Journal of Elementology ISSN 1644-2296

Kabay, T. (2026)
'The effect of different potassium doses on the ion content of hyacinths under salt stress',
Journal of Elementology, 31(4), 745-757,
available: https://doi.org/10.5601/jelem.2026.31.1.3786

RECEIVED: 14 February 2026
ACCEPTED: 30 September 2026

ORIGINAL PAPER

The effect of different potassium doses on the ion content of hyacinths under salt stress*

Turgay Kabay

Department of Horticulture
Van Yuzuncu Yil University, Van, Turkiye

Abstract

This study aimed to determine the responses and ion exchange of hyacinth plants to different doses of potassium and salt. The *Hyacinth orientalis* cv. Pink Pearl was used as plant material. To observe the effects of different doses of potassium and salt on the leaves of hyacinths planted in one-liter pots filled with peat and perlite, all flowers were removed after pink blossom formation. The study was designed based on factorial randomized plots with four replicates and five plants per replicate. The study employed four different potassium and salt doses: 0 K mg kg^{-1} (control), 500 mg kg^{-1} K, 1000 mg kg^{-1} K, and 2000 mg kg^{-1} K, and salt doses: 0 mmol (control), 50 mmol, 100 mmol, and 150 mmol NaCl. Hyacinths were kept in a growth chamber with daytime temperatures of 24-26°C and nighttime temperatures of 19-20°C. The hyacinths were exposed to potassium and salt doses for 15 days from the first application. Fifteen days after the salt applications, K, Ca, Mg, and Na analyses were performed on leaves taken from the hyacinths. Membrane damage index and leaf water potential were also examined. At the end of the study, increasing the applied salt doses decreased the amounts of K, Ca, and Mg, and the relative water content of hyacinth leaves, while increasing the membrane damage index. Adding K doses to the salt doses increased the amounts of K, Ca, and Mg, and the relative water content of hyacinth leaves, while decreasing the membrane damage index. The best effect was observed with the K3 application, which is 2000 mg kg^{-1} K. K3 application has been shown to reduce the negative effects of salt and to improve plant growth.

Keywords: hyacinth, ion, leaf, potassium, salt stress

Turgay Kabay, Associate Professor Dr., Department of Horticulture, Faculty of Agriculture, Van Yuzuncu Yil University, Van, Turkiye, e-mail: tkabay@yyu.edu.tr
* No funding was obtained for the study.

INTRODUCTION

Hyacinths are highly valued for their beautiful fragrance and colorful appearance, making it popular choices both indoors and in parks and gardens. However, high salinity in hyacinth-growing areas negatively impacts their development. Incorrect fertilization and agricultural practices in production areas increase soil salinity. In ornamental plants, salt stress negatively affects aesthetic quality, causing symptoms such as leaf tip burning, discoloration, and necrosis, thereby diminishing their landscape value and commercial appeal. Growth performance, including biomass production, plant height, and leaf expansion, is limited due to osmotic stress, ion toxicity, and nutrient imbalances. Salinity also reduces chlorophyll content, leading to decreased leaf greenness and photosynthetic efficiency through impaired stomatal conductivity and transpiration. Additionally, saline water disrupts ion uptake, increasing Na and Cl accumulation and upsetting the balance of essential nutrients such as K and Ca (Wang et al. 2025). It has been demonstrated that nutrients given to plants increase their resistance to salt and drought stress, and reduce the harmful effects of salinity and drought (Kabay 2018, Basdinc, Kabay 2022, Kabay 2022).

It has been reported that $(NH_4)_2SO_4$ and Na_2HPO_4 applications to Pink Pearl and Jon Bos hyacinth varieties improve vegetative growth, bulb and bulblet yield (Addai 2011). In a study where 100-500 mmol NaCl and 10 mmol $CaCl_2$ applications were tested on hyacinth bean seedlings, it was found that seedlings under NaCl stress showed decreased growth index and relative water content, and that these parameters decreased following an application of $CaCl_2$ (D'souza, Devaraj 2013). In water hyacinths under salt stress, it has been reported that the use of nutrient elements reduces the negative effects of salt (Bick et al. 2020). In another study investigating the effect of cow manure compost on water hyacinths under 150 mmol NaCl stress, it was observed that animal manure reduced the negative effects of salt stress and increased the root depth, shoot height, leaf area, and fresh/dry weight of roots and shoots (Ali et al. 2019).

