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Original Article

Attenuation of negative effects of saltwater irrigation stress on the physiological-agronomic characteristics of maize through foliar application of selenium and proline

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Abstract

Irrigation with saline water significantly reduces maize cultivation and productivity worldwide. Therefore, it is essential to investigate sustainable approaches to mitigate diverse effects of irrigation with saline water on various physiological and agronomical characteristics of maize, such as foliar application of selenium and proline. Two experiments, consequently, were carried out in the experimental farm of the College of Sciences and Humanities, Shaqra University, Al-Quwayiyah Governorate, Kingdom of Saudi Arabia during the two successive autumn seasons of 2022 and 2023. Three saltwater irrigation treatments were separately applied using a randomized complete block design with a split-plot arrangement with three replications. In each one of these, three rates of selenium were distributed in the main plots, whereas three rates of proline were applied in the sub-plots. Selenium and proline applications, individually or combined, significantly reduced the effects of saltwater irrigation stress on physiological and agronomic traits of maize. Obviously, optimal results were achieved with selenium at 10 mg L^{-1} and proline at 10 mM, effectively mitigating the adverse effects of saltwater irrigation on the physiological and agronomic traits of maize. At a moderate salinity level of 2000 mg L^{-1} NaCl, the application of 5, and 10 mM proline improved grain yield per plant by 7.76 and 5.54 %, as well as 17.62 & 7.99%; grain yield per hectare by 7.18 and 7.72 %, along with 19.11 & 8.33 %; and stover yield per hectare by 8.56 and 6.87 %, as well as 16.38 and 9.05 %, in both seasons, respectively under the application of 5, and 10 mg L^{-1} selenium, respectively, as compared to severe salinity level of 3000 mg L^{-1} NaCl. This in turn showed that exogenous selenium and proline application, individually or combined, were effective strategies in mitigating the harmful effects of salinity on physiological and agronomic traits of maize.

Keywords: Grain yield, Maize, Proline, Saline irrigation stress, Selenium

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Introduction

Considerable consequences on the growth and other related grain yield traits had been observed from saltwater for irrigation stress, which is regarded as a major stressor (Abbaszadeh et al., 2011). Saltwater stress interferes with metabolic processes and results in an excess of reactive oxygen species and oxidative damage. In response, plants have developed adaptive strategies to mitigate this stress (Abdelaleem et al., 2019; Abdelsatar et al., 2021; Kaur et al., 2022; Hu et al., 2022; Abdelsatar et al., 2024).

Maize, a commonly grown cereal crop, is sensitive to salt stress, which can result in reduced growth, nutritional imbalance, and decreased productivity (Abdelaleem et al., 2019). Excessive use of saltwater irrigation was proved to both hamper maize growth and yield and have elicited adverse effects on the development of corn, photosynthetic pigments and the plant in total. Salty irrigation water and even hydrogen peroxide were noted to have adverse effects on the growth and yield of corn (Sheteiwy et al., 2022). Hence, it is essential to formulate more effective salinity mitigation strategies, aiming to enhance physiological and agronomic traits, particularly maize yield, in order to satisfy the needs of the continuously increasing global population.

Our hypothesis was formulated based on observations made by maize agronomy scientists, who noted that the use of exogenous applications of selenium and proline on maize plants adapted maize plants to be tolerant of diverse effects of saltwater irrigation stress (Hu et al., 2022). It had been proven that the most effective method to reduce the negative impact of salt stress on corn plants is to use selenium and proline foliar application on leaves (Abdelaleem et al., 2019).

Selenium has been reported as a micronutrient with antioxidant activity that plays an essential role and has been found to alleviate abiotic stresses in plants by boosting their antioxidant defense system. In this context, the use of selenium has been reported to increase the net photosynthetic rate and improve chlorophyll content, thus promoting plant growth and productivity under salinity stress (Jiang et al., 2017; Ashraf et al., 2018; Desoky et al., 2021; Naseem et al., 2023). Furthermore, the application of exogenous selenium has been found to enhance the salt tolerance of soybeans, improve physiological resistance to salinity stress, and positively influence the microbial community within the rhizosphere (Wang et al., 2023). In this investigation, the selenium concentration utilized (10 mg L^{-1}, or approximately 127 μM) is significantly higher than that reported in some studies, such as Jiang et al. (2017), which employed concentrations of up to 25 μM in hydroponic systems. This gap is narrowed by studies on foliar applications, such as Nawaz et al. (2016), which examined concentrations of up to 40 mg L^{-1} on drought-stressed maize, and Mrština et al. (2024), which applied up to 250 µg per pot for biofortification.

In a related context, Moukhtari et al. (2020) found that the addition of proline may improve plant growth under salinity stress as it helped in nutrient and water uptake and biological nitrogen fixation. Likewise, Shahid et al. (2022) investigated that 20 mM proline application rescued growth, yield, gas exchange, and salt-stressed tissues of peas, with better growth and protein contents in the round variety than in other varieties. Similarly, gradual increases were detected in the gas exchange traits, photosynthetic pigments, plant growth, and hence grain yield under salt irrigation stress when proline applications were made (El-Nwehy, 2022). Furthermore, proline significantly increased the activity of the antioxidant enzymes and mitigated oxidative damage (Urmi et al., 2023).

The available information concerning the potential of selenium and proline foliar applications for mitigating diverse effects of irrigation with saline water on various physiological and agronomical characteristics of maize is limited. Consequently, it was worthwhile to hypothesize the role of these nutrients in alleviating the negative effects of salinity irrigation stress on gas exchange attributes, photosynthetic pigments, plant growth, grain yield, and associated attributes of maize.

Material and Methods

Two field trials were conducted on Cv. Pio-3444 at the Experimental Farm of the College of Science and Humanities, Shaqra University, Al-Quwayiyah Governorate, during the autumn seasons of 2022 and 2023. The location of the experimental farm was at 819 m above sea level, 24º 22' E longitude, and 44º 46' N latitude in the center of Saudi Arabia's kingdom. This site recorded an average precipitation of 19 mm/day and an average relative humidity of 45.80-46.75% with an average temperature of 34.11°C during the day and 19.20°C at night over the experimental period. To identify the soil properties, samples of soil were taken prior to sowing and then prepared via air-drying, grinding, sieving, and maintaining for further analysis. The comprehensive analysis of physical and chemical parameters was conducted in the soil experiment according to the methods outlined by Jackson (1973), as detailed in Table 1. The experimental fields had loamy soil with pH values of 7.08 and 7.12. Additional, available nitrogen levels were 8.4 and 7.02 ppm, phosphorus levels were 2.41 and 2.52 ppm, and potassium levels were 47 and 56 ppm in both seasons, respectively (Table 1).

The previously planted crop was wheat in both seasons. Prior to planting, the grains were subjected to the prescribed fungicides to mitigate the potential adverse effects of soil diseases. Thinning was done on one plant per hill before 20 days after sowing, when the plant was 15 cm tall and in the 3-4 leaf stage. Nitrogen, phosphorus, and potassium fertilizers were applied as recommended doses. Phosphorus fertilizer in the form of calcium superphosphate, with 15.5% P_2O_5, was applied at 476 kg per hectare in one dose before planting during soil preparation. Potassium fertilizer in the form of potassium sulfate (48% K_2O) was applied at a rate of 119 kg per hectare concurrently with the application of phosphorus fertilizer. Nitrogen fertilizer was applied in the form of ammonium sulfate (20.6% N) at 1428 kg/ha in eight equal doses, starting seven days after planting and finishing before flowering.

Three adjacent trials representing three levels of saline irrigation (SI) were performed in a randomized complete block design using a split-plot scheme with three replications, leveling from mild (SI_1 = 1000 mg L^{-1} NaCl, T_1) to moderate (SI_2 = 2000 mg L^{-1} NaCl, T_2) to severe (SI_3 = 3000 mg L^{-1} NaCl, T_3). Selenium foliar application at three different levels, with no application, low application (5 mg L^{-1}), and high application (10 mg L^{-1}), in the form of sodium selenite (Na_2SeO_4) as the source of selenium, was assigned in the main plot. On the other hand, proline foliar application with concentrations of 0, 5, and 10 mM was allocated in sub-plots. Tested applications of selenium and proline were performed before and after a week of tasseling.

The plants were irrigated using a drip irrigation system consisting of three plastic tanks of 6,000 liters capacity each. Where, each level of saltwater irrigation level was irrigated from the respective tank for the treatment being investigated. Plastic tanks were filled with saline solutions of different concentrations representing the salt stress level investigated to simulate the salinity stress level of the soil, thereby accurately controlling the salinity concentration in irrigation water. The tank was properly marked according to the specific salt concentration for each treatment. The size of the subplot was 10.5 square meters (3.5 × 3 meters), consisting of 5 rows with a distance of 60 cm between rows and a distance of 30 cm between hills. This allowed optimum growth and management of the corn plant. Other conventional growing practices of maize cultivation, from planting to harvesting, were performed in accordance with the guidelines established by the Ministry of Environment, Water, and Agriculture of the Kingdom of Saudi Arabia.

On the 75th day after sowing, in order to simultaneously measure the gas exchange characteristics of the leaves, such as photosynthetic rate (μmol $CO_2/m^2/s$), stomatal conductance ($mol/m^2/s$), intracellular CO_2 concentration (μmol/mol), and transpiration rate (mmol $H_2O/m^2/s$), five plants were randomly selected. Valuable insights into the physiological functions of maize plants were detected from these measurements. Using a portable LI-6400XT photosynthesis system (Li-Cor Inc., 1998), the gas exchange characteristics of the third leaf on the upper part of each plant were measured between 9 AM and 11 AM on sunny days. To keep the optimal environmental conditions in the leaf chambers, the best management was achieved when using a battery. The estimation of the water use efficiency (WUE) was recorded by dividing the net photosynthesis rate (Pn) by the transpiration rate (TR).

Photosynthetic pigments, such as carotenoids (mg g^{-1} FW), chlorophyll a (mg g^{-1} FW), chlorophyll b (mg g^{-1} FW), and chlorophyll a + b (mg g^{-1} FW), concentrations (as mg g^{-1} fresh weight), were determined in fresh maize leaves at 75 days after sowing using spectrophotometrically analyzed following the recommended method of Moran (1982). From each plot of three replications, ten guarded plants were randomly chosen. At harvest, plant height (cm), fresh shoot weight/plant (g), dry shoot weight/plant (g), number of leaves/plant, and cob length (cm) were registered.

At the time of harvesting, randomly select 10 plants from each experimental plot and measure various variables such as kernel rows cob^{-1}, kernel number row^{-1}, kernels cob^{-1}, cob diameter (cm), cobs $plant^{-1}$, 100-grain weight (g) and grain yield/plant (g), grain yield (Mg ha^{-1}), and stover yield (Mg ha^{-1}). The final grain yield and stover yield per plot in Mg were obtained from 5 square meters of test area, and then converted to Mg per hectare.

Each sub-plot in a randomized complete block design with a split-plot arrangement with three replications was analyzed for leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and its related traits. The treatments were evaluated by comparing their mean differences using the least significant difference (L.S.D.$_{5\%}$), as per Gomez and Gomez (1984).

Table-1. Physicals and chemicals analyses of experimental farm at 30 cm depth of soil.

Seasons	Available nutrients (ppm)			pH	EC dS/m	Clay %	Silt %	Fine sand %	Texture
	N	P	K						
2022	8.4	2.41	47	7.08	1.15	25.24	33.62	41.14	Loam
2023	7.02	2.52	56	7.12	1.02	24.58	35.44	39.98	Loam

Results and Discussion

Analysis of variances

The greatest variations in leaf gas exchange traits (Table 2a), photosynthetic pigments (Table 2b), plant growth (Table 2c), grain yield (Table 2e), and their related traits (Table 2d) were observed due to the highest variations in saline irrigation levels, followed by proline and selenium foliar application in both seasons. It means that salinity levels had the highest impact on leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and their related traits with significant differences in both seasons. This in turn also verified that the use of proline and selenium as foliar nutrients could have a beneficial effect on gas exchange, photosynthetic pigments, and plant growth traits in terms of an effective role in reducing the negative effects of saltwater stress on maize plants. Exogenous selenium could improve the photosynthetic capacity, boost antioxidant enzyme activities, and help regulate Na+ homeostasis in maize, as per Jiang et al. (2017). Similarly, Thuc et al. (2021) noticed that the use of selenium at a concentration of 5 mg L^{-1} as a foliar application promoted drought resistance in sesame, increased the number of leaves, and enhanced plant biomass as well as the yield per plant. It has also been confirmed by Wang et al. (2023) that the exogenous use of selenium significantly improved salt tolerance in soybean plants through its promotion of physiological resistance to salt stress with an optimization of the rhizosphere microbial community structure and function. On the other hand, foliar application of silicon on maize leaves, according to Tobiasz-Salach et al. (2023), acted in the alleviation of the adverse salt effects on the soil to assure enhanced physiological performance, biochemical, and epigenetic for maize plants in its response against soil salt stress.

Moreover, the dual interactions of saline irrigation levels with selenium foliar application were found to have greater variations than with proline foliar application in leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and its related traits in both seasons. This showed that there was a significant interaction between saltwater irrigation concentrations and exogenous selenium application in improving leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and its related characteristics. Moreover, this confirmed that selenium application was considered more effective in improving leaf gas exchange, photosynthetic pigments, plant growth, grain yield, and related characteristics under saltwater stress conditions than proline, probably for its antioxidant properties (Ashraf et al., 2018). Conversely, water stress negatively affected the growth of corn leaves, photosynthetic pigments, and the overall growth of the plant, as highlighted by Anjorin (2020).

