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Effect of ultraviolet radiation treatment to increase the ability of *Gypsophila elegans* Crimson to tolerate salinity

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Abstract

This experiment was designed at the Horticultural Research Institute, Ornamental Department Nursery, in two consecutive years 2021-2022 and 2022-2023. The experiment was directed to improve the tolerance of *Gypsophila elegans* Crimson to salinity by planting gypsophila seeds after treating them with UV rays for 0, 1, 2 or 4 hours in seed growing beds, then they were transplanted after the seedlings became 8 to 10 cm long in pots. The plants were irrigated with water containing sodium chloride in concentrations of (0, 1000, 2000 or 4000 ppm).

The experiment has proven that the treatment with ultraviolet ray had significant improvement in plant height, fresh and dry weight of plant, early flowering, enhanced floral traits and increased levels of chlorophyll (a and b), total carbohydrates and proline were observed with longer exposure periods, reaching the highest results after 2 hours of exposure compared to unexposed seeds.

Exposure to UV treatments for plants treated with different salinity levels had a significant effect in improving all vegetative and floral traits, as treating seeds with UV rays for one or two hours before planting removed the harmful effect of salinity at a concentration of 1000 or 2000 ppm for most vegetative and floral traits and leaf content of chlorophyll (a and b) and carbohydrates in leaves with significant superiority for the two hours radiation.

Gypsophila exhibits partial salinity tolerance; however, higher salinity levels reduce vegetative and floral traits, decrease chlorophyll (a and b) content, increase the proline accumulation in the leaves.

Keywords: *Gypsophila elegans*, ultraviolet radiation, plant quality, salinity.

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1. Introduction

Gypsophila a flowering plant is belonging to Caryophyllaceae family, commonly known as “Annual baby's-breath” native to central and eastern in Europe and western Asia. The plant is used as cutting flowers arrangements in bouquets and vases and grown at garden for garden coordination **[1,2]**. As for the size of the plant, it is a small, compact plant, and the flowers are small and star-shaped **[3,4]**. Those possesses a woody taproot capable of penetrating the soil to depths of up to 4 meters **[5]** enabling the plants to survive and persist through winter in cold climates **[6]**. *Gypsophila elegans* Crimson is an herbaceous perennial characterized by its branching stems that carry masses of small, white flowers. It grows in mound-like shapes, typically reaching about four feet in both height and width. The plant favors dry, sandy, and stony soils, often with a calcareous composition **[7]**.

Many researchers may use low concentrations of UV rays to improve many vegetative, floral and fruit characteristics and pest and disease resistance. Exposure to low doses of ultraviolet radiation induces moderate oxidative stress, which can enhance the resistance of plant to pathogens **[8,9,10,11]**. Also, enhance the nutritional quality of plant-derived products **[12,13]**. To date, relatively few studies have investigated a potential use low doses of UV radiation employed during the plant growth to elevate the quality of fruits, vegetables or ornamental plants **[14,15,16,17,18,19]**. Nonetheless, according to the comprehensive review by Urban et al. **[20]** explore the physiological impacts of UV-C radiation and evaluate the agronomic techniques applied to it during both pre- and post-harvest stages. It remains crucial to ensure the resistance enhancements induced by UV-C exposure do not negatively affect yield or compromise fruit quality at harvesting or during the postharvest storage.

Salinity is the major environmental stressor that adversely effects on growth and plant productivity. The high salt levels in the soil and water irrigation reduce a plant's ability to absorb water through its roots. Moreover, high salinity interferes with the absorption of vital nutrients, leading to nutrient imbalances in plants, as the excess salts disrupt the normal functioning of root cells and ion transport mechanisms. This nutrient imbalance can lead to deficiencies that stunt growth and reduce yields **[21]**.The effect of salinity on plants is through two main factors, which are: osmotic stress and ionic toxicity. These stresses affect all vital processes in the plant, such as intracellular and photosynthesis metabolism **[22,7]**.

The study aims to increase the tolerance of Gypsophila plants to salinity by exposing the seeds to ultraviolet radiation.

