J. Hortic. Agric. Sci. Vol. 1(1), 14-27, 2024 *https://doi.org/10.63459/jhas.2024.1.3*
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Research article Available on: https://jahps.org OPEN ACCESS

Journal of Horticulture and Agricultural Sciences

Effect of Brackish Water on the Growth of Globe Artichoke *(Cynara cardunculus var.scolymus* L.)

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Submitted on: 26-08-2024 ***Revised on: 08-10-2024*** ***Accepted on: 07-12-2024***

ABSTRACT

Salinity is a critical environmental factor that has a profound injurious impact on plant growth, development, and productivity, hence investigated in globe artichoke. The current research was done at Institute of Horticultural Sciences, University of Agriculture, Faisalabad, during 2015-16 to investigate the response of Globe artichoke to different levels of brackish water. The experiment followed a Completely Randomized Design (CRD) with four treatments and three replications for each treatment. Brackish water was applied at concentrations of 25% (T1), 50% (T2) and 75% (T3) with a control group (T0) receiving no brackish water. The application of brackish water significantly impacted artichoke growth, with the control group exhibiting superior performance across various parameters. Results showed that highest (47.33 cm) plant height was observed in the control group, followed by 33.5 cm (T2), 33.16 cm (T1), and 30.23 cm (T3) at the highest brackish water dose. In control treatment, plant canopy per plant was observed 59 cm followed by 42.73 cm (T2), 42 cm (T1), and 41 cm (T3) at the highest dose. Maximum leaf width, number of leaves per plant and chlorophyll content was also found in the plants that were not irrigated with brackish water. Post-harvest measurements showed the control plants had the highest fresh and dry weight (85 g and 14 g), respectively. Overall, brackish water had a detrimental effect on all measured parameters. Future research should be done to explore salt-tolerant artichoke varieties for breeding programs to improve crop resilience.

Keywords: Artichoke, brackish water concentrations, vegetative growth, salinity

INTRODUCTION

The globe artichoke (*Cynara cardunculus* L.) is one of the important perennial plants of Asteraceae family. Globally, it is cultivated in many countries such as Italy, Egypt, Spain, Algeria and Peru being the top producers. The estimated annual production for these countries is around 376,280 tons in Italy, 315,408 tons in Egypt, 214,560 tons in Spain, 120,932 tons in Algeria, and 99,518 tons in Peru (Stea *et al*., 2023). Food and Agriculture Organization (FAO) has reported that global artichoke production has increasingly risen in the past decade, increasing from around 1.4 million tons in 2010 to 1.9 million tons in 2019 (FAO, 2021). It thrives in a Mediterranean-type climate, characterized by cool, wet winters and hot, dry summers (Sonnante *et al*., 2007). The globe artichoke provides abundant dietary fiber and essential vitamins such as vitamin K and vitamin C (Stea *et al*., 2023). It also includes antioxidants like Quercetin and Rutin, along with additional beneficial plant compounds such as Cynarin, Inulin, Flavonoids, and minerals, which may offer health benefits (Rezazadeh *et al*., 2018; Cavini *et al*., 2022).

Salinity is a critical environmental factor that has a profound damaging effect on plant growth, development, and productivity. Salt stress leads to alterations in the morphological, physiological, and biochemical responses exhibited by plants (Rahimbareshi, 2021). It occurs naturally in soil or arises from poorly managed

irrigation water (Hakim *et al*., 2010).

The elevation in soil salinity results in loss of water from the leaf cell but, this loss of cell volume and turgor is transient. Within hours, cells regain their original volume and turgor for osmotic adjustment, but cell elongation rates are reduced (Rosca, 2023). Injury to plants caused due to the accumulation of salt in the soil is common in nurseries and outdoor plants. The salt solutions were added to ornamental plants under various amounts of sodium chloride (0.6 percent, 1.4 percent and 2.2 percent) that caused salinity. Based on salinity tolerance, the decorative plants are classified into different groups (Seleiman et al., 2022). Salinity effect by different NaCl levels on germination, seedling, carbohydrates, protein and proline accumulation in various crops is well documented (Babu *et al*., 2012). Soil salinity severely damage crop plants through osmotic effects, ion specific and oxidative stress (Colla *et al*., 2013).

Cabrera (2001) investigated the effects of salt stress and nitrogenous fertilizers on productivity and nutrient content of roses. They reported that there is no noteworthy effect on any flowering or quality. However, they noted visual indications of injury due to salt during flowering cycles. The results indicated that leaf Cl concentration was significantly increased by salt additions. Ahmad and Riffat (2005) tested the salinity effect on physiological and biochemical parameters in pea plants against four treatments of salt (50, 100, 150 and 200 mM NaCl) in an experiment of sand culture for 30 days. They concluded that at high levels of NaC1 there was considerable decrease in the fresh and dry leaves weight and roots, but numbers of leaves were not significantly influenced. They reported that these all changes were due to a decrease in potassium ion uptake and relative water contents. Salinity affects plants in diverse ways, and there are multiple studies highlighting its negative impact on forage crops (Niu *et al*., 2012; Cornacchione and Suarez, 2017). The recent studies have shown that salinity affects various crops, including wheat (Seleiman, 2022), maize (Shahzad, 2019) and tomato (Roșca, 2023). Chili and peppers (Hassen et al., 2013) and tomato (Foolad., 2004).

