Kirkuk University Journal for Agricultural Sciences
ISSN:2958-6585
https://kujas.uokirkuk.edu.iq

RESEARCH ARTICLE https://doi.org. 10.58928/ku24.16205

Influence of Irrigation Water Electrical Conductivity (EC) Growth and Yield of Lettuce (*Lactuca sativa* L.)

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Received: 09/04/2025 **Revised: 13/05/2025** **Accepted: 20/05/2025** **Published: 01/06/2025**

ABSTRACT

This research, conducted at Bakrajo Technical Institute in a multi-span greenhouse during the 2024-2025 growing season, investigates Influence of Irrigation Water Electrical Conductivity EC on Lettuce Growth and Yield, Treatment 1 (EC = 1.6 dS m^{-1}), Treatment 2 (EC = 4.4 dS m^{-1}), Treatment 3 (EC = 3.98 dS m^{-1}), Treatment 4 (EC = 2.67 dS m^{-1}), Treatment 5 (EC = 2.86 dS m^{-1}), and Treatment 6 (EC = 0.750 dS m^{-1}). Experiment design plant height, leaf number, chlorophyll Content change to intensity, fruit change to head diameter, fresh weight, root weight, and dry matter yield. The study reveals a clear negative correlation between higher EC levels and plant development, with lower EC values (0.750 dS m^{-1}) promoting optimal growth across nearly all the measured parameters. Plants exposed to the 0.750 dS m^{-1} EC level exhibited the highest average values for key growth metrics, including plant height (42.0 cm), leaf number (45), and chlorophyll SPAD readings (87.4), indicating superior growth and photosynthesis. As the EC levels increased, plant performance steadily declined. Specifically, EC values above 2.67 dS m^{-1} significantly reduced growth indicators, including plant height, leaf number, and head size. This decline in performance is attributed to osmotic stress and nutrient uptake limitations caused by high salinity. The study also found that excessive salinity severely affected other growth parameters, leading to marked reductions in fresh weight, root weight, and dry matter, especially at EC levels of 3.98 dS m^{-1} and 4.4 dS m^{-1}. Further correlation analysis confirmed strong positive relationships between several growth parameters, such as plant height, number of leaves, and yield. The findings of this study underscore the critical importance of effectively managing irrigation EC levels to maintain plant health and optimize agricultural productivity. It suggests that excessive salinity in irrigation water can hinder plant growth, limit nutrient absorption, and negatively affect overall plant development, highlighting the need for careful monitoring and control of EC in irrigation systems.

***Keywords*:** Electrical Conductivity (EC), Abiotic Stress, Vegetative Growth, Irrigation Management.

INTRODUCTION

Lettuce (Lactuca sativa L.) is one of the most widely consumed leafy vegetables globally, known for its rapid growth cycle, low caloric value, and significant nutritional benefits, including vitamins, minerals, and fiber [1]. However, its cultivation for increasingly challenged by environmental stressors, among which water quality is of paramount importance [2]. Specifically, the Electrical Conductivity (EC) of irrigation water, a key indicator of salinity, plays a critical role in determining plant health and productivity. High EC levels can be made to increased soil salinity, resulting in osmotic stress that disrupts water and nutrient uptake, ultimately impairing growth, yield, and quality of the crops [3]. The effects of saline stress on plant physiology are particularly pronounced in arid and semi-arid regions where water scarcity and salinization are major agricultural concerns [4]. Understanding the interaction between EC levels and lettuce growth is, therefore, essential for improving irrigation practices and ensuring sustainable crop production in these regions [5]. The effect of salinity on lettuce growth has been extensively studied, with various reports indicating that elevated EC levels can reduce both biomass accumulation and overall plant development [6]. The physiological mechanisms underlying these effects include alterations in photosynthesis, chlorophyll content, and water use efficiency, as well as changes in metabolic pathways that control nutrient assimilation. Given the increasing prevalence of saline water resources due to many such as climate change and improper irrigation management, it is vital to explore the specific EC thresholds at which lettuce growth is still viable and productive [7]. Research in this area can help identify key adaptive traits in lettuce that could mitigate the negative effects of salinity, offering practical solutions for growers facing water quality challenges [8]. The aim of this study is to evaluate the effects of varying EC levels in irrigation water on the growth, yield, and physiological responses of lettuce, with a focus on optimizing irrigation practices under saline conditions. The investigation was assessed several key parameters, including plant height, number of leaves per, head fruit diameter, head of fresh fruit, roots weight, and dry biomass, as well as physiological traits such as chlorophyll content, by identifying the threshold EC values for optimal lettuce growth and productivity, and study suggest to provide evidence-based guidelines for managing irrigation in regions impacted by saline water.