2. Materials and Methods

The experiment was carried out in The Horticultural Research Institute. Ornamental Department Nursery, in two consecutive years of 2021- 2022 and 2022- 20 23. This experiment was carried out by planting *Gypsophila elegans* Crimson seeds on 3/10/2021 after treating them with UV treatments in seed growing beds, then they were transplanted after the seedlings became 8 to 10 cm long to pots with 20 cm diameter in 1:1 sand and clay(V/V) soil under open field conditions. The second season was planted on 2/10/2022 after being treated as was done in the first one. The fertilization recommended for the plant was carried out and irrigation was done every three days.

Treatments were done as follows:

1- Control 2- UV 1 hour 3- UV 2 hours 4- UV 4 hours

The specifications of the UV lamps were 90cm long and radiation of T4IS lamp IS. The two lamps were placed at a height of 55 cm from the seeds.

The treatment of salinity:

[a- Control (tap water) b- 1000 ppm c- 2000 ppm d- 4000 ppm from NaCl (saline water containing sodium chloride).

However, four salinity concentrations and four radiation coefficients equal to 16 treatments were included.

Regular agricultural practices were carried out wherever the plants were needed.

Data recorded:

2.1. Vegetative growth parameters:

Plant height (cm), number of leaves/plants, number of branches, fresh and dry weights of leaves (g) and stem diameter (cm).

2.2. Flowering specifications:

Number of days from planting to flowering, flower diameter (cm) and number of flowers/ plant.

2.3. Chemical constituents of the leaves:

- Photosynthetic pigments content of total chlorophyll (a and b) mg/g f.w. of fresh leaves which collected from all plots to determine the total chlorophyll contents using the methodology established by Wellburn and Lichtenthaler **[23]**.

-The free proline (mg/g d.w.) content in dry leaves was measured using the methodology described by Bates et al. **[24]**.

- Total carbohydrate content (% in dry matter) determined according to the methodology of Dubois et al. **[25]**.

- The concentration of malondialdehyde (MDA) (nmol/g f.w.) in fresh leaves determined following the procedure of Du and Bramlage **[26]**.

- Catalase (CAT) activity (units/mg protein) assayed according to the methodology of Jiang and Zhang **[27]**.

-The percentages of nitrogen were estimated according to Pregle **[28]**, phosphorous by Luatanab and Olswn **[29]** and potassium by Jackson **[30]**.

2.4. Statistical analysis:

The data were analyzed using analysis of variance (ANOVA) based in a completely randomized design in a factorial experiment in accordance with the methodology outlined by Gomez and Gomez **[31]**. The analysis was performed with the aid of "MSTAT-C" software package MSTAT Development Team **[32]**, which enabled a rigorous evaluation of the data. To assess the significance of differences between treatment means, Duncan's multiple range test was employed at a 5% level of probability, as described by Duncan **[33]**.

3. Results:

3.1. The effect of ultraviolet radiation, salinity levels and their interaction on Vegetative growth parameters:

3.1.1. Plant height and stem diameter:

The data recorded in Table (1) showed that for the effect of UV radiation, there were increases in plant height and stem diameter across the expanding UV measurements. It can be noted that the seeds covered UV radiation for two hours accomplished plant height (56.46 1st and 59.17 2nd cm, respectively) in both seasons separately whereas stem diameter was (0.67 1st and 0.69 2nd cm, respectively) in both seasons individually.

Regarding the impact of salinity, the same data in Table (1) showed that plants irrigated with saline water were affected and increasing salinity levels graduated decrease in plant height and stem diameter. The lowest plant height was recorded at a salinity level of 4000 ppm (35.38 and 38.67 cm) and stem diameter was (0.53 and 0.49 cm) in the first and second seasons, respectively. The combined effect of UV treatment and salinity had a notable impact on both plant height and stem diameter. Seeds treatment with UV rays essentially moderated the unfavorable impacts of salinity on plant height. It can notice that treatments with UV for two hours led to alleviating stress irrigation with salty water at a concentration of 1000 ppm on plant height (60.0 cm in 1st and 2nd, respectively). .As for the treatment effect on the stem diameter due to salinity is almost eliminated at the concentration of 1000 ppm under two hours of UV was recorded (0.65 and 0.73 cm in 1st and 2nd, respectively).

Table (1): Effect of UV, salinity, and their interaction on plant height (cm) and stem diameter (cm) of *G. elegans* during the two.