Artichoke is considered moderately salt-tolerant during the vegetative stage; however, its quality and yield of its buds are significantly impaired by salinity (Saleh *et al*., 2012). In a greenhouse experiment, it showed tolerance up to a salinity threshold of 4.9 dS/m^{-1} (Bahreininejad and Allahdadi, 2020). Bahreininejad (2014) observed that higher salinity levels led to a notable decrease in vegetative growth characteristics and prolonged the time to blooming, flowering, and maturity in artichoke plants. Although some studies have explored water management for artichoke, there remains a need for fundamental research to establish the ideal water requirements for globe artichoke production using lower-quality water. Therefore, this study examines how varying concentrations of brackish water influence the globe artichoke growth, with the aim of identifying optimal irrigation practices to sustain yield and quality under saline conditions.

MATERIAL AND METHODS

The study was done at the Institute of Horticultural Sciences, University of Agriculture, Faisalabad, during the year 2015-2016 aimed to evaluate the impact of varying concentrations of brackish water on quality production of Globe Artichoke (*Cynara cardunculus var. scolymus* L) transplants. The study was designed through Completely Randomized Design (CRD) with four treatments and three replications, resulting in a total of twelve treatment combinations. Treatments commenced eight weeks after germination including Control (with no application of brackish water), T1 (25% brackish water), T2 (50% brackish water), and T3 (75% brackish water). Globe Artichoke seeds were collected from Horticultural Laboratory, University of Agriculture, Faisalabad. Initially seeds were sown manually in pots filled with sandy loam soil. Approximately 15 seeds were sown in each pot, and after germination, each individual plant was transplanted into a separate pot.

The solutions were prepared by dissolving 30 grams of NaCl in one liter of water to create a mother solution. Subsequently, this mother solution was diluted to produce brackish water solutions with different salinity concentrations. For the 25% brackish water solution, 2.5 liters of the mother solution were mixed with 7.5 liters of fresh water. Similarly, for 50% brackish water solution, 5 liters of mother solution were combined with an equal volume of fresh water. Finally, for 75% brackish water solution, 7.5 liters of the mother solution were added to 2.5 liters of fresh water. These meticulous preparations ensured precise salinity levels in each solution, facilitating accurate experimentation and reliable results.

Data Recorded: Various morphological parameters were recorded on weekly basis, including:

Plant height (cm): The height of each plant was taken from the base of the stem to the tip of the tallest leaf using a measuring tape.

Plant canopy (cm): The size of the plant canopy or the spread of foliage was measured by determining the diameter or width of the plant's leafy growth using a measuring tape.

Leaf width (cm): The width of the leaves was measured by taking a leaf from the plant and placing it flat on a surface. The widest part of the leaf was then measured using a ruler.

Number of leaves per plant: The total number of leaves on each plant was counted manually by visually

inspecting the plant and tallying the number of individual leaves present
Chlorophyll content: Chlorophyll content was assessed using SPAD chlorophyll meter. For analysis, the healthy leaves were chosen and readings were taken at top, middle, and bottom locations of leaves.
Fresh weight (gm): To measure the fresh weight, each plant was carefully removed from its pot, and excess soil was gently shaken off. The entire plant, including roots and foliage, was then weighed using a scale.
Dry weight (gm): After measuring fresh weight, the plants were dried in an oven at specific temperature for a predetermined period to remove all moisture. Once completely dried, the plants were weighed again to determine their dry weight.
Statistical Analysis: Data analysis was performed using Fisher's analysis of variance (ANOVA) technique. The significance of treatments was determined using the Least Significant Difference (LSD) test at 5% probability level (Steel *et al.,* 1997). Statistical analysis was conducted using appropriate software packages.

RESULTS

The results, demonstrates the significant effect of brackish water application on artichoke growth and development, highlighting the importance of considering both genetic and environmental factors in understanding plant growth and development.