The variation in the two-way interaction between selenium and proline foliar applications was found to be greater than the three-way interaction between saltwater irrigation levels in terms of most leaf gas exchange characteristics, photosynthetic pigments, plant growth, grain yield, and related traits in both seasons. This meant that the optimization of selenium and proline application can be more promising for improving most of the leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and its related traits in plants under whatever the salinity levels. The application of selenium through leaves can substantially enhance the selenium concentration in wheat and corn grains as reported by Wang et al., 2017. However, it had been noticed that selenium concentration dropped in the grains of subsequent crops. Furthermore, the use of proline can accelerate plant growth under high salinity conditions by enhancing nutrient absorption, water usage, and biological nitrogen stability, according to research by Moukhtari et al. (2020). In the same positive trend, the application of silicon significantly improved photosynthesis in corn in saline-alkali soil, thereby enhancing growth and yield, according to a study by Xie et al. (2015). Similarly, the application of foliar sodium selenate significantly increased the selenium content in corn grains by 19.37 times and accumulation by 19.30 times, as shown by Deliboran (2023).

Table-2a. Mean squares of saline irrigation levels (SI), selenium (S), proline (P) foliar application and their interactions on maize gas exchange traits in both seasons.

S.O.V.	df	Net photosynthesis		Transpiration rate		Stomatal conductance		Water use efficiency		Intercellular CO_2	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
SI	2	161.6812**	234.3635**	4.3229**	7.6774**	0.0474**	0.0626**	1.2668**	0.3575**	5348.72**	10141.34**
Reps within SI	6	0.6571	1.0682	0.0059	0.0213	0.0004	0.0007	0.0282	0.0779	8.61	3.344
S	2	73.6338**	105.8490**	1.8277**	3.3557**	0.0212**	0.0281**	1.0156**	0.3873**	2505.02**	4553.48**
SI ×S	4	13.4189**	22.0482**	0.2682**	0.6160**	0.0041**	0.0062**	0.7841**	0.5431**	576.40**	934.60**
Pooled Error A	12	0.1109	0.3891	0.0017	0.0051	0.0001	0.0002	0.0093	0.0320	2.07	1.32
P	2	94.2180**	135.8702**	2.5271**	4.3488**	0.0276**	0.0374**	0.8664**	0.3673*	3168.15**	6140.52**
SI × P	4	7.2937**	12.9293**	0.1322**	0.3525**	0.0023**	0.0036**	0.7181**	0.5722**	341.06**	532.98**
S × P	4	3.1795**	5.6922**	0.0614**	0.1561**	0.0010**	0.0013**	0.4968**	0.4678**	142.30**	213.81**
SI × S × P	8	3.4627**	4.9584**	0.0718**	0.1569**	0.0009**	0.0010**	0.4876**	0.4099**	109.00**	213.33**
Pooled Error B	36	0.1356	0.2258	0.0015	0.0022	0.0001	0.0001	0.0222	0.0769	1.7718	1.6833

*, ** Significant at 0.05 and 0.01 probability level, respectively.

Table-2b. Mean squares of saline irrigation levels (SI), selenium (S), and proline (P) foliar application and their interactions on maize photosynthetic pigments traits in both seasons.

S.O.V.	df	Chlorophyll a		Chlorophyll b		Chlorophyll a+b		Carotenoid	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
SI	2	1.7352**	4.5138**	1.2183**	2.3035**	5.8612**	13.2646**	4.70**	3.54**
Reps within SI	6	0.0008	0.0078	0.0024	0.0069	0.0045	0.0290	0.04	0.046
S	2	0.7814**	2.0348**	0.5428**	0.9999**	2.6266**	5.8873**	2.03**	1.59**
SI ×S	4	0.1585**	0.4110**	0.1119**	0.1685**	0.5366**	1.1050**	0.38**	0.30**
Pooled Error A	12	0.0003	0.0036	0.0007	0.0017	0.0011	0.0095	0.01	0.01
P	2	1.0240**	2.7045**	0.7110**	1.3319**	3.4414**	7.8309**	2.79**	2.00**
SI × P	4	0.0954**	0.2424**	0.0716**	0.0934**	0.3313**	0.6338**	0.21**	0.18**
S × P	4	0.0365**	0.0898**	0.0294**	0.0393**	0.1312**	0.2469**	0.09**	0.06**
SI × S × P	8	0.0336**	0.0661**	0.0236**	0.0444**	0.1129**	0.2179**	0.11**	0.06**
Pooled Error B	36	0.0007	0.0020	0.0006	0.0011	0.0011	0.0051	0.0072	0.0057

*, ** Significant at 0.05 and 0.01 probability level, respectively.

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Table-2c. Mean squares of saline irrigation levels (SI), selenium (S), and proline (P) foliar application and their interactions on maize plant growth traits in both seasons.

S.O.V.	df	Plant height		Shoot FW/plant		Shoot DW/plant		No. of leaves/plant		Cob length	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
SI	2	9224.64**	12233.69**	12390.44**	16127.24**	812.89**	1432.30**	45.51**	58.34**	106.23**	202.74**
Reps within SI	6	418.68	535.19	457.55	536.39	28.24	52.97	1.87	2.29	2.62	4.398
S	2	4082.75**	5413.37**	5475.89**	7111.35**	357.08**	642.09**	20.43**	24.58**	46.86**	90.17**
SI ×S	4	772.97**	1487.44**	1175.37**	1884.19**	83.93**	162.21**	4.41**	5.61**	9.09**	18.78**
Pooled Error A	12	121.58	154.50	160.88	185.21	9.63	19.17	0.55	0.60	0.89	1.37
P	2	5466.43**	5983.75**	7183.01**	8578.26**	463.90**	721.15**	26.63**	29.73**	61.55**	99.55**
SI × P	4	407.86**	551.30**	695.25**	756.17**	48.80**	55.78**	2.71**	1.84**	5.03**	5.76**
S × P	4	163.75*	240.33**	246.39*	337.47**	18.63**	24.79*	1.04**	0.83*	1.90**	3.35**
SI × S × P	8	183.52**	212.28**	222.09**	310.96**	15.81**	23.49**	0.79**	0.69*	1.85**	2.76**
Pooled Error B	36	56.93	57.74	69.75	77.52	3.90	6.45	0.23	0.23	0.38	0.54

*, ** Significant at 0.05 and 0.01 probability level, respectively.

Table-2d. Mean squares of saline irrigation levels (SI), selenium (S), and proline (P) foliar application and their interactions on maize grain yield related traits in both seasons.

S.O.V.	df	Kernel rows/cob		Kernel number/row		Kernels/cob		Cob Diameter		Cobs /plant	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
SI	2	159.27**	171.37**	731.93**	943.24**	118367.37**	155625.34**	30.13**	42.19**	3.52**	3.56**
Reps within SI	6	2.05	4.83	10.52	17.34	2875.73	4934.16	0.42	0.80	0.08	0.087
S	2	62.23**	65.57**	326.13**	396.55**	54883.46**	65978.97**	11.13**	13.97**	1.57**	1.54**
SI ×S	4	11.32**	15.61**	64.80**	94.68**	14744.46**	16320.95**	2.95**	3.72**	0.24**	0.42**
Pooled Error A	12	0.50	1.31	3.31	5.72	1015.58	1487.88	0.11	0.24	0.02	0.04
P	2	85.46**	77.44**	435.34**	496.62**	70119.75**	80508.22**	14.30**	17.11**	2.12**	1.81**
SI × P	4	6.42**	5.85**	35.10**	37.51**	8444.22**	6407.30**	1.91**	1.68**	0.13**	0.17**
S × P	4	1.95**	2.05**	15.03**	15.12**	3322.23**	2702.47**	0.58**	0.62**	0.07**	0.07**
SI × S × P	8	2.27**	1.77**	15.80**	12.41**	3013.28**	2559.34**	0.67**	0.59**	0.07**	0.06**
Pooled Error B	36	0.23	0.45	1.41	2.26	389.79	612.22	0.06	0.10	0.01	0.01

*, ** Significant at 0.05 and 0.01 probability level, respectively.

Table-2e. Mean squares of saline irrigation levels (SI), selenium (S), and proline (P) foliar application and their interactions on maize grain yield in both seasons.

S.O.V.	df	100-grainweight		Grain yield plant^{-1}		Grain yield ha^{-1}		Stover yield ha^{-1}	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
SI	2	760.31**	1211.13**	14610.80**	29636.27**	4.3985**	8.8021**	11.6105**	16.3929**
Reps within SI	6	29.69	34.62	404.39	751.71	0.0382	0.0485	0.3241	0.3722
S	2	318.91**	508.08**	6444.27**	11817.61**	1.8192**	3.6424**	4.2660**	6.8027**
SI ×S	4	71.08**	140.65**	1472.80**	2900.03**	0.3011**	0.8613**	1.0843**	1.7903**
Pooled Error A	12	8.44	11.01	157.42	267.47	0.0091	0.0201	0.0871	0.1272
P	2	415.99**	519.48**	8521.02**	13533.24**	2.4631**	4.0329**	5.5270**	7.4778**
SI × P	4	42.43**	45.80**	884.98**	836.39**	0.1642**	0.2580**	0.7193**	0.5139**
S × P	4	13.12*	21.11**	292.12**	367.36**	0.0583**	0.1236**	0.1870**	0.2418**
SI × S × P	8	10.94**	16.74**	290.60**	295.23**	0.0692**	0.1180**	0.1633**	0.2679**
Pooled Error B	36	3.51	3.24	69.63	90.24	0.0057	0.0073	0.0368	0.0463

*, ** Significant at 0.05 and 0.01 probability level, respectively.

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Main Effects

1-Effect of saltwater irrigation levels

A negative effect was pronounced when sowing maize under saltwater irrigation stress on leaf gas exchange characteristics, photosynthetic pigments, plant growth, grain yield, and related characteristics, as shown in Table 3. In these diverse conditions, a significant decline was detected in gas exchange characteristics in leaves, photosynthetic pigments, plant growth, grain yield, and related characteristics. This indicated that maize plants may experience severe saltwater irrigation stress, which appeared in the characteristics of the plants. Similar results were presented by Lacerda et al. (2022) found that a negative effect on growth, and hence maize yield was observed when irrigating maize with high saltwater concentration, and also with hydrogen peroxide, which negatively affected both its growth and yield. Conversely, the negative effect was recorded when reducing transpiration rate and CO_2 absorption.

High saltwater irrigation levels significantly decreased gas exchange characteristics in leaves (Table 3a), as clearly in photosynthesis rates by 29.42 and 20.07 & 33.77 and 23.83%, transpiration rates by 26.35 and 17.10 & 34.50 and 23.91%, stomatal conductance by 32.33 and 22.69 & 33.83 and 24.06%, water use efficiency by 7.10 and 6.64 & 2.89 and 3.91%, and cellular CO_2 by 11.47 and 7.59 & 15.71 and 10.16% when compared to mild and moderate saltwater irrigation levels in 1st and 2nd seasons, respectively. This could be a consequence of the adverse consequences of salt at higher levels on plant physiological processes. The observed reduction of gas exchange characteristics could therefore be a function of the resultant increase in osmotic stresses on the plant cells, thereby facilitating a decline in the rate of photosynthesis and transpiration (Dekhil et al., 2020). Additional, the reduction in stomatal conductance and water use efficiency could further reflect inefficiency in the ability to control water intake and loss for the plants under such high salt concentration in irrigation water. Generally, the diverse effects from high saltwater irrigation levels tend to be detrimental, as they relate to the health and productivity of the plants (Abdallah et al., 2020).

High saltwater irrigation levels have diverse effects (Table 3b), resulting in decreased chlorophyll a by 26.50 and 17.88, 34.57 and 24.45%, chlorophyll b by 24.74 and 16.84, 35.13 and 24.27%, chlorophyll a + b by 25.67 and 17.39, 34.80 and 24.37%, and carotenoids by 34.61 and 23.96, 34.26 and 24.19% when compared to mild and moderate, respectively. This might be due to a high salt level in irrigation water that has osmotically stressed the plants, thereby causing them to produce less chlorophyll and carotenoids (Ashraf et al., 2018). On the other hand, such higher levels of concentration of salts disrupt the balance within the plant cells and result in further reductions of the pigment contents.

High saline irrigation levels significantly decreased plant growth traits (Table 3c), including plant height by 14.12 and 8.96 & 15.97 and 10.80%, fresh shoot weight by 13.15 and 8.53 & 15.57 and 10.51 %, dry shoot weight/plant by 12.31 and 8.06 & 16.10 and 10.63 %, the number of leaves/plant by 14.95 and 9.82 & 18.10 and 11.94 %, and cob length by 15.26 and 9.87 & 20.07 and 13.16 %, as compared to mild saline watered levels and moderate saline water stress in both seasons, respectively. It can be attributed to the high concentration of salt in the water that probably delayed the absorption of necessary nutrients in plant roots, causing poor growth and low yield. High levels of salt also led to stress in water for plants, which further restricts them from performing photosynthesis to produce a higher yield (Jiang et al., 2017). These results prove how high salinity has an adverse effect on plant development and crop yield altogether.

