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Effect of urea and potassium sulfate fertilization on some growth traits of *Myrtus communis* L. plants grown under salt stress

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Abstract

The work was done in the shade house covered in Saran cloth at the College of Agriculture, University of Basrah, during the agricultural seasons of 2022–2023, to study the effect of nitrogen and potassium treatments on myrtle plants growing under saline stress and their interaction. Urea was used as a nitrogen source at concentrations of (0, 50, 100) mg L-1, and potassium sulfate was used as a potassium source at concentrations of (0, 50, 100) mg L-1. As for saline water, drainage water was used at concentrations of (1, 3, 6) ds.m-1. The results showed what the three study factors did. When the salinity stress level was set to 6 ds.m-1, many of the traits of the plants did better, including their rate of growth, number of stems, leaf area, and percentage of dry matter in their vegetative mass, reaching (76.67 cm, 4.81 branches plant-1, 8.93 cm, 5960 cm2, 60.07 %) respectively. The salinity stress treatment at 1 ds.m-1 outperformed the relative water content % rate and protein ratio % (54.13%, 12.15%), respectively. Meanwhile, the urea treatment at 50 mg L-1 outperformed the rate of vegetative mass dry matter percentage, nitrogen percentage, and protein (58.34%, 1.86%, 11.66%), respectively. A 50 mg L-1 dose of potassium sulphate was used for the treatment outperformed the rate of relative water content, nitrogen, and protein (54.63%, 1.83%, 11.46%), respectively. The binary and tertiary interactions were significant.
Keywords: potassium sulfate, fertilization, *Myrtus communis L.*, plants growth

Introduction

There is a well-known plant called myrtle (*Myrtus communis* L.) ornamental and fragrant plant belonging to the Myrtaceae family, which includes about 100 genera and 3,000 species (Sumbule et al. 2021). The plant is described as a small shrub that grows throughout the Mediterranean region and often grows in moist, shady areas with abundant water and along riverbanks. Myrtle shrubs can grow up to two meters when the conditions are favourable, and they have many branches filled with leaves that contain glands with a beautiful, fragrant scent. It is an evergreen plant, and its leaves retain their lustre for long. The leaves also secrete antiseptic substances that purify the air and kill microorganisms. Many fragrant oils are extracted from the myrtle plant's leaves, flowers, fruits, and bark. Myrtle fruits are also of nutritional and medicinal value, as the drink extracted from their fruits shows high nutritional and medicinal value (Aydın and Özcan 2007). Myrtle flowers appear between May and August in the Mediterranean region, and they are considered sacred plants and a symbol of love and life due to their evergreen nature and the fragrance hidden in their leaves and flowers. It has been used in religious rituals and ancient celebrations to symbolize youth and beauty, and Myrtle has been used to decorate tombs (Kaya et al. 2020).

All irrigation water, especially recycled wastewater, contains a certain amount of salt due to surface runoff and groundwater. Every time a farmer irrigates the crops, As the amount of salt in the land rises, in addition to the salts in the irrigation water. Natural and industrial fertilizers also add salts to the soil. The two main sources of human-made salinity are irrigation water and fertilization (Agriculture and Natural Resources Department, 2021). The water crisis is complex and is expected to continue, with implications for the human, social, economic, security, and population movement. Iraq, like many other countries, is facing this crisis. Therefore, increasing irrigation water efficiency is the most effective measure to reduce water scarcity (Serraglio and Adaawen 2023). (Feizi et al. 2007) showed that irrigation water salinity with a concentration of (12,9,4) ds.m-1 increased soil salinity, and the use of saline irrigation water of (12,9) ds.m-1 led to an increase in the sodium content in the soil by 56% and 67%, respectively. They also found that the effects of irrigation water salinity on the soil's upper part were higher than the lower soil layer.