Effect of brackish water on plant height (cm), plant canopy (cm), leaf width (cm) and number of leaves of artichoke after one month of application of brackish water

The artichoke plant height was significantly impacted by the using of different brackish water doses. After one month, the treatment groups showed notable differences in plant height, with T1 (10.36 cm) exhibiting the highest growth followed by T3 (10.26 cm). The lowest plant height was observed in T2 (9.33 cm), while the control group had plant height of (9.66 cm) (Fig. 1). The canopy of plant was notably impacted by the application of different brackish water doses. After one month, the treatment groups showed notable differences in plant canopy width, with T2 exhibiting the widest canopy (10.53 cm), followed by T3 (9.90 cm) and T1 (8.30 cm). The control group had the narrowest canopy (8 cm) (Fig. 1). The leaf width was significantly impacted by the application of different brackish water doses. After one month, the treatment groups showed notable differences in leaf width, with the control group having the widest leaves (1.66 cm), followed by T2 (50%) (1.63 cm) and T3 (75%) (1.23 cm). The narrowest leaves were observed in T1 (25%) (1.13 cm) as shown in Fig. 1. The number of leaves was significantly impacted by the application of different brackish water doses. As shown in Fig. 1, every treatment showed a significant response at various stages of artichoke growth. T1 had the maximum leaves (3), followed by T2 and T3, which had similar numbers of leaves (2). The control group had a similar number of leaves (2) as T2 and T3 (Fig. 1). While the treatment groups were significantly different from the control, there were no significant differences among them. The results indicate that higher levels of salinity resulting from brackish water application decrease leaf number throughout the experiment.

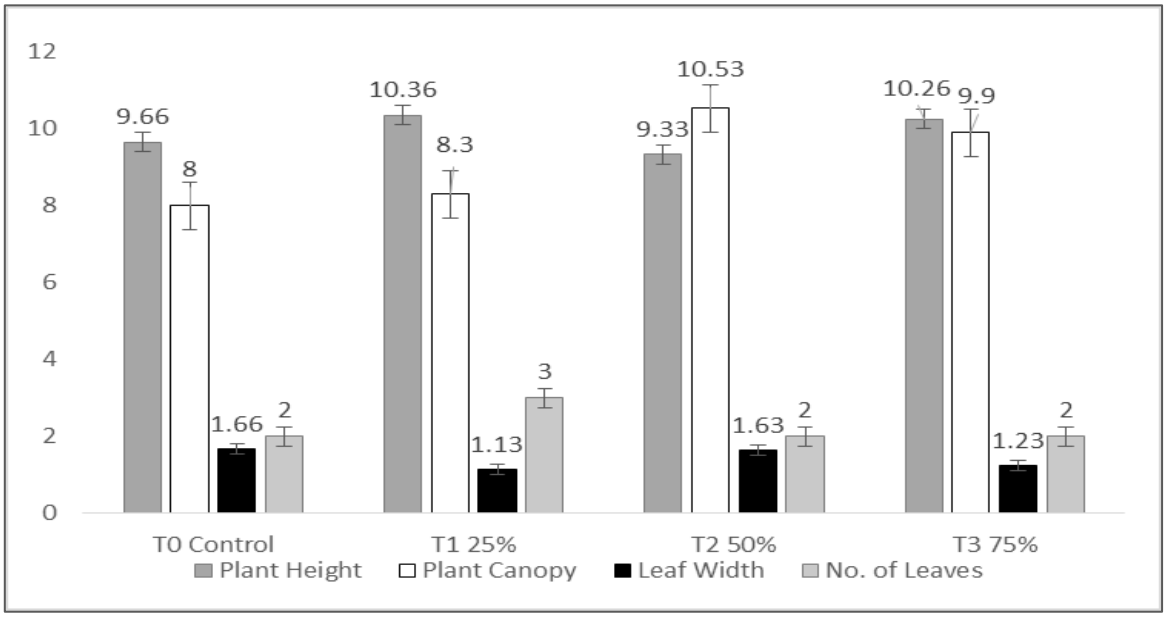


Figure 1. Effect of brackish water on Plant Height, Plant canopy, Leaf width, number of leaves of artichoke after one month of application of brackish water

Effect of brackish water on plant height (cm), plant canopy (cm), leaf width (cm) and number of leaves of artichoke after two months of application of brackish water

The results indicate that the plant height was significantly impacted by the application of different brackish water doses. After two months, the treatment groups showed notable differences in plant height, with the control group being the tallest (15.8 cm), followed by T1 (14.76 cm) and T2 (14.57 cm) (Fig 2). The shortest plants were observed in T3 (14.23 cm), indicating a potential inverse relationship between brackish water dose and plant height. Canopy of plant was significantly impacted by using of different brackish water doses. After two months, the treatment groups showed notable differences in plant canopy width, with T2 (50%) exhibiting the widest canopy (13.3 cm), followed closely by T3 (75%) (13.2 cm) and the control group (13 cm). The narrowest canopy was observed in T1 (25%) (12.23 cm) as shown in Fig 2. The leaf width, a trait influenced by both genetics and soil nutritional status, was significantly impacted by the application of different brackish water doses. After 2 months, the treatment groups showed notable differences in leaf width, with T2 (50%) exhibiting the widest leaves (3.5 cm), followed by the control group (3.33 cm) and T1 (25%) (3.13 cm). The narrowest leaves were observed in T3 (75%) (3.13 cm) as shown in Fig 2. The number of leaves was significantly impacted by the application of different brackish water doses. Every treatment showed a significant response at various stages of artichoke growth. The control group had the highest number of leaves (5), followed by T2 (4) and T1 (4), while the lowest number of leaves was observed in T3 (3) (Fig 2).