High salinity irrigation levels significantly reduced grain yield (Table 3e) and related characteristics (Table 3d) in both seasons, as clearly in kernel rows/cob by 19.70 and 12.31 & 24.17 and 15.71%, kernel number/row by 17.36 and 11.44 & 21.98 and 14.47%, kernels/cob by 14.91 and 10.10 & 19.71 and 12.90%, cob diameter by 18.27 and 11.55 & 25.45 and 15.81%, cobs/plant by 23.57 and 15.22 & 22.98 and 15.48%, 100-grain weight by 19.84 and 12.94 & 25.31 and 17.96%, grain yield per plant by 18.23 and 12.05 & 26.56 and 18.60%, total grain yield by 19.76 and 12.82 & 28.32 and 19.78%, and stover yield by 22.92 and 14.83 & 28.09 and 19.82% when compared with use of saltwater irrigation levels at mild and moderate stress, in respective order. This may be due to the higher salinity levels of irrigation waters, which could cause osmotic stress to plants, which eventually resulted in lower growth and yield parameters (Deliboran, 2023). A higher concentration of salt in irrigation water might interfere with nutrient uptake and the absorption of water, adding to the decline in overall performance of the plants. In this regard, Lacerda et al. (2022) found that saline water reduced the growth, transpiration, and stomatal conductance of maize but did not affect dry matter formation.

Effect of selenium foliar application

The use of foliar selenium at various levels ranging from zero to 5 to 10 mg/L had led to a gradual increase in the gas exchange traits of the leaf, as shown in Table 3a. In addition, the use of foliar selenium at 5 and 10 mg/L significantly improved the gas exchange traits of the leaf compared to no application at the same time. The application of selenium at 5 and 10 mg/l when compared to no application resulted in a significant increase in the leaf gas exchange characteristics during both seasons, with photosynthesis rates of 19.90 and 25.32 and 24.07 and 30.35%, transpiration rates of 16.42 and 21.04 and 24.24 and 30.71%, stomatal conductance of 22.02 and 28.63 and 24.04 and 30.29%, water use efficiency of 6.16 and 6.94 and 3.84 and 3.77%, and intracellular CO_2 of 2.6.70 and 9.30.70 and 11.62%, in respective order. This might be owing to selenium being proven to play a major role in the regulation of photosynthesis and other physiological processes. On applying selenium at their respective optimum concentrations, the enhancement of carbon dioxide absorption and utilization allowed plants to improve their net photosynthesis rates and overall gas exchange characteristics (Desoky et al., 2021). This evidences the importance of selenium application in respect of the improvement of plant growth and productivity under conditions of saltwater stress. Moreover, Ding et al. (2020) found that when upland rice was subjected to moderate arsenic moderate stress, selenium application significantly increased photosynthesis pigments traits. Similarly, Dekhil et al. (2020) reported that the application of 2.5 micromoles of selenium on corn leaves increased leaf dry mass, overall yield, and seed filling but decreased sodium concentration and the sodium/calcium ratio.

The use of selenium foliar application on leaves with concentrations of 5 and 10 mg/l significantly increased the photosynthetic pigment properties in both seasons compared to those not treated (Table 3b): chlorophyll a by 17.41 and 21.86 & 25.29 and 31.14%, chlorophyll b by 16.09 and 19.81 & 24.97 and 31.31%, chlorophyll a + b by 16.78 and 20.88 & 25.16 and 31.21%, and carotenoids by 23.93 and 30.75 & 24.53 and 30.83%, in respective order. This may be due to the role of selenium in enhancing chlorophyll synthesis and protecting the photosynthetic apparatus from oxidative damage (Ashraf et al., 2018). The significant improvement in photosynthetic pigments reflected that selenium foliar application can improve the general photosynthetic efficiency of plants, which may finally led to increase growth and productivity (Semida et al., 2021).

The application of 5 and 10 mg/liter selenium leaves in comparison to non-application led to a significant increase in plant growth characteristics in both seasons (Table 3c): plant height by 7.96 and 10.21 & 9.14 and 11.84%; shoot fresh weight/plant by 7.49 and 9.38 & 8.67 and 11.55%; shoot dry weight/plant by 6.91 and 8.70 & 9.14 and 12.06%; leaves/plants by 8.81 and 10.90 & 10.01and 13.40%, and the length of the cob by 8.69 and 11.16 & 11.72 and 15.58%, respectively. This could be owing to the fact that selenium improved growth and development in plants. This is supported by several findings indicating that selenium is a key player in numerous important physiological processes in plants, which include photosynthesis and nutrient uptake (Ding et al., 2020). Besides, it is regarded that selenium enhanced the plant's resistance to various saltwater stresses, which finally is reflected in its positive action on plant growth characteristics (Jiang et al., 2017). Overall, the application of selenium leaves at 5 and 10 mg/liter has been advantageous for plant growth and yield during both seasons.

In comparison with the non-application, the selenium foliar application of 5 and 10 mg/l significantly increased the grain yield (Table 3e) and its associated traits in both seasons (Table 3d), with kernel rows/cob increasing by 11.00 and 14.04 & 14.14 and 17.75%, kernel number/row by 10.10 and 13.06 & 13.21 and 16.64 %, kernels/cob by 8.91 and 11.11 & 11.63 and 14.66 %, cob diameter by 9.72 and 12.48 & 13.76 and 17.56 %, cobs/plant by 14.89 and 18.69 & 14.38 and 17.7 %, 100-grain weight by 11.60 and 14.71 & 15.75 and 19.91 %, grain yield/plant by 10.76 and 13.70 & 16.20 and 20.56 %, grain yield by 11.40 and 14.55 & 17.94 and 22.80%, stover yield by 13.01 and 16.22 & 17.85 and 22.59 %, respectively. It likely can be related to the application of selenium foliar, as improvement in various growth parameters of corn plants has been noted after its application. Similarly, in the earlier work conducted by Dekhil et al. (2020), where selenium concentrations were 2.5 μmol, there was an improvement in the dry weight of the maize leaf and stem, seed yield along with seed quantity. The application of 25-50 mg L^{-1} selenium foliar in the case of onions on alkaline soil improved growth characteristics and antioxidant capacity, photosynthetic efficiency according to Semida et al. (2021). In the same positive trend, Shao et al. (2022) carried out numerous studies that showed how the exogenous selenium greatly increased the selenium

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concentration and, hence, the productivity of the sweet corn seeds.

Effect of proline foliar application

The application of proline foliar, when applied at various levels from zero to 5 up to 10 mM, showed a gradual increase in leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and its related traits as demonstrated in Table 3. Furthermore, proline foliar application at 5 and 10 mM significantly improved leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and its related traits in both seasons compared to non-application. In this concern, Shahid et al. (2022) found that the application of proline at 20 mM increased gas exchange traits, growth, and yield in pea plants with cv. Round under salt stress.

Proline foliar application at 5 and 10 mM showed significant improvement in leaf gas exchange traits in both seasons (Table 3a). It increased the photosynthetic rate by 20.52 and 29.94 & 25.38 and 36.03%, transpiration rate by 17.55 and 25.94 & 25.41 and 36.71%, stomatal conductance by 23.79 and 33.98 & 26.64 and 36.63%, water use efficiency by 5.65 and 6.40 & 3.88 and 3.50%, and intercellular CO_2 by 7.02 and 9.62 & 9.79 and 13.97% over the control treatment, respectively. This might be due to the proline foliar application, enhancing the potential of better uptake of water and nutrients, leading to enhanced photosynthetic efficiency and a healthful state of the plant under irrigation with saline-water (Moukhtari et al., 2020). Additionally, this increase in both stomatal conductance and intercellular CO_2 implied that foliar application with proline might be beneficial regarding overall carbon assimilation inside the plant. These significant enhancements in leaf gas exchange traits appear to indicate that proline foliar can be one of the promising tools for the improvement of crop performance and productivity under saltwater stress conditions (Abdallah et al., 2020).

Application of proline foliar at 5 and 10 mM concentrations had significantly improved photosynthetic pigments traits in both seasons (Table 3b), namely, chlorophyll a by 18.47 and 26.13 & 27.35 and 37.87%, chlorophyll b by 17.04 and 23.70 & 26.56 and 38.14 %, chlorophyll a+b by 17.79 and 24.97 & 27.02 and 37.99 %, and carotenoids by 26.01 and 37.96 & 25.35 and 36.31 %, respectively, over non-application. This is likely due to proline playing a valuable role in plant growth and enhancement of photosynthetic efficiency (El-Nwehy, 2022). Besides, this may have promoted chlorophyll and carotenoid production, hence leading to the significant improvements of these traits when applied at desired concentrations. Overall, the results of the proline foliar application improved photosynthetic performance in plants across saltwater stress conditions.

The use of proline foliar treatments at 5 and 10 mM substantially promoted plant growth in both two seasons over saltwater stress conditions (Table 3c), in terms of plant height increasing by 8.46 and 12.22 & 8.10 and 12.91%, shoot fresh weight/plant by 7.87 and 11.12 & 8.41 and 13.08%, shoot dry weight/plant by 7.23 and 10.25 & 8.30 and 13.21%, the number of leaves/plant by 9.35 and 12.89 & 9.64 and 15.22%, and length of cob by 9.18 and 13.21 & 10.81 and 16.84%, over non-application, respectively. It may be so due to the role of proline in enhancing metabolic conditions within plants for efficient uptake of nutrients and thereby affecting all aspects of their growth and development. Likewise, an important contribution can also be its exogenous foliar application, which might enhance the plant's resistance against saltwater stress conditions and the resulting healthy and strong growth (El-Nwehy, 2022). In this context, overall improvement in the plant growth parameters in both seasons evidenced that proline foliar application can be used as an effective strategy for promoting plant growth and productivity.

In both seasons, proline foliar applied exogenously at 5 and 10 mM significantly improved grain yield (Table 3e) and its associated traits (Table 3d), such as kernel rows/cob, which increased by 11.89 and 17.09 & 12.64 and 20.24%; kernel number/row by 10.85 and 15.59 & 12.65 and 19.52%; kernels/cob by 9.48 and 12.94 & 10.93 and 16.95%; cob diameter by 10.27 and 14.59 & 12.40 and 20.38%; cobs/plant by 15.61 and 22.80 & 13.02 and 20.30%; 100-grain weight by 12.49 and 17.35 & 10.29 and 20.96%; grain yield/plant by 11.37 and 16.34 & 11.56 and 23.03%; grain yield by 12.03 and 17.63 & 12.55 and 25.04; and stover yield by 13.75 and 19.18 & 11.82 and 24.68%, respectively over non-application. These improved results in kernel/cob ratio, cob diameter, cobs/plant, 100-grain weight, grain yield/plant, grain yield, and stover yield suggest that exogenous application of proline foliar can improve overall crop productivity under saltwater-stressed conditions. Other similar works also reported an increase in the growth of quinoa seed, its yield, and nutritional value by the addition of compost and spraying proline or trehalose under salt stress

(Abdallah et al., 2020). In a similar manner, proline application was also found to improve soybean growth and thus grain yield under salinity stress conditions (Calzada et al., 2022).

Table-3a. The main effects of saline irrigation levels (SI), selenium (S), and proline (P) foliar application on maize gas exchange traits in both seasons.

Traits / Main effects	Net photosynthesis (μmol CO_2/m^2/s)		Transpiration rate (mmol H_2O/m^2/s)		Stomatal conductance (mol/m^2/s)		Water use efficiency (mmol CO_2/mol H_2O)		Intercellular CO_2 (μmol/mol)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Saline irrigation levels (mg L^{-1})										
SI_{1000}	16.52±1.22^{a}	17.30±1.87^{a}	3.02±0.25^{a}	3.07±0.25^{a}	0.26±0.05^{a}	0.28±0.06 a	5.46±0.06^{a}	5.63±0.22^{ab}	242.44±24.92^{a}	244.81±23.97^{a}
SI_{2000}	14.59±0.79b	15.04±1.80^{b}	2.69±0.23^{b}	2.64±0.20^{b}	0.22±0.05^{b}	0.25±0.05 b	5.44±0.18^{ab}	5.69±0.39^{a}	232.25±26.07^{b}	229.68±24.75^{b}
SI_{3000}	11.66±0.58^{c}	11.46±1.53^{c}	2.23±0.19^{c}	2.01±0.14^{c}	0.17±0.04^{c}	0.19±0.04 c	5.07±0.18^{c}	5.46±0.43^{abc}	214.62±26.91^{c}	206.34±25.2^{c}
LSD 0.05	0.20	0.37	0.02	0.04	0.0070	0.0085	0.06	0.11	0.85	0.68
Selenium foliar application (mg L^{-1})										
S_0	12.39±0.67^{c}	12.36±1.53^{c}	2.35±0.21^{c}	2.18±0.15^{c}	0.19±0.04^{c}	0.20±0.04^{c}	5.10±0.17^{c}	5.45±0.38^{abc}	218.83±26.64^{c}	212.26±25.12^{c}
S_5	14.85±0.91^{b}	15.33±1.79^{ab}	2.74±0.22^{b}	2.71±0.21^{b}	0.23±0.05^{ab}	0.25±0.05^{ab}	5.42±0.12^{ab}	5.66±0.36^{a}	233.50±25.78^{b}	231.63±24.40^{b}
S_{10}	15.52±1.01^{a}	16.11±1.82^{a}	2.85±0.24^{a}	2.85±0.22^{a}	0.24±0.05^{a}	0.26±0.05^{a}	5.46±0.13^{a}	5.66±0.31^{a}	236.99±25.47^{a}	236.93±24.40^{a}
LSD 0.05	0.20	0.37	0.02	0.04	0.0070	0.0085	0.06	0.11	0.85	0.68
Proline foliar application (mM)										
P_0	12.20±0.58^{c}	12.12±1.55^{c}	2.31±0.20^{c}	2.13±0.16^{c}	0.18±0.04^{c}	0.20±0.04^{c}	5.12±0.19^{c}	5.46±0.38^{abc}	217.70±26.77^{c}	210.29±25.00^{c}
P_5	14.71±0.88^{b}	15.20±1.79^{b}	2.72±0.22^{b}	2.68±0.20^{b}	0.23±0.05^{b}	0.25±0.05^{b}	5.41±0.13^{ab}	5.67±0.37^{a}	232.98±25.88^{b}	230.88±24.80^{b}
P_{10}	15.85±1.13^{a}	16.49±1.80^{a}	2.91±0.25^{a}	2.92±0.23^{a}	0.25±0.05^{a}	0.27±0.05^{a}	5.45±0.11^{a}	5.65±0.29^{ab}	238.64±25.24^{a}	239.67±24.12^{a}
LSD 0.05	0.20	0.26	0.02	0.03	0.0043	0.0053	0.08	0.15	0.73	0.72

†Different letters indicate significant differences at $p<0.05$.
‡The data of three replicates ± SD (standard deviation) are shown.