It has been reported that increasing doses of salt affect the phenological components of hyacinth plants (Calıskan et al. 2017). In a study where hyacinth plants were treated with 0, 25, 50, 75, 100, 200, 400, and 600 mmol NaCl at two-day intervals for 15 days, it was demonstrated that high concentrations of NaCl (75 mmol and above) caused a sharp decrease in the K/Na and Ca/Na ratios (Koksal et al. 2014).

In a study conducted on ornamental cabbage, where 30, 60, 90, and 120 mmol NaCl and 5, 10, and 15 mmol $Ca(NO_3)_2$ doses were applied, it was observed that calcium nitrate applications under salt stress conditions had positive and increasing effects on all parameters examined, except for chlorophyll and ion leakage in the leaf tissues of the plant. It was found that with increasing calcium nitrate concentration, there were increases in the

morphological and physiological characteristics of the plants (Karagoz, Dursun 2021). In a study where *Limonium stocksii (*Boiss.*) Kuntze* seedlings were treated with 0 and 600 mmol NaCl and 15 mmol Ca for 15 days, it was reported that in plants treated with NaCl, plant biomass decreased by 50 mmol, MDA content increased by 50 mmol, leaf water content and relative water content decreased, the Na/K ratios and Na secretion rate increased, and photosynthesis decreased. However, Ca application resulted in 25% higher fresh mass and enhanced water content, while reducing tissue osmotic potential and membrane damage, and decreasing Na accumulation in plants exposed to high salinity (Ahmed et al. 2021). In a study on lily plants subjected to 30 mmol salinity stress, foliar application of 500 and 750 mg l^{-1} calcium-silicon nanoparticles (Ca-Si NPs) was tested. It was found that salinity negatively affected flower quality and biochemical parameters, but the application of Ca-Si NPs had positive effects on flower quality, increasing flower size and fresh biomass, biochemical parameters, chlorophyll content in leaves (up to 38.1 mmol), vitamin C (9.4 mmol), and antioxidant capacity (19.2-23.8 mmol) – Gómez-Santos et al. (2023).

In a study where different salt stresses were applied to Chinese rose (*Rosa chinensis*) plants, it was determined that salt stress negatively affected the leaf water content and ion balance, causing large decreases in the Ca/Na, Mg/Na and especially K/Na ratios and leaf damage; furthermore, increasing the Na concentration and decreasing the K/Na ratio negatively affected dry matter production, and it was concluded that soluble potassium should be applied in irrigation to overcome this negative effect (Li et al. 2016). In a study on ornamental cabbage under salt stress (0, 75, 150 and 300 mM) where manganese (4000 mg kg^{-1} Mn) was applied foliarly, it was demonstrated that 75 mM NaCl mitigated the negative effects of salinity on shoot fresh weight and shoot dry weight, significantly increased the K content, and also decreased the Na/K and Na/Ca ratios, which are important indicators of salt stress, under saline conditions with Mn application (Altıntaş et al. 2024). It has been reported that the application of graphene oxide, nanoparticles, and quercetin to mint plants under salt stress reduces the negative effects of salt (Gül, Kurt 2025). In a study on lettuce plants under salt stress (50, 100, 150, and 200 mM NaCl) treated with 500 mg L^{-1} potassium nitrate, it was observed that the negative effects of salt were mitigated by the applied potassium nitrate (Kaya 2023). Scanning electron microscopy and transmission electron microscopy results of the application of salt doses of 1.6, 2.4, 3.2, and 4.0 mS cm^{-1} to the external and internal morphology of geranium (*Pelargonium graveolens* L.) leaves indicate that the number of trichomes on the lower surface of the leaf is greater than on the upper surface, and that high density of head-shaped trichomes is present at high salinity levels (Malebo et al. 2013). In a study investigating the interactions of salinity and ammonium nitrate on seed germination, vegetative growth, and sodium and potassium concentrations in French marigold (*Tegeta patula*) flowers, it was found that different salinity concentrations negatively affected all