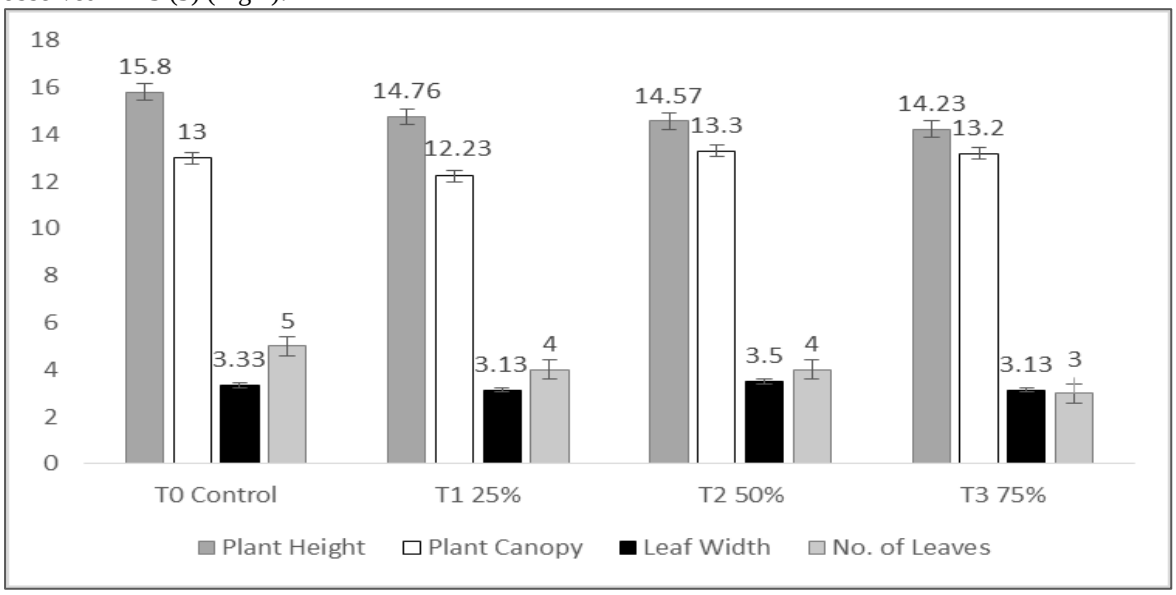


Figure 2. Effect of brackish water on Plant Height, Plant canopy, Leaf width, number of leaves of artichoke after two months of application of brackish water

Effect of brackish water on plant height (cm), plant canopy (cm), leaf width (cm) and number of leaves of artichoke after three months of application of brackish water

The plant height was significantly impacted by the application of different brackish water doses. After 3 months, the treatment groups showed notable differences in plant height, with the control group had the tallest plants with height (29.66 cm), followed by T3 (24.8 cm) and T1 (24.6 cm), and the shortest with T2 (23.43 cm) as shown in Fig 3. The plant canopy, a key indicator of artichoke growth, was significantly impacted by the application of different brackish water doses. After 3 months of application, the treatment groups showed notable differences in plant canopy width, with the control group exhibiting the widest canopy (32.3 cm), followed by T3 (28.48 cm) and T2 (28 cm), and the narrowest canopy in T1 (27.66 cm), as shown in Fig. 3. The leaf width, a key trait in artichoke growth, was significantly impacted by the application of different brackish water doses. Every treatment showed a significant response at various stages of growth, with the control group exhibited the widest leaves (7.5 cm), followed by T3 (3.66 cm) and T1 (3.63 cm), and the narrowest leaves in T2 (3.50 cm), as shown in Fig. 3. The number of leaves, a key indicator of artichoke growth, was significantly impacted by the application of different brackish water doses. Every treatment showed a significant response at various stages of growth, with the control group exhibiting the highest number of leaves (8), followed by T2 and T3 (7 leaves each), and the lowest number in T1 (6 leaves), as shown in Fig. 3.