Table-3b. The main effects of saline irrigation levels (SI), selenium (S), and proline (P) foliar application on maize photosynthetic pigments traits in both seasons.

Traits / Main effects	Chlorophyll a (mg g^{-1} FW)		Chlorophyll b (mg g^{-1} FW)		Chlorophyll a+b (mg g^{-1} FW)		Carotenoid (mg g^{-1} FW)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Saline irrigation levels (mg L^{-1})								
SI_{1000}	1.90±0.07^{a}	2.35±0.21^{a}	1.70±0.15^{a}	1.65±0.15^{a}	3.60±0.08^{a}	4.00±0.36^{a}	2.40±0.52^{a}	2.10±0.49^{a}
SI_{2000}	1.70±0.08^{b}	2.03±0.18^{b}	1.54±0.13^{b}	1.42±0.12^{b}	3.24±0.05^{b}	3.45±0.31^{b}	2.06±0.43^{b}	1.82±0.44^{b}
SI_{3000}	1.40±0.09^{c}	1.54±0.14^{c}	1.28±0.11^{c}	1.07±0.09^{c}	2.68±0.04^{c}	2.61±0.23^{c}	1.57±0.34^{c}	1.38±0.32^{c}
LSD 0.05	0.0101	0.0355	0.0161	0.0241	0.0193	0.0578	0.0658	0.0713
Selenium foliar application (mg L^{-1})								
S_0	1.47±0.08^{c}	1.66±0.15^{c}	1.35±0.11^{c}	1.16±0.10^{c}	2.82±0.04^{c}	2.82±0.25^{c}	1.70±0.37^{c}	1.49±0.35^{c}
S_5	1.73±0.08^{b}	2.08±0.19^{ab}	1.56±0.14^{b}	1.45±0.13^{b}	3.29±0.06^{b}	3.53±0.31^{ab}	2.11±0.45^{ab}	1.85±0.44^{ab}
S_{10}	1.79±0.08^{a}	2.18±0.2^{a}	1.61±0.14^{a}	1.53±0.14^{a}	3.41±0.07^{a}	3.70±0.34^{a}	2.22±0.48^{a}	1.95±0.46^{a}
LSD 0.05	0.0101	0.0355	0.0161	0.0241	0.0193	0.0578	0.0658	0.0713
Proline foliar application (mM)								
P_0	1.45±0.09^{c}	1.62±0.14^{c}	1.33±0.11^{c}	1.14±0.09^{c}	2.78±0.03^{c}	2.75±0.24^{c}	1.66±0.36^{c}	1.46±0.35^{c}
P_5	1.72±0.08^{b}	2.06±0.19^{b}	1.55±0.13^{b}	1.44±0.13^{b}	3.27±0.06^{b}	3.50±0.31^{b}	2.09±0.44^{b}	1.83±0.43^{b}
P_{10}	1.83±0.07^{a}	2.23±0.20^{a}	1.64±0.14^{a}	1.57±0.14^{a}	3.47±0.08^{a}	3.80±0.34^{a}	2.28±0.49^{a}	1.99±0.47^{a}
LSD 0.05	0.0143	0.0249	0.0137	0.0182	0.0185	0.0395	0.0469	0.0418

†Different letters indicate significant differences at $p<0.05$.
‡The data of three replicates ± SD (standard deviation) are shown.

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Table-3c. The main Effects of saline irrigation levels (SI), selenium (S), and proline (P) foliar application on maize plant growth traits in both seasons.

Traits / Main effects	Plant height (cm)		Shoot FW/plant (g)		Shoot DW/plant (g)		No. of leaves/plant (No)		Cob length (cm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Saline irrigation levels (mg L^{-1})										
SI_{1000}	260.17±27.49^{a}	263.30±28.34^{a}	322.86±34.42^{a}	310.14±37.28^{a}	88.23±10.02^{a}	89.61±10.32^{a}	17.20±1.68^{a}	16.11±1.55^{a}	25.79±2.76^{a}	27.11±3.09^{a}
SI_{2000}	245.43±20.5^{ab}	248.05±20.8^{ab}	306.54±27.85^{ab}	292.59±32.18^{ab}	84.15±8.45^{ab}	84.13±8.12^{ab}	16.22±1.24^{ab}	14.98±1.11^{ab}	24.25±2.31^{ab}	24.95±2.48^{b}
SI_{3000}	223.44±11.03^{c}	221.25±9.85^{c}	280.39±17.23^{c}	261.85±21.03^{c}	77.37±5.79^{c}	75.18±4.52^{c}	14.63±0.59^{c}	13.19±0.49^{c}	21.85±1.46^{c}	21.67±1.48^{c}
LSD 0.05	6.54	7.37	7.52	8.07	1.84	2.60	0.44	0.46	0.56	0.69
Selenium foliar application (mg L^{-1})										
S_0	229.13±13.54^{bc}	228.24±12.92^{bc}	287.12±19.67^{bc}	270.00±23.69^{c}	79.13±6.52^{bc}	77.50±5.38^{bc}	15.03±0.76^{c}	13.69±0.64^{bc}	22.48±1.68^{c}	22.53±1.72^{c}
S_5	247.38±21.51^{ab}	249.11±21.61^{ab}	308.62±28.82^{ab}	293.41±31.87^{ab}	84.60±8.59^{ab}	84.58±8.37^{ab}	16.36±1.32^{ab}	15.06±1.12^{ab}	24.43±2.34^{ab}	25.17±2.54^{ab}
S_{10}	252.53±23.92^{a}	255.26±24.35^{a}	314.05±30.98^{a}	301.17±34.44^{a}	86.02±9.14^{a}	86.84±9.19^{a}	16.67±1.42^{a}	15.53±1.32^{a}	24.99±2.52^{a}	26.03±2.75^{a}
LSD 0.05	6.54	7.37	7.52	8.07	1.84	2.60	0.44	0.46	0.56	0.69
Proline foliar application (mM)										
P_0	227.35±12.84^{c}	228.22±12.77^{c}	285.20±19.30^{c}	268.93±23.72^{c}	78.66±6.29^{c}	77.42±5.39^{c}	14.91±0.73^{c}	13.63±0.61^{c}	22.30±1.64^{c}	22.50±1.74^{c}
P_5	246.57±21.01^{ab}	246.70±20.56^{ab}	307.66±28.02^{ab}	291.54±31.05^{ab}	84.35±8.49^{ab}	83.85±7.99^{ab}	16.31±1.28^{ab}	14.94±1.09^{ab}	24.35±2.32^{ab}	24.93±2.46^{b}
P_{10}	255.13±25.13^{a}	257.68±25.62^{a}	316.93±32.17^{a}	304.11±35.4^{a}	86.73±9.47^{a}	87.65±9.57^{a}	16.84±1.50^{a}	15.70±1.40^{a}	25.25±2.58^{a}	26.29±2.83^{a}
LSD 0.05	4.16	4.19	4.61	4.86	1.09	1.40	0.27	0.27	0.34	0.41

†Different letters indicate significant differences at $p<0.05$.
‡The data of three replicates ± SD (standard deviation) are shown.

Table-3d. The main Effects of saline irrigation levels (SI), selenium (S), and proline (P) foliar application on maize yield related traits in both seasons.

Traits / Main effects	Kernel rows cob^{-1} (No)		Kernel number row^{-1} (No)		Kernels cob^{-1} (No)		Cob Diameter (cm)		Cobs $plant^{-1}$ (No)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Saline irrigation levels (mg L^{-1})										
SI_{1000}	24.58±1.70^{a}	20.74±3.75^{a}	59.45±4.67^{a}	53.43±9.04^{a}	876.82±75.20^{a}	764.85±128.95^{a}	11.51±0.87^{a}	9.81±1.43^{a}	3.05±0.47^{a}	3.13±0.55^{a}
SI_{2000}	22.51±1.19^{b}	18.66±3.08^{b}	55.47±3.72^{b}	48.74±7.71^{b}	829.92±60.38^{ab}	705.01±107.53^{ab}	10.64±0.67^{b}	8.68±1.11^{b}	2.75±0.39^{b}	2.85±0.5^{ab}
SI_{3000}	19.73±0.55^{c}	15.73±2.00^{c}	49.13±2.07^{c}	41.69±5.68^{c}	746.12±32.60^{c}	614.08±73.01^{c}	9.41±0.38^{c}	7.31±0.71^{c}	2.33±0.28^{c}	2.41±0.38^{c}
LSD 0.05	0.42	0.68	1.08	1.42	18.90	22.87	0.19	0.29	0.09	0.11
Selenium foliar application (mg L^{-1})										
S_0	20.56±0.75^{c}	16.61±2.32^{c}	50.76±2.53^{c}	43.61±6.21^{c}	766.47±39.98^{c}	638.67±82.78^{c}	9.79±0.47^{c}	7.79±0.85^{c}	2.44±0.30^{c}	2.53±0.41^{c}
S_5	22.82±1.27^{ab}	18.96±3.15^{ab}	55.89±3.74^{ab}	49.37±7.86^{ab}	834.79±60.94^{ab}	712.93±109.37^{ab}	10.75±0.69^{ab}	8.86±1.14^{ab}	2.80±0.40^{ab}	2.89±0.49^{ab}
S_{10}	23.44±1.42^{a}	19.56±3.34^{a}	57.39±4.19^{a}	50.87±8.37^{a}	851.60±67.1^{a}	732.33±117.13^{a}	11.01±0.74^{a}	9.15±1.26^{a}	2.89±0.43^{a}	2.98±0.52^{a}
LSD 0.05	0.42	0.68	1.08	1.42	18.90	22.87	0.19	0.29	0.09	0.11
Proline foliar application (mM)										
P_0	20.31±0.67^{c}	16.56±2.32^{c}	50.25±2.33^{c}	43.31±6.16^{c}	760.77±37.55^{c}	635.59±80.50^{c}	9.71±0.46^{c}	7.75±0.85^{c}	2.40±0.30^{c}	2.52±0.4^{c}
P_5	22.73±1.29^{b}	18.66±3.05^{b}	55.71±3.75^{b}	48.79±7.71^{b}	832.90±61.11^{ab}	705.04±107.68^{ab}	10.71±0.67^{b}	8.71±1.10^{b}	2.78±0.39^{b}	2.85±0.49^{b}
P_{10}	23.78±1.48^{a}	19.92±3.44^{a}	58.09±4.38^{a}	51.76±8.57^{a}	859.19±69.36^{a}	743.31±121.11 a	11.13±0.78^{a}	9.33±1.30^{a}	2.95±0.44^{a}	3.03±0.53^{a}
LSD 0.05	0.27	0.37	0.65	0.83	10.90	13.66	0.13	0.17	0.06	0.06

†Different letters indicate significant differences at $p<0.05$.
‡The data of three replicates ± SD (standard deviation) are shown.

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Table-3e. The main effects of saline irrigation levels (SI), selenium (S), and proline (P) foliar application on maize grain yield in both seasons.