parameters examined except germination rate, and ammonium nitrate application brought the examined parameters to the same level as in the control plants (Aboutalebi Jahromi, Farahi 2016). In a study investigating the germination levels of Petunia x hybrida hort. Vilm E. ex., *Torenia fournieri* Lind, and *Tagetes patula* L. at 0, 25, 50, 75, and 100 mM salt doses, it was observed that salt stress negatively affected seed germination, emergence, and seedling development of these three ornamental plant species (Ferraz et al. 2016). Scanning electron microscopy (SEM) analysis of marigold seeds exposed to 0, 50, 100, and 150 mM NaCl revealed the presence of C, O, Ca, Si, Na, S, and Cl at 0, 50, and 100 mM salt concentrations, whereas sulfur (S) was not detected at 150 mM NaCl. It was observed that increasing salt concentration increased cell shrinkage and contraction in the seed coats (Kabay 2026*a*). Similarly, zinnia seeds exposed to 0, 50, 100, and 150 mM salt doses and submitted to scanning electron microscopy revealed the presence of C, O, Ca, Si, Na, S, and Cl elements at 0, 50, and 100 mM salt doses, while silicon was not observed at the 150 mM salt dose. It has been concluded that increasing salt concentration leads to increased cell shrinkage and contraction in seed coats (Kabay, 2026*b*).

Hyacinthus orientalis cv. Pink Pearl was chosen as the model plant to analyze its physiological response and ion exchange mechanisms under varying potassium levels and salt stress. The study aims to evaluate how this specific cultivar adapts to environmental stressors through potassium management.

MATERIALS AND METHODS

This study, which determined the responses and ion exchange of hyacinth plants to different potassium and salt doses, used the *Hyacinth orientalis* Pink Pearl variety. To observe the effects of different potassium and salt doses on hyacinth leaves grown in 1-liter pots containing 1:1 mixture of peat and perlite, all flowers were removed at the beginning of flowering. After flower removal, four different potassium (K, in the form of K_2SO_4) doses (0 K mg kg^{-1} control, 500 mg kg^{-1} K, 1000 mg kg^{-1} K, and 2000 mg kg^{-1} K) and salt doses (0 mmol control, 50 mmol, 100 mmol, and 150 mmol NaCl) were applied. The study was designed as factorial randomized plots with four replicates and five plants per replicate.

The hyacinths were kept in a growth chamber with daytime temp. of 24-26°C and nighttime temp. of 19-20°C. The plants were exposed to potassium and salt doses for 15 days starting from the first application. Fifteen days after the salt doses were applied, analyses of K, Ca, Mg, and Na were performed on hyacinth leaves. The membrane damage index and leaf water potential were also examined.

Mineral element analysis

At the end of the study, hyacinth leaves were dried at 65°C for 72 hours. The dried samples (200 mg) were ground, pre-ignited with ethyl alcohol, and ignited at 550°C until complete ashing. The resulting ash was dissolved in a 3.3 g kg^{-1} HCl solution and filtered through blue-band filter paper. The concentrations of Na, K, Ca, and Mg were then determined using an atomic absorption spectrophotometer – AAS (D'souza, Devaraj 2013, Kabay, Sensoy 2016).

Determination of the relative water content of leaves

At the end of the study, fresh leaf samples were taken, weighed (FW), and soaked in distilled water for 4 h to calculate their turgor weights (TW). Then, the samples were kept in an oven (65°C) for 48 h and weighed (DW). The following formula was used to calculate the relative water content in hyacinth leaves:

LRWC (%) = (FW – DW) × 100 (TW – DW) (Basdinc, Kabay 2022).

Determination of the membrane damages in leaf cells

Membrane damage index (MDI) in hyacinth leaves was calculated by measuring the electrolyte excreted from the cells. 17 mm diameter discs taken from the 2nd leaf from the bottom were incubated in 10 ml of distilled water for 5 h and their EC values were measured.

The same disc samples were kept at 100°C for 10 min and their EC values were measured again. The Membrane Damage Index (MDI) was calculated using the following formula (Basdinc, Kabay 2022).

$$MDI\ (\%) = Lt - Lc \times 100\ 1 - Lc,$$

were: Lt – first EC value of leaf disc samples under salt stress / second EC value of leaf disc samples under salt stress after being held at 100°C for 10 minutes,

Lc – the first EC value of control leaf disk samples / the second EC value of control disk samples kept at 100°C for 10 min.

The statistical analysis

Analysis of variance based on general linear models was performed using the SAS 9.4.1 statistical program. The Duncan multiple comparisons were tested to adjust for statistical differences (Basdinc, Kabay 2022).

RESULTS AND DISCUSSION

The effects of potassium and salt doses applied to hyacinth plants were examined in terms of K, Ca, Mg, and Na content in hyacinth leaves. Addi-

tionally, the membrane damage index and relative water content of the leaves were also investigated in relation to the salt doses.