Materials and Methods

Experimental Site and Design

The study was conducted at the Bakrajo Technical Institute, located in the greenhouses of the institute, with GPS points 35°32'55.9"N 45°21'36.6"E in 2024-2025. A completely randomized design (CRD) was employed with three replications for each of the different levels of electrical conductivity (EC) of the irrigation water. The experiment used soil growing culture system to simulate a controlled environment with varying salinity levels. Data soil properties show in (appendix Table.1), Lettuce grows best in temperatures ranging from 20°C to 30°C, ensuring normal development. The plant requires moderate light intensity, ideally around 9 -11 hours of sunlight. Lettuce planted in November typically reaches harvest maturity by late February. Proper irrigation and nutrient management further support healthy growth and yield.

Plant Materials

Lettuce (Lactuca sativa Lognifolia), a commonly grown vegetable, was chosen for the study. The variety used was (Lognifolia variety), which was selected for its suitability in greenhouse conditions. Healthy lettuce seedlings were transplanted into soil growing culture. The seedlings were maintained under normal conditions for growth.

Experimental Treatments

The experiment aimed to assess the impact of different salinity levels on lettuce growth and yield by applying six treatments with varying electrical conductivity (EC) levels in the irrigation water the concentration ranges selected for determination which types were caused to decreased yield, representing typical saline conditions: Treatment 1 (EC = 1.6 dS m^{-1}), Treatment 2 (EC = 4.4 dS m^{-1}), Treatment 3 (EC = 3.98 dS m^{-1}), Treatment 4 (EC = 2.67 dS m^{-1}), Treatment 5 (EC = 2.86 dS m^{-1}), and Treatment 6 (EC = 0.750 dS m^{-1}). The concentration differences among the treatments (EC = 0.750, 1.6, 2.67, 2.86, 3.98, and 4.4 dS/m) were selected to represent a gradient of salinity stress and assess its impact on plant growth and yield. These values simulate varying levels of irrigation water salinity, from optimal conditions (low EC) to moderate and high salinity stress, commonly encountered in agricultural irrigation systems.

Treatment 6 (0.750 dS m^{-1}) serves as the control, representing freshwater conditions with minimal salinity effects.

- **Treatment 1 (1.6 dS m^{-1})** represents mild salinity stress, which may slightly impact plant metabolism but is still within a tolerable range for many crops.
- **Treatment 4 (2.67 dS m^{-1}) and Treatment 5 (2.86 dS m^{-1})** reflect moderate salinity levels, which can begin to impair water uptake, nutrient absorption, and photosynthesis due to osmotic stress.
- **Treatment 3 (3.98 dS m^{-1}) and Treatment 2 (4.4 dS m^{-1})** represent high salinity stress, which disrupts ion homeostasis, reduces chlorophyll synthesis, and leads to growth inhibition due to excessive sodium and chloride ion accumulation.

This range of treatments allows for evaluating the threshold at which salinity becomes detrimental and identifying critical EC levels for effective irrigation management. The EC of the irrigation water was consistently monitored using a portable EC meter to maintain treatment accuracy throughout the study.

Growing Conditions

The experiment was conducted in greenhouse conditions, with controlled temperature, humidity, and light. The greenhouse temperature recorded by the thermometer was maintained between (20 to 30 °C), and the Digital Hygrometer kept relative humidity around (45 – 55 %).

Irrigation and Fertilization

The plants were irrigated with water adjusted to the specified EC levels. The irrigation was done twice a week, depending on the moisture requirement of the plants. Fertilization was done using a (NPK 20:20:20) Jordanian origon, ensuring that all plants received the necessary nutrients for optimal growth. Fertilization was carried out using NPK 20:20:20 three weeks after planting in November to support healthy growth. This balanced nutrient supply enhanced lettuce development and yield.

