: 15 minutes

Plants were subjected to UV-C exposure for seven consecutive days. Following the treatment period, they were randomly redistributed among their respective replicates to reduce any positional bias.

Salinity Stress Treatment

Salinity treatments were applied (one month after the application of the first factor) using saline solutions prepared by dissolving sodium chloride (NaCl) in distilled water at the following concentrations:

S0: 0 (control(

S1: 100Mm

S2: 150 Mm

Salt solutions were prepared by dissolving 6 g NaCl in 1 liter , 9 g of NaCl in 1 liters of distilled water, respectively. Plants were irrigation with the salt solution once-twice per week for a duration of one month, depending on water requirements.

Statistical Analysis

A factorial experiment with two interacting factors was set up using the RCBD

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(Randomized Complete Block Design) and included three replications.

Data Collection and Analysis

The experimental data were analyzed according to the experimental design using Analysis of Variance (ANOVA) to test the significance of differences among treatments, utilizing the statistical software GenStat version 12 (GenStat 12). When significant differences were detected, the Least Significant Difference (LSD) test was applied at a 5% probability level to compare means. Additionally, the Coefficient of Variation (CV%) was calculated to estimate the homogeneity of data within treatments. To enhance the accuracy of the analysis and improve prediction of responses, artificial intelligence (AI) tools were employed to interpret complex interactions among the studied factors and correlations, providing more precise and applicable recommendations for various agricultural environments [11.[

Studied Traits

Field Traits

Plant Height (cm(

Plant height was measured using a measuring tape from the crown area to the top of the plant, and the average was recorded.

Leaf Area per Plant (cm^2(

The leaf area was calculated by randomly selecting three leaves from each plant, and their area was measured using the Image J [12.[

Days to Flower Bud Initiation(day.(

The plants were monitored daily to observe the appearance of the first flower buds, and the average number of days was recorded along with the date of appearance.

Days to Flower Bud Opening(day.(

The opening of flower buds was observed regularly, and the number of opened buds was counted manually and averaged.

Total Number of Inflorescences per Plant (number.(

The total number of inflorescences per plant was counted manually, and the average was recorded.

%Dry of f.blossoms.(%)

The plant samples were dried in an oven for four days The dry matter percentage was calculated by measuring the fresh weight and dry weight of the vegetative parts. The percentage was determined using the formula:

))dry weight)/(fresh weight))×100.

Results and Discussion

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Table 1. Effect of Ultraviolet (UV) Radiation and Salinity Stress(NaCl) on Vegetative and Floral Growth Traits of Gypsophila paniculata.

Treatment	Plant height cm	Paper area mm^2	beginning of the formation of floral buds day	Flower buds open day	number of pink Shamrocks	% Dry percentage of pink beets
p-value (V)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
p-value (S)	<0.001	<0.001	0.047	0.003	<0.001	<0.001
Interaction (V×S)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
η^2 (V)	49.0 %	65.7 %	34.6 %	29.4 %	26.1 %	20.1 %
η^2 (S)	0.5 %	14.4 %	0.03%	3.8 %	8.7 %	13.9 %
CV%	0.1 %	0.2 %	0.8 %	2.9 %	3.4 %	5.6 %
control (T1/V0S0)	70.600	11071.7	15.167	13.800	11.667	0.1960
High treatment	V2S0 (85.200)	V2S0 (38400)	V0S2 (10.133)	V3S2 (12.100)	V2S0 (30.000)	V2S0 (0.2943)
% Improvement	+20.7%	+246.8%	-33.2%	-12.3 %	+157.1 %	+50.2 %
Lower treatment	V1S0 (56.167)	V0S2 (6200)	V2S2 (20.500)	V1S1 (16.933)	V1S0 (10.000)	V1S0 (0.1863)
% Deterioration	-20.4%	-44.0%	+35.2%	+22.7 %	-14.3 %	-4.9 %
Interpretation of the effect size	effect of V is stronger than S	Huge impact for V	Best: Least valuable (appears faster)	Best: Least valuable (accelerate blooming)	V2S0 superiority is clear	Strong interaction between V and S

p-value = Significance of variation , η^2 (eta squared) = Effect size, CV (Coefficient of Variation) = Measure of variability , V (UV) = Ultraviolet radiation factor , S (Salinity) = Salinity stress factor.

Plant Height (cm:(

The results of the statistical analysis for the trait of plant height (L.Plant-cm), revealed significant differences among the main factors the first factor (V), representing ultraviolet (UV) radiation exposure, the second factor (S), representing salt stress (NaCl), and their interaction (V × S). The significance level (p-value) was found to be less than 0.001. The high treatment was T7 (V2S0), corresponding to 10 minutes of UV exposure (V2) with no salt stress (S0 = 0 mM), which recorded a plant height of 85.200 cm per plant, showing a significant increase compared to other treatments. This treatment improved plant height by 20.7% relative to the control treatment (V0S0), which recorded 70.600 cm per plant. In contrast, the lowest value was observed in treatment T4 (V1S0), corresponding to 5 minutes of UV exposure (V1) and no salt stress, which recorded 67.56 cm per plant, reflecting a 20.4% reduction compared to the control. Effect size analysis (η^2) indicated that UV radiation had a greater influence on plant height, accounting for 49.0% of the total variation, compared to salt stress, which accounted for only 0.5%.