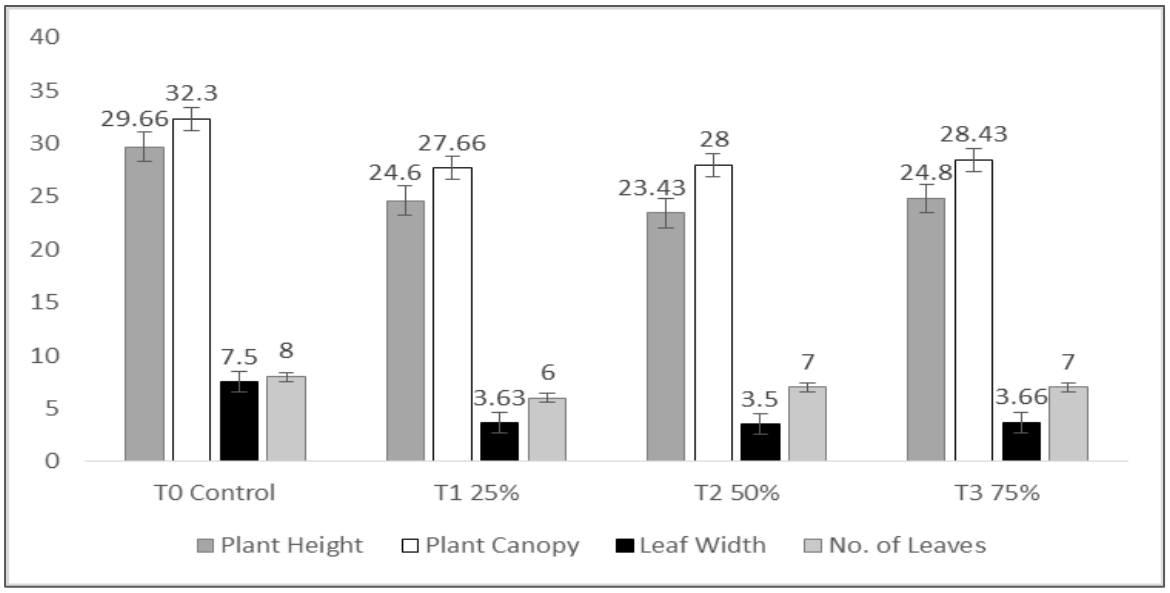


Figure 3. Effect of brackish water on plant height, plant canopy, leaf width, number of leaves of artichoke after three months of application of brackish water

Effect of brackish water on plant height (cm), plant canopy (cm), leaf width (cm) and number of leaves of artichoke after four months of application of brackish water

The plant height, a key indicator of artichoke growth, was significantly impacted by the application of different brackish water doses. Every treatment showed a significant response at various stages of growth, with the control group exhibiting the tallest plants (47.33 cm), followed by T2 (33.5 cm) and T1 (33.16 cm), and the shortest plants in T3 (30.23 cm). The plant canopy, a trait influenced by both genetic and soil nutritional factors, showed significant differences in response to various doses of brackish water applied to artichoke growth. Just one month after application, the control group exhibited the widest canopy (59 cm), followed by T2 (42.73 cm) and T1 (42 cm), while the narrowest canopy was observed in T3 (41 cm). After 4 months of brackish water application, the leaf width was significantly impacted by the different doses. The control group had the widest leaves (16.33 cm), followed by T1 (11.1 cm) and T2 (8.86 cm), while the narrowest leaves were observed in T3 (6.2 cm) as shown in fig 4. The number of leaves was significantly impacted by the different doses. The control group had the highest number of leaves (8), followed by T1 (5) and T2 (4), while the lowest number of leaves was observed in T3 (3), as shown in Fig. 4. Every treatment showed a significant response at various stages of artichoke growth, highlighting the effectiveness of brackish water application. The results indicate a potential inverse relationship between brackish water dose and leaf production, with the highest dose resulting in the fewest leaves.