Statistical Analysis

The data were analyzed using Analysis of Variance (ANOVA) to assess the effects of the different EC levels on the growth, physiological, and yield parameters of lettuce. The significance of the differences between treatment means was determined using Duncan's Multiple Range Test (DMRT), with a significance level set at $p \leq 0.05$. The statistical analyses were conducted using XLSTAT 2019.2.2.59614.

Results and Discussion

This analysis summarizes quantitative data from 18 observations, focusing on plant growth and yield parameters with no missing values. Plant height ranged from 16.0 to 43.0 cm (mean: 31.1 cm, SD: 8.8 cm), while the number of leaves per plant varied from 22.0 to 46.0 (mean: 33.7, SD: 8.4). Chlorophyll SPAD readings showed significant variability (42.1–88.4, mean: 67.4, SD: 18.2), and fresh Head diameter ranged from 4.8 to 9.1 cm (mean: 7.1 cm, SD: 1.6 cm). Fresh weight per plant varied from 244.0 to 465.0 g (mean: 368.0 g, SD: 86.3 g), root weight ranged from 24.0 to 64.0 g (mean: 43.7 g, SD: 13.9 g), and dry matter content spanned 43.1 to 127.0 g (mean: 91.5 g, SD: 34.2 g).

3.1 Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on plant height (cm)

Table 1 shows the analysis of the effect of irrigation electrical conductivity (EC) on plant height, revealing significant differences across the categories, with varying degrees of impact as the EC value increased. The plants in the C (0.750 dS m^{-1}) group showed the highest average height of 42.0 cm, significantly outperforming all other groups. As EC values increased, plant height progressively decreased, with the EC 1 (1.6 dS m^{-1}) group showing a height of 37.7 cm and EC 4 (2.67 dS m^{-1}) showing 35.3 cm, both significantly lower than the C group but similar to each other. Further increases in EC, particularly in EC 5 (2.86 dS m^{-1}), EC 3 (3.98 dS m^{-1}), and EC 2 (4.4 dS m^{-1}), resulted in progressively poorer growth, with EC 2 showing the lowest plant height of 18.3 cm. The observed trend indicates that while low EC values positively affect plant growth, higher EC values lead to significantly reduced plant height. Studies have confirmed this negative correlation, with increasing EC causing osmotic stress that hampers nutrient uptake and overall plant growth [9].

Table 1. Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on plant height (cm)

Category	LS means	Standard error	Groups				
C (0.750)	42.0	1.1	A				
EC 1(1.6)	37.7	1.1		B			
EC 4(2.67)	35.3	1.1		B			
EC 5(2.86)	31.0	1.1			C		
EC 3(3.98)	22.0	1.1				D	
EC 2(4.4)	18.3	1.1					E

3.2 Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on a number of leaves per plant

The results presented in Table 2, which analyzes the effect of irrigation electrical conductivity (EC) on the number of leaves per plant, reveal a significant decrease in leaves number as EC increases beyond a certain threshold. At EC levels of 0.750 dS m^{-1} (Category C), plants exhibited the highest average number of leaves, with 45 leaves per plant, and were grouped in the same statistical category (A) as the reference, indicating a positive and stable effect on plant development. However, the number of leaves significantly decreases as the EC value increases. At EC levels of 1.6 dS m^{-1} (Category EC 1), the number of leaves decreased to 41 per plant, still relatively high but statistically distinct from Category C (B), indicating a moderate adverse effect. As the EC continues to rise, plant growth further deteriorates: at EC 4 (2.67 dS m^{-1}, Category C), the number of leaves decreases to 36, and at EC 5 (2.86 dS m^{-1}, Category D), it drops to 33.3 leaves per plant. Notably, at higher EC levels (EC 3 at 3.98 dS m^{-1} and EC 2 at 4.4 dS m^{-1}, Categories E), the number of leaves sharply declines to 23.7 and 23.3 per plant, respectively, indicating a significant adverse effect at these high salinity levels. The overall trend suggests that while low EC values (0.750 dS m^{-1}) promote healthy leaf production, higher EC values have a detrimental effect, which becomes progressively more severe as EC increases. The analysis of these results indicates that irrigation water with EC values above 1.6 dS m^{-1} starts to have a statistically significant negative impact on the number of leaves, and the negative effect intensifies as EC levels rise further. This result is supported by research suggesting that increased salinity affects plant growth by causing osmotic stress, limiting nutrient uptake, and potentially damaging cellular structures, which ultimately impacts leaf formation and overall plant health [10].