UV (A) (hours)	Water salinity levels (ppm) (B)				
	Control (0)	1000	2000	4000	Mean A
Plant height (cm.)					
2021/2022 season					
Control (0)	57.67cd	45.17f	34.17h	27.33j	**41.08d**
1	57.00d	48.38e	35.83h	31.00i	**43.17c**
2	71.67a	60.00c	51.17e	43.00fg	**56.46a**
4	63.00b	58.83cd	41.67g	40.17g	**50.92b**
Mean B	**62.33a**	**53.21b**	**40.71c**	**35.38d**	
2022/2023 season					
Control (0)	62.00cd	55.67e	36.33k	29.00l	**45.75c**
1	63.00c	50.33g	39.00j	34.67k	**46.75c**
2	77.33a	60.00d	52.00fg	47.33h	**59.17a**
4	69.67b	53.33f	44.00i	43.67i	**52.67b**
Mean B	**68.00a**	**54.83b**	**42.83c**	**38.67d**	
Stem diameter (cm)					
2021/2022 season					
Control (0)	0.63e	0.59h	0.49k	0.45m	**0.54c**
1	0.67c	0.60gh	0.50k	0.47l	**0.56c**
2	0.76a	0.65d	0.61fg	0.67cd	**0.67a**
4	0.70b	0.62ef	0.56i	0.52j	**0.60b**
Mean B	**0.69a**	**0.62b**	**0.54c**	**0.53d**	
2022/2023 season					
Control (0)	0.61de	0.58f	0.49ij	0.44k	**0.53d**
1	0.62de	0.60e	0.50i	0.48j	**0.55c**
2	0.77a	0.73b	0.63d	0.54g	**0.69a**
4	0.70c	0.60e	0.57f	0.52h	**0.60b**
Mean B	**0.67a**	**0.63b**	**0.55c**	**0.49d**	

Means shared within the same letter are not significantly different at the 0.05 probability level, according to Duncan's Multiple Range Test (Duncan, 1955).

3.1.2. Number of branches and leaves/plant:

The data presented in Table (2) show the effect of UV radiation, as there were increases in number of branches/plants with increasing UV doses. It can be detected that seeds exposed to UV radiation for 2 hours recorded the highest values among the UV radiation treatments for branch number (21.83 and 24.33 1st and 2nd, respectively). Treating the seeds with radiation for two hours led to an increase in number of leaves/plants by about 30% in the first season and 24% in the second season compared with control.

Regarding salinity, the number of branches/plant in the same Table (2), increasing salinity concentrations resulted in a gradual reduction in number of branches/plant from 22.83 to 12.92 in 1st and 25.29 to 14.50 in 2nd. While the number of leaves/plants irrigated with 4000 concentration saline water decreased by approximately 45% in the first and approximately 40% in the second one.

For interaction between UV radiation and salinity, treating seeds with UV radiation significantly mitigated the adverse impact of salinity on the number of branches/plant and leaf number/plant the most effective treatment was 2 hours of UV radiation without salinity (control) after that irrigated with 1000ppm for number of branches/plant and number of leaves/plant.

Table (2): Effect of UV, salinity, and their interaction on number of branches and leaves/plants of *G. elegans* during the two seasons.

UV (A) (hours)	Water salinity levels (ppm) (B)				
	Control (0)	1000	2000	4000	Mean A
Number of branches/plant					
2021/2022 season					
Control (0)	18.33d	17.00e	14.33gh	10.00j	**14.92d**
1	20.33c	18.33d	15.67f	11.67i	**16.50c**
2	29.67a	23.00b	18.67d	16.00ef	**21.83a**
4	23.00b	18.33d	15.33fg	14.00h	**17.67b**
Mean B	**22.83a**	**19.17b**	**16.00c**	**12.92d**	
2022/2023 season					
Control (0)	22.00d	19.00e	16.67gh	11.67i	**17.33d**
1	23.67c	21.67d	18.33ef	12.67i	**19.08c**
2	32.67a	25.33b	21.67d	17.67fg	**24.33a**
4	25.33b	21.33d	18.33ef	16.00h	**20.25b**
Mean B	**25.92a**	**21.83b**	**18.75c**	**14.50d**	
Number of leaves/plant					
2021/2022 season					
Control (0)	40.33ef	38.33g	29.00j	21.00l	**32.17d**
1	42.33d	40.00ef	31.67i	22.00l	**34.00c**
2	51.00a	45.67b	39.33fg	31.00i	**41.75a**
4	44.33c	41.00e	33.67h	24.67k	**35.92b**
Mean B	**44.50a**	**41.25b**	**33.42c**	**24.67d**	
2022/2023 season					
Control (0)	45.33de	43.33f	34.00i	26.00k	**37.17d**
1	47.33c	45.00de	36.67h	27.00jk	**39.00c**
2	56.00a	50.67b	44.33ef	36.00h	**46.75a**
4	49.33b	46.00cd	38.66g	28.00j	**40.50b**
Mean B	**49.50a**	**46.25b**	**37.42c**	**29.25d**	