Foliar fertilization is a complementary method of adding nutrient solutions at appropriate concentrations by spraying them on the leaves at times that allow the plant to absorb the nutrients it needs for growth and development it gets in through the stomata or the cell walls and membranes, and to reduce obstacles the absorption of nutrients available in the soil (Jamal et al. 2007). Foliar fertilization is important to prevent nutrient deficiencies and overcome problems nutrients in the earth and how easy it is to get them, especially micro-elements. It can also avoid problems that hinder the delivery of mineral elements to the roots, as root feeding is related to the strength and nature of the soil and its physical properties (Bocharov 2007). Nitrogen is one of the significant nutritional elements. Although it is the most abundant in the air at 78%, it is rarely available in the soil for plant growth. Modern agriculture relies on adding large quantities of chemical fertilizers containing nitrogen. Excessive addition of chemical fertilizers can create economic and environmental problems (Sheoran et al. 2021). (Al-Delfi 2013) found a decrease in nitrogen, phosphorus, and potassium availability by 4.3, 1.2, and 2.40%, respectively, due to increasing irrigation water salinity from 1.5 to 8 ds.m-1. He attributed the decrease to reducing organic waste decomposition and chemical fertilizer and the dominance of calcium ions that is in the dirt. Because there was less nitrogen and phosphorus in the soil after irrigation, (Niste et al. 2014) found that with saline water led to competition between Na+ and Cl- ions with elements K+, NO3-, and Ca+2, and formation of a highly precipitated Ca-P compound. Potassium is one of the macronutrients that plants need in large quantities, and they cannot complete their life cycle without it. Potassium is in the plant in ionic form and is involved in forming organic compounds. The presence of potassium over the required level for the plant can disrupt many functions in the plant. Potassium is second only to nitrogen in importance for plants to grow and get stronger. Potassium activates more than 60 enzymes in the plant, and its function is to regulate enzymes. Potassium also increases the plant's tolerance to environmental stress (Johnson et al. 2022).

Material and methods

For the 2022–2023 growing season, the experiment was done in the shade under a Saran cloth from the Department of Horticulture and Landscape Engineering at the College of Agriculture, University of Basrah. The goal was to find out what effect foliar fertilisation had on plants using nitrogen and potassium on some vegetative characteristics of myrtle (Elyas) plants (*Myrtus communism* L.) grown under salt stress. The plants came from one of the farms in Basra and were put into plastic pots that were 24 cm in diameter, 22 cm high, and could hold 7 kg. The pots were then filled with a growth medium that was made up of equal parts sand and peat moss. As a factorial experiment, the study used a full randomized block design (RCBD) to plan the test that included 27 factorial treatments (333) each treatment was done three times. This means that there are 81 trial units, and each one has three plants so the total number of plants is 243 (khashie Mahmoud and Aziz 2000). All measurements studied were taken on the experimental plants one month after the last spraying in addition to the following traits:

height Plant (cm); branches number (branch. plant-1); Leaf area (cm2)

(EASLON and BLOOM 2014) method was used to figure out the leaf area using the Image J programme. Six leaves for each treatment were placed on a scale in the scanner, and the data was entered into the computer. The readings were taken using the program's tools, representing leaf area. The leaf area (cm2) was then calculated according equation:

plant Leaf area (cm^2) = (leaves number × leaf area (cm^2)

Relative water content

The method outlined by (Barrs and Weatherley 1962) was used to find the relative water content. The leaves were cut into small pieces (fresh leaves), and the tissue was weighed initially (FW), then put in a closed Petri dish with pure water and left for three hours. The wet weight (TW) of the leaves was found, and then they were put in an oven set to 80 degrees Celsius until the dry weight (DW) was set. To figure out RWC, use the following equation:

RWC % = (FW – DW)/ (TW – DW) * 100

Percentage of dry matter of the total vegetative mass (%)

The following equation calculated the amount of dry matter as a share of the total mass of plants:

% of dry matter of the total vegetative mass = (DW / FW) * 100

nitrogen Percentage in the leaves

A certain weight of leaves was taken from the selected plants and then dried in an electric oven at 70 °C for 72 hours, or until the weight stayed the same. After that, it was ground up well, and the samples were broken down using the method described by (Cresser and Parsons 1979). After completing the digestion of the samples, the total nitrogen in the digested leaf samples was estimated using steam distillation (Kjeldahl) based on the method of (Page 1982).

Percentage of protein (%)

The following method was used to figure out the total proteins:

% Protein = nitrogen Percentage * 6.25 (Agroindustriais 2013).

Results

Height Plant (cm)

The three study factors and how they interacted with each other on the plant height trait are shown in Table 1. During the test season, the plants that were told to deal with 6 ds.m-1 of salt stress grew the tallest, reaching 76.67 cm, while the treatment with salt stress at 1 ds.m-1 showed a decrease in the plant height rate, reaching 68.84 cm. The table also showed the effect of the plants treated with urea on the plant height rate with the treatment of 100 mg. L-1 of urea gave the highest rate, reaching 74.93 cm, while a comparison treatment showed a decrease in plant height rate, reaching 69.55 cm. Spraying with potassium sulfate also significantly affected the plant height rate, with the treatment at 50 mg. L-1 gives a highest plant height, reaching 74.42 cm, compared to comparison plants, whose height rate reached 69.18 cm.