Changes in potassium and sodium levels in hyacinth leaves were correlated with the salt and potassium doses applied to the potted plants. The K content in hyacinth leaves was the highest under the K3T0 treatment (6.073 g kg^{-1}), whereas the lowest K content in hyacinth leaves was observed under the K0T2 treatment (0.674 g kg^{-1}), and a low one under the K0T3 treatment (0.735 g kg^{-1}), both of which were statistically in the same group (Table 1). The K/Na ratio reached the maximum under the K3T0 treatment (10.636) and the minimum under the K0T3 treatment (0.151) – Table 1.

Table 1

K and Na content (g kg^{-1}) and K/Na ratio in hyacinth leaves

K (mg kg^{-1}) applications	NaCl (mmol) applications	K (g kg^{-1})	Na (g kg^{-1})	K/Na
Ko (0)	T0 (0)	1.361 *j**	0.597 *e**	2.279
	T1 (50)	0.773 *k*	2.682 *bc*	0.289
	T2 (100)	0.674 *k*	4.395 *a*	0.153
	T3 (150)	0.735 *k*	4.878 *a*	0.151
K1 (500)	T0 (0)	2.984 *g*	0.576 *e*	5.181
	T1 (50)	2.488 *h*	2.291 *c*	1.086
	T2 (100)	2.517 *h*	3.472 *b*	0.725
	T3 (150)	1.958 *i*	3.109 *b*	0.629
K2 (1000)	T0 (0)	5.715 *b*	0.568 *e*	10.062
	T1 (50)	5.749 *b*	1.983 *d*	2.899
	T2 (100)	4.639 *e*	2.934 *bc*	1.581
	T3 (150)	4.193 *f*	2.328*c*	1.801
K3 (2000)	T0 (0)	6.073 *a*	0.571 *e*	10.636
	T1 (50)	5.324 *c*	1.423 *d*	3.741
	T2 (100)	4.916 *d*	2.293 *c*	2.144
	T3 (150)	5.792 *d*	2.184 *c*	2.652

* Different letters in each column denote significant differences ($p<0.05$).

At the end of the study, the highest Ca content in hyacinth leaves was found under the K3T0 treatment (3.367) and similarly high under the K3T1 (3.329) treatment, both values being statistically in the same group, while the lowest Ca content was observed under the K0T3 treatment (2.415) – Table 2. The Ca/Na ratio reached the maximum under the K3T0 treatment (5.897) and the minimum under the K0T3 treatment (0.495) – Table 2.

The highest Mg content in hyacinth leaves was observed under the K3T0 treatment (2.487 g kg^{-1}), whereas the lowest was observed under the K0T3

Table 2

Ca and Na content (g kg^{-1}) and Ca/Na ration in hyacinth leaves

K (mg kg^{-1}) applications	NaCl (mmol) applications	Ca (g kg^{-1})	Na (g kg^{-1})	Ca/Na
K0 (0)	T0 (0)	2.817 *cd**	0.597 *e**	4.719
	T1 (50)	2.794 *cd*	2.682 *bc*	1.042
	T2 (100)	2.579 *e*	4.395 *a*	0.587
	T3 (150)	2.415 *g*	4.878 *a*	0.495
K1 (500)	T0 (0)	2.875 *c*	0.576 *e*	4.991
	T1 (50)	2.829 *cd*	2.291 *c*	1.235
	T2 (100)	2.714 *d*	3.472 *b*	0.782
	T3 (150)	2.683 *d*	3.109 *b*	0.863
K2 (1000)	T0 (0)	3.137 *b*	0.568 *e*	5.523
	T1 (50)	2.729 *d*	1.983 *d*	1.376
	T2 (100)	2.582 *e*	2.934 *bc*	0.880
	T3 (150)	2.519 *f*	2.328*c*	1.082
K3 (2000)	T0 (0)	3.367 *a*	0.571 *e*	5.897
	T1 (50)	3.329 *a*	1.423 *d*	2.339
	T2 (100)	2.861 *c*	2.293 *c*	1.248
	T3 (150)	2.769 *cd*	2.184 *c*	1.268

* Different letters in each column denote significant differences (p<0.05).

treatment with (1.085 g kg^{-1}) – Table 3. Similarly, the highest Mg/Na ratio reached the maximum under the K3T0 treatment (4.356) and its minimum under the K0T3 treatment (0.223) – Table 3.

The study showed that as the potassium (K) dose applied to hyacinth plants increased, the percentage of K in hyacinth leaves also increased. It was observed that increasing K doses also increased the Ca and Mg content in leaves (Tables 1, 2, 3).

