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Effects of salt applications on growth and development of ornamental cabbage (*Brassica oleracea* var. *acephala*)

Hakan KARTAL[1]*, Saliha ERDOĞDU[1], Fulya OKATAR[1]

[1]Tokat Gaziosmanpaşa University, Faculty of Agriculture, Department of Horticulture, Tokat, Türkiye

***Corresponding author e-mail:** kartalhakan09@gmail.com

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Abstract: This study was conducted during 2024 and 2025 to determine the effects of varying doses of salt application to the growing medium on the growth, and development of ornamental Cabbage (Brassica oleracea var. acephala) plants. Different salinity doses (EC 0 mM (Control), EC 25 mM, EC 50 mM, EC 100 mM and EC 200 mM) were applied to the growth medium (70% peat + 30% perlite). Data relating to plant height (cm), head diameter (mm), root length (cm), number of leaves (number), leaf length (cm), leaf width (cm), stem wet weight (g), stem diameter (mm), stem length (cm), root dry-wet weight (g), leaf wet-dry weight (g), chlorophyll index (Spad), proportional water (%), ion flow (%), and cell membrane damage rate (%) were collected. Results revealed that increasing salt concentrations raised relative water content, ion flow, and cell membrane damage rate compared to the control. However, control treatment gave better results for other analysed traits. It was observed that there were proportional decrease in the treatments in parallel with the increase in salinity doses.

Keywords: EC, hydroponics, ornamental cabbage (*Brassica oleracea* var. *acephala*)

Tuz uygulamalarının süs lahanası (*Brassica oleracea* var. *acephala*) bitkisinin büyüme ve gelişimine etkileri

Öz: Bu çalışma, yetiştirme ortamına farklı dozlarda tuz uygulamasının Süs Lahanası (*Brassica oleracea* var. *acephala*) bitkisinin büyüme ve gelişimine etkilerini belirlemek amacıyla 2024-2025 yılları arasında yürütülmüştür. Çalışmada, yetiştirme ortamına (hacim esasına göre %70 torf + %30 perlit) farklı dozlarda tuz (EC 0 mM (Kontrol), EC 25 mM, EC 50 mM, EC 100 mM ve EC 200 mM) uygulanmıştır. Bu çalışmada, bitki boyu (cm), baş çapı (mm), kök uzunluğu (cm), yaprak sayısı (adet), yaprak boyu (cm), yaprak eni (cm), gövde yaş ağırlık (g), gövde çapı (mm), gövde uzunluğu (cm), kök yaş-kuru ağırlık (g), yaprak yaş-kuru ağırlık (g), klorofil indeksi (Spad), oransal su (%), iyon akışı (%) ve hücre zarı zarar oranı (%) gibi parametreler incelenmiştir. Çalışma sonunda, uygulamalar arasında, oransal su kapsamı, iyon akışı ve hücre zarı zarar oranı bakımından tuz konsantrasyonları arttıkça bu değerlerde kontrole kıyasla artmıştır. Ancak diğer incelenen parametreler açısından, kontrol uygulamalarının daha iyi sonuç verdiği; Tuz uygulama dozlarının artmasına paralel olarak uygulamalarda oransal olarak azalmalar olduğu gözlenmiştir.

Anahtar kelimeler: EC, süs lahanası (*Brassica oleracea* var. *acephala*), topraksız tarım

1. Introduction

Ornamental cabbage (*Brassica oleracea* var. *acephala*) belongs to genus Brassica in Cruciferae family. It is used for outdoor ornamental purposes. It is commonly employed as ground cover in essential habitats and along roadsides and it plays a crucial role in landscape design due to its unique leaf morphology and pigmentation (Ağar, 2015; Błażewicz-Woźniak et al., 2021). The central leaves do not form a head in ornamental cabbage. Various vegetables belonging to the *Brassica oleracea* species, including broccoli, cauliflower, and Brussels sprouts, are also included in this group (Carter, 2019). This species exhibits a biennial life cycle. Vegetative organs, i.e., roots and leaves which are formed during the first year. Similarly, the reproductive organs, i.e., flowers, and seeds are

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formed during second year, (Kishimoto et al., 2014; Carter, 2019). The varied leave colors like purple, pink, white, green, and red, is a defining feature that makes ornamental cabbage as a preferred component in landscape design (Carter, 2003; Oral, 2004; Zhu et al., 2017). Despite its classification as a cold climate plant, it exhibits a high degree of adaptability to diverse geographical regions, enabling cultivation in a broad spectrum of climates. Furthermore, it has demonstrated capacity to adapt to hot climates, though its initial development may be hindered under excessively high temperatures.