Table 2. Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on number of leaves per plant

Category	LS means	Standard error	Groups				
C (0.750)	45.0	0.6	A				
EC 1(1.6)	41.0	0.6		B			
EC 4(2.67)	36.0	0.6			C		
EC 5(2.86)	33.3	0.6				D	
EC 3(3.98)	23.7	0.6					E
EC 2(4.4)	23.3	0.6					E

3.3 Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on chlorophyll

The analysis of Electrical Conductivity (EC) in irrigation water and its impact on chlorophyll readings (SPAD) reveals a significant relationship between EC levels and plant chlorophyll intensity. Table 3 illustrates the Least Squares (LS) means for various EC categories, corresponding standard errors, and Duncan's post-hoc test results grouped based on a 95% confidence interval. The results show a clear trend: lower EC values (such as EC 1, with a value of 1.6 dS m^{-1}) correspond to higher chlorophyll SPAD readings, as evidenced by the LS mean of 87.4, which falls in group A. This suggests that a lower EC (indicating less salinity) facilitates higher chlorophyll production, which is typically associated with better plant health and photosynthetic efficiency. As EC increases (moving from EC 1 to EC 5), the chlorophyll content progressively increases, with EC 5 (2.86 dS m^{-1}) showing an LS mean of 70.3, falling into group D, and EC 2 (4.4 dS m^{-1}) and EC 3 (3.98 dS m^{-1}) showing even lower values (44.0 and 43.4, respectively), both classified into group E. The significant decline in chlorophyll content at higher EC levels (above 2.67 dS m^{-1}) suggests that increasing salinity impairs the plant's ability to photosynthesize efficiently, likely due to salt stress that affects nutrient uptake and metabolic processes. The study highlights that EC values of 1.6 and 0.750 dS m^{-1} have a positive and significant impact on chlorophyll intensity, while EC values of 4.4 and 3.98 dS m^{-1} indicate a non-significant or detrimental effect on plant health. Also, Higher irrigation water electrical conductivity (EC) significantly reduced chlorophyll content. Salinity stress disrupts ion homeostasis, leading to oxidative damage and reduced chlorophyll biosynthesis due to Na^+ and Cl^- accumulation, which inhibits key enzymes like chlorophyll synthase. The sharp decline in chlorophyll at EC levels above 2.67 dS m^{-1} indicates severe physiological stress, impairing photosynthetic efficiency and plant growth. These findings agree with existing research demonstrating high salinity's adverse effects on plant growth and productivity, as elevated EC levels can lead to osmotic stress and ion toxicity [11]. The results also emphasize the importance of maintaining optimal irrigation water quality, as excessive salinity can significantly hinder plant performance, evidenced by the clear categorization of higher EC levels in lower SPAD groups [12].

Table 3. Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on chlorophyll

Category	LS means	Standard error	Groups				
EC 1(1.6)	87.4	0.7	A				
C (0.750)	83.8	0.7		B			
EC 4(2.67)	75.6	0.7			C		
EC 5(2.86)	70.3	0.7				D	
EC 2(4.4)	44.0	0.7					E
EC 3(3.98)	43.4	0.7					E

3.4 Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on fresh head diameter (cm)

The results from Table 4, which details the analysis of the differences in head diameter (cm) based on varying irrigation electrical conductivity (EC) values, provide insightful findings regarding the effects of EC on head size. The results indicate that as EC levels increase, there is a noticeable reduction in fresh head diameter, starting from the highest measurement at EC 0.750 (8.8 cm) in category C, which was significantly higher than all other groups. The positive correlation between low EC and larger head size is evident, with the groups showing EC 1 (8.4 cm) and EC 4 (7.8 cm) still maintaining fruit diameters within a similar range to category C, though with statistical differences (A, B groups). However, once the EC values increased further, particularly at EC 5 (2.86 dS m^{-1}), the diameter decreases to 7.6 cm, and the effect becomes negative. This negative trend becomes even more pronounced at EC 2 (4.4 dS m^{-1}) and EC 3 (3.98 dS m^{-1}), where the fresh fruit diameter significantly drops to 5.0 cm, indicating a detrimental impact on growth at high salinity levels, placing these groups in the same statistical category (D). The observed results reflect a threshold effect of EC on plant growth, with smaller EC values yielding better fruit growth, while higher EC concentrations lead to reduced fruit size. The significant cause behind these observations could be attributed to the osmotic stress exerted by higher salinity, which inhibits water uptake and disrupts nutrient availability, ultimately impacting fruit development.