The two-way interaction between the salt stress and urea factors significantly affected the plant height trait. The plants were treated with salt stress at 6 ds.m-1 and urea at 100 mg. L-1 had a highest height, reaching a height of 80.04 cm, while the plants that were treated with salt stress at a concentration of 1 ds.m-1 and urea at 0 mg. L-1 had the shortest height of 63.99 cm. How the two-way relationship between the salt stress and potassium sulfate factors in this trait was also significant. The plants were treated with salt stress at 6 ds.m-1 with potassium sulfate at 50 mg. L-1 gave a highest height, reaching 79.60 cm, compared to lowest height of 66.07 cm for comparison plants. The two-way interaction between the urea treatment and spraying with potassium sulfate was significant in this trait. A 100 mg dose of urea was used for the treatment. 50 mg of potassium sulphate was added to L-1. The tallest plant was L-1, which measured 76.87 cm, while the shortest plant in the comparison group measured 65.95 cm. There was a three-way interaction between the three study factors. The plants were given urea at 100 mg and salt stress at a quantity of 6 ds.m-1. Amounts of L-1 and 50 mg of potassium sulphate. The plants from L-1 were different because they grew to be 85.29 cm tall, while the plants from the comparison group grew to be 58.33 cm tall.

Table 1. Effect of salt stress, urea, and potassium sulfate on plant height cm in Myrtle

Salt stress ds.m-1	Urea mg/L	Potassium sulfate mg/L			Interaction effect of urea and salt stress
		0	50	100	
1	0	58.33	64.59	69.05	63.99
	50	70.96	70.77	68.31	70.02
	100	68.92	73.76	74.85	72.51
3	0	72.44	76.07	69.94	72.82
	50	63.48	74.27	67.14	68.30
	100	68.88	71.55	76.29	72.24
6	0	67.07	74.21	74.22	71.83
	50	74.07	79.30	81.07	78.15
	100	78.48	85.29	76.35	80.04
L.S.D. 0.05	9.697				5.599
Interaction effect					Salt stress effect
Salt stress	Potassium sulfate				
	0		50	100	
1	66.07		69.71	70.74	68.84
3	68.27		73.96	71.13	71.12
6	73.21		79.60	77.21	76.67
L.S.D. 0.05	5.599				3.232
Interaction effect					
urea	Potassium sulfate				Urea effect
	0		50	100	
0	65.95		71.62	71.07	69.55
50	69.50		74.78	72.18	72.15
100	72.09		76.87	75.83	74.93
L.S.D. 0.05	5.599				3.232
Potassium sulfate effect	69.18		74.42	73.03	
L.S.D. 0.05	3.232				

Branches number (branches plant^{-1})

Table 2 shows the significant effect of three study factors and their interactions on the number of branch traits. A dose of 6 ds.m-1 of salt stress was put on the plants had the highest number of branches in the experimental season, reaching 4.81 branches plant-1, while the treatment with salt stress at 1 ds.m-1 showed a decrease in the number of branches rate, reaching 4.33 branches plant-1. The table also showed that giving the plants urea had a big impact on how fast they grew new shoots. The medicine is 100 mg. It reached 4.92 branches plant-1 when urea was used as the comparison treatment, while it only reached 3.77 branches plant-1 when used as the comparison treatment. Spraying with potassium sulphate had a big effect on the amount of branches as well.

There are 100 mg of the medicine in the body. The plants in L-1 gave the most branches (5.48 branches plant-1), while the plants in the comparison group only gave 3.14 branches plant-1.

The two-way interaction between the salt stress and urea factors significantly affected the number of branches trait. The plants were treated with salt stress at 6 ds.m-1 and urea at 100 mg. L-1 had a highest branches number, reaching 5.33 branches plant-1, The lowest rate was 3.33 stems plant-1 for plants that were stressed by salt at a concentration of 3 ds.m-1 and urea at 0 mg. L-1.

The result of the salt stress acting in two directions and potassium sulfate factors in this trait was also significant. The plants were treated with salt stress at 1 ds.m-1 potassium sulphate in a 100 mg dose. It took 5.66 branches plant-1 for L-1 to produce the most branches, while the comparison plants only produced 3.11 branches plant-1 . As for the two-way interaction between the urea treatment and spraying with potassium sulfate in this trait, the treatment with 100 mg of urea. L-1 in potassium sulphate at a level of 100 mg/L. While the reference plants had an average of 2.66 branches per plant, L-1 had 6.11 branches per plant, which was the most of any plant tested.

There was a three-way interaction between the three study factors. The plants were given urea at 50 mg and salt stress at a quantity of 3 ds.m-1. Amounts of L-1 and 50 mg of potassium sulphate. A-1 plants had the most branches, with 7.00 branches plant-1, while the comparison plants and plants treated with salt stress at a concentration of 3 ds.m-1 and urea at a concentration of 50 mg had the fewest branches, with 2.33 and 2.33, respectively. L-1 and potassium sulphate that is 0 mg strong. L-1, which didn't find an important change between them.