Ornamental cabbage exhibits a moderate degree of resistance to saline soils. However, saline soils, and inadequate irrigation conditions pose significant challenges during the cultivation of this species. Soil salinity, and irrigation water constitutes a primary abiotic limiting factor in agriculture worldwide. This phenomenon has been observed to increase over the past two decades, primarily due to the escalating demand for irrigation in arid, and semi-arid regions. Consequently, salinity has emerged as the predominant stress factor hindering crop productivity (Parwaiz & Satyavati, 2008; Çulha & Çakırlar, 2011; Yılmaz et al., 2011). Salinity poses considerable agricultural challenges, arising from soil characteristics and irrigation water attributes. However, anthropogenic factors, such as irregular irrigation, improper fertilization, and environmental pollution from industrial activities, have also been demonstrated to be effective in increasing salinity levels (Ouhibi et al., 2014; Farooq, 2021). A global perspective reveals that 20% of irrigated agricultural land, and 2.1% of dry-land agricultural areas are confronted with salinity challenges (Munns & Tester, 2008; Daliakopoulos et al., 2016). Furthermore, approximately one-third of the global agricultural landscape is susceptible to salinity (Rengasamy, 2006; Squires & Glenn, 2011). An average of 2,000 hectares of agricultural land worldwide are converted to non-agricultural use due to salt damage daily (Qadir et al., 2014). It is also predicted that 50% of agricultural land will become unavailable for agriculture due to salinity problems by 2050 (Kızılgeçi, 2021; Ludwiczak et al., 2021).

Plants may recognize salt stress through their root systems, which then initiate two main physiological challenges. The first is osmotic stress due to water deficiency, and the other is ionic toxicity caused by nutrient imbalances due to ion accumulation in the cytosol in the long term. These two main stress factors severely limit plant growth due to excessive sodium (Na^+), and chlorine (Cl^-) intake. Indirectly, this situation leads to calcium (Ca^{2+}), and potassium (K^+) deficiency, and imbalances in other nutrients; thus, negatively affects plant metabolism. Furthermore, salt stress has been shown to induce oxidative stress, resulting in the generation of reactive oxygen species (ROS). Plants have been observed to initiate a variety of physiological, and biochemical processes to mitigate the adverse effects of salinity stress. According to Munns & Tester (2008), Çulha & Çakırlar (2011), Yılmaz et al. (2011), Cassaniti et al. (2013), and Acosta-Motos et al. (2017), such mechanisms include morphological, anatomical, water relations, photosynthetic, hormonal, and biochemical changes. The issue of salinity has been demonstrated to induce complications in the growth, and development of ornamental plants. Several studies have reported that losses in growth, and development due to salt stress are also reflected in advanced developmental stages of the plant, such as the formation of flowers, fruits, and seeds. Plants exposed to salt stress experience a range of physiological, morphological, and developmental disorders, which collectively result in a substantial decline in their overall performance, and aesthetic value.

The objective of this study is to examine the impact of salinity on the growth of ornamental cabbage. Determining the effects of salt stress on the growth, and development parameters of plants is of particular importance because it provides guiding information to producers, and landscape designers.

2. Materials and Methods

2.1. Materials

This study was carried out in a 450 m^2 glass greenhouse (40°19'55 'N 36°28'33 'E) with roof ventilation, and no heating, and cooling system at Tokat Gaziosmanpaşa University Agricultural Research, and Application Centre between 2024-2025. Ornamental cabbage variety (*Brassica oleraceae* var. *acephala*) of pink head type was used as plant material (Figure 1). Plants were grown in pots with dimensions of 24.5×20.3×13.7 cm. Four plants were used in each replicate, one plant was used in each pot, and observations were taken on 12 plants in total. Hoagland's nutrient solution was used as nutrient solution for growing ornamental cabbage (Hoagland & Arnon, 1950).