Traits / Main effects	100-grainweight (g)		Grain yield plant^{-1} (g)		Grain yield (Mg ha^{-1})		Stover yield (Mg ha^{-1})	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Saline irrigation levels (mg L^{-1})								
SI_{1000}	53.13±8.75^{a}	52.18±8.23^{a}	252.97±43.61^{a}	246.67±41.21^{a}	4.06±0.54^{a}	3.99±0.55^{a}	5.69±0.89^{a}	5.48±0.84^{a}
SI_{2000}	48.92±7.06^{ab}	47.50±6.54^{ab}	235.18±38.31^{ab}	222.56±33.65^{ab}	3.74±0.47^{b}	3.57±0.50^{b}	5.15±0.70^{b}	4.92±0.69^{ab}
SI_{3000}	42.59±4.64^{c}	38.97±3.54^{c}	206.85±27.53^{c}	181.17±19.22^{c}	3.26±0.38^{c}	2.86±0.38^{c}	4.39±0.43^{c}	3.94±0.41^{c}
LSD 0.05	1.72	1.97	7.44	9.70	0.057	0.084	0.175	0.211
Selenium foliar application (mg L^{-1})								
S_0	44.33±5.27^{bc}	41.31±4.35^{c}	214.20±30.11^{c}	193.14±22.86^{c}	3.39±0.41^{c}	3.06±0.41^{c}	4.63±0.52^{c}	4.21±0.48^{c}
S_5	49.47±7.27^{ab}	47.82±6.66^{ab}	237.26±38.71^{ab}	224.42±34.17^{ab}	3.78±0.48^{ab}	3.61±0.51^{ab}	5.23±0.72^{ab}	4.97±0.69^{ab}
S_{10}	50.85±7.85^{a}	49.53±7.27^{a}	243.54±40.62^{a}	232.84±37.04^{a}	3.88±0.5^{a}	3.76±0.52^{a}	5.38±0.78^{a}	5.17±0.76^{a}
LSD 0.05	1.72	1.97	7.44	9.70	0.057	0.084	0.175	0.211
Proline foliar application (mM)								
P_0	43.85±5.16^{c}	41.86±4.58^{c}	212.08±29.54^{c}	194.39±23.69^{c}	3.35±0.40^{c}	3.09±0.43^{c}	4.58±0.50^{c}	4.26±0.49^{c}
P_5	49.33±7.21^{ab}	46.17±6.06^{b}	236.20±38.18^{ab}	216.85±31.47^{b}	3.76±0.47^{b}	3.47±0.48^{b}	5.21±0.72^{ab}	4.77±0.64^{b}
P_{10}	51.46±8.05^{a}	50.63±7.65^{a}	246.73±41.73^{a}	239.16±38.90^{a}	3.94±0.52^{a}	3.86±0.53^{a}	5.45±0.81^{a}	5.32±0.80^{a}
LSD 0.05	1.03	0.99	4.61	5.24	0.041	0.047	0.106	0.119

†Different letters indicate significant differences at p<0.05.
‡The data of three replicates ± SD (standard deviation) are shown.

Interaction effects

Interaction between levels of saline irrigation and selenium foliar application was significant for all leaf gas exchange characteristics, photosynthetic pigments, plant growth, grain yield and its attributes that were promising at 10 mg/l selenium foliar application under saline irrigation levels (Table 4). That was an indication that higher concentrations of selenium foliar improved the plant's tolerance to saline irrigation, hence resulting in improved leaf gas exchange traits, photosynthetic pigments, growth, grain yield, and its related traits. According to the findings of Desoky et al. (2021), exogenous application of selenium mainly 8 µM alleviated salt stress and increases wheat yield by improvement in antioxidant defense systems and photosynthetic capacity. Application of selenium at 20 mg L^{-1} during the respective phenological stage was reported to increase growth and chlorophyll in maize plants under salinity stress through the decrease in oxidative damage and improvement of antioxidant defense mechanism (Ashraf et al., 2018).

The interaction between the irrigation levels of salinity and proline foliar application significantly affected leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and their related attributes. It caused maximum values ever recorded when proline foliar application was applied at 10 mM under differential levels of saline irrigation, especially the mild ones (Table 4). That also meant that proline foliar at 10 mM has the ability to mitigate the adverse effects of saline irrigation on leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and its related traits (El-Nwehy, 2022).

The combination of selenium foliar application and proline foliar application significantly improved leaf gas exchange traits, photosynthetic pigments, plant growth, grain yield, and its related traits, with the highest values observed when selenium application was increased to 10 mg/l and proline application was up to 10 mM. This indicated that complementary effects of selenium and proline were observed on all studied traits and resulted in alleviating oxidative stress and proline's compatibility with the solute, and hence preserving cell turgor and stability. This clearly indicated that selenium and proline foliar application possessed the ability to influence together to enhance grain yield and its associated traits (Ashraf et al. 2018; El-Nwehy, 2022).

Foliar applications of selenium and proline had mitigating effects on gas exchange traits in leaves, photosynthetic pigments, plant growth, yield, and related traits in both seasons under saltwater irrigation stress conditions. Since, the promising triple interaction was observed when selenium application was increased to 10 mg/L and 10 Mm of proline under diverse conditions of saltwater irrigation on all studied traits, especially at mild levels of saline irrigation. It emerged that the collaborative effect of selenium and proline, as mitigating tools, significantly reduced the negative effects of saltwater irrigation stress on all studied traits.

Table-4a. Interaction of saline irrigation levels (SI) with selenium (S), and proline (P) foliar application on maize gas exchange traits in both seasons.

SI	S (mgL^{-1})	P (mM)	Net photosynthesis (µmol CO_2/m²/s)		Transpiration rate (mmol H_2O/m²/s)		Stomatal conductance (mol/m²/s)		Water use efficiency (mmol CO_2/mol H_2O)		Intercellular CO_2 (µmol/mol)	
			1stseason	2ndseason	1stseason	2ndseason	1stseason	2ndseason	1stseason	2ndseason	1stseason	2ndseason
SI_{1000}	S_0	P_0	13.83 ± 0.56^{npq}	$14.31\pm1.85^{n-q}$	2.56 ± 0.20^{pq}	2.51 ± 0.19^{pq}	$0.21\pm0.05^{n-q}$	$0.24\pm0.05^{n-q}$	$5.42\pm0.22^{a-r}$	$5.69\pm0.46^{a-i}$	228.71 ± 26.92^{pq}	225.13 ± 24.84^{pq}
		P_5	$15.57\pm1.01^{g-j}$	$16.14\pm1.83^{g-k}$	2.85 ± 0.23^{ijk}	2.87 ± 0.23^{ijk}	$0.24\pm0.05^{f-k}$	$0.27\pm0.06^{g-k}$	$5.47\pm0.09^{a-h}$	$5.62\pm0.25^{a-r}$	$237.94\pm25.41^{h-k}$	237.87 ± 24.05^{ijk}
		P_{10}	17.21 ± 1.47^{cd}	18.14 ± 1.94^{bcd}	3.17 ± 0.28^{cd}	3.22 ± 0.27^{c}	$0.27\pm0.06^{a-d}$	$0.29\pm0.06^{a-d}$	$5.43\pm0.05^{a-l}$	$5.63\pm0.20^{a-q}$	245.92 ± 24.73^{cd}	250.25 ± 24.27^{cd}
	S_5	P_0	15.73 ± 0.97^{ghi}	16.45 ± 1.81^{ghi}	2.9 ± 0.23^{ghi}	2.92 ± 0.22^{i}	$0.25\pm0.05^{f-i}$	0.27 ± 0.06^{ghi}	$5.43\pm0.1^{a-l}$	$5.62\pm0.26^{a-r}$	238.42 ± 25.18^{ghi}	238.66 ± 24^{i}
		P_5	$16.94\pm1.33^{c-f}$	$17.8\pm1.83^{c-f}$	3.09 ± 0.25^{ef}	$3.15\pm0.25^{c-f}$	$0.26\pm0.05^{b-f}$	$0.29\pm0.06^{a-f}$	$5.48\pm0.04^{a-d}$	$5.64\pm0.17^{a-p}$	$244.57\pm24.5^{c-f}$	247.55 ± 24.06^{f}
		P_{10}	17.99 ± 1.61^{ab}	18.95 ± 1.93^{ab}	3.27 ± 0.3^{ab}	3.37 ± 0.32^{ab}	0.28 ± 0.06^{ab}	0.31 ± 0.06^{ab}	5.5 ± 0.01^{ab}	$5.62\pm0.12^{a-r}$	249.98 ± 23.61^{ab}	255.63 ± 23.73^{ab}
	S_{10}	P_0	16.19 ± 1.11^{gh}	16.8 ± 1.90^{gh}	2.95 ± 0.23^{gh}	3.01 ± 0.21^{gh}	$0.25\pm0.05^{d-h}$	0.28 ± 0.06^{fgh}	5.49 ± 0.08^{abc}	$5.56\pm0.28^{a-y}$	240.28 ± 25.50^{gh}	241.41 ± 23.56^{gh}
		P_5	17.11 ± 1.37^{cde}	18.09 ± 1.92^{cde}	3.15 ± 0.26^{cde}	3.2 ± 0.27^{cde}	$0.27\pm0.05^{a-e}$	$0.29\pm0.06^{a-e}$	$5.43\pm0.03^{a-l}$	$5.65\pm0.20^{a-n}$	245.81 ± 24.83^{cde}	249.98 ± 24.47^{cde}
		P_{10}	18.09 ± 1.61^{a}	19.04 ± 1.91^{a}	3.28 ± 0.30^{a}	3.4 ± 0.31^{a}	0.28 ± 0.06^{a}	0.31 ± 0.06^{a}	5.52 ± 0.02^{a}	$5.6\pm0.07^{a-u}$	250.35 ± 23.62^{a}	256.82 ± 22.81^{a}
SI_{2000}	S_0	P_0	$12.12\pm0.50^{a-w}$	$11.89\pm1.73^{a-w}$	$2.26\pm0.22^{a-w}$	$2.09\pm0.14^{a-w}$	$0.18\pm0.04^{a-w}$	$0.19\pm0.04^{a-w}$	$5.39\pm0.41^{a-v}$	$5.69\pm0.65^{a-i}$	$216.49\pm28.09^{a-w}$	$209.08\pm25.42^{a-w}$
		P_5	13.56 ± 0.52^{pqr}	14.09 ± 1.77^{pqr}	2.52 ± 0.20^{qr}	2.44 ± 0.19^{qr}	$0.21\pm0.05^{n-r}$	0.23 ± 0.05^{pqr}	$5.4\pm0.23^{a-t}$	5.76 ± 0.40^{abc}	227.72 ± 26.69^{pqr}	222.08 ± 25.39^{r}
		P_{10}	14.49 ± 0.78^{n}	15.05 ± 1.86^{mn}	2.67 ± 0.22^{n}	2.64 ± 0.17^{n}	0.22 ± 0.05^{mn}	0.25 ± 0.05^{mn}	$5.43\pm0.16^{a-}$l	$5.7\pm0.43^{a-g}$	232.52 ± 25.70^{n}	230.17 ± 25.92^{n}
	S_5	P_0	$13.51\pm0.49^{p-s}$	$14.03\pm1.82^{p-s}$	2.51 ± 0.20^{qrs}	2.43 ± 0.20^{qrs}	$0.21\pm0.05^{n-s}$	$0.23\pm0.05^{p-s}$	$5.39\pm0.23^{a-v}$	$5.75\pm0.43^{a-d}$	$227.63\pm26.78^{p-s}$	221.67 ± 25.39^{rs}
		P_5	$15.36\pm10^{i-m}$	$15.74\pm2.03^{i-m}$	$2.81\pm0.23^{j-m}$	2.77 ± 0.19^{lm}	$0.24\pm0.05^{g-m}$	$0.26\pm0.05^{g-m}$	$5.48\pm0.09^{a-d}$	$5.66\pm0.45^{a-l}$	$236.6\pm25.56^{i-m}$	235.55 ± 24.61^{lm}
		P_{10}	16.22 ± 1.10^{g}	16.82 ± 1.90^{g}	2.96 ± 0.23^{g}	3.02 ± 0.21^{g}	$0.25\pm0.05^{d-g}$	0.28 ± 0.06^{fg}	$5.48\pm0.09^{a-d}$	$5.56\pm0.28^{a-y}$	240.72 ± 25.16^{g}	242.16 ± 22.75^{g}
	S_{10}	P_0	$13.15\pm0.36^{a-u}$	$13.37\pm1.76^{a-u}$	2.42 ± 0.21^{au}	2.3 ± 0.18^{au}	$0.2\pm0.05^{a-u}$	$0.21\pm0.04^{a-u}$	$5.46\pm0.34^{a-i}$	5.81 ± 0.48^{ab}	224.22 ± 26.64^{au}	217.62 ± 24.94^{au}
		P_5	$15.57\pm1.01^{g-j}$	$16.15\pm1.83^{g-j}$	2.86 ± 0.24^{ij}	2.89 ± 0.22^{ij}	$0.24\pm0.05^{f-j}$	$0.27\pm0.06^{g-j}$	$5.46\pm0.1^{a-I}$	$5.59\pm0.25^{a-v}$	238.15 ± 25.33^{hij}	238 ± 24.18^{j}
		P_{10}	17.29 ± 1.47^{c}	18.24 ± 1.99^{abc}	3.18 ± 0.29^{c}	3.22 ± 0.28^{c}	0.27 ± 0.06^{abc}	0.3 ± 0.06^{abc}	$5.43\pm0.05^{a-l}$	$5.65\pm0.19^{a-n}$	246.22 ± 24.72^{c}	250.79 ± 24.24^{c}
SI_{3000}	S_0	P_0	$2.73\pm0.49^{a-a}$	$0.33\pm0.08^{a-a}$	$0.92\pm0.12^{a-a}$	$0.09\pm0.03^{a-a}$	$0.02\pm0.01^{a-a}$	$0.01\pm0.01^{a-a}$	$2.95\pm0.20^{a-a}$	$3.67\pm0.61^{a-a}$	$159.43\pm25.84^{a-a}$	$133.57\pm27.01^{a-a}$
		P_5	$10.27\pm0.48^{a-y}$	$9.73\pm1.72^{a-y}$	$2.01\pm0.16^{a-y}$	$1.73\pm0.11^{a-y}$	$0.15\pm0.03^{a-y}$	$0.16\pm0.03^{a-y}$	$5.12\pm0.22^{a-y}$	$5.59\pm0.74^{a-v}$	$206.46\pm28.52^{a-y}$	$195.45\pm24.79^{a-y}$
		P_{10}	$11.7\pm0.52^{a-x}$	$11.55\pm1.65^{a-x}$	$2.22\pm0.22^{a-x}$	$2.01\pm0.09^{a-x}$	$0.18\pm0.04^{a-x}$	$0.18\pm0.04^{a-x}$	$5.3\pm0.42^{a-x}$	$5.73\pm0.67^{a-e}$	$214.32\pm27.98^{a-x}$	$206.79\pm24.63^{a-x}$
	S_5	P_0	$10.27\pm0.48^{a-y}$	$9.73\pm1.72^{a-y}$	$2.01\pm0.16^{a-y}$	$1.73\pm0.11^{a-y}$	$0.15\pm0.03^{a-y}$	$0.16\pm0.03^{a-y}$	$5.12\pm0.22^{a-y}$	$5.59\pm0.74^{a-v}$	$206.46\pm28.52^{a-y}$	$195.45\pm24.79^{a-y}$
		P_5	$13.48\pm0.49^{q-t}$	$13.98\pm1.81^{p-t}$	$2.5\pm0.2^{q-t}$	2.4 ± 0.22^{rst}	$0.21\pm0.05^{p-t}$	$0.22\pm0.05^{p-t}$	$5.41\pm0.23^{a-s}$	5.82 ± 0.44^{a}	$227.07\pm26.50^{q-t}$	221.23 ± 25.77^{rst}
		P_{10}	14.17 ± 0.77^{nop}	14.51 ± 1.75^{nop}	2.61 ± 0.21^{nop}	2.55 ± 0.19^{p}	0.22 ± 0.05^{nop}	0.24 ± 0.05^{nop}	$5.44\pm0.14^{a-k}$	$5.69\pm0.41^{a-i}$	230.02 ± 26.37^{p}	226.8 ± 24.59^{p}
	S_{10}	P_0	12.28 ± 0.48^{abv}	12.16 ± 1.77^{abv}	2.28 ± 0.21^{abv}	2.12 ± 0.15^{abv}	$0.18\pm0.04^{a-v}$	0.19 ± 0.04^{abv}	$5.4\pm0.35^{a-t}$	$5.72\pm0.61^{a-f}$	217.64 ± 27.61^{abv}	209.99 ± 25.32^{abv}
		P_5	14.49 ± 0.78^{n}	15.05 ± 1.86^{mn}	2.67 ± 0.22^{n}	2.64 ± 0.17^{n}	0.22 ± 0.05^{mn}	0.25 ± 0.05^{mn}	$5.43\pm0.16^{a-l}$	$5.7\pm0.43^{a-g}$	232.52 ± 25.70^{n}	230.17 ± 25.92^{n}
		P_{10}	$15.54\pm1.03^{g-l}$	$16.08\pm1.87^{g-l}$	$2.84\pm0.24^{i-l}$	$2.84\pm0.19^{i-l}$	$0.24\pm0.05^{g-l}$	$0.27\pm0.05^{g-l}$	$5.48\pm0.10^{a-d}$	$5.66\pm0.31^{a-l}$	$237.69\pm25.35^{i-l}$	$237.62\pm24.25^{i-l}$
LSD0.05			0.61	0.79	0.06	0.08	0.0130	0.0158	0.25	0.46	2.20	2.15