Leaf Area per Plant (cm^2:(

For the trait of leaf area (L.Area), the statistical analysis showed significant differences for all factors, with a p-value less than 0.001. The highest value was recorded in treatment T7 (V2S0), with 10 minutes of UV

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exposure and 0 mM NaCl, which reached 38,400 mm² per plant, compared to the control treatment (V0S0), which recorded 11,071.7 mm² per plant. This reflects an improvement of 246.8% over the control. The lowest value was recorded in treatment T3 (V0S2), corresponding to no UV exposure and 150 mM NaCl, with a leaf area of 6,200 mm² per plant, indicating a 44.0% reduction compared to the control. Effect size analysis for this trait showed that UV radiation had a dominant influence on leaf area, accounting for 65.7% of the variation, while salt stress contributed 14.4%.

Days to Flower Bud Initiation(day:(

The statistical analysis of this trait showed significant differences among the main factors and their interaction. The p-value for the first factor (V), representing UV radiation exposure, was less than 0.001. Similarly, the second factor (S), representing salt stress (NaCl), also showed a p-value less than 0.001, and the interaction between both factors (V × S) was also highly significant ($p < 0.001$). The best treatment was T3 (V0S2), with no UV exposure (V0 = 0 min) and high salt stress (S2 = 150 mM), which recorded the earliest flower bud initiation at 10.133 days, compared to the control treatment (V0S0) that required 15.167 days. The latest initiation was observed in treatment T9 (V2S2), which received 10 minutes of UV exposure and 150 mM NaCl,taking20.500days, (Note: Fewer days indicate earlier flower bud formation.) Effect size analysis (η^2) indicated that UV radiation had a strong effect (34.6%), while the effect of salinity was minimal, accounting for only 0.03% of the variation.

Days to Flower Bud Opening(day:(

Statistical analysis revealed significant differences for all individual factors and their interaction. The p-values for both UV radiation (V) and salt stress (S) were less than 0.001, as was their interaction. The earliest flower bud opening was recorded in treatment T12 (V3S2), which received 15 minutes of UV exposure (V3) and 150 mM NaCl (S2), with an average of 12.100 days, compared to the control treatment (V0S0), which took 13.800 days. The latest bud opening occurred in treatment T5 (V1S1), which received 5 minutes of UV (V1) and 100 mM NaCl (S1), recording 16.933 days, representing a 22.7% delay. Meanwhile, the improvement in flowering speed under T12 was -12.3% compared to the control. The effect size analysis (η^2) showed that UV radiation accounted for 29.4% of the variation, whereas salt stress explained 3.8%.

no.f.blossoms(number:(

According to the analysis in Table 6, this trait also showed significant differences among the studied factors and treatments ($p < 0.001$). The highest value was observed in T7 (V2S0), with 10 minutes of UV exposure (V2) and no salt stress (S0 = 0 mM), which recorded 30 flowering stalks per plant, reflecting an increase of 157.1% over the control treatment (V0S0), which had 11.667 stalks per plant.

The lowest value was found in treatment T4 (V1S0), with 5 minutes of UV exposure and no salt, which recorded 10.000 stalks per plant, representing a 14.3% reduction from the control. Effect size (η^2) showed that UV radiation had a more prominent influence (26.1%) than salinity, which accounted for 8.7%.

%Dry of f.blossoms:(%)

The statistical analysis of this trait revealed significant differences among the main factors and their interaction. The p-values for UV radiation (V), salt stress (S), and their interaction (V × S) were all less than 0.001, indicating highly significant effects.

The highest value was recorded in treatment T7 (V2S0), corresponding to 10 minutes of UV exposure (V2) and 0 mM NaCl (S0), with a dry flower blossoms percentage of 0.2943%,

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which represents a statistically significant increase compared to the control treatment (V0S0), which recorded 0.1960%. This treatment resulted in a +50.2% improvement in this trait over the control. In contrast, the lowest value was observed in T4 (V1S0), with 5 minutes of UV exposure and no salt stress, which resulted in a -4.9% reduction compared to the control.

The effect size analysis (η^2) presented in Table 6 indicates that UV radiation had a substantial effect, accounting for 20.1% of the variation in this trait, compared to the 13.9% effect contributed by salt stress. This highlights the dominant influence of UV exposure on the dry weight accumulation of floral structures under the studied conditions.

Conclusion

The study showed that UV radiation and salinity significantly affected plant height, leaf area, flowering time, number of flowering stalks, and dry matter percentage. UV had a stronger effect than salinity in most traits, with treatment T7 (V2S0) showing the best results. It improved growth and accelerated flowering, while treatments with low UV or high salinity performed poorly. Effect size analysis confirmed that UV exposure played a dominant role in enhancing physiological responses under stress conditions.

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