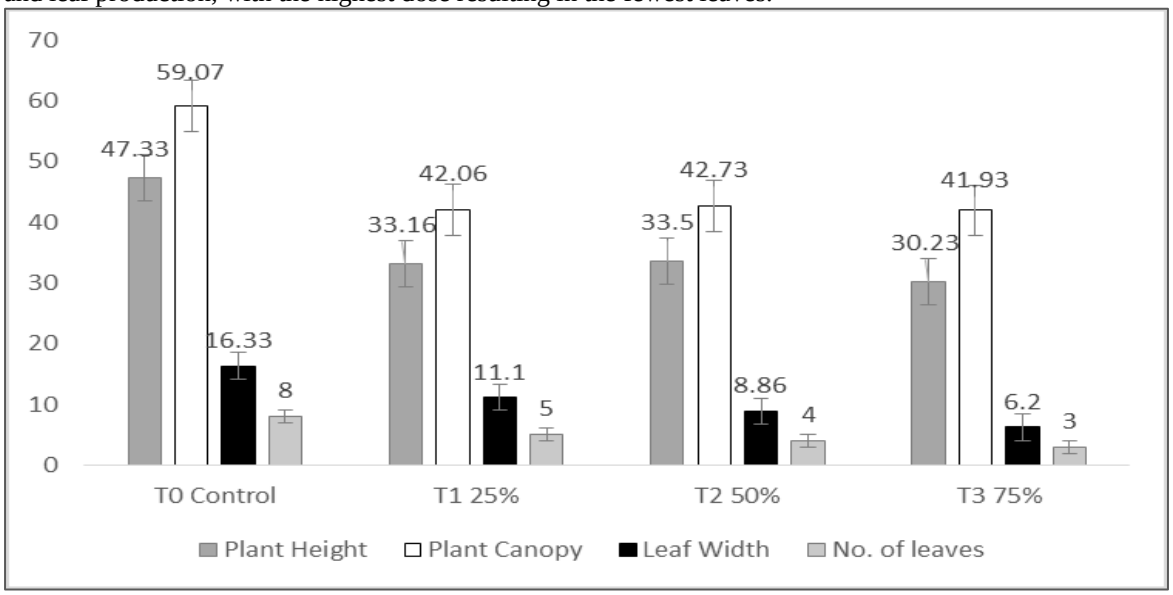


Figure 4. Effect of brackish water on Plant Height, Plant canopy, Leaf width, number of leaves of artichoke after four months of application of brackish water

Chlorophyll Content: The chlorophyll content, a key indicator of photosynthetic activity, was significantly impacted by the application of different brackish water doses after just 1 month. The control group had the highest chlorophyll content (17.93 cci), followed by T1 (12.36 cci) and T2 (11.9 cci), while the lowest chlorophyll content was observed in T3 (7.23 cci) as shown in Fig. 5.

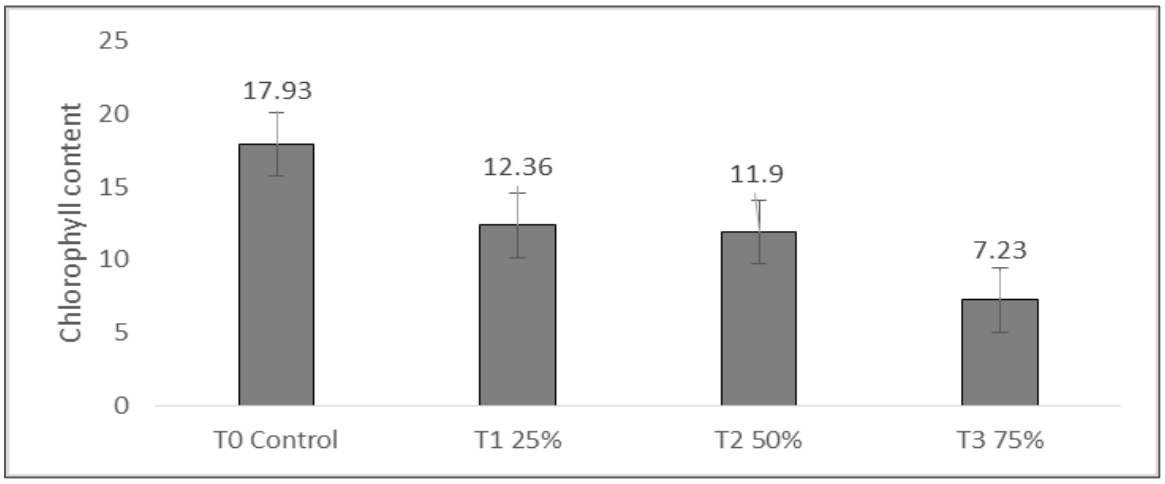


Figure 5. Post-Harvest Effect of brackish water on Chlorophyll Content of artichoke by application of brackish water

Post-Harvest effect of brackish water on Fresh weight and Dry weight of artichoke by application of brackish water

The fresh weight, a trait influenced by both genetics and soil nutritional status, was significantly impacted by the application of different brackish water doses. The control group had the highest fresh weight (85 g), followed by T1 (32.4 g) and T2 (15.5 g), while the lowest fresh weight was observed in T3 (8.93 g). Every treatment showed a significant response at various stages of artichoke growth, highlighting the effectiveness of brackish water application (Fig, 6). The dry weight, a trait influenced by both genetics and soil nutritional status, was significantly impacted by the application of different brackish water doses. The control group had the highest dry weight (14 g), followed by T2 (8.33 g), while the lowest dry weight was observed in T1 and T3 (4.33 g), as shown in Fig.7.