†Different letters indicate significant differences at $p<0.05$.

‡The data of three replicates ± SD (standard deviation) are shown.

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Table-4b. Interaction of saline irrigation levels (SI) with selenium (S), and proline (P) foliar application on maize photosynthetic pigments traits in both seasons.

SI	S (mg L^{-1})	P (mM)	Chlorophyll a (mg g^{-1} FW)		Chlorophyll b (mg g^{-1} FW)		Chlorophyll a+b (mg g^{-1} FW)		Carotenoid (mg g^{-1} FW)	
			1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
SI_{1000}	S_0	P_0	1.64±0.10^{pq}	1.92±0.18^{pq}	1.49±0.12^{pq}	1.34±0.10^{pq}	3.14±0.04^{pq}	3.26±0.28^{pq}	1.94±0.40^{n-q}	1.73±0.41^{n-q}
		P_5	1.81±0.08^{ijk}	2.21±0.20^{ijk}	1.62±0.15^{g-k}	1.53±0.15^{ijk}	3.43±0.08^{ijk}	3.74±0.35^{ijk}	2.22±0.46^{g-k}	1.95±0.46^{g-k}
		P_{10}	1.97±0.06^{cd}	2.45±0.21^{cd}	1.76±0.14^{cd}	1.74±0.16^{cd}	3.72±0.08^{cd}	4.19±0.37^{cd}	2.54±0.56^{a-d}	2.18±0.51^{bcd}
	S_5	P_0	1.83±0.08^{ghi}	2.23±0.19^{i}	1.64±0.15^{ghi}	1.56±0.15^{ghi}	3.47±0.08^{i}	3.79±0.35^{hi}	2.26±0.48^{ghi}	1.99±0.47^{ghi}
		P_5	1.94±0.05^{c-f}	2.42±0.22^{c-f}	1.73±0.14^{c-f}	1.71±0.16^{c-f}	3.67±0.09^{c-f}	4.13±0.38^{c-f}	2.48±0.54^{b-f}	2.14±0.48^{c-f}
		P_{10}	2.03±0.05^{ab}	2.56±0.22^{ab}	1.83±0.17^{ab}	1.83±0.17^{ab}	3.86±0.12^{ab}	4.39±0.39^{ab}	2.64±0.58^{ab}	2.31±0.57^{ab}
	S_{10}	P_0	1.87±0.08^{gh}	2.31±0.21^{gh}	1.66±0.15^{gh}	1.60±0.15^{gh}	3.53±0.08^{gh}	3.91±0.37^{gh}	2.32±0.49^{gh}	2.06±0.48^{c-h}
		P_5	1.96±0.07^{cde}	2.44±0.21^{cde}	1.75±0.15^{cde}	1.74±0.16^{cde}	3.72±0.08^{cde}	4.18±0.37^{cde}	2.53±0.57^{a-e}	2.18±0.51^{b-e}
		P_{10}	2.05±0.06^{a}	2.57±0.23^{a}	1.84±0.17^{a}	1.84±0.17^{a}	3.88±0.12^{a}	4.41±0.40^{a}	2.64±0.57^{a}	2.32±0.57^{a}
SI_{2000}	S_0	P_0	1.42±0.10^{a-w}	1.55±0.13^{a-w}	1.30±0.09^{a-w}	1.11±0.10^{a-w}	2.73±0.02^{a-w}	2.66±0.23^{a-w}	1.66±0.38^{a-w}	1.41±0.36^{a-w}
		P_5	1.61±0.10^{qr}	1.88±0.18^{qr}	1.48±0.12^{pqr}	1.31±0.10^{pqr}	3.08±0.02^{qr}	3.19±0.28^{qr}	1.89±0.38^{pqr}	1.69±0.42^{n-r}
		P_{10}	1.71±0.06^{n}	2.06±0.22^{n}	1.54±0.12^{n}	1.40±0.11^{n}	3.25±0.07^{n}	3.46±0.33^{n}	2.06±0.44^{lmn}	1.82±0.42^{k-n}
	S_5	P_0	1.60±0.11^{rs}	1.88±0.18^{qrs}	1.47±0.12^{p-s}	1.31±0.10^{p-s}	3.07±0.02^{rs}	3.18±0.27^{qrs}	1.88±0.38^{p-s}	1.68±0.42^{n-s}
		P_5	1.77±0.07^{j-m}	2.18±0.20^{i-m}	1.59±0.15^{i-m}	1.49±0.14^{j-m}	3.37±0.08^{lm}	3.67±0.34^{i-m}	2.17±0.44^{h-m}	1.92±0.46^{g-m}
		P_{10}	1.87±0.08^{g}	2.32±0.21^{g}	1.66±0.15^{g}	1.61±0.15^{g}	3.54±0.08^{g}	3.92±0.36^{g}	2.33±0.49^{g}	2.06±0.48^{c-g}
	S_{10}	P_0	1.54±0.10^{au}	1.75±0.16^{au}	1.42±0.11^{au}	1.23±0.09^{au}	2.96±0.03^{au}	2.98±0.25^{au}	1.79±0.38^{a-u}	1.61±0.4^{a-u}
		P_5	1.82±0.08^{ij}	2.22±0.20^{ij}	1.63±0.15^{g-j}	1.54±0.15^{hij}	3.44±0.08^{ij}	3.76±0.35^{ij}	2.22±0.46^{g-j}	1.97±0.45^{g-j}
		P_{10}	1.97±0.06^{c}	2.46±0.20^{c}	1.76±0.14^{c}	1.75±0.16^{c}	3.73±0.08^{c}	4.21±0.37^{c}	2.55±0.57^{abc}	2.20±0.51^{abc}
SI_{3000}	S_0	P_0	0.45±0.07^{a-a}	0.06±0.01^{a-a}	0.48±0.07^{a-a}	0.05±0.01^{a-a}	0.93±0.01^{a-a}	0.10±0.01^{a-a}	0.05±0.02^{a-a}	0.08±0.03^{a-a}
		P_5	1.26±0.11^{a-y}	1.30±0.12^{a-y}	1.17±0.11^{a-y}	0.92±0.08^{a-y}	2.42±0.06^{a-y}	2.22±0.19^{a-y}	1.33±0.33^{a-y}	1.17±0.25^{a-y}
		P_{10}	1.39±0.09^{a-x}	1.50±0.13^{a-x}	1.28±0.10^{a-x}	1.07±0.10^{a-x}	2.67±0.03^{a-x}	2.57±0.23^{a-x}	1.61±0.36^{a-x}	1.36±0.33^{a-x}
	S_5	P_0	1.26±0.11^{a-y}	1.30±0.12^{a-y}	1.17±0.11^{a-y}	0.92±0.08^{a-y}	2.42±0.06^{a-y}	2.22±0.19^{a-y}	1.33±0.33^{a-y}	1.17±0.25^{a-y}
		P_5	1.59±0.11^{rst}	1.85±0.17^{q-t}	1.47±0.12^{p-t}	1.30±0.10^{q-t}	3.07±0.02^{rst}	3.15±0.26^{q-t}	1.88±0.38^{p-s}	1.67±0.41^{p-t}
		P_{10}	1.67±0.08^{nop}	1.98±0.19^{p}	1.50±0.11^{nop}	1.36±0.11^{nop}	3.17±0.04^{p}	3.34±0.30^{np}	1.98±0.40^{nop}	1.75±0.42^{nop}
	S_{10}	P_0	1.44±0.10^{abv}	1.57±0.14^{abv}	1.31±0.10^{abv}	1.12±0.10^{abv}	2.75±0.02^{abv}	2.69±0.23^{abv}	1.67±0.38^{a-v}	1.43±0.36^{abv}
		P_5	1.71±0.06^{n}	2.06±0.22^{n}	1.54±0.12^{n}	1.40±0.11^{n}	3.25±0.07^{n}	3.46±0.33^{n}	2.06±0.44^{lmn}	1.82±0.42^{k-n}
		P_{10}	1.80±0.08^{i-l}	2.20±0.21^{i-l}	1.61±0.15^{i-l}	1.52±0.15^{i-l}	3.42±0.09^{i-l}	3.72±0.36^{i-l}	2.21±0.46^{g-l}	1.95±0.46^{g-l}
LSD 0.05			0.0430	0.0746	0.0410	0.0547	0.0554	0.1185	0.1407	0.1255

†Different letters indicate significant differences at $p<0.05$.

‡The data of three replicates ± SD (standard deviation) are shown.

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Table-4c. Interaction of saline irrigation levels (SI) with selenium (S), and proline (P) foliar application on maize plant growth traits in both seasons.