Table 2. Effect of salt stress, urea, and potassium sulfate on branches number (branches plant^{-1}) in Myrtle

Salt stress ds.m-1	Urea mg/L	Potassium sulfate mg/L			Interaction effect of urea and salt stress
		0	50	100	
1	0	2.33	3.33	4.66	3.44
	50	3.33	5.66	6.33	5.11
	100	3.66	3.66	6.00	4.44
3	0	2.66	3.66	6.00	3.33
	50	2.33	7.00	5.66	5.00
	100	3.33	5.00	6.66	5.00
6	0	3.00	5.66	5.00	4.55
	50	3.66	4.33	5.66	4.55
	100	4.00	6.33	5.66	5.33
L.S.D. 0.05	1.0079				0.5819
Interaction effect					Salt stress effect
Salt stress	Potassium sulfate				
	0		50	100	

1	3.11	4.22	5.66	4.33
3	2.77	5.22	5.33	4.44
6	3.55	5.44	5.44	4.81
L.S.D. 0.05	0.5819			0.3360
Interaction effect				
urea	Potassium sulfate			Urea effect
	0	50	100	
0	2.66	4.22	4.44	3.77
50	3.11	5.66	5.88	4.88
100	3.66	5.00	6.11	4.92
L.S.D. 0.05	0.5819			0.3360
Potassium sulfate effect	3.14	4.96	5.48	
L.S.D. 0.05	0.3360			

Leaf area (cm^2)

Table 3 shows the non-significant effect of the three study factors and the leaf size trait and how they interact with each other. No big differences were found between the three treatments, according to the data, as well as the interaction treatment between urea and potassium sulfate. But there were big differences between them in the interaction methods.

The two-way interaction between the salt stress and urea factors significantly affected the leaf area trait. The plants were treated with salt stress at 6 ds.m-1 and urea at 100 mg L-1 had a highest value, reaching 8702 cm2, compared lowest leaf area of 3948 cm2 for the plants that were given urea at a concentration of 0 mg. L-1 and salt stress at a concentration of 6 ds.m-1.

As for the two-way interaction between the salt stress and potassium sulfate factors in this trait, We put plants through salt stress at a level of 6 ds.m-1 and gave them 0 mg of potassium sulphate. The rate for L-1 was 7732 cm2, while the rate for plants treated with salt stress at 3 ds.m-1 and potassium sulphate at a concentration of 0 mg was 3690 cm2. L-1.

There was a three-way interaction between the three study factors. The plants were given urea at 100 mg and salt stress at a quantity of 6 ds.m-1. L-1 and potassium sulphate that is 0 mg strong. These plants had the highest rate of leaf area, which reached 12744 cm2, compared to those that were treated with salt stress at a concentration of 3 ds.m-1 and urea at a concentration of 0 mg. These plants had the lowest rate of leaf area, which was 2816 cm2. L-1 and 100 mg of potassium sulphate. L-1.

Table 3. Effect of salt stress, urea, and potassium sulfate on Leaf area (cm2) in Myrtle

Salt stress ds.m-1	Urea mg/L	Potassium sulfate mg/L			Interaction effect of urea and salt stress
		0	50	100	
1	0	2851	7300	7155	5769
	50	6383	6921	5737	6347
	100	4399	3376	7297	5024
3	0	3656	6411	2816	4294
	50	3696	6092	4359	4716
	100	3718	4090	4164	3991
6	0	4489	3216	4139	3948
	50	5964	4320	5405	5230
	100	12744	6096	7267	8702
L.S.D. 0.05	617.9				356.7

Interaction effect				Salt stress effect
Salt stress	Potassium sulfate			
	0	50	100	
1	4544	5866	6730	5713
3	3690	5531	3779	4333
6	7732	4544	5604	5960
L.S.D. 0.05	356.7			N.S

Interaction effect				
urea	Potassium sulfate			Urea effect
	0	50	100	
0	3665	5642	4703	4670
50	5348	5778	5167	5431
100	6954	4521	6243	5906
L.S.D. 0.05	N.S			N.S
Potassium sulfate effect	5322	5314	5371	
L.S.D. 0.05	N. S			

Relative water content (%)

Table 4 shows the significant effect three study factors and their interactions on trait of relative water content. The plants with salt stress at 1 ds.m-1 had the highest rate in the experimental season, reaching 54.13%, while the treatment with salt stress at 6 ds.m-1 showed a decrease in this trait, reaching 39.87%.