Table 4. Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on fresh head diameter (cm)

Category	LS means	Standard error	Groups			
C (0.750)	8.8	0.2	A			
EC 1(1.6)	8.4	0.2	A	B		
EC 4(2.67)	7.8	0.2		B	C	
EC 5(2.86)	7.6	0.2			C	
EC 2(4.4)	5.0	0.2				D

EC 3(3.98)	5.0	0.2				D

The data suggest that lower EC values (especially around 0.750 dS m^{-1}) are conducive to better fruit growth, while higher EC values (above 2.67 dS m^{-1}) result in a significant decrease in fruit size, highlighting the importance of maintaining optimal salinity levels for agricultural productivity [13]. The non-significant differences between the higher EC groups (EC 2 and EC 3) reinforce the conclusion that the detrimental effect becomes more pronounced as EC surpasses a certain threshold, further emphasizing the critical impact of managing soil salinity in irrigation practices [14].

3.5 Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95%on fresh weight (g) per plant^{-1}

The results presented in Tables 5, 6 and 7 indicate significant differences in fresh weight of head (g per plant) as influenced by varying levels of irrigation electrical conductivity (EC), with a confidence interval of 95%. Table 5 shows that plants irrigated with a low EC of 0.750 dS m^{-1} (Category C1) the highest fresh weight (459.0 g per plant), which was statistically significantly different from other categories. As the EC value increased, there was a noticeable decline in fresh weight, with the second-lowest EC of 1.6 dS m^{-1} (EC 1) Gave plant fresh head of yield of 448.0 g per plant, still significantly higher than the subsequent categories (EC 5, EC 4). In fact, the highest EC values of 3.98 dS m^{-1} (EC 3) and 4.4 dS m-1 (EC 2) resulted in the lowest fresh of 257.3 g and 251.7 g plant $^{-1}$, respectively, which were statistically the worst-performing groups (D). This decline suggests a negative impact on plant growth and development as EC levels increase beyond a certain threshold, possibly due to salinity stress that hinders nutrient uptake, water absorption, and overall plant health.

Table 5. Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on head weight yield (g)

Category	LS means	Standard error	Groups			
C (0.750)	459.0	3.1	A			
EC 1(1.6)	448.0	3.1		B		
EC 5(2.86)	397.0	3.1			C	
EC 4(2.67)	395.0	3.1			C	
EC 3(3.98)	257.3	3.1				D
EC 2(4.4)	251.7	3.1				D

Table 6. Analysis of variance of Fresh Weight Yield (g)

Source	DF	Sum of squares	Mean squares	F	> F
Model	7	126431.7	18061.7	613.6	< 0.0001
Error	10	294.3	29.4		
Corrected Total	17	126726.0			
Computed against model Y=Mean(Y)					

Table 7. Irrigation Electrical conductivity dS m^{-1} and analysis of the differences between the categories with a confidence interval of 95%on head weight Yield per hectare (kg/ha)

Category	Yield per hectare (kg/ha)
C (0.750)	4590.0
EC 1(1.6)	4480.0
EC 5(2.86)	3970.0
EC 4(2.67)	3950.0
EC 3(3.98)	2573.0
EC 2(4.4)	2517.0