SI	S (mgL^{-}	P (mM)	Plant height (cm)		Shoot FW/plant (g)		Shoot DW/plant (g)		No. of leaves/plant (No)		Cob length (cm)	
			1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
SI_{1000}	S_0	P_0	240.08±17.67^{j-q}	244.54±19.64^{i-q}	301.86±26.28^{i-q}	286.51±30.91^{i-q}	83.11±8.53^{i-q}	82.55±7.57^{l-q}	15.90±1.11^{j-q}	14.66±1.01^{l-q}	23.70±2.1^{m-q}	24.19±2.25^{m-q}
		P_5	253.29±24.05^{c-k}	257.20±25.2^{c-i}	315.10±30.53^{c-k}	303.17±34.9^{c-i}	86.10±9.07^{c-k}	87.65±9.64^{c-i}	16.78±1.43^{c-j}	15.67±1.32^{c-i}	25.07±2.57^{f-k}	26.44±3.02^{e-i}
		P_{10}	265.43±29.48^{a-d}	267.78±30.21^{a-e}	328.43±36.38^{a-d}	316.07±39.16^{a-e}	89.83±10.67^{a-d}	91.30±11.02^{a-e}	17.55±1.87^{a-d}	16.52±1.76^{a-e}	26.37±3^{a-d}	27.78±3.19^{a-e}
	S_5	P_0	254.77±25.18^{c-i}	257.20±25.2^{c-i}	316.70±31.4^{c-i}	303.17±34.9^{c-i}	86.81±9.33^{c-i}	87.65±9.64^{c-i}	16.90±1.59^{c-i}	15.67±1.32^{c-i}	25.19±2.6^{e-i}	26.44±3.02^{e-i}
		P_5	263.73±29.19^{a-f}	266.71±30.15^{a-f}	325.71±34.6^{a-f}	313.69±38.55^{a-f}	88.93±10.11^{a-f}	90.70±10.84^{a-f}	17.42±1.79^{a-f}	16.33±1.62^{a-f}	26.16±2.92^{a-f}	27.51±3.1^{a-f}
		P_{10}	270.81±33.19^{ab}	273.76±33.59^{ab}	334.69±40.34^{ab}	322.17±40.61^{ab}	91.06±11.24^{ab}	93.19±11.51^{ab}	17.83±1.94^{ab}	16.83±1.91^{ab}	26.91±2.95^{ab}	28.48±3.45^{ab}
	S_{10}	P_0	257.19±26.02^{a-h}	260.12±27.04^{a-h}	320.13±33.38^{a-h}	306.82±37.83^{a-h}	87.41±9.53^{b-h}	88.54±10.29^{b-h}	17.06±1.62^{a-h}	15.87±1.44^{c-h}	25.51±2.79^{c-h}	26.76±3.11^{c-h}
		P_5	264.82±29.43^{a-e}	268.19±30.31^{abc}	328.24±36.37^{a-e}	316.50±39.02^{abc}	89.55±10.49^{a-e}	91.49±10.93^{abc}	17.53±1.85^{a-e}	16.53±1.76^{abc}	26.31±2.97^{a-e}	27.86±3.23^{abc}
		P_{10}	271.41±33.36^{a}	274.21±34^{a}	334.87±40.55^{a}	323.11±40.9^{a}	91.28±11.26^{a}	93.43±11.56^{a}	17.87±1.94^{a}	16.88±1.91^{a}	26.92±2.94^{a}	28.54±3.47^{a}
SI_{2000}	S_0	P_0	226.61±13.88^{a-w}	227.59±11.56^{a-w}	283.32±19.89^{a-w}	269.64±25.77^{a-w}	78.22±6.03^{a-w}	77.25±5.2^{a-w}	14.77±0.63^{a-w}	13.47±0.58^{a-w}	22.17±1.71^{a-w}	22.18±1.67^{a-w}
		P_5	237.38±16.9^{m-r}	241.80±17.82^{l-r}	299.63±25.1^{j-r}	284.19±30.5^{m-r}	82.56±8.27^{j-r}	81.48±6.86^{m-r}	15.75±1.06^{n-r}	14.45±0.92^{m-r}	23.47±2.1^{n-r}	23.86±2.21^{o-r}
		P_{10}	245.84±20.26^{g-n}	248.85±20.9g-o	306.92±27.8^{g-n}	294.37±32.28^{g-o}	84.37±8.71^{g-n}	84.35±8.65^{g-o}	16.29±1.23^{g-n}	15.07±1.18^{g-o}	24.26±2.23^{i-n}	24.92±2.42^{l-o}
	S_5	P_0	237.33±16.86^{m-s}	241.80±17.82^{l-r}	299.07±25.6^{k-s}	284.19±30.5^{m-r}	82.25±7.83^{l-s}	81.48±6.86^{m-r}	15.73±1.07^{n-s}	14.45±0.92^{m-r}	23.42±2.07^{n-s}	23.86±2.21^{o-r}
		P_5	251.32±23.02^{d-m}	250.50±21.85^{g-m}	311.92±28.95^{f-m}	296.98±32.72^{f-m}	85.56±8.79^{f-m}	85.22±8.88^{g-m}	16.66±1.36^{c-m}	15.24±1.21^{g-m}	24.73±2.44^{g-m}	25.38±2.64^{i-m}
		P_{10}	257.38±25.84^{a-g}	260.57±26.94^{a-g}	320.71±33.59^{a-g}	307.36±37.8^{a-g}	87.49±9.62^{b-g}	88.69±10.36^{a-g}	17.08±1.63^{a-g}	15.92±1.45^{c-g}	25.59±2.86^{c-g}	26.80±3.1^{c-g}
	S_{10}	P_0	232.98±14.72^{a-u}	236.65±15.73^{m-t}	292.87±23.02^{a-u}	277.33±28.25^{p-t}	80.87±7.14^{a-u}	79.82±6.22^{o-t}	15.40±0.87^{a-u}	14.06±0.79^{p-t}	23.06±1.88^{a-u}	23.28±1.9^{p-t}
		P_5	253.62±24.42^{c-j}	256.50±25.13^{c-k}	315.50±30.38^{c-j}	302.75±34.57^{c-k}	86.13±9.09^{c-j}	87.36±9.32^{c-k}	16.78±1.43^{c-j}	15.65±1.32^{c-k}	25.12±2.55^{f-j}	26.40±3^{e-k}
		P_{10}	266.43±29.66^{abc}	268.19±30.31^{abc}	328.90±36.71^{abc}	316.50±39.02^{abc}	89.89±10.69^{abc}	91.49±10.93^{abc}	17.57±1.87^{abc}	16.53±1.76^{abc}	26.40±3.01+	27.86±3.23^{abc}
SI_{3000}	S_0	P_0	157.31±18.02^{a-a}	145.83±20.24^{a-a}	201.45±18.7^{a-a}	173.72±17.81^{a-a}	56.69±2.39^{a-a}	50.12±5.87^{a-a}	9.78±1.35^{a-a}	8.51±1.37^{a-a}	14.78±1.11^{a-a}	12.84±1.49^{a-a}
		P_5	212.39±6.44^{a-y}	195.90±1.29^{a-z}	267.41±12.78^{a-y}	235.72±12.59^{a-z}	73.89±4.11^{a-y}	66.64±0.91^{a-z}	13.87±0.46^{a-y}	11.59±0.57^{a-z}	20.62±1.01^{a-y}	18.71±0.62^{a-z}
		P_{10}	223.83±12.74^{a-x}	224.68±11.3^{a-x}	279.96±17.37^{a-x}	266.57±24.75^{a-x}	77.41±5.61^{a-x}	76.13±4.7^{a-x}	14.60±0.48^{a-x}	13.29±0.51^{a-x}	21.86±1.51^{a-x}	21.83±1.77^{a-x}
	S_5	P_0	212.39±6.44^{a-y}	212.03±6.65^{a-y}	267.41±12.78^{a-y}	248.34±14.4^{a-y}	73.89±4.11^{a-y}	71.88±3.54^{a-y}	13.87±0.46^{a-y}	12.45±0.48^{a-y}	20.62±1.01^{a-y}	20.67±1.56^{a-y}
		P_5	236.71±16.30^{n-t}	233.35±13.58^{a-u}	298.48±25.9^{m-t}	274.95±27.73^{a-u}	82.09±7.9^{m-t}	79.04±5.83^{a-u}	15.72±1.06^{n-t}	13.89±0.68^{a-u}	23.39±2.07^{n-t}	22.94±1.86^{a-u}
		P_{10}	241.97±18.45^{i-p}	246.04±19.71^{g-p}	302.89±26.47^{i-p}	289.86±32.66^{i-p}	83.30±8.53^{i-p}	83.38±8.09^{i-p}	16.02±1.15^{i-p}	14.77±1.03^{i-p}	23.87±2.15^{m-p}	24.41±2.23^{m-p}
	S_{10}	P_0	227.46±14.1^{a-v}	228.25±11.86^{a-v}	284.03±20.51^{a-v}	270.66±26.24^{a-v}	78.72±6.52^{a-v}	77.52±5.35^{a-v}	14.81±0.62^{a-v}	13.54±0.59^{a-v}	22.25±1.73^{a-v}	22.30±1.58^{a-v}
		P_5	245.84±20.26^{g-n}	250.15±21.54^{g-n}	306.92±27.8^{g-n}	295.89±32.79^{g-n}	84.37±8.71^{g-n}	85.08±8.84^{g-n}	16.29±1.23^{g-n}	15.16±1.18^{g-n}	24.26±2.23^{i-n}	25.29±2.61^{i-n}
		P_{10}	253.06±24.04^{c-l}	255.05±24.13^{c-l}	314.97±30.55^{c-l}	300.95±33.87^{c-l}	85.95±8.94^{e-l}	86.86±9.51^{c-l}	16.74±1.4^{c-l}	15.53±1.3^{f-l}	25.04±2.57^{f-l}	26.02±2.75^{g-l}
LSD0.05			12.49	12.58	13.83	14.58	3.27	4.21	0.80	0.80	1.01	1.22

†Different letters indicate significant differences at $p<0.05$.

‡The data of three replicates ± SD (standard deviation) are shown.

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Table-4d. Interaction of saline irrigation levels (SI) with selenium (S), and proline (P) foliar application on maize yield related traits in both seasons.

SI	S (mgL^{-1})	P (mM)	Kernel rows cob^{-1} (No)		Kernel number row^{-1} (No)		Kernels cob^{-1} (No)		Cob Diameter (cm)		Cobs $plant^{-1}$ (No)	
			1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season	1^{st} season	2^{nd} season
SI_{1000}	S_0	P_0	22.26±1.19^{nop}	18.43±2.93^{k-p}	53.94±3.17^{n-q}	47.63±7.01^{m-q}	817.34±54.61^{m-q}	690.74±101.47^{k-q}	10.73±0.65^{k-n}	8.83±1.14^{k-n}	2.64±0.33^{n-q}	2.80±0.49^{l-q}
		P_5	23.67±1.57^{g-j}	20.24±3.67^{c-i}	57.51±4.29^{g-k}	52.00±8.6^{1-i}	856.20±71.8^{e-k}	747.05±122.50^{c-I}	11.22±0.83^{f-j}	9.60±1.37^{c-h}	2.90±0.42^{g-j}	3.07±0.53^{c-i}
		P_{10}	25.30±1.82^{abc}	21.27±3.95^{abc}	60.85±5.06^{a-d}	54.83±9.49^{a-d}	894.04±80.96^{a-d}	782.58±137.39^{a-e}	11.72±0.93^{abc}	10.02±1.52^{a-d}	3.15±0.51^{a-d}	3.20±0.58^{a-e}
	S_5	0	23.85±1.6^{ghi}	20.21±3.67^{c-j}	57.89±4.25^{f-i}	51.79±8.54^{g-j}	858.68±72.46^{c-i}	740.10±118.87^{c-j}	11.28±0.84^{c-h}	9.58±1.37^{c-i}	2.93±0.42^{ghi}	3.04±0.54^{c-j}
		150	25.04±1.8^{a-f}	21.11±3.95^{a-f}	59.92±4.8^{c-f}	54.65±9.48^{a-f}	888.46±78.8^{a-f}	779.79±134.92^{a-f}	11.65±0.91^{a-f}	9.97±1.47^{a-e}	3.11±0.49^{b-f}	3.19±0.57^{a-f}
		300	25.78±1.92^{ab}	21.84±3.93^{ab}	62.72±5.57^{ab}	56.33±10.06^{ab}	908.66±84.86^{ab}	799.46±139.81^{ab}	11.91±0.97^{ab}	10.23±1.54^{ab}	3.29±0.55^{ab}	3.30±0.57^{a}
	S_{10}	0	24.23±1.64^{g}	20.44±3.79^{c-g}	58.51±4.34^{fgh}	52.33±8.75^{c-h}	865.44±69.64^{c-h}	758.10±126.92^{a-h}	11.41±0.83^{c-g}	9.69±1.38^{a-g}	3.00±0.47^{c-h}	3.08±0.53^{c-h}
		150	25.24±1.88^{a-e}	21.27±3.95^{abc}	60.79±5.06^{a-e}	54.83±9.49^{a-d}	892.90±79.47^{a-e}	784.56±137.54^{abc}	11.72±0.93^{abc}	10.04±1.51^{abc}	3.14±0.5^{a-e}	3.21±0.57^{abc}
		300	25.81±1.94^{a}	21.89±3.93^{a}	62.93±5.58^{a}	56.46±10.01^{a}	909.64±84.33^{a}	801.28±141.75^{a}	11.95±0.97^{a}	10.28±1.56^{a}	3.30±0.56^{a}	3.30±0.57^{a}
SI_{2000}	S_0	P_0	19.92±0.46^{a-w}	16.19±2.04^{a-w}	50.10±2.27^{a-w}	42.72±6.35^{a-w}	760.82±39.75^{a-w}	631.89±81^{a-w}	9.69±0.53^{a-w}	7.59±0.97^{a-w}	2.36±0.29^{a-w}	2.50±0.39^{a-w}
		P_5	21.61±0.97^{n-r}	17.74±2.75^{n-s}	53.58±3.06^{n-r}	46.48±7.10^{n-s}	808.36±53.01^{n-r}	675.06±96.34^{m-s}	10.27±0.58^{o-r}	8.23±0.93^{o-s}	2.60±0.33^{n-r}	2.72±0.47^{n-s}
		P_{10}	22.46±1.23^{mn}	18.76±3.08^{k-n}	55.54±4.23^{k-n}	49.18±7.66^{j-n}	832.55±62.12^{g-n}	710.44±108.84^{i-n}	10.65±0.61^{k-o}	8.78±1.12^{k-o}	2.74±0.38^{j-n}	2.88±0.52^{j-n}
	S_5	P_0	21.49±0.83^{p-s}	17.79±2.81^{n-r}	53.50±3.10^{n-s}	46.69±6.93^{n-r}	806.12±50.19^{n-s}	676.01±97.10^{m-r}	10.25±0.58^{o-s}	8.25±0.95^{n-r}	2.59±0.33^{n-s}	2.73±0.48^{n-r}
		P_5	23.19±1.5^{i-m}	19.21±3.38^{g-m}	56.88±4.41^{g-m}	50.08±7.98^{g-m}	849.96±66.61^{g-m}	720.32±113.29^{g-m}	10.91±0.71^{h-m}	8.86±1.16^{klm}	2.85±0.4^{g-m}	2.94±0.54^{g-m}
		P_{10}	24.09±1.65^{gh}	20.36±3.76^{c-h}	58.61±4.39^{fg}	52.48±8.79^{c-g}	868.74±74.09^{c-g}	759.58±128.18^{a-g}	11.25±0.85^{e-i}	9.52±1.32^{c-j}	3.01±0.47^{c-g}	3.09±0.53^{c-g}
	S_{10}	P_0	20.94±0.69^{a-u}	17.23±2.51^{a-u}	51.94±2.78^{a-u}	45.25±6.66^{a-u}	790.63±44.52^{a-u}	659.26±89.08^{a-u}	10.02±0.54^{a-u}	8.00±0.90^{a-u}	2.51±0.37^{a-u}	2.65±0.44^{a-u}
		P_5	23.55±1.63^{g-k}	19.38±3.43^{g-l}	57.79±4.17^{f-j}	50.75±8.31^{g-l}	856.56±71.97^{e-j}	727.95±116.95^{g-l}	11.00±0.70^{e-k}	8.95±1.2^{kl}	2.90±0.42^{g-j}	2.97±0.55^{g-l}
		P_{10}	25.30±1.82^{abc}	21.27±3.95^{abc}	61.29±5.17^{abc}	55.01±9.59^{abc}	895.57±81.38^{abc}	784.56±137.54^{abc}	11.68±0.94^{a-e}	9.97±1.47^{a-e}	3.18±0.51^{abc}	3.21±0.57^{abc}
SI_{3000}	S_0	P_0	11.84±0.98^{a-a}	7.97±0.44^{a-a}	29.94±1.91^{a-a}	21.67±1.67^{a-a}	475.37±51.94^{a-a}	349.55±28.56^{a-a}	5.57±0.62^{a-a}	3.41±0.65^{a-a}	1.06±0.34^{a-a}	1.11±0.42^{a-a}
		P_5	18.27±0.34^{a-y}	13.11±0.92^{a-z}	46.16±0.92^{a-y}	35.97±4.10^{a-z}	706.94±17.82^{a-y}	542.27±50.69^{a-z}	8.76±0.31^{a-y}	6.13±0.34^{a-z}	2.17±0.27^{a-y}	2.02±0.27^{a-z}
		P_{10}	19.68±0.40^{a-x}	15.80±1.96^{a-x}	49.25±1.94^{a-x}	42.02±6.01^{a-x}	746.64±29.33^{a-x}	618.49±74.92^{a-x}	9.53±0.49^{a-x}	7.50±0.93^{a-x}	2.32±0.30^{a-x}	2.46±0.38^{a-x}
	S_5	P_0	18.27±0.34^{a-y}	14.51±1.47^{a-y}	46.16±0.92^{a-y}	38.75±5.23^{a-y}	706.94±17.82^{a-y}	580.40±54.75^{a-y}	8.76±0.31^{a-y}	6.80±0.57^{a-y}	2.17±0.27^{a-y}	2.25±0.32^{a-y}
		P_5	21.48±0.83^{p-t}	17.25±2.53^{p-t}	53.19±2.95^{p-t}	45.42±6.57^{p-t}	804.20±49.7^{n-t}	662.57±93.24^{o-t}	10.21±0.56^{o-t}	8.01±0.91^{q-t}	2.59±0.33^{n-s}	2.66±0.44^{p-t}
		P_{10}	22.15±1.09^{n-q}	18.37±2.91^{l-q}	54.16±3.34^{nop}	48.15±7.17^{l-p}	821.30±55.29^{i-p}	698.12±105.61^{j-p}	10.49±0.63^{m-q}	8.51±1.01^{l-q}	2.67±0.34^{nop}	2.83±0.5^{k-p}
	S_{10}	P_0	20.00±0.47^{bv}	16.30±2.10^{a-v}	50.31±2.20^{a-v}	42.92±6.41^{a-v}	765.56±38.26^{a-v}	634.26±81.62^{a-v}	9.71±0.53^{a-v}	7.63±0.97^{a-v}	2.38±0.32^{a-v}	2.51±0.40^{a-v}
		P_5	22.46±1.23^{mn}	18.59±2.92^{k-o}	55.54±4.23^{k-n}	48.89±7.74^{k-o}	832.55±62.12^{g-n}	705.75±106.68^{i-o}	10.65±0.61^{k-o}	8.63±1.07^{k-p}	2.74±0.38^{j-n}	2.86±0.51^{j-o}
		P_{10}	23.46±1.56^{g-l}	19.67±3.57^{g-k}	57.43±4.33^{g-l}	51.39±8.39^{g-k}	855.60±72.27^{e-l}	735.28±116.9^{f-k}	10.99±0.70 $^{g-}$l	9.18±1.27^{g-k}	2.89±0.41^{g-l}	3.01±0.56 $^{f-k}$
LSD0.05			0.80	1.11	1.96	2.49	32.69	40.97	0.40	0.52	0.18	0.18