Means shared within the same letter are not significantly different at the 0.05 probability level, according to Duncan's Multiple Range Test (Duncan, 1955).

3.1.3. Fresh and dry weight of leaves:

The average fresh and dry weights of the leaves in Table (3) indicate a significant increase due to the effect of exposure to UV rays for two hours, followed by the treatment for four hours. However, the heaviest fresh and dry weight of leaves was determined when irrigation with saline water with a gradual decrease as the concentration of the salt in the irrigation water increased. While the treatment with UV rays succeeded in eliminating the harmful effect of salinity at all levels.

Table (3): Effect of UV, salinity, and their interaction on fresh and dry weight (g) /leaves of *G. elegans* during the two seasons .

UV (A) (hours)	Water salinity levels (ppm) (B)				
	Control (0)	1000	2000	4000	Mean A
Fresh weight of leaves(g)					
2021/2022 season					
Control (0)	2.73d	2.08f	1.67g	0.84j	**1.83d**
1	2.82cd	2.13e	1.77g	1.00ij	**1.98c**
2	3.46a	2.93c	2.45e	1.45h	**2.57a**
4	3.17b	2.77cd	2.04f	1.13i	**2.26b**
Mean B	**3.03a**	**2.52b**	**1.98c**	**1.11d**	
2022/2023 season					
Control (0)	2.40ef	1.92h	1.51i	0.68l	**1.63d**
1	2.59cd	2.10g	1.61i	0.90k	**1.80c**
2	3.14a	2.72c	2.31f	1.15j	**2.33a**
4	2.93b	2.49de	1.90h	0.99jk	**2.08b**
Mean B	**2.76a**	**2.31b**	**1.83c**	**0.93d**	
Dry weight of leaves(g)					
2021/2022 season					
Control (0)	0.70d	0.59f	.043h	0.11k	**0.46d**
1	0.78b	0.61f	0.50g	0.13k	**0.50c**
2	0.87a	0.74c	0.65e	0.26i	**0.63a**
4	0.81b	0.65e	0.52g	0.17j	**0.54b**
Mean B	**0.79a**	**0.65b**	**0.52c**	**0.17d**	
2022/2023 season					
Control (0)	0.67e	0.57g	0.40i	0.11k	**0.44d**
1	0.74c	0.58g	0.48h	0.11k	**0.48c**
2	0.84a	0.71d	0.62f	0.23j	**0.60a**
4	0.78b	0.62f	0.47h	0.13k	**0.50b**
Mean B	**0.76a**	**0.62b**	**0.49c**	**0.14d**	

Means shared within the same letter are not significantly different at the 0.05 probability level, according to Duncan’s Multiple Range Test (Duncan, 1955).

3.2. Flower parameters:

3.2.1. Days from planting to flowering and number of flowers /plant:

Data exhibited in Table (4) shows that, for the period between planting and flowering; radiation treatment for two hours led to an early emergence of 14 days in the first season and 13 days in the second one. For number of flowers/plant data in Table (4) indicate a steady increase in number of flowers/plants, reaching the highest number 28.67 in 1st and 30.67 in 2nd, respectively for those seeds subjected to UV radiation for two hours, showing a minor significant difference in the second place for those plants that received radiation for four hours.

Furthermore, the rise in salinity concentration led to a noticeable delay in flowering, with flowering occurring at 117.17 days in the first season and 112.42 days in the second. The highest salinity concentration resulted in a reduction in the number of flowers /plant by approximately 41% in the first season, and 39% in the second. For interaction between UV radiation and salinity, the two-hours radiation conduct of the seeds that did not receive any amount of salt water resulted in flowering after 90 and 86 days in both seasons, respectively. Exposing the seeds to two and four hours of UV significantly increased number of flowers for plants that were not exposed to salinity or those that were exposed to different salinity levels, reaching the best treatment when exposed to radiation for two hours. The Exposure of the seeds to radiation for two hours improved the number of flowers at a salinity concentration of 1000 ppm.