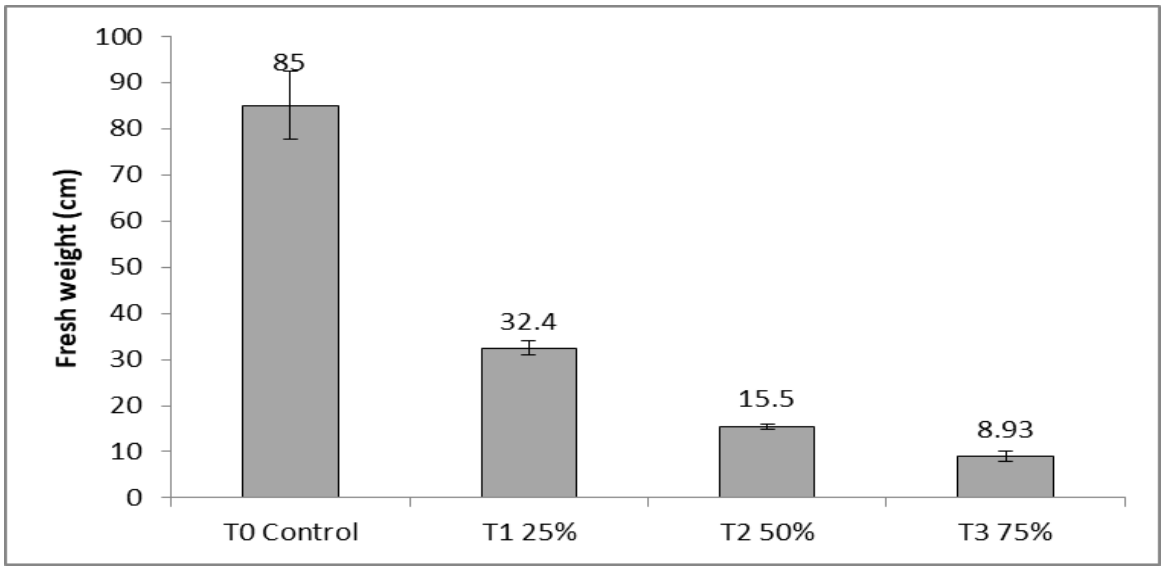


Figure 6. Post-Harvest Effect of brackish water on Fresh weight and Dry weight of artichoke by application of brackish water

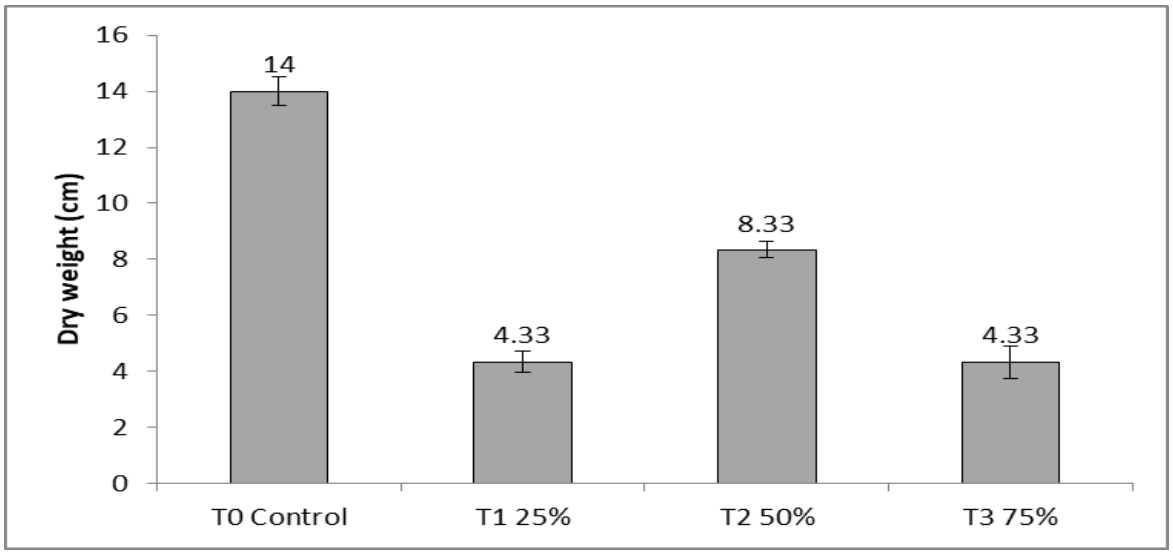


Figure 7. Post-Harvest Effect of brackish water on Dry weight of artichoke by application of brackish water

DISCUSSION

The results of present study demonstrated that the plant height showed significant sensitivity to increasing salinity levels, with noticeable reductions observed at 75% concentrations. The control group had the tallest height (47.33 cm), while at 75% salinity, the height dropped to 30.23 cm. These findings are consistent with those of (Jorenush and Rajabi, 2015), who noted that shoot length was highly sensitive to salinity, showing significant decreases at 100 mM and 150 mM levels. In their study, the control group had the longest shoot length at 30.07 mm, whereas it was shortest at 15.60 mm under 150 mM salinity conditions. Plant canopy showed significant response to increasing salinity levels, with noticeable reductions observed at 75% concentrations. The control group had the widest canopy at (59 cm), while at 75% salinity, the height dropped to (41 cm). The reduction in canopy height due to salinity is caused by several underlying processes. Like water stress, salinity lowers soil water potential because of osmotic effects (Perri *et al*., 2017; Perri, Entekhabi, & Molini, 2018; Perri, 2023). As canopy height increases, the osmotic stress makes it harder for the plant to maintain a leaf water potential, causing it to become increasingly negative (Klein *et al*., 2015). As a result, salinity may set a species-specific upper limit on canopy height. Mangrove ecosystems experiencing prolonged and severe salt stress tend to maintain a shorter canopy to avoid xylem cavitation (Rossi *et al*., 2020).