Increasing the salt dose applied to hyacinth plants was found to cause an increase in the Na content in leaves. With the increasing Na content, the amounts of K, Ca, and Mg in leaves decreased (Tables 1, 2, 3). The K/Na, Ca/Na, and Mg/K ratios varied according to the applied K and salt doses. In applications where the ratios decreased, the Na content in the leaves increased, while the amounts of K, Ca, and Mg decreased (Tables 1, 2, 3). It has been reported that saline solution disrupts ion uptake, increasing Na and Cl accumulation and upsetting the balance of essential nutrients such as K and Ca (Wang et al. 2025). NaCl applications (75 mmol and above) in hyacinths have been shown to cause a sharp decrease in the K/Na and Ca/Na ratios (Koksal et al. 2014). In a study where *Limonium stocksii* (Boiss.) Kuntze seedlings were treated with 0 and 600 (mmol) NaCl and 15 (mmol) Ca for 15 days, the Na/K ratios and Na secretion rate increased

Table 3

Mg and Na content (g kg^{-1}) and Mg/Na ration in hyacinth leaves

K (mg kg^{-1}) applications	NaCl (mmol) applications	Mg (g kg^{-1})	Na (g kg^{-1})	Mg/Na
K0 (0)	T0 (0)	1.567 *h**	0.597 *e**	2.625
	T1 (50)	1.514 *hi*	2.682 *bc*	0.565
	T2 (100)	1.463 *i*	4.395 *a*	0.332
	T3 (150)	1.085 *k*	4.878 *a*	0.223
K1 (500)	T0 (0)	1.677 *g*	0.576 *e*	2.912
	T1 (50)	1.503 *hi*	2.291 *c*	0.656
	T2 (100)	1.285 *j*	3.472 *b*	0.370
	T3 (150)	1.007 *l*	3.109 *b*	0.324
K2 (1000)	T0 (0)	2.067 *d*	0.568 *e*	3.639
	T1 (50)	1.854 *e*	1.983 *d*	0.935
	T2 (100)	1.791 *f*	2.934 *bc*	0.610
	T3 (150)	1.703 *g*	2.328*c*	0.732
K3 (2000)	T0 (0)	2.487 *a*	0.571 *e*	4.356
	T1 (50)	2.392 *b*	1.423 *d*	1.681
	T2 (100)	2.274 *c*	2.293 *c*	0.992
	T3 (150)	2.226 *c*	2.184 *c*	1.019

* Different letters in each column denote significant differences ($p<0.05$).

while photosynthesis decreased, whereas the Ca application resulted in 25% higher fresh mass at enhanced water content (Ahmed et al. 2021).

It was observed that the membrane damage index and leaf water potential content ratios in hyacinth plants changed after the application of K and salt doses. The highest membrane damage index was observed under the K0T3 and K0T2 treatments (87.93 and 87.65%, respectively), while the lowest values were observed under the K3T0 (31.43), K2T0 (31.65), K1T0 (32.71), and K0T0 (36.45) treatments, and they were statistically in the same group (Table 4).

The leaf relative water content in hyacinth plants reached the highest values under the K3T0 (91.34), K2T0 (88.69), and K0T0 (87.16) treatments, while its lowest value was observed under the K0T3 treatment (18.67%) – Table 4.

The membrane damage index in hyacinth leaves was observed to increase with the applied salt doses (Table 4). The leaf membrane damage index was observed to decrease as the applied potassium doses increased (Table 4). The hyacinth leaf membrane damage index was higher under the potassium (K0) and salt (T3) treatments.

The highest relative water content of hyacinth leaves was observed under the K3 treatment, which supplied the highest dose of potassium, and

Table 4

Leaf membrane damage index (%) and leaf relative water content (%)

K (mg kg^{-1}) applications	NaCl (mmol) applications	Leaf membrane damage index	Leaf relative water content
K0	To (0)	36.45 *d**	87.16 *a**
	T1 (50)	68.42 *b*	75.16 *b*
	T2 (100)	87.65 *a*	20.18 *d*
	T3 (150)	87.93 *a*	18.67 *d*
K1	To (0)	32.71 *d*	81.94 *ab*
	T1 (50)	39.12 *d*	71.45 *b*
	T2 (100)	72.37 *b*	40.42 *c*
	T3 (150)	76.59 *b*	43.74 *c*
K2	To (0)	31.65 *d*	88.69 *a*
	T1 (50)	34.93 *d*	79.46 *ab*
	T2 (100)	41.18 *d*	70.19 *b*
	T3 (150)	76.24 *b*	48.79 *c*
K3	To (0)	31.43 *d*	91.34 *a*
	T1 (50)	56.44 *c*	72.61 *b*
	T2 (100)	67.46 *b*	68.44 *b*
	T3 (150)	68.25 *b*	69.18 *b*