From the analysis of variance (Table 6), the model is highly significant ($F = 613.6$, $p < 0.0001$), confirming that the variation in fresh weight yield is explained by the changes in EC levels, underscoring the importance of proper irrigation management to optimize crop yield. The significant difference between the groups suggests that a low EC of 0.750 dS m^{-1} is optimal for maximizing head fresh weight, while higher EC values cause detrimental effects on plant growth, likely due to salt-induced osmotic stress that reduces water availability to the plant roots [15]. The results also indicate that the effect of EC on head fresh weight is non-linear, where lower EC values (C and EC 1) are positively correlated with higher yields, while higher EC values (EC 2, EC 3) show a marked negative effect, which aligns with previous research that has observed similar trends in crop production under saline conditions. Also, increasing irrigation water electrical conductivity (EC) significantly reduced head weight yield per hectare at a 95% confidence level. The highest yield was observed in the control (0.75 dS m^{-1}), while the lowest yields occurred at the highest EC levels (3.98 and 4.4 dS/m). The decline in yield suggests that higher salinity levels negatively impact plant growth and productivity. Significant differences between categories indicate that salinity stress is crucial in yield reduction. As such, the study provides valuable insight into the need for maintaining appropriate EC levels in irrigation water to optimize plant productivity, confirming that excessive salinity, as represented by higher EC values, can be detrimental to crop performance. Therefore, growers should aim for EC values closer to 0.75 dS m^{-1} for optimal growth, avoiding higher EC levels to mitigate negative impacts on yield [16].

3.6 Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on root weight (g)

The results presented in Table 8 regarding the effect of irrigation Electrical Conductivity (EC) on root weight (g) show significant and non-significant differences between the categories, as indicated by the Duncan analysis with a 95% confidence interval. The LS means for each category show a clear trend where the root weight decreases as the EC value increases. The control group (C) with EC value of 0.750 dS m^{-1} had the highest root weight at 63.0 g, grouped as "A." This group significantly differs from all other EC categories, suggesting a positive effect on root growth under lower EC conditions. The EC 1 (1. dS m^{-1}) category, with a root weight of 55.0 g, was grouped as "B" and is significantly lower than the control, but it still showed positive root growth compared to higher EC levels. EC 5 (2.86 dS m^{-1}) and EC 4 (2.67 dS m^{-1}) groups, with root weights of 46.0 g and 44.3 g respectively, are in group "C," show a continued decline in root weight as EC values increase, although not significantly different from each other. The EC 3 (3.98 dS m^{-1}) group, with a root weight of 28.7 g, and EC 2 (4.4dS m^{-1}) group, with the lowest root weight of 25.0 g, fall into groups "D" and "E," show significant reductions in root growth [10]. These results suggest that an increase in EC generally has a negative effect on root weight, with the EC 3 and EC 2 categories demonstrating the most pronounced decrease, which could be attributed to increasing salinity, potentially causing osmotic stress that hampers root growth. The lower EC values (0.750, and 1.6) appear to be more favorable for root development, supporting the idea that lower salinity conditions encourage better root weight gain. The findings align with the hypothesis that higher EC values result in diminished plant root growth due to salinity stress, and though there is a slight positive effect seen in EC 1, this effect diminishes significantly as EC increases beyond 2.86 dS m^{-1}, underscoring the negative impact of higher salinity on root biomass production [16, and 17].

Table 8. Irrigation Electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on root weight (g)

Category	LS means	Standard error	Groups				
C (0.750)	63.0	0.8	A				
EC 1(1.6)	55.0	0.8		B			
EC 5(2.86)	46.0	0.8			C		
EC 4(2.67)	44.3	0.8			C		
EC 3(3.98)	28.7	0.8				D	
EC 2(4.4)	25.0	0.8					E