Leaf width was noticeably affected by increasing salinity levels, particularly at 75% concentration, as illustrated in Figure 4. The control group had the widest leaves, measuring 16.33 cm, whereas at 75% salinity, the width decreased substantially to 6.2 cm, this highlights salinity's adverse effects on plant development (Bagherifard and Ghasemnezhad, 2014). The number of leaves (8) was significantly higher in the control group compared to the treatment groups. Older leaves showed higher sodium content than younger leaves, suggesting a potential inverse relationship between brackish water dosage and leaf count, with higher doses (75% of brackish water) resulting in fewer leaves (3). Similar trends have been observed in non-halophytes grown under saline conditions (Saleh *et al*., 2012). In another study, (Colla *et al*., 2013) comprehensively demonstrated that increasing the salinity of the nutrient solution consistently decreased the number of leaves per plant across all treatment levels.

The chlorophyll content was significantly impacted by increasing salinity levels, especially at 75% concentration. In the control group, chlorophyll content was highest at 17.93 cci, whereas it substantially decreased to 7.23 cci under 75% salinity, as depicted in Figure 5. This demonstrates how salinity can notably reduce chlorophyll levels in plants, aligning with findings by (Licandro and Ierna, 2006), who observed that moderate salinity had no significant effect on photosynthesis or chlorophyll content but did reduce carbon assimilation. It is well-established that chlorophyll concentration decreases under stressful environmental conditions (Ranjbar and Dehghani, 2016; Baghbani-Arani *et al*., 2017).

Statistical analysis revealed that irrigation with saline water significantly reduced plant fresh weight (8.93 g) at highest (75%) brackish water application. The highest fresh weight (51,551 kg/ha) was obtained at the lowest salinity level (Bahreininejad, and Allahdadi, 2020). The present results demonstrated that plant dry weight decreased with increasing salinity levels, consistent with findings in sweet sorghum cultivars (Almodares *et al*., 2007) and wheat (Akbari *et al*., 2007). The lowest salinity level led to the highest plant dry weight, measuring 9,000 kg/ha (Bahreininejad and Allahdadi, 2020), which aligns with previous reports on these crops. Saline irrigation significantly reduced both fresh weight and dry weight in artichoke plants,

corroborating findings from other studies indicating a decrease in plant biomass under salinity stress (Rezaei *et al*., 2017). Tunçtürk *et al*., (2011) observed that salt-induced osmotic potential restricted water absorption by root cells and limited the uptake of essential mineral nutrients dissolved in water, thereby inhibiting plant growth due to metabolic impairments. Additionally, Bahreininejad (2014) reported significant reductions in plant height, fresh and dry yield of aerial parts, and the dry to fresh weight ratio in artichoke plants irrigated with saline water. These findings underscore the consistent impact of salinity stress on artichoke growth and development. In this investigation the application of brackish water significantly impacted artichoke growth, with the control group exhibiting superior performance across various parameters. Further research is needed that could explore alternative methods such as soil amendments, different irrigation strategies to mitigate the adverse effects of salinity on crop development, explore salt-tolerant artichoke varieties for breeding programs to improve crop resilience.

CONCLUSION

The current study demonstrated significant impacts of varying levels of brackish water on the growth parameters of artichoke plants. Compared to the control group, which consistently outperformed treatments of 25%, 50%, and 75% brackish water across multiple traits, salinity adversely affected growth of the artichoke. Future research is needed to focus on exploring mitigation strategies such as soil amendments and alternative irrigation methods to mitigate these effects. Additionally, developing salt-tolerant artichoke varieties through breeding programs is crucial for maintaining production in regions facing water salinity issues, thereby enhancing agricultural resilience and ensuring food security.

ACKNOWLEDGMENT

The authors would like to express their sincere appreciation to the dedicated research team for their tireless support, expert guidance, and invaluable contributions throughout the duration of this study.

AUTHOR'S CONTRIBUTION

Designed the study and wrote the initial draft of the manuscript: Samiullah, KY Abbasi, performed the study and collected data: Q Habib, Helped in data analysis: M Abro, Provided technical help: A Jabbar, Assisted in assembling the data: H Baloch, Assisted in data analysis: Z A Sheikh,: Offered technical input and helped in writing of manuscript: M Abro, Assisted in review and editing of the manuscript: S Zaman

CONFLICTS OF INTEREST

The authors have declared no conflict of interest

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