Table (4): Effect of UV, salinity, and their interaction on number of days from planting to flowering and number of flowers/plant of *G. elegans* during the two seasons .

UV (A) (hours)	Water salinity levels (ppm) (B)				
	Control (0)	1000	2000	4000	Mean A
Number of days till flowering					
2021/2022 season					
Control (0)	104.33gh	111.33de	115.00c	125.33a	**114.00a**
1	102.00hi	106.67fg	114.67c	121.00b	**111.08b**
2	90.00k	97.67j	104.67gh	108.33f	**100.17d**
4	96.67j	100.67i	109.00ef	114.00cd	**105.08c**
Mean B	**98.25d**	**104.08c**	**110.83b**	**117.17a**	
2022/2023 season					
Control (0)	99.33fg	106.33de	110.00c	120.33a	**109.00a**
1	96.00hi	100.67f	108.67cd	115.00b	**105.08b**
2	86.00k	93.67ij	100.67f	104.33e	**96.17d**
4	92.67j	96.67gh	105.00e	110.00c	**101.08c**
Mean B	**93.50d**	**99.33c**	**106.08b**	**112.42a**	
Number of flowers/plants					
2021/2022 season					
Control (0)	25.00de	20.67g	17.67h	13.67i	**19.25d**
1	25.67d	22.67f	18.33h	14.67i	**20.33c**
2	35.33a	31.00bc	26.00d	22.33f	**28.67a**
4	32.00b	29.67c	23.67ef	18.67h	**26.00b**
Mean B	**29.50a**	**26.00b**	**21.42c**	**17.33d**	
2022/2023 season					
Control (0)	27.00de	23.00f	21.00g	15.00i	**21.50d**
1	28.33d	26.00e	21.00g	17.00h	**23.08c**
2	38.00a	33.00bc	27.67de	24.00f	**30.67a**
4	33.67b	32.00c	26.00e	21.00g	**27.17b**
Mean B	**31.75a**	**28.50b**	**23.92c**	**19.25d**	

Means shared within the same letter are not significantly different at the 0.05 probability level, according to Duncan's Multiple Range Test (Duncan, 1955).

3.2.2. Flower diameter (cm):

The data presented in Table (5) clearly exhibited that seeds treated with radiation were better at two and four hours in terms of their effect on the flower diameter. Increasing salinity levels resulted in a steady reduction in flower diameter and the treatment with UV rays for two or four hours reduced the deleterious effect of salinity on flower diameter.

Table (5): Effect of UV, salinity, and their interaction on flower diameter (cm) of *G. elegans* during the two seasons.

UV (A) (hours)	Water salinity levels (ppm) (B)				
	Control (0)	1000	2000	4000	Mean A
Flower diameter (cm)					
2021/2022 season					
Control (0)	1.50cd	1.47de	1.38g	1.17j	**1.38b**
1	1.52bc	1.43f	1.38g	1.21i	**1.38b**
2	1.61a	1.54b	1.45ef	1.27h	**1.47a**
4	1.60a	1.53bc	1.45ef	1.25h	**1.46a**
Mean B	**1.56a**	**1.49b**	**1.41c**	**1.22d**	
2022/2023 season					
Control (0)	1.53d	1.48e	1.41f	1.14i	**1.39c**
1	1.56c	1.48e	1.42f	1.25h	**1.43b**
2	1.68a	1.59b	1.50e	1.30g	**1.52a**
4	1.67a	1.58b	1.50e	1.30g	**1.51a**
Mean B	**1.62a**	**1.52b**	**1.46c**	**1.25d**	

Means shared within the same letter are not significantly different at the 0.05 probability level, according to Duncan's Multiple Range Test (Duncan, 1955).

3.3. Effect on chemical constituents:

3.3.1. Effect of total chlorophyll and carbohydrate content:

The data presented in Table (6) indicate that the treatment with UV radiation had a good effect on total chlorophyll (a and b) (mg/g fw) as well as total carbohydrate percentage in the leaves. The most effective treatment was achieved through two hours of UV radiation exposure. They decreased as salinity concentration in the irrigation water increased, reaching the lowest value at the highest salinity concentration (4000 ppm). Substantial differences were observed compared to the control. Ultraviolet radiation treatments for plants exposed to salinity had a significant effect in improving both total chlorophyll (a and b) and total carbohydrate.