3.7 Irrigation electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on dry matter (g)

The results presented in Tables 9 and 10 offer significant insights into the effects of irrigation electrical conductivity (EC) on dry matter yield. Table 9 displays the least squares (LS) means of dry matter (g) for various EC categories, with EC values ranging from 0.750 dS m^{-1} to 4.4 dS m^{-1}. The LS means indicate a clear trend in the dry matter, with category C (0.750 dS m^{-1}) showing the highest mean at 125.3 g, which is significantly different (< 0.05) from all other categories, grouping it in the "A" category. As EC values increase, the mean dry matter declines progressively. EC 1 (1.6 dS m^{-1}) follows with a lower yield of 120.7 g, categorized under group "B", while EC 5 (2.86 dS m^{-1}) and EC 4 (2.67 dS m^{-1}) yield 106.3 g and 105.4 g, respectively, both of which fall into group "C". EC 3 (3.98 dS m^{-1}) and EC 2 (4.4 dS m^{-1}) show the most significant decrease in dry matter yield, at 46.7 g and 44.6 g, respectively, both of which belong to group "E", indicating a marked decline in the effectiveness of irrigation as EC increases. These results suggest that while low EC values support better plant growth, as EC increases, the negative effects on dry matter become more pronounced, signaling a detrimental impact on plant health and growth with higher salinity levels [18]. Furthermore, Table 10 provides an analysis of variance (ANOVA) on dry matter (g), which confirms the significance of these differences. The model F-value is 2100.164, with a corresponding p-value of < 0.0001, indicating that the differences in dry matter yield across the EC treatments are statistically significant. This high F-value, coupled with the low P-value supports the conclusion that EC has a substantial effect on dry matter yield. The sum of squares for the model is 19856.876, highlighting the considerable variance explained by the EC treatment, whereas the error sum of squares is minimal at 13.507, further validating the strength of the model. This statistical evidence confirms that irrigation with higher EC values significantly reduces dry matter production, particularly at EC values greater than 2.67 dS m^{-1}, with a sharp decline observed as EC approaches 4.4 dS m^{-1}. These effects become more pronounced as EC rises, making irrigation with high-salinity water less effective for promoting healthy plant growth. This suggests maintaining a lower EC in irrigation water is crucial for optimal dry matter production. The study's findings align with previous research that demonstrates the negative impact of high EC on plant growth, highlighting the importance of managing irrigation water quality for agricultural productivity [19].

Table 9. Irrigation electrical conductivity dS m^{-1} / Duncan / Analysis of the differences between the categories with a confidence interval of 95% on dry matter (g)

Category	LS means	Standard error	Groups				
C (0.750)	125.3	0.7	A				
EC 1(1.6)	120.7	0.7		B			
EC 5(2.86)	106.3	0.7			C		
EC 4(2.67)	105.4	0.7			C		
EC 3(3.98)	46.7	0.7				D	
EC 2(4.4)	44.6	0.7					E

Table 10. Analysis of variance of dry matter (g)

Source	DF	Sum of squares	Mean squares	F	P > F
Model	7	19856.876	2836.697	2100.164	< 0.0001
Error	10	13.507	1.351		
Corrected Total	17	19870.383			
Computed against model Y=Mean(Y)					

3.8 Correlation coefficient (Correlation matrix) (Pearson) between Growth and yield parameters of lettuce

The correlation matrix in Table 11 shows strong and statistically significant ($\alpha = 0.05$) positive Pearson correlations among all growth and yield parameters, indicating highly interrelated plant performance. Plant height is strongly correlated with number of leaves, chlorophyll SPAD values, fresh head diameter, fresh weight per plant, root weight, and dry matter content, while leaf number shows particularly high associations with fresh weight and root development, suggesting its key role in biomass accumulation [20]. Root weight and dry matter content further exhibit very strong correlations with other parameters, highlighting their contribution to overall growth. Although these positive relationships reflect optimal performance under favorable conditions, increasing electrical conductivity (EC) may negatively affect these traits by causing nutrient imbalance and stress; thus, low EC levels enhance growth, whereas excessive EC can reduce yield, emphasizing the need for careful management of irrigation and nutrient conditions [21 and 22].

Table 11. Correlation coefficient (Correlation matrix) (Pearson) between Growth and yield parameters of lettuce

Variables	Plant height (cm)	number of leaves plant^{-1}	Chlorophyll SPAD reading	Fresh head diameter (cm)	Fresh weight(g) Plant^{-1}	Root weight (g)	Dry matter (g)
Plant height (cm)	1						
Number of Leaves Plant^{-1}	0.971	1					
Chlorophyll SPAD reading	0.946	0.961	1				
Fresh head diameter (cm)	0.937	0.954	0.975	1			
Fresh weight (g) plant^{-1}	0.955	0.968	0.985	0.971	1		
Root weight (g)	0.957	0.983	0.950	0.959	0.970	1	