Figure 1. Pink ornamental cabbage grown in the trial area

Different salinity doses (i.e., EC 0 (Control), EC 25 mM, EC 50 mM, EC 100 mM, and EC 200 mM) were used in the study. NaCl salt was used to create the irrigation water salinity levels, and peat:perlite was used as growing medium at a ratio of 2:1 (Table 1).

Table 1. Chemical properties of peat used in the study

Properties	Values
Organic matter (%)	95
pH	5.5
EC (dS/m)	2.5
N (mg/l)	140
P_2O_5 (mg/l)	160
K_2O (mg/l)	180
MgO (mg/l)	10
SO_3 (mg/l)	187
Fe (mg/l)	0.9
Mn (mg/l)	1.6
B (mg/l)	0.3
Zn (mg/l)	0.4
Cu (mg/l)	1.5
Mo (mg/l)	0.5

2.2. Methods

Some morphological traits, including (plant height (cm), head diameter (cm), stem length (cm), stem diameter (mm), number of leaves (number) were recorded to determine the effects of salinity doses on the growth, and development of ornamental cabbage, and to reveal its visual quality, leaf width (mm), and length (mm), stem wet weight (g), root length (cm), root wet weight (g), and dry weight (g), and physiological parameters (chlorophyll index (SPAD), proportional water coverage (%), ion flux (%), and cell membrane damage rate (%)) were measured. The measurements were performed as described below.

2.3. Morphological parameters

Plant height (cm): The length between the top of the plant, and the root collar was measured in cm with a metre. Head diameter (cm) was determined by measuring the widest part of the head in cm with a metre. Stem length (cm) was determined by measuring the distance from the bottom of the head to the root collar in cm with a meter rod. Stem diameter (mm) was determined by measuring the widest part of the stem with a digital caliper. Number of leaves (number) was determined by counting the healthy leaves on the plants. Leaf width (mm) was determined by measuring from the widest part of the leaf blade with the help of a digital caliper. Random leaves were taken from different parts of the plant, and 3 different measurements were made, and the average was recorded. Leaf length (mm) was determined by measuring the distance between the point where the petiole ends, and the extreme point of the leaf in mm with the help of a digital caliper. Leaves were randomly taken from different points of the plants, and 3 different measurements were made, and the average was recorded. Stem wet weight (g) was determined by cutting the upper part of each plant at the soil level, and weighing it on a precision balance, and measuring in grams. Root Length (cm) was recorded by measuing the distance from the root tip to the root collar of the plants was determined by measuring with a meter rod. Root fresh weight (g) was recorded by removing the plant roots from the pots, washed with tap water, and dried on blotting paper to remove excess water. Afterwards, root fresh weight was determined by weighing on a precision balance. Roots were dried in an oven at 65 °C until they reached constant weight. The weights of the dried roots were measured on a precision balance to determine root dry weight.

Figure 2. Morphological observations in ornamental cabbage

2.4. Physiological parameters

Leaf chlorophyll content (SPAD) was measured every seven days. Two readings per replicate were taken from fully developed leaves using a SPAD device (SPAD-502, Minolta, Osaka, Japan). Fresh weight (FW) of the leaf samples was taken from the plants at the termination of the experiment to determine the proportional water content. Afterwards, the leaves were kept in distilled water for 6 hours, and the turgor weight value (TW) was determined by weighing the leaves again on a precision balance. After drying the weighed leaf samples in an oven at 65 °C for 48 hours, dry weights (DW) were recorded in grams. Leaf proportional water content (%) was calculated by proportioning the fresh, and dry weights obtained by using the following formula (Kuşvuran, 2010).