There was also a big change in the rate of relative water content in the plants that were treated with urea (100 mg/mL). This was shown in the figure. It was 55.69% for L-1, and it was 50 mg of urea for the treatment that gave the best rate. At 43.08%, L-1 showed a drop in the rate of relative water content.

The effect of spraying with potassium sulfate was also significant on the rate of relative water content, the treatment with 50 mg. L-1 gave a highest rate, reaching 54.63%, compared to the comparison plants, whose rate reached 45.89%.

The results of the two-way interaction between the salt stress and urea factors in the trait of relative water content showed plants were given urea at a dose of 100 mg and salt stress at a level of 6 ds.m-1. The rate for L-1 was 72.10%, while the rate for plants that were treated with salt stress at a concentration of 6 ds.m-1 and urea at a concentration of 50 mg was 32.60%. L-1.

The effect of interaction between the salt stress and potassium sulfate factors in this trait was also significant. The plants were treated with salt stress at 1 ds.m-1 when 50 mg of potassium sulphate is added. The best rate was 58.55% for L-1, while the worst rate was 26.77% for plants that were treated with salt stress at a concentration of 6 ds.m-1 and potassium sulphate at 0 mg. L-1. As for the two-way interaction between the urea treatment and spraying with potassium sulfate in this trait, the treatment with urea at a concentration of 100 mg. L-1 with potassium sulfate at a concentration of 50 mg. L-1 recorded the highest rate, reaching 60.66%, compared to the lowest rate of 40.70% for the plants treated with urea at a concentration of 50 mg. L-1 and potassium sulfate at a concentration of 0 mg. L-1.

Also important was the three-way relationship between the three study factors. The plants were given urea at a dose of 100 mg and salt stress at a level of 6 ds.m-1. Amounts of L-1 and 50 mg of potassium sulphate. The plants that were treated with salt stress at a concentration of 6 ds.m-1 and urea at a concentration of 50 mg had the lowest rate, which was only 24.15%. The plants that were treated with urea at a concentration of 50 mg had the highest rate, which was 84.83%. Amounts of L-1 and 50 mg of potassium sulphate. L-1.

Table 4. Effect of salt stress, urea, and potassium sulfate on Relative water content (%) in Myrtle

Salt stress ds.m-1	Urea mg/L	Potassium sulfate mg/L			Interaction effect of urea and salt stress
		0	50	100	
1	0	54.55	56.61	45.37	52.17
	50	58.41	71.35	50.47	60.08
	100	51.28	47.69	51.47	50.15
3	0	57.42	67.67	50.23	58.44
	50	55.84	56.43	57.44	56.57
	100	52.48	49.45	32.50	44.81
6	0	24.19	53.52	30.66	34.90
	50	27.85	24.15	25.80	32.60
	100	54.63	84.83	76.84	72.10
L.S.D. 0.05	3.008				1.737
Interaction effect					Salt stress effect
Salt stress	Potassium sulfate				
	0	50	100		
1	54.75	58.55	49.10		54.13
3	55.25	57.85	46.72		53.27
6	27.67	47.50	44.43		39.87
L.S.D. 0.05	1.737				1.003
Interaction effect					
urea	Potassium sulfate				Urea effect
	0	50	100		
0	44.16	59.26	42.08		48.50
50	40.70	43.98	44.57		43.08
100	52.80	60.66	53.60		55.69
L.S.D. 0.05	1.737				1.003
Potassium sulfate effect	45.89	54.63	46.75		
L.S.D. 0.05	1.003				

Dry matter percentage of vegetative part (%)

The three study factors and how they interacted with each other had a big impact on the percentage of dry matter in the plant part, as shown in Table 5. During the test season, the plants that were stressed with salt at a level of 6 ds.m-1 had the highest percentage rate, reaching 60.07%, while the treatment with salt stress at 3 ds.m-1 showed a decrease in the rate, reaching 50.72%.

The table also showed the effect of plants treated with urea on the vegetative part's percentage rate of dry matter. The treatment with urea at 50 mg. L-1 gave a highest rate, reaching 58.34%, while the treatment with urea at 100 mg. L-1 showed a decrease in a percentage rate of dry matter in vegetative part, reaching 51.03%.

The percentage rate of dry matter in the growing part changed significantly after potassium sulphate was sprayed on it. The amount used in the medicine is 0 mg. The plants treated with L-1 had a higher percentage of dry matter in the vegetative part (57.62%) than plants treated with 100 mg. L-1 showed that 52.31% of the dry matter in the plant part was made up of water.

The results of the two-way interaction between the salt stress and urea factors in the percentage of dry matter of the vegetative part showed that the plants treated with salt stress at a concentration of 6 ds.m-1 and urea at a concentration of 50 mg. L-1 had the highest percentage rate of dry matter of the vegetative part, reaching 67.57, compared to the lowest percentage rate of dry matter of the vegetative part of 47.72 for the plants treated with salt stress at a concentration of 3 ds.m-1 and urea at a concentration of 100 mg. L-1.