Table (6): Effect of UV, salinity, and their interaction on total chlorophyll (a and b) (mg/g f.w.) and total carbohydrates (%d.w) of *G. elegans* during season (2022/2023)

UV (A) (hours)	Water salinity levels (ppm) (B)				
	Control (0)	1000	2000	4000	Mean A
Total chlorophyll (a+b) (mg/g f.w.)					
Control (0)	1.91g	1.88h	1.71j	1.57k	**1.77d**
1	1.97e	1.91g	1.81i	1.71j	**1.85c**
2	2.21a	2.19b	2.06d	1.95f	**2.10a**
4	2.09c	1.97e	1.89h	1.80i	**1.94b**
Mean B	**2.05a**	**1.99b**	**1.87c**	**1.76d**	
Total carbohydrates (%d.w)					
Control (0)	18.19cd	17.27fg	15.21l	13.97n	**16.16d**
1	18.33c	17.64e	15.62k	14.25m	**16.46c**
2	19.62a	18.08d	17.15g	16.37i	**17.81a**
4	18.99b	17.35f	16.89h	15.82j	**17.26b**
Mean B	**18.79a**	**17.59b**	**16.21c**	**15.10d**	

Means shared within the same letter are not significantly different at the 0.05 probability level, according to Duncan's Multiple Range Test (Duncan, 1955).

3.3.2. Effect of nitrogen, phosphorus and potassium content:

The data presented in Table (7), indicate that UV radiation treatment increased the percentages of nitrogen, phosphorus, and potassium, with the highest levels observed under the two-hour UV exposure. In the same Table (7), we can find that the irrigation with saline water led to a reduction of the nitrogen, potassium and phosphorus percentages, with the lowest levels recorded at the highest salinity concentration (4000 ppm). However, seeds treated with UV radiation showed a mitigating effect, reducing the negative impact of salinity on the absorption of these essential nutrients.

Table (7): Effect of UV, salinity, and their interaction on nitrogen, phosphorus and potassium content (%) of *G. elegans* during season (2022/2023)

UV (A) (hours)	Water salinity levels (ppm) (B)				
	Control (0)	1000	2000	4000	Mean A
Nitrogen (%)					
Control (0)	1.51g	1.31i	1.18j	0.88k	**1.22d**
1	1.57f	1.33i	1.34i	0.89k	**1.28c**
2	2.72a	2.48b	2.06d	1.80e	**1.27a**
4	2.37c	1.60f	1.43h	1.18j	**1.64b**
Mean B	**2.04a**	**1.68b**	**1.50c**	**1.19d**	
Potassium (%)					
Control (0)	1.38de	1.19g	0.95i	0.75k	**1.07d**
1	1.41d	1.21g	1.22g	0.83j	**1.17c**
2	1.7a	1.62b	1.48c	1.30f	**1.52a**
4	1.62b	1.48c	1.34ef	1.08h	**1.38b**
Mean B	**1.53a**	**1.38b**	**1.25c**	**1.00d**	
Phosphorus (%)					
Control (0)	0.69ef	0.66fg	0.51i	0.41j	**0.57d**
1	0.70def	0.7de1	0.51i	0.45j	**0.60c**
2	1.02a	0.85b	0.77c	0.70ef	**0.83a**
4	0.78c	0.74cd	0.62g	0.58h	**0.68b**
Mean B	**0.80a**	**0.74b**	**0.61c**	**0.53d**	

Means shared within the same letter are not significantly different at the 0.05 probability level, according to Duncan's Multiple Range Test (Duncan, 1955).

3.3.3. Effect of enzymes (MDA), catalase and proline content:

The analysis of the enzymes (MDA) and Catalase (CAT) in Table (8) showed that the enzyme analysis in the table showed that exposure to UV rays resulted in a significant increase and was highest when exposed to radiation for two hours in Catalase while decrease in MDA enzyme . However, there was a direct relationship between the salinity of the irrigation water and the rate of two enzymes. Thus, it can be concluded that salt stress led to an increase in oxidative enzymes. Although these enzymes are naturally active under natural conditions, salt stress significantly increased their activity, which may explain the reduced vegetative characteristics. However, a gradual decrease in MDA enzyme activity was observed in plants grown from seeds exposed to UV radiation, which coincided with a significant increase in the Catalase content.