* Different letters in each column denote significant differences ($p<0.05$).

the T0 treatment without salt applications, while the lowest relative water content of leaves was observed under the T3 treatment, which supplied the highest dose of salt, and the K0 treatment, which is a zero dose of potassium (Table 4).

It has been determined that plants supplemented with nutrients improve their resistance to salt and drought stress and are more resilient to the harmful effects of salinity and drought (Kabay 2018, Basdinc, Kabay 2022, Kabay 2022). In hyacinth beans, it has been reported that the growth index and relative water content of seedlings under NaCl stress decreased, and that these decreases were reduced by the application of $CaCl_2$ (D'souza, Devaraj 2013). In water hyacinths under salt stress, it has been found that the negative effects of salt were alleviated when nutrient elements were used (Bick et al. 2020). In water hyacinths, it has been observed that cow manure compost at 150 mM reduced the damage from NaCl stress, increasing the root depth, shoot height, leaf area, and fresh/dry weight of roots and shoots (Ali et al. 2019). It has been reported that the application of $(NH_4)_2SO_4$ or Na_2HPO_4 to Pink Pearl and Jon Bos hyacinth varieties increased vegetative growth, bulb and bulblet yield (Addai 2011). It has been determined that morphological and physiological traits negatively affected by salt doses applied to ornamental cabbage were improved by the application of $Ca(NO_3)_2$

(Karagoz and Dursun 2021). It has been reported that calcium-silicon nanoparticles applied to lilies under salt stress increased flower quality, flower size and fresh biomass, biochemical parameters, and chlorophyll content in leaves (Gómez-Santos et al. 2023).

Under salt stress, Chinese roses exhibit significant reductions in leaf water content, alongside decreased Ca/Na, Mg/Na, and K/Na ratios; however, exogenous potassium application can effectively reverse these declines (Li et al. 2016). In salt-stressed ornamental cabbage, manganese application markedly enhances K content while lowering both the Na/K and Na/Ca ratios (Altıntaş et al. 2024). Similarly, the administration of graphene oxide, nanoparticles, and quercetin to mint plants has been shown to mitigate the adverse effects of salinity (Gul, Kurt 2025). Furthermore, applying 500 mg L^{-1} potassium nitrate to lettuce plants under salt stress alleviated the negative impacts of salinity (Kaya 2023).

Elemental analysis reveals that marigold seeds contain C, O, Ca, Si, Na, S, and Cl at salinity levels of 0, 50, 100, and 150 mM, although sulfur becomes undetectable at 150 mM (Kabay 2026*a*). Similarly, zinnia seeds exhibit the presence of C, O, Ca, Si, Na, S, and Cl across the same salt concentrations, with the exception of silicon, which is absent at 150 mM (Kabay 2026*b*). Regarding plant development, salinity doses ranging from 0 to 100 mM have been shown to adversely affect seed germination, emergence, and seedling growth in *Petunia x hybrida*, *Torenia fournieri*, and *Tagetes patula* (Ferraz et al. 2016). Anatomical adaptations also occur under stress; for instance, rose geranium (*Pelargonium graveolens*) leaves develop higher trichome density on the lower surface compared to the upper surface under elevated salt concentrations (Malebo et al. 2013). Furthermore, while high salinity impairs the vegetative growth parameters of French marigolds, the application of ammonium nitrate effectively restores these parameters to control levels (Aboutalebi Jahromi, Farahi 2016).

The findings indicate that elevated salinity doses led to a decline in K, Ca, and Mg levels in hyacinth leaves, accompanied by a concomitant increase in the Na content (Tables 1, 2, 3). However, the introduction of K doses mitigated these adverse effects, effectively restoring the accumulation of K, Ca, and Mg (Tables 1, 2, 3). Consequently, while the K/Na, Ca/Na, and Mg/Na ratios decreased under increasing salt stress, supplementary K applications counteracted this trend, significantly elevating these nutrient ratios (Tables 1, 2, 3). Furthermore, increasing salinity exacerbated the membrane damage index and reduced the relative water content (RWC) of hyacinth leaves; conversely, incremental K doses alleviated salt-induced stress, resulting in a diminished membrane damage index and enhanced leaf RWC (Table 4). These outcomes align with the established literature, confirming that salt stress reduces K, Ca, and Mg levels as well as RWC while increasing Na accumulation and membrane damage. Conversely, potassium supplementation reverses these detrimental impacts by enhancing key nutrient levels and water status and minimizing Na toxicity and cellular damage.