The effect of interaction between the salt stress and potassium sulfate factors in this trait gave plants treated with salt stress at 6 ds.m-1 with potassium sulfate at 50 mg. L-1 reached 64.12%, compared to the lowest rate of 48.93% for the plants treated with salt stress at 3 ds.m-1 with potassium sulfate at 50 mg. L-1. As for the two-way interaction between the urea treatment and spraying with potassium sulfate in this trait, the treatment with urea at 50 mg. L-1 with potassium sulfate at 50 mg. L-1 recorded the highest rate, reaching 65.71%, compared to the lowest percentage rate of dry matter of the vegetative part of 47.04%, which was for the plants treated with urea at 100 mg. L-1 and potassium sulfate at a concentration of 50 mg. L-1.

There was a three-way interaction between the three study factors. The plants were given urea at 50 mg and salt stress at a quantity of 6 ds.m-1. Amounts of L-1 and 50 mg of potassium sulphate. The plants that were treated with salt stress at a concentration of 3 ds.m-1 and urea at a concentration of 100 mg had the lowest percentage rate of dry matter in the vegetative part, at 43.34%. The plants that were treated with urea at a concentration of 100 mg had the highest percentage rate, at 85.79%. Amounts of L-1 and 50 mg of potassium sulphate. L-1.

Table 5. Effect of salt stress, urea, and potassium sulfate on dry matter percentage of the vegetative part (%) in Myrtle

Salt stress ds.m-1	Urea mg/L	Potassium sulfate mg/L			Interaction effect of urea and salt stress
		0	50	100	
1	0	66.33	51.58	52.10	56.67
	50	54.98	56.32	52.84	54.71
	100	50.76	53.30	54.40	52.83
3	0	56.53	48.46	50.19	51.72
	50	54.56	55.00	48.61	52.72
	100	47.04	43.34	52.77	47.72
6	0	71.41	62.07	46.72	60.07
	50	62.08	85.79	54.84	67.57
	100	54.84	44.49	58.34	52.56
L.S.D. 0.05	5.05				2.916
Interaction effect					Salt stress effect
Salt stress	Potassium sulfate				
	0	50	100		
1	57.36	53.73	53.11		54.73
3	52.71	48.93	50.52		50.72
6	62.78	64.12	53.30		60.07
L.S.D. 0.05	2.916				1.683
Interaction effect					
urea	Potassium sulfate				Urea effect
	0	50	100		
0	64.76	54.03	49.67		56.15
50	57.21	65.71	52.10		58.34
100	50.88	47.04	55.17		51.03
L.S.D. 0.05	2.916				1.683
Potassium sulfate effect	57.62	55.59	52.31		
L.S.D. 0.05	1.683				

Percentage of nitrogen (%)

Table 6 shows a significant effect of factors and their interactions on the percentage of nitrogen. The plants with salt stress at 1 ds.m-1 had the highest percentage, reaching 1.9%, while those treated with salt stress 3 ds.m-1 showed a decrease in percentage, reaching 1.54%.

The table also showed effect of a plants treated with urea on the percentage of nitrogen. The treatment with urea at 50 mg. L-1 gave ahighest rate, reaching 1.86%, while the treatment with urea at 100 mg. L-1 showed a decrease in the percentage rate of nitrogen, reaching 1.59%.

The effect of spraying with potassium sulfate was insignificant between the treatments in this trait.

The results of the two-way interaction between the salt stress and urea factors in the percentage of nitrogen were significant. The plants were treated with salt stress at 1 ds.m-1 and urea at 50 mg. L-1 had a highest percentage rate of nitrogen, reaching 2.48%, compared to the lowest percentage of nitrogen of 1.42% for a plants with salt stress at 3 ds.m-1 and urea at 50 mg. L-1.

The effect of interaction between salt stress and potassium sulfate factors in this trait was also significant. The plants were treated with salt stress at 1 ds.m-1 with potassium sulfate at 50 mg. L-1 The plants that were treated with salt stress at a concentration of 3 ds.m-1 and potassium sulphate at 0 mg had the lowest nitrogen rate, at 1.46%. The plants that were treated with potassium sulphate at 0 mg had the highest nitrogen rate, at 2.05%. L-1.

As for the two-way interaction between the urea treatment and spraying with potassium sulfate in this trait, the treatment with urea at 50 mg. L-1 with potassium sulfate at 100 mg. L-1 recorded the highest rate, reaching 2.12%, compared to lowest percentage rate of nitrogen, 1.36%, for the plants with urea at 100 mg. L-1 and potassium sulfate at 100 mg. L-1.