LPWC=(FW-DW)/(TW-KA)×100 (FW: Fresh Weight, DW: Dry Weight, TW: Turgor Weight)

The leaf samples were first washed in tap water, and then rinsed in pure water, and prepared for analysis. For each treatment, 12 discs with a diameter of 1.5 cm were taken from the leaves. The discs were placed in glass tubes, and 20 ml of distilled water was added, and incubated for 24 hours on a mechanical shaker (100 rpm). After 24 hours, the electrical conductivity of the samples was measured with an EC metre. This value was recorded as EC-1. Then, the tissues were killed by autoclaving at 121 °C for 20 minutes. When the autoclaved samples reached room temperature, a second reading (EC-2) was taken with an EC metre. Ion leakage rates of leaves were calculated according to the following formula. Ion Leakage (%): (EC1/EC2) × 100 (EC1: 1st reading, EC2: 2nd reading) (Özden et al., 2009).

Cell membrane damage rate (CMDR) (%) was calculated using ion leakage rates of leaf tissues. It was calculated according to the following formula based on the damage in control samples (Dlugokecka & Kacperska-Palacz, 1978; Fan & Blake, 1994).

CMDR(%)=[1-(1-(1-EC1÷EC2) ÷(1-EC×1÷EC×2) ×100]

CMDR (%) = [(Application ion flow (%) - Control ion flow (%)) / 100 - Control ion flow] × 100

The study was carried out according to the random plots design with 3 replications. The results were evaluated by analysis of variance (ANOVA) in SPSS (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.). The Duncan multiple range test was applied to determine the differences between treatments. Mathematical model of randomised plots experimental plan is given below.

$Y_{ij} = \mu + \alpha_i + e_{ij}$.

Here, Yij= the observation value of the jth replicate of the ith treatment, μ = general population mean, αi = ith treatment effect, eij = the random error of the jth repetition of the i-th transaction, means.

3. Results and Discussion

The effects of different salinity doses on the studied traits of ornamental cabbage are given in Tables 2, 3, 4, 5, 6. Significant difference was observed between plant height, and root length of different salt doses applied to ornamental cabbage at 0.001 level, and head diameter at 0.01 level. The highest values for plant height, head diameter, and root length were 29.93 cm, 10.67 mm, and 16.25 cm in the control treatment, respectively (Table 4). Akat Saraçoğlu & Akat (2022) applied three different salt doses (S0, S1 and S2) on ornamental cabbage, and reported that plant height varied between 29.63 cm, and 26.50 cm. In a separate study, Salachna et al. (2017) investigated the effects of varying salt concentrations (50, 100, 200, 400, and 800 mmol dm^{-3} NaCI) on the growth of ornamental cabbage. The findings revealed that plants exposed to the highest salt concentration (800 mmol dm^{-3} NaCI) exhibited a substantial reduction in plant height compared to other groups. The range of plant heights observed varied from 28.20 to 43.00 cm. In their seminal study, Prabucki et al. (1999) investigated the effects of salt stress on plant growth, and rooting performance of cuttings in Chrysanthemum morifolium. It was reported that the rooting of cuttings taken from plants decreased by 70% for root length, and 52% for root weights. Similarly, Figueiredo et al. (2017) observed that excessive fertilization, and irrigation practices in Zantedeschia aethiopica plants decreased plant height, and root length under salt stress. Studies investigating the effects of salinity on different ornamental plant species reported that different salinity levels did not affect the appearance of the flower, but the flower (head) diameter decreased with increasing salt levels (Sonneveld, 2000). Likewise, Li et al. (2016), Carvalho et al. (2017), Oliveira et al. (2017), and Sun et al. (2018) reported that salt stress had a reducing effect on plant height in various studies. The differences in plant height, head diameter, and root length may be due to the differences in light intensity, soil (medium), and plant species as well as salt concentrations applied. Different salt doses significantly (at 0.001 level) altered number of leaves, and leaf length, while leaf width remained unaffected. The longest leaf length was noted from the control treatment (15.69 cm), and the highest number of leaves was obtained from the control (21.27 pieces), and EC 25 mM (21.18 pieces) treatments (Table 5). Yasemin (2020) examined the effects of different salt (EC 0-50-100-150-200) doses in Zinnia cultivation, and reported that the number of leaves varied between 17-78/plant, leaf width between 2.23-4.14 cm, and leaf length between 5.81-9.96 cm. Cirillo et al. (2016)

reported that salinity reduced morphological traits such as number of lateral branches, lateral branch length, number of leaves, and leaf area of Viburnum lucidum L. and Callistemon citrinus. Similarly, Figueiredo et al. (2017), and Sun et al. (2018) reported that salt stress reduced the number of leaves, and leaf area in their studies on Zantedeschia aethiopica, and velvet. In general, the decrease in leaf and stem development led to a decrease in shoot biomass, and plant height. In plants grown under stress conditions, differences in plant growth parameters such as number of leaves, leaf area, and number of lateral branches, which may occur separately, also cause a cumulative decrease in plant biomass.