CONCLUSIONS

Hyacinths are highly favored for both indoor and outdoor cultivation due to their exceptional fragrance and vibrant coloration; however, fluctuating soil salinity severely compromises their yield and quality. This study evaluated the effects of varying potassium doses (0, 500, 1000, and 2000 mg kg^{-1} K) and sodium chloride concentrations (0, 50, 100, and 150 mmol NaCl) on hyacinth performance. The results demonstrated that escalating salinity levels depleted the K, Ca, and Mg content, reduced the leaf relative water content (RWC), and exacerbated the membrane damage index. Conversely, the incorporation of exogenous K successfully mitigated these detrimental effects, enhancing macronutrient accumulation and leaf hydration while decreasing cellular membrane disruption. Among the treatments, the K3 application (2000 mg kg^{-1} K) demonstrated the most prominent protective effect. Consequently, this study confirms that the K3 application effectively alleviates salt-induced stress and optimizes vegetative growth, offering a viable management strategy for hyacinth production under saline conditions.

Author contributions

T.K – investigation, resources, writing–original draft, conceptualization, methodology, validation, investigation, resources, writing–original draft, methodology, formal analysis, writing–review and editing, visualization, supervision. The authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors ensure that they have neither professional nor financial connections related to the manuscript sent to the Editorial Board.

REFERENCES

Aboutalebi Jahromi, A., Hosseini Farahi, M. (2016) 'Seed germination, plant growth and concentration of some elements in French marigold (*Tageta patula*) under the influence of salinity and ammonium nitrate', *International Journal of Horticultural Science and Technology*, 3(2), 199-209, available: https://doi.org/10.22059/ijhst.2017.212510.145

Addai, I.K. (2011) 'Influence of cultivar or nutrients application on growth, flower production and bulb yield of the common hyacinth', *American Journal of Scientific and Industrial Research*, 2(2), 229-245, available: https://doi.org/10.5251/ajsir.2011.2.2.229.245

Ahmed, M.Z., Hussain, T., Gulzar, S., Adnan, M.Y., Khan, M.A. (2021) 'Calcium improves the leaf physiology of salt treated *Limonium stocksii*: A floriculture crop', *Scientia Horticulturae*, 285, available: https://doi.org/10.1016/j.scienta.2021.110190

Ali, S.S., Nessem, A.A., Sun, J., Li, X. (2019) 'The effects of water hyacinth pretreated digestate on *Lupinus termis* L. seedlings under salinity stress: A complementary study', *Journal of Environmental Chemical Engineering*, 7(3), 103-159, available: https://doi.org/10.1016/j.jece.2019.103159

Altıntas, S., Yasemin, S., Catkın, S., Inal, B. (2024) 'Effectiveness of manganese foliar spraying to mitigate salt stress in ornamental cabbage: Insights into morphological, physiological biochemical adaptations and mTERF gene responses', *South African Journal of Botany*, 168, 462-475, available: https://doi.org/10.1016/j.sajb.2024.03.039.0254-6299

Basdic, M.A., Kabay, T. (2022) 'Effects of vermicompost and seaweed on some physiological elements in spinach under salt stress', *Turkish Journal of Agriculture and Natural Sciences*, 9(1), 188-194, available: https://doi.org/10.30910/turkjans.1020090

Bick, E., de Lange, E.S., Kron, C.R., da Silva Soler, L., Liu, J., Nguyen, H.D. (2020) 'Effects of salinity and nutrients on water hyacinth and its biological control agent, *Neochetina bruchi*', *Hydrobiologia*, 847(15), 3213-3224, available: https://doi.org/10.1007/s10750-020-04314-x

Caliskan, O., Radusiene, J., Temizel, K.E., Staunis, Z., Cirak, C., Kurt, D., Odabas, M.S. (2017) 'The effects of salt and drought stress on phenolic accumulation in greenhouse-grown *Hypericum pruinatum*', *Italian Journal of Agronomy*, 12(3), 918, available: https://doi.org/10.4081/ija.2017.918