Dry matter (g)	0.952	0.958	0.983	0.977	0.996	0.959	1

Values in bold are different from 0 with a significance level alpha=0.05

Conclusion

Lower irrigation electrical conductivity (EC), especially 0.750 dS m^{-1}, significantly improved plant growth and yield parameters, including plant height, leaf number, chlorophyll content, head size, root weight, and overall yield. In contrast, higher EC levels above 1.6 dS m^{-1} negatively affected plant performance due to increased salinity stress, which impaired water uptake, nutrient absorption, and metabolic activity. These results emphasize the importance of maintaining low to moderate EC levels in irrigation water to achieve optimal crop productivity. Careful monitoring and management of irrigation water quality, particularly in saline-prone regions, are essential to reduce the adverse effects of salinity and sustain healthy plant growth and agricultural yield.

Acknowledgments

The authors would like to express their sincere gratitude to the Dean and Vice Dean of Bakrajo Technical Institute for their invaluable support and guidance throughout the research studies. Special thanks to the heads of the Garden Design, Protective Agriculture, Food Science, and Quality Control departments for their expert advice and encouragement. Also, deeply thankful to all friends who have offered their assistance, shared their knowledge, and supported during this academic journey. Their contributions have been instrumental in the completion of this study, and authors truly appreciates their help and camaraderie.

Appendix Table1. Soil physiochemical properties

Property	Value	Unit
Soil Texture	Silty Clay	
pH	7.5	-
EC (Electrical Conductivity)	0.326	dS m^{-1}
Organic Matter	2.5	%
Available Phosphorus (P)	5	mg/kg
Available Potassium (K)	205	mg/kg
Calcium Carbonate ($CaCO_3$)	15	%
Bulk Density	1.3	g/cm^3

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تأثير التوصيلية الكهربائية (EC) لمياه الري على نمو وإنتاج الخس(*Lactuca sativa. L*) .

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الخلاصة

اجريت هذا البحث في معهد بكرجوَ التقني في البيوت البلاستيكية 2024-2025، في تأثير التوصيل الكهربائي للري على عوامل نمو مختلفة الخس، بما في ذلك ارتفاع النبات، وعدد الأوراق ومحتوى الكلوروفيل، وقطر الرؤس ، والوزن الطازج ووزن الجذر، وإنتاجية المادة الجافة. تظهر النتائج وجود علاقة سلبية واضحة بين مستويات التوصيلية الكهربائية المرتفعة حيث تعمل قيم التوصيلية الكهربائية المنخفضة (0.750 ديسي سيمنز/م) على تعزيز النمو الأمثل عبر معظم معاملات. أظهرت النباتات المعرضة لمستويات *EC* البالغة 0.750 ديسيسيمنز/م أعلى متوسط ارتفاع النبات (42 سم)، وعدد الأوراق (45)، وقراءات الكلوروفيل *SPAD* (87.4)، مما يعكس تحسن النمو والتمثيل الضوئي. ومع زيادة التوصيل الكهربائي أدت مستويات التوصيل الأوروبي التي تزيد عن 2.67 ديسي سيمنز/م إلى انخفاضات كبيرة في مقاييس النمو، مثل ارتفاع النبات وعدد الأوراق وحجم الرؤس، وذلك بسبب الإجهاد الأسموزي وقيود امتصاص المغذيات الناجمة عن الملوحة. وقد لوحظ انخفاض ملحوظ في الوزن الطازج، ووزن الجذر، وإنتاجية المادة الجافة مع ارتفاع التوصيلية الكهربائية، خاصة عند قيم التوصيلية الكهربائية البالغة 3.98 ديسيسيمنز/م و4.4 ديسيسيمنز/م. أكد تحليل الارتباط وجود علاقات إيجابية قوية بين عوامل النمو الرئيسية، مثل ارتفاع النبات وعدد الأوراق والمحصول. تؤكد الدراسة على الأهمية الحاسمة لإدارة مستويات *EC* في الري للحفاظ على صحة النبات وتحسين الإنتاجية الزراعية، مما يشير إلى أن الملوحة المفرطة في مياه الري يمكن أن تعيق النمو وامتصاص العناصر الغذائية وتطوير النبات بشكل عام.

الكلمات المفتاحية: التوصيلية الكهربائية(*EC*) ، الإجهاد غير الحيوي، النمو الخضري، إدارة الري.