Proline acts as a defense compound, helping plants to mitigate the adverse effects of salinity, by reading the data at the same Table (8), UV radiation contributed to further increasing proline accumulation in the plants. There was a clear direct relationship between increasing salinity concentrations in the irrigation water and the plant's proline content, which reached a maximum of (0.79 mg/100g d.w.). As for the interaction, the two and four hours effects were similar in increasing the proline content at salinity concentration of 4000ppm, where the treatment with UV radiation for two hours came in the first place, followed by four hours at a concentration of 4000 ppm.

Table (8): Effect of UV, salinity, and their interaction on MDA (nmol/g f.w.), Catalase (units/mg protein) enzymes and proline content (mg/g d.w)of *G. elegans* during the two seasons (2022/2023)

UV (A) (hours)	Water salinity levels (ppm) (B)				
	Control (0)	1000	2000	4000	Mean A
MDA enzyme(nmol/g f.w.)					
Control (0)	14.43fg	15.60c	17.40b	19.53a	**16.74a**
1	14.60ef	15.60c	17.50b	19.73h	**16.86a**
2	13.93h	13.07j	14.87de	15.13d	**14.25 b**
4	13.73h	12.93h	13.37i	14.27g	**13.76c**
Mean B	**14.18c**	**14.30c**	**15.78b**	**17.17a**	
Catalase enzyme(units/mg protein)					
Control (0)	12.30j	13.47i	15.47g	17.53e	**14.69d**
1	13.43i	14.53h	16.73f	18.67d	**15.84c**
2	13.50i	15.53g	18.73d	20.37c	**17.03b**
4	13.57i	17.53e	21.40b	24.37a	**19.22a**
Mean B	**13.20d**	**15.27c**	**18.08b**	**20.23a**	
Proline content (mg/g d.w)					
Control (0)	0.45jk	0.47ij	0.56g	0.73d	**0.55d**
1	0.46jk	0.48i	0.61f	0.76c	**0.57c**
2	0.46k	0.56g	0.73d	0.86a	**0.65a**
4	0.46k	0.51h	0.70e	0.81b	**0.62b**
Mean B	**0.45d**	**0.51c**	**0.65b**	**0.79a**	

Means shared within the same letter are not significantly different at the 0.05 probability level, according to Duncan's Multiple Range Test (Duncan, 1955).

4. Discussion

Experimental findings revealed that *Gypsophila aucheri* exhibits tolerance to drought and salinity levels up to 100 mM NaCl, effectively managing oxidative stress through its antioxidant defense system. However, exposure to 300 mM of NaCl had significant adverse effects on plant growth and compromised membrane integrity. At this elevated concentration, even though the activities of antioxidant enzymes such as SOD, POX, and APX increased, the plant was unable to fully counteract oxidative stress. These results indicate that *G. aucheri*, a xerophytic species, functions as a moderate halophytic plant, relying on a robust antioxidant system to cope with saline conditions **[34]**. Salinity in the growing medium can influence seed germination by reducing the ease with which seeds absorb water, causing delay or slower progression of the typical processes associated with germination. Salinity caused by NaCl may impair germination by increasing the absorption of toxic ions, which can interfere with vital enzymatic and hormonal processes within the seed **[35]**. Such physicochemical disruptions generally result in slower or diminished germination.