Also important was the three-way relationship between the three study factors. A salt load of 1 ds.m-1 and 50 mg of urea were put on the plants. L-1 and 100 mg of potassium sulphate. The plants that were treated with salt stress at a concentration of 6 ds.m-1 and urea at 100 mg had the lowest nitrogen rate, at 1.24%. The plants that were treated with L-1 had the highest nitrogen rate, at 3.29%. L-1 and 100 mg of potassium sulphate. L-1.

Table 6. Effect of salt stress, urea, and potassium sulfate on Percentage of nitrogen (%) in Myrtle

Salt stress ds.m-1	Urea mg/L	Potassium sulfate mg/L			Interaction effect of urea and salt stress
		0	50	100	
1	0	1.89	2.08	1.31	1.76
	50	1.81	2.34	3.29	2.48
	100	1.61	1.74	1.37	1.57
3	0	1.51	1.55	1.94	1.67
	50	1.43	1.54	1.29	1.42
	100	1.45	1.67	1.46	1.53
6	0	1.67	1.54	1.64	1.62
	50	1.46	1.82	1.78	1.68
	100	1.58	2.19	1.24	1.67
L.S.D. 0.05	0.4867				0.2810
Interaction effect					Salt stress effect
Salt stress	Potassium sulfate				
	0	50	100		
1	1.77	2.05	1.99		1.94

3	1.46	1.59	1.56	1.54
6	1.57	1.85	1.55	1.66
L.S.D. 0.05	0.2810			0.1622
Interaction effect				
urea	Potassium sulfate			Urea effect
	0	50	100	
0	1.69	1.72	1.63	1.68
50	1.57	1.90	2.12	1.86
100	1.55	1.86	1.36	1.59
L.S.D. 0.05	0.2810			0.1622
Potassium sulfate effect	1.60	1.83	1.70	
L.S.D. 0.05	0.1622			

Percentage of protein (%)

Table 7 shows the significant effect of factors and their interactions on the percentage of protein. The plants with salt stress at 1 ds.m-1 had the highest percentage rate in the experimental season, reaching 12.15%. In comparison, the plants with salt stress at 3 ds.m-1 showed a decrease in the percentage rate, reaching 9.63%.

The table also showed a significant effect of treated with urea on the percentage of protein. The treatment with urea at 50 mg. L-1 gave a highest rate, reaching 11.66%, while the treatment with urea at 100 mg. L-1 showed a decrease in the percentage rate of protein, reaching 9.96%.

It was also important to note that spraying with potassium sulphate had a big effect on the protein percentage. There are 50 mg of the medicine in the body. Compared to the control plants, which only gave 10.03% protein, L-1 plants gave 11.46% protein, the highest amount of protein any plant could give.

It was clear from Table 7 that the two-way interaction between salt stress and urea factors had a big impact on the protein percentage. A salt load of 1 ds.m-1 and 50 mg of urea were given to the plants. The plants that were treated with salt stress at a dose of 3 ds.m-1 and urea at 50 mg had the lowest percentage of protein, at 8.90%. The plants that were treated with L-1 had the highest percentage of protein, at 15.53%. L-1.

The effect of interaction between salt stress and potassium sulfate factors in this trait was also significant. The plants were treated with salt stress at 1 ds.m-1 with potassium sulfate at 50 mg. L-1 gave the highest percentage rate of protein, reaching 12.86%, compared to the lowest percentage of protein, reaching 9.15%, for the plants treated with salt stress at 3 ds.m-1 with potassium sulfate at 0 mg. L-1. The interaction between urea and spraying with potassium sulfate was also significant. The treatment with urea at 50 mg. L-1 with potassium sulfate at 100 mg. L-1 recorded the highest rate, reaching 13.28%, compared to the lowest percentage rate of protein, reaching 8.50%, for the plants treated with urea at 100 mg. L-1 and potassium sulfate at 100 mg. L-1.

As for interaction between factors, the plants were treated with salt stress at 1 ds.m-1 with urea at 50 mg. L-1 and potassium sulfate at 100 mg. L-1 had a highest percentage rate of protein, reaching 20.60, compared the lowest percentage rate, which was 7.75, for the plants treated with salt stress at 6 ds.m-1 with urea at 100 mg. L-1 and potassium sulfate at 100 mg. L-1.