Statistically significant difference (at 0.001 level) was observed among salinity doses for shoot fresh weight, stem diameter, and stem length. The highest values of stem length (16.78 cm), and stem diameter (12.15 mm) were obtained from the control treatment, whereas the highest shoot fresh weight was obtained from 25 mM (112.36 g) salinity dose (Table 6). Yasemin (2020) examined the effects of different salt levels (EC 0-50-100-150-200) on stem growth in his study on Zinnia plant, and reported that stem diameter and length varied between 3.64-5.22 mm, and 9.9-15.6 cm, respectively. Álvarez & Sánchez-Blanco (2014), and Gómez-Bellot et al. (2013) reported an increase in the root/stem ratio of C. citrinus, and Euonymus plants under moderate salinity conditions, and several studies have reported that salt stress has a significant effect on the root/stem ratio of plants (Bañón et al., 2011; Valdez-Aguilar et al., 2011; Álvarez et al., 2012; Fernández-García et al., 2014). The main reason for these significant differences between treatments is that salt causes both osmotic stress, and ion toxicity in plants. High salt concentrations limit the plant's ability to take up enough water, leading to a decrease in turgor pressure, which in turn slows down cell expansion, and division (Munns & Tester, 2008). Furthermore, excessive accumulation of sodium and chlorine ions limits enzyme activity, photosynthesis capacity, and may cause toxic effects on cell structures (Parida & Das, 2005). There was a statistically significant difference at 0.001 level between salinity doses for root fresh weight, and leaf wet-dry weight, while root dry weight remained unaffected. The highest leaf fresh weight was recorded from the control (81.09 g), and the highest leaf dry weight, and root wet weight were obtained from the control (9.57-6.27 g), EC 25 mM (9.73-6.96 g), and EC 50 mM (9.31-7.06 g) treatments, respectively (Table 5). In the studies on different species, Yasemin (2020) reported that root wet weight of Zinnia varied between 2.23-7.90 g, and root dry weight between 0.157-0.594 g under different salt (EC 0-50-100-150-200) concentrations. Similarly, Köksal & Külahlıoğlu (2013) reported that increasing salt levels caused a decrease in leaf dry weight, and leaf proportional dry weight in Jan Boss Hyacinth cultivar grown under different salt concentrations (0, 25, 50, 75, 75, 100, 200, 400, and 600 mM NaCl). Likewise, Figueiredo et al. (2017) reported that over-fertilization, and irrigation in Zantedeschia aethiopica under salt stress decreased root fresh and dry weight. Various studies have reported that fresh, and dry weight values of Sedum rupestre, S. telephium, S. reflexum, and Evolvulus glomeratus (Hooks & Niu, 2019), Crysanthemum paludosum (Yasemin et al., 2017), Tagetes patula (Darwish et al., 2016) and Zinnia marylandica (Niu et al., 2012) decreased under salt stress. Many studies on ornamental plants reported that the fresh, and dry weights of plants decreased under salt stress (Sun et al., 2018; Gomes et al., 2017; Ashrafi & Nejad, 2017; Acosto-Motos et al., 2017; Kumar et al., 2016; Cai et al., 2014; Cordovilla et al., 2014). All these literature findings are in parallel with the results obtained in our study, and reveal that salt stress has suppressive effects on wet, and dry biomass of plants.

Table 2. Effect of salinity doses on plant height, head diameter, and root length in ornamental cabbage.