D'souza, M.R., Devaraj, V.R. (2013) 'Role of calcium in increasing tolerance of hyacinth bean to salinity', *Journal of Applied Biology & Biotechnology*, 1(3), available: https://doi.org/10.7324/JABB.2013.1302

Ferraz, M.V., Franco, C.F., Batista, G. S., Pivetta, K.F.L. (2016) 'Effect of salinity on seed germination and germination rate index of three ornamental plant species', *Ornamental Horticulture*, 22(2), 196-201, available: https://doi.org/10.14295/oh.v22i2.919

Gómez-Santos, M., González-García, Y., Pérez-Álvarez, M., Cadenas-Pliego, G., Juárez--Maldonado, A. (2023) 'Impact of calcium-silicon nanoparticles on flower quality and biochemical characteristics of *Lilium* under salt stress', *Plant Stress*, 10, available: https://doi.org/10.1016/j.stress.2023.100270

Gül, I., Kurt, B.O. (2025) 'Using nanoparticles to mitigate salinity stress in Mentha species', *Journal of Elementology*, 31(1), 173-188, available: https://doi.org/10.560/jelem.2025.30.2.3571

Kabay, T.. Şensoy S., (2016) 'Drought stress-induced changes in enzymes, chlorophyll and ions of some bean genotypes', *Yuzuncu Yıl University Journal of Agricultural Sciences,* 26(3), 380-395, available: https://dergipark.org.tr/en/download/article-file/267050

Kabay, T. (2018) 'The effect of humic acid on plant growth in lettuce produced at different salt doses', *EJONS International Journal on Mathematic, Engineering and Natural Sciences*, 2(5), 37-43, available: https://ejons.org/index.php/ejons/issue/view/5

Kabay, T. (2022) 'Effects of different potassium doses on growth rates and micronutrients of drought-sensitive beans', *Journal of Elementology*, 27(2), 239-247, available: https://doi.org/10.5601/jelem.2021.26.4.2181

Kabay, T. (2026*a*) 'Germination test of marigold seeds under salt stress and Scanning Electronic Microscope (SEM) Analysis', *MAS Journal of Applied Sciences*, 11(1), 98-106, available: https://doi.org/10.5281/zenodo.19060574

Kabay, T. (2026*b*) 'Germination test and Scanning Electronic Microscope analysis of Zinnia (*Chrysogonum peruvianum* L.) seeds under salt stress', *Ejons International Journal on Mathematic, Engineering and Natural Sciences*, 10(1), 66-74, available: https://doi.org/10.5281/zenodo.19357792

Karagoz, F.P., Dursun, A. (2021) 'Calcium nitrate on growth and ornamental traits at salt -stressed condition in ornamental kale (*Brassica oleracea* L. var. *acephala*)', *Ornamental Horticulture*, 27(2), 196-203, available: https://doi.org/10.1590/2447-536X.v27i2.2246

Koksal, N., Kulahlıoglu, I., 'Ertargın, E., Torun, A.A. (2014) 'Relationship between salinity stress and ion uptake of hyacinth (*Hyacinthus orientalis*)', *Türk Tarım ve Doğa Bilimleri Dergisi*, 1(Özel Sayı-1), 578-583, available: https://dergipark.org.tr/en/download/article-file/142144

Kaya, G. (2023) 'Ameliorative effects of foliar potassium nitrate on the growth, physiological, and stomatal properties of lettuce plants under salinity stress', *Journal of Plant Nutrition*, 46(12), 2882-2892, available: https://doi.org/10.1080/01904167.2022.2160758

Li, X., Wan, S., Kang, Y., Chen, X., Chu, L. (2016) 'Chinese rose (*Rosa chinensis*) growth and ion accumulation under irrigation with waters of different salt contents', *Agricultural Water Management*, 163, 180-189, available: https://doi.org/10.1016/j.agwat.2015.09.020

Malebo, N., Sedibe, M.M., Khetsha, Z.P. (2013) 'Salinity effects on external and internal morphology of rose geranium (*Pelargonium graveolens* L.) leaf', *Life Science Journal*, 10(11), 109-115, available: http://www.lifesciencesite.com

Wang, Z., Poudyal, S., Kopp, K., Zhang, Y. (2025) 'Response of ornamental plants to salinity: impact on species-specific growth, visual quality, photosynthetic parameters, and ion uptake', *Frontiers in Plant Science*, 16, available: https://doi.org/10.3389/fpls.2025.1611767