Arshi et al. **[36]** investigated the effects of different NaCl concentrations (0, 40, 80, 120, and 160 mM) on senna plants and found that increasing salinity levels significantly reduced total chlorophyll contents, while proline accumulation in the leaves increased markedly. Supporting these observations, Koskal et al. **[37]** reported comparable outcomes in their study on Freesia hybrids (Obren, Athena, and Cordula varieties) grown in a soilless system. They examined the influence of varying saline irrigation levels on flowering characteristics and flower quality under Mediterranean greenhouse conditions. Barsoom et al. **[7]**, in their study on *Iris tingitana* cv. Wedgewood subjected to varying salinity levels (0, 1000, 2000, and 4000 ppm), observed a gradual decline on vegetative growing parameters such as plant height, number of leaves/plant, inflorescence count, stem length and stem diameter—as salinity levels increased. Similarly, Jaleel et al. **[38]** , reported that increased salinity levels negatively affected all measured plant parameters of *Catharanthus roseus*. These included vegetative growth height, rooting traits (such as root length and both fresh and dry root weights), and reproductive traits (including number of flowers and branches per plant), all of which showed noticeable reductions with higher salinity levels. Raghda'a et al. **[39]** found that irrigating Calendula seed hybrid Costa Yellow with saline water resulted decreases in several vegetative growth traits, such as leaf area, chlorophyll content, and dry matter percentage of leaf, as well as in most floral growth traits. El-Shawa et al. **[40]** demonstrated that Calendula exposes to salt stress exhibited the significant decline in both vegetative and floral growth. Furthermore, key physiological and biochemical features such as photosynthetic pigment levels, relative water content (%RWC), and leaf mineral concentrations (% Mg, Ca, N, P, and K) were markedly reduced. In contrast, levels of sodium and proline in plant leaves were increased under salinity stress.

Experimental results indicate that *Gypsophila aucheri* demonstrates tolerance to drought and salinity levels up to 100 mM NaCl, effectively managing oxidative stress through its antioxidant defense mechanisms. However, exposure to 300 mM NaCl caused substantial negative effects on both plant growth and membrane integrity. At the higher salinity level, although antioxidant enzyme activity increased, it was insufficient to fully counteract oxidative stress. These findings suggest that G. aucheri, a xerophytic species, exhibits moderate halophytic characteristics and relies on a strong antioxidant system to adapt to saline environments **[34]**. ing et al. **[41]** reported that treatment with (100, 150, and 200 mM NaCl) led to elevated levels of malondialdehyde (MDA) and increased production of reactive oxygen species (ROS), resulting in compromised cell membrane integrity and impaired protein function. Consistent with these findings, the present study also observed a rise in MDA levels with increasing salinity, indicating enhanced oxidative stress. Those results are in agreement with those of Hnilicková et al. **[42]** , who documented a similar increase of MDA concentration in *Portulaca oleracea* L. under elevated salinity levels in irrigation water.

Similarly, Guzmán and Marques **[43]** examined the impact of salinity on three *Tagetes patula* species, focusing on the activity of antioxidant enzymes such as catalase (CAT). Their findings revealed a steady increase in antioxidant compound levels, with CAT activity rising proportionally in response to higher salinity concentrations. Seed and seedling priming with UV radiation has demonstrated a range of beneficial effects across various crop species. Positive responses have been documented in *Vigna mungo* and *V. aconitifolia* according to Dwivedi et al. **[44]**. Similarly, Vigna unguiculata as intended to Mishra et al. **[45]** and green bean (*Phaseolus vulgaris*) as mentioned to Aboul Fotouh et al. **[46]** also showed favorable outcomes following UV treatment.

Although UV radiation is generally perceived as a stress factor in plants, exposure to low doses can trigger a beneficial priming effect. Numerous studies have demonstrated that, positive impact of low-level UV irradiation on plant growth and development **[47,48]**. UV-B radiation has been shown to enhance plant productivity by increasing stress tolerance, improving resistance to herbivores and pathogens, while enhancing the quality of agricultural products factors that are critical for food security **[48]**. The seed treatments with low levels of UV radiation have proven to be a safe and effective approach for increasing yield and inducing resistance to the various biotic stresses **[49]**.

Exposure to low doses of UV-B and UV-C triggers the activation of both enzymatic and non-enzymatic antioxidant defense mechanisms in plants, enabling them to cope with stress more effectively. This approach pre-conditioning plants with mild biotic or abiotic stimuli to enhance resilience against future stress is widely known as "priming" **[50,51]**. The use of UV radiation as a priming agent has attracted growing scientific interest, with numerous studies reporting encouraging outcomes **[52,53,54]**. This review explores UV-induced priming in seeds and seedlings of major agricultural crops, emphasizing the morphological, physiological, and biochemical adaptations that contribute to enhanced tolerance to abiotic stress.

5. Conclusion

From the previous results, treating seeds with ultraviolet radiation for two hours before planting eliminated the harmful effect of salinity at concentrations of 1000 and 2000 ppm on most vegetative and floral traits.

6. Conflict of interest

The authors declare that they have no conflict of interest.

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