Treatments	Plant Height (cm)	Head Diameter (mm)	Root Length (cm)
Control	29.93 ± 0.53^{a}	10.67 ± 1.01^{a}	16.25 ± 0.25^{a}
25 mM	27.18 ± 0.60^{b}	9.59 ± 0.39^{ab}	15.58 ± 0.11^{b}
50 mM	25.93 ± 0.65^{c}	8.90 ± 0.57^{bc}	14.25 ± 0.50^{c}
100 mM	22.43 ± 0.95^{d}	8.84 ± 0.52^{bc}	13.38 ± 0.45^{d}
200 mM	18.87 ± 0.54^{e}	8.10 ± 0.39^{c}	12.24 ± 0.25^{e}
level of significance	0.000	0.005	0.000
p-value	***	**	***

*** : Significant at P≤0.001 level; **: Significant at P≤0.01 level

Table 3. Effect of salinity doses on leaf number, leaf width, and leaf length in ornamental cabbage.

Treatments	Number of Leaves ($plant^{-1}$)	Leaf Width (cm)	Leaf Length (cm)
Control	21.27 ± 0.45[a]	8.42 ± 0.38	15.69 ± 0.56[a]
25 mM	21.18 ± 0.93[a]	8.34 ± 0.37	15.09 ± 0.39[ab]
50 mM	18.84 ± 0.64[b]	8.03 ± 0.38	14.09 ± 0.62[bc]
100 mM	18.34 ± 0.52[b]	7.75 ± 0.00	13.02 ± 0.87[cd]
200 mM	14.82 ± 0.90[c]	7.69 ± 0.50	11.90 ± 0.57[d]
level of significance	0.000	0.116	0.000
p-value	***	ns	***

*** : Significant at P≤0.001 level; ns: not significant.

Table 4. Effect of salinity doses on shoot fresh weight, stem diameter, and stem length in ornamental cabbage

Treatments	Shoot fresh Weight (g)	Stem Diameter (mm)	Stem Length (cm)
Control	99.25 ± 0.76[b]	12.15 ± 0.70[a]	16.78 ± 0.21[a]
25 mM	112.36 ± 0.65[a]	11.50 ± 0.59[ab]	14.84 ± 0.80[b]
50 mM	99.98 ± 1.57[b]	10.67 ± 0.46[bc]	11.93 ± 0.52[cd]
100 mM	101.33 ± 1.86[b]	10.13 ± 0.60[cd]	12.17 ± 0.81[c]
200 mM	80.65 ± 1.43[c]	9.17 ± 0.73[d]	10.86 ± 0.34[d]
level of significance	0.000	0.001	0.000
p-value	***	***	***

***: Significant at P≤0.001

Table 5. Effect of different salinity doses on root fresh-dry weight, and leaf fresh-dry weight in ornamental cabbage.

Treatments	Root Fresh Weight (g)	Root Dry Weight (g)	Leaf Fresh Weight (g)	Leaf Dry Weight (g)
Control	6.27 ± 0.23[a]	1.27 ± 1.27	81.09 ± 1.66[a]	9.57 ± 0.50[a]
25 mM	6.96 ± 0.68[a]	1.22 ± 0.01	75.50 ± 1.20[bc]	9.73 ± 0.65[a]
50 mM	7.06 ± 0.48[a]	1.30 ± 0.03	77.34 ± 0.01[b]	9.31 ± 0.17[a]
100 mM	5.11 ± 0.12[b]	0.86 ± 0.01	75.08 ± 0.43[c]	7.36 ± 0.02[b]
200 mM	4.80 ± 0.39[b]	1.05 ± 0.55	51.26 ± 0.96[d]	4.75 ± 0.61[c]
level of significance	0.000	0.230	0.000	0.000
p-value	***	ns	***	***

*** : Significant at P≤0.001 level; ns: not significant.

Table 6. Effect of different salinity doses on chlorophyll index, propotional water coverage, ion flow, and cell membrane damage rate in ornamental cabbage.