Table 7. Effect of salt stress, urea, and potassium sulfate on Percentage of protein (%) in Myrtle

Salt stress ds.m-1	Urea mg/L	Potassium sulfate mg/L			Interaction effect of urea and salt stress
		0	50	100	
1	0	11.85	13.04	8.23	11.04
	50	11.35	14.63	20.60	15.53
	100	10.10	10.92	8.58	9.87
3	0	9.44	9.73	12.17	10.44
	50	8.94	9.67	8.08	8.90
	100	9.08	10.44	9.17	9.56
6	0	10.46	9.63	10.29	10.13
	50	9.15	11.38	11.15	10.56
	100	9.88	13.69	7.75	10.44
L.S.D. 0.05	3.042				1.756
Interaction effect					Salt stress effect
Salt stress	Potassium sulfate				
	0	50	100		
1	11.10	12.86	12.47		12.15
3	9.15	9.94	9.81		9.63
6	9.83	11.56	9.73		10.37
L.S.D. 0.05	1.756				1.014
Interaction effect					
urea	Potassium sulfate				Urea effect
	0	50	100		
0	10.58	10.80	10.23		10.54
50	9.81	11.89	13.28		11.66
100	9.69	11.68	8.50		9.96
L.S.D. 0.05	1.756				1.014
Potassium sulfate effect	10.03	11.46	10.67		
L.S.D. 0.05	1.014				

Discussion

As can be seen from Tables (1, 2, 3, 5, 6), At a concentration of 6 ds.m-1, the salt stress treatment had the best results for plant height, number of branches, leaf area, and dry matter % of the vegetative part. These results indicate the tolerance of Myrtle to high soil salinity levels, which gives a positive indication for its cultivation in private and public gardens and the median islands of the streets. These results are consistent with those of Sahou (2022) on mangrove plants, as increasing salinity led to increased plant height and leaf area.

As Tables (3, 6, 7) showed, salt stress did not affect the rate of the traits of the leaves' relative water content and the amounts of nitrogen and protein they contain, where the control treatment outperformed in these traits. This may be because high levels of salinity cause a decrease in nitrogen absorption, which occurs due to the osmotic effect on root growth, which affects the absorption of elements and the formation of amino acids and proteins (Papadopoulos and Rendig 1983). Tables 1 through 4 show how the urea treatment changed the plant's height, number of branches, leaf area, and relative water content. The 100 mg L-1 urea treatment had the most significant effect on these traits. This might be because nitrogen is an important element. It raises the level of plant hormones in the plant by helping to make amino acids, such as tryptophan. Tryptophan is an amino acid that starts the formation of auxins, which cause cells to divide more and get bigger (Al-Shaqs, 1989). The findings of (Al Taher, Hassan, and Hassan 2020) on the Paulownia plant are in line with this.

Figures 5–10 show that the urea treatment, at a level of 50 mg L–1, was better at increasing the amounts of dry matter in the plant's stems and leaves, as well as the amounts of nitrogen and protein in those parts. The reason could be that nitrogen helps the carnation plant make more important proteins by building up more nucleic acids (Mohammed and Al-Yunis 1991).

From Tables (1, 4, 7, 6), we can see that the 50 mg L-1 potassium sulphate treatment had the best results for plant height, relative water content, and the amount of nitrogen and protein in the leaves. In this case, potassium is one of the ways that plants can handle bad environmental conditions better. This is because plants absorb more potassium when they are stressed, which improves the balance of hormones (Shahid et al. 2019), which is in line with what (Abdullah, Sh Al-Jabir, and Shareef 2023) on the Indian almond plant. It can be seen in Tables 2 and 3 that the potassium sulphate treatment, which was 100 mg L-1, improved the rate of the traits of branch number and leaf area. This is because potassium is a key part of dividing the plant's living cells, which prompts the growth of meristematic tissue and makes the leaf thicker (Tavori et al. 2004). According to (Elias et al. 2013), this may also be because the plant needs enough potassium to grow, especially for cell division. Potassium also improves the work of plant hormones like auxins and gibberellins, which directly affect cell extension and elongation, which makes the leaf area bigger. This was shown in Tables 5, 7, and 8. The potassium sulphate treatment did not change the rate of the trait of the percentage of dry matter in the green part.

Conclusion

The study demonstrated that salinity stress, urea, and potassium sulfate can significantly influence plant growth and development. Salinity stress at 6 ds.m-1 promoted plant growth parameters, while stress at 1 ds.m-1 enhanced water retention and protein synthesis. Urea application at 50 mg L-1 improved plant biomass, nitrogen uptake, and protein content. Similarly, potassium sulfate at 50 mg L-1 enhanced water status, nitrogen assimilation, and protein accumulation. The observed binary and tertiary interactions highlight the complex interplay between these factors in regulating plant physiology. These findings suggest that judicious application of salinity stress, urea, and potassium sulfate can optimize plant growth and productivity under diverse environmental conditions.

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