†Different letters indicate significant differences at $p<0.05$.
‡The data of three replicates ± SD (standard deviation) are shown.

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Table-4e. Interaction of saline irrigation levels (SI) with selenium (S), and proline (P) foliar application on maize grain yield in both seasons.

SI	S (mgL^{-1})	P (mM)	100-grainweight (g)		Grain yield plant^{-1} (g)		Grain yield (Mg ha^{-1})		Stover yield (Mg ha^{-1})	
			1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
SI_{1000}	S_0	P_0	48.33±6.66[i-p]	46.32±6.27[l-p]	230.56±37.5[j-q]	216.87±31.79[l-p]	3.6267±0.43[n-q]	3.46±0.51[op]	5.21±0.73[i-n]	4.81±0.66[j-p]
		P_5	51.64±8.37[c-j]	50.14±7.36[e-j]	245.50±41.01[c-k]	235.92±36.78[e-j]	3.8867±0.48[g-k]	3.82±0.53[g-j]	5.54±0.84[c-j]	5.19±0.79[f-j]
		P_{10}	54.32±9.15[abc]	53.72±8.75[a-d]	258.63±44.92[a-d]	255.71±44.21[a-d]	4.18±0.58[a-d]	4.13±0.55[cd]	5.81±0.94[abc]	5.68±0.91[a-d]
	S_5	P_0	51.87±8.44[c-I]	50.93±7.60[c-I]	247.46±42.13[c-I]	237.67±37.78[e-I]	3.9233±0.50[ghi]	3.84±0.55[ghi]	5.58±0.85[c-h]	5.25±0.79[e-i]
		P_5	53.86±8.89[a-f]	52.94±8.59[a-f]	256.22±43.76[a-f]	250.74±42.90[a-f]	4.1533±0.58[c-f]	4.06±0.57[c-f]	5.76±0.93[a-f]	5.55±0.83[a-f]
		P_{10}	55.6±9.74[ab]	55.10±9.13[ab]	264.64±47.67[ab]	263.87±46.85[ab]	4.29±0.58[ab]	4.28±0.56[ab]	5.95±0.99[ab]	5.93±0.97[ab]
	S_{10}	P_0	52.68±8.88[a-g]	51.43±7.83[c-h]	250.72±42.73[a-h]	241.05±39.68[c-h]	3.9933±0.54[gh]	3.93±0.58[fg]	5.63±0.86[a-g]	5.37±0.80[c-h]
		P_5	54.21±9.07[a-e]	53.38±8.62[a-e]	257.99±44.71[a-e]	253.54±44.24[a-e]	4.1733±0.57[b-e]	4.11±0.56[cde]	5.81±0.94[abc]	5.62±0.87[a-e]
		P_{10}	55.71±9.78[a]	55.69±9.93[a]	265.04±48.12[a]	264.67±46.89[a]	4.3133±0.58[a]	4.31±0.55[a]	5.96±1.00[a]	5.95±0.97[a]
SI_{2000}	S_0	P_0	43.04±4.82[a-w]	41.65±4.53[a-w]	211.20±30.75[a-w]	191.09±25.23[a-w]	3.3167±0.40[a-w]	3.05±0.43[a-w]	4.47±0.47[a-w]	4.25±0.48[a-w]
		P_5	46.97±6.17[n-r]	45.10±5.82[m-s]	225.90±35.93[n-r]	208.97±29.15[n-s]	3.5967±0.42[n-r]	3.32±0.49[p-s]	4.95±0.64[n-r]	4.62±0.61[m-s]
		P_{10}	49.23±7.17[g-n]	47.96±6.64[i-n]	236.56±39.05[g-n]	226.14±34.02[g-n]	3.7167±0.47[mn]	3.61±0.51[lmn]	5.18±0.72[k-o]	4.97±0.72[g-n]
	S_5	P_0	46.73±6.25[n-s]	45.53±5.86[l-r]	225.42±35.81[n-s]	212.27±29.81[m-r]	3.59±0.42[n-s]	3.38±0.48[o-r]	4.93±0.63[n-s]	4.71±0.66[l-r]
		P_5	50.76±7.89[c-m]	48.45±6.85[g-m]	241.81±41.10[f-m]	229.00±35.06[i-m]	3.83±0.47[i-m]	3.68±0.52[j-m]	5.33±0.77[g-m]	5.02±0.73[g-m]
		P_{10}	52.31±8.62[a-h]	51.52±7.94[c-g]	251.19±43.07[a-g]	241.82±40.05[c-g]	4.0133±0.55[g]	3.93±0.58[fg]	5.56±0.84[c-I]	5.38±0.80[c-g]
	S_{10}	P_0	45.55±5.65[a-u]	44.64±5.71[n-t]	219.62±33.21[a-u]	205.98±30.12[o-t]	3.48±0.42[a-u]	3.26±0.49[rst]	4.78±0.57[a-u]	4.55±0.58[o-t]
		P_5	51.39±8.26[c-k]	48.82±6.95[g-l]	245.68±41.08[c-j]	231.33±35.80[g-l]	3.8967±0.47[g-j]	3.71±0.53[i-l]	5.41±0.79[e-k]	5.06±0.74[g-l]
		P_{10}	54.32±9.15[abc]	53.87±8.69[abc]	259.24±44.94[abc]	256.42±43.82[abc]	4.19±0.59[abc]	4.16±0.53[bc]	5.77±0.93[a-e]	5.71±0.93[abc]
SI_{3000}	S_0	P_0	23.82±2.86[a-a]	17.58±3.84[a-a]	119.84±9.16[a-a]	82.97±20.58[a-a]	1.9333±0.14[a-a]	1.09±0.03[a-a]	2.13±0.39[a-a]	1.47±0.57[a-a]
		P_5	39.31±3.16[a-y]	28.58±0.27[a-z]	191.71±22.06[a-y]	133.33±1.71[a-z]	2.9833±0.34[a-y]	2.07±0.21[a-z]	3.97±0.25[a-y]	2.77±0.18[a-z]
		P_{10}	42.30±4.52[a-x]	40.75±3.93[a-x]	207.91±29.02[a-x]	187.23±23.67[a-x]	3.2833±0.40[a-x]	2.99±0.43[a-x]	4.39±0.43[a-x]	4.17±0.5[a-x]
	S_5	P_0	39.31±3.16[a-y]	36.80±3.04[a-y]	191.71±22.06[a-y]	169.00±13.83[a-y]	2.9833±0.34[a-y]	2.69±0.38[a-y]	3.97±0.25[a-y]	3.67±0.32[a-y]
		P_5	46.62±6.23[n-t]	42.15±4.47[a-u]	224.39±35.06[n-t]	194.69±27.49[a-u]	3.5733±0.41[p-t]	3.09±0.43[au]	4.91±0.61[n-t]	4.31±0.52[a-u]
		P_{10}	48.17±6.64[j-q]	46.93±6.58[j-o]	232.48±37.97[i-p]	220.67±34.06[i-o]	3.6467±0.44[nop]	3.51±0.51[no]	5.09±0.68[k-q]	4.87±0.69[i-o]
	S_{10}	P_0	43.35±5.06[a-v]	41.85±4.45[a-v]	212.17±30.99[a-v]	192.56±25.64[a-v]	3.3333±0.40[abv]	3.07±0.42[a-v]	4.49±0.48[a-v]	4.30±0.50[a-v]
		P_5	49.23±7.17[g-n]	45.97±6.02[l-q]	236.56±39.05[g-n]	214.12±30.61[l-q]	3.7167±0.47[mn]	3.42±0.48[opq]	5.18±0.72[k-o]	4.75±0.68[l-q]
		P_{10}	51.21±8.10[c-l]	50.14±7.36[e-j]	244.87±41.02[c-l]	235.92±36.78[e-j]	3.8667±0.47[g-l]	3.82±0.53[g-j]	5.38±0.78[g-l]	5.19±0.79[f-j]
LSD0.05			3.10	2.98	13.82	15.73	0.124	0.142	0.318	0.356

†Different letters indicate significant differences at p<0.05.
‡The data of three replicates ± SD (standard deviation) are shown.

Conclusion

The findings of this study promote our hypothesis, which indicates that the exogenous application of selenium and proline efficiently mitigated the negative effect of saltwater irrigation on physiological and agronomic traits in maize. In particular, 10 mg/L selenium treatment and 10 mM proline application were effective strategies to alleviate saltwater stress and thus might constitute a viable approach to improve physiological and agronomical traits in maize under saltwater stress conditions. Furthermore, determining the mechanisms that contribute to the positive effects of the integrative application of selenium and proline on maize under saltwater stress could provide precise insights for formulating optimized strategies to improve crop resilience in saline environments.

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