Treatments	Chlorophyll İndex (SPAD)	Proportional Water Coverage (%)	Ion Flow (%)	Cell Membrane Damage Rate (%)
Control	57.26 ± 0.53[a]	74.59 ± 3.57[cd]	13.23 ± 0.64[d]	0.00 ± 0.00[d]
25 mM	54.72 ± 0.51[cd]	70.86 ± 2.04[d]	19.37 ± 1.41[c]	7.75 ± 0.86[c]
50 mM	55.77 ± 0.37[b]	83.46 ± 0.96[ab]	19.06 ± 1.02[c]	7.39 ± 0.23[c]
100 mM	55.37 ± 0.53[bc]	80.49 ± 1.38[bc]	25.19 ± 2.38[b]	15.46 ± 1.23[b]
200 mM	53.89 ± 0.37[d]	88.29 ± 6.62[a]	46.33 ± 2.03[a]	39.48 ± 1.19[a]
level of significance	0.000	0.001	0.000	0.000
p-value	***	***	***	***

*** : Significant at P≤0.001

It was observed that the difference between chlorophyll index, proportional water, ion flow, and cell membrane damage rate of different salt doses was statistically significant at 0.001 level. The control treatment yielded the highest chlorophyll index (57.53 SPAD), while the EC 200 mM salt treatment resulted in a proportionate water content of 88.29%, ion flow of 46.33%, and a cell membrane damage rate of 39.48% (Table 6). Proportional water coverage, ion flow, and cell membrane damage rates also increased with increasing salt concentrations. Yasemin (2020) examined the effects of different salt doses (EC 0-50-100-150-200) in Zinnia cultivation, and found ion leakage between 25%, and 58%, chlorophyll index between 23-35 SPAD, and proportional water content between 44%, and 79%. Bizhani et al. (2013), determined salt stress tolerance in Zinnia elegans plant and found that plant height, leaf area, and chlorophyll content decreased, and general growth slowed down with increasing salt doses. Köksal & Külahlıoğlu (2013) reported that chlorophyll content, and salt symptom scale of Jan Boss hyacinth cultivar grown under different salt concentrations (0, 25, 50, 75, 75, 100, 200, 400, and 600 mM NaCl) did not show a statistical difference under salt stress. Sun et al. (2018) found that SPAD values in two of the marigold cultivars (Discovery Orenage and Taishan Gold) grown under saline conditions were like the control, while the other two (Discovery Yellow and Taishan Yellow) were lower than the control. Sayyed et al. (2014), and Carvalho et al. (2017) reported that salt stress decreased chlorophyll content in rose, and marigold in their studies. Yasemin et al. (2017) reported that salt stress had no effect on leaf relative water content in C. paludosum, while Bres et al. (2016) reported that salt stress had no positive effect on leaf relative water content in Pelargonium. In the same way Veatch-Blohm et al. (2012) reported that salt stress had no positive effect on leaf relative water content in calla lily. Trivellini et al. (2014) reported that 200 mM salt applications increased ion leakage in H. rosa-sinensis plants under stress conditions. Similarly, Yasemin et al. (2017) reported that ion leakage increased in parallel with increasing salt concentrations in C. paludosum plants. In addition, studies conducted in different species such as tomato, melon, chili pepper, bean, and zucchini agreed on the point that there was a decrease in leaf proportional water ratio at increasing doses of salt applications, and this value reached the highest level in control plants (Kuşvuran, 2010; Topaloğlu, 2010; Kaya, 2011; Bayat et al., 2012).

These results generally indicate that salt stress suppresses chlorophyll synthesis, makes water uptake difficult, and increases ion leakage by disrupting cell membrane integrity. While osmotic and ionic stresses caused by salt decreases photosynthesis capacity, structural disruptions in the cell membrane can be explained as increased ion flux, and increased membrane damage rate.

4. Conclusion

This study investigated the effects of different salt doses on growth, and the development of ornamental cabbage. It was observed that increasing salt doses had significant but negative effects on all measured traits. There was a significant decrease in plant growth (morphological characteristics) parameters with increasing salt doses. Since salt is an abiotic stress factor, the presence of Na, and CI in the plant more than the plant needs adversely affects photosynthesis, and enzyme activities. In addition, it was observed that the rate of cell membrane damage increased with salt accumulation, and metabolic functions of plants slowed down. Plant growth and development were adversely affected by high salt dose in ornamental cabbage. The concurrent rise in salt concentrations adversely impacts morphological traits, resulting in aesthetic issues and decreased production. Consequently, ornamental cabbage should be grown in minimal to moderate saline conditions.

Conflict of interest

The authors declare no conflicts of interest.

Authorship contribution statement

The authors contributed equally to the article.

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