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Effect of Deficit Irrigation with Saline Water on Chemical Properties for Red Cabbage (*Brassica oleracea var. capitate L.*) under Drip Irrigation

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Abstract. One potential management approach that can minimize water use with just a slight reduction in crop output is deficit irrigation. In addition, there is a dearth of research on how the semiarid environment of Kirkuk affects the Mineral Composition of green crops like red cabbage due to a combination of water shortage and water quality. Therefore, this study was initiated to unveil the combined effect of varying deficit irrigation levels (0.5, 0.75, 1, and 1.2 of full irrigation) and two types of water quality (fresh and saline water) on Total sugar, chlorophyll, and proline of red cabbage under drip irrigation with evaluating two types of(Gr, Turbo) emitters. The results indicated that there is a steady increase in Total sugar with an increase in the level of irrigation with saline water over the entire range of applied water. The highest proline content was achieved under the combined effect of saline water and GR emitter when the level of applied water at full irrigation was reduced by a factor of 0.5 (163.03 µmol/g). Furthermore, the highest value for chlorophyll content for Gr emitter under 1.2%IF with fresh water was (142 mg/100g). The drip irrigation system was evaluated at the beginning and middle of the experiment. The result was shown to outperform the GR emitter on the Turbo emitter in four qualities Standard Deviation of Discharges (Lh^{-1}), Statistical Uniformity Coefficient Us(%), Coefficient of manufactured variation (CV%), and Design Emission Uniformity (EU%) which was (0.0605 Lh^{-1}),(98.07 %),(0.01%) and (99.45%) respectively.

Keywords. Slain water, Red cabbage, Proline content, Sugar content, Drip irrigation, Deficit irrigation.

1. Introduction

Deficit irrigation is a method of water management that boosts both water efficiency and agricultural yields. Many kinds of irrigation systems may be used to implement deficit irrigation (DI). In dry and semiarid regions, water production may be increased by the use of deficit irrigation [1].

Water is the most vital resource and a constraint to agricultural development. As a result, methods that improve water use efficiency (WUE) while minimizing the quantity of additional water are critical for water conservation [2]. Furthermore, farmers are forced to utilize water with moderate to high saline levels because of a paucity of high-quality water. Irrigation with salty water causes salts to accumulate in the soil over time [3]. Saline water is an essential resource in dry environments and locations where groundwater resources are of poor quality. The use of low-quality water results in significant yield and plant growth losses [4]. Saline water can negatively affect plant growth and crop yield, highly saline water quality can cause problems with irrigated, the specific plant species and growth stage, and the amount of water that is able to pass through the root zone [5].

Water sustainability in agriculture has emerged as a key global concern. Adopting irrigation water-saving measures while maintaining acceptable yields may help preserve this increasingly scarce resource [6] .In locations where water is scarce and summers are long, boosting the productivity of water is more helpful to farmers than optimizing agricultural output. Conventional deficit irrigation is a modern novel way of saving agricultural water (DI). To irrigate a crop with less water than is necessary for maximum plant development is known as deficit irrigation, the purpose of this is to lessen the quantity of water needed for irrigating crops. [7] It's a method for conserving water by deliberately exposing plants to drought conditions during part of the growth cycle or the whole season.

Drip irrigation is a cost-effective and productive form of vegetable watering. Drip irrigation provides the highest potential for water efficiency. The use of Fertigation and Drip Irrigation is vital for decreasing irrigation and fertilizer costs because it maximizes nutrient absorption while utilizing the least amount of water and fertilizer [8]. When compared to traditional irrigation, drip irrigation enhances water usage efficiency by 60-200%, water saves 20-60%, lessens the need for fertilization 20-33% through fertigation, provides higher crop quality, and boosts yield 7-25% [9].

Like other brassica vegetables, Red Cabbage (Brassica oleracea L) has a high nutritional value and is one of the richest sources of antioxidants. According to several studies, eating green leaves and especially Brassica vegetables, which are strong in mineral elements and antioxidant vitamins, glycoside content, and flavonoids, could prevent cancer, heart disease, and other long-term health problems [10] . Winter vegetables, or crops, need a temperate growing environment and a chilly time while the plant's heads are developing [11].

Plants are exposed to many stresses and try to overcome them by increasing some special compounds such as proline [12]. Proline plays the role of an effective osmotic protector protecting against external tensions, as well as being known as salinity tolerance limiters[13] . Chlorophyll is the most important pigment for photosynthesis in plants, as it is included in the light-harvesting complex (LHC) embedded in thylakoid membranes, so its decrease leads to a decrease in plant productivity directly. The low concentration of chlorophyll due to salinity is due to many reasons, including the activity of the enzyme to catabolize chlorophylls (Chlorophylls), inhibition of enzymes necessary for chlorophyll synthesis Imbalance in the structure of the porphyrinic structure of chlorophyll [14,15]. [16] argue that salinity causes very high soluble sugar content due to loss of control over complex polysaccharide synthesis or increased concentration of Sucrose due to high starch hydration.

2. Materials and Methods

Research on red cabbage (Brassica oleracea L) under two emitter types with saline water and deficiency irrigation conditions was conducted from July 12, 2022, to December 7, 2022, in the Altun Kopri area of the Kirkuk governorate near of Hasar Al- Kabeer village in clay-loam soil.

On July 7, 2022, plates were prepared by placing one seed in each chamber of 4 cm in diameter peat moss. On August 8, 2022, after the seeds had been germinating for 37 days when they had 5-6 leaves and measured 10-15 cm in length, and had 40 cm of spacing between each seed. According to [17], fertilizers have been added. There were 16 distinct irrigation levels used as treatments in this field experiment, spread out in a factorial split-split plot design with three replications for a total of 48 experimental treatments. The main plot used an emitter type, the secondary plots experienced water salinity stress, and the third secondary plots experienced was for water deficit irrigation. The number of plots used in the experiment was kept at six, and there was a 2-meter spacing between each pair of plots, a 1.2-meter space between subplots, and a 1-meter spacing between sub-sub plots. Each plot has 8 rows of red cabbage, with 9 plants in each row; the row-to-row and plant-to-plant spacing were 0.60 and 0.40 m, respectively [18].Statistical analysis of plant data was performed in Excel 2010 and SAS

2000. To illustrate the dissimilarities between the components and means, the F-test and Duncan's test were carried out. Three depths of soil were sampled using the zigzag technique (Table 1).

Table 1. Chemical properties of soil.

Soil depth (cm)	**Ec ds m^{-1}**	**PH**	**OM %**	**$CaCo_3$ %**	**HCO_3^- meq/l**	**CO_3^- meq/l**	**K^+ meq/l**	**Na^+ meq/l**	**Mg^{+2} meq/l**	**Ca^{+2} meq/l**	**Cl^- meq/l**
0-30	1.07	7.3	1.51	29.4	1.2	0	0.084	0.869	1.5	0.8	1.4
30-60	0.45	7.5	1	31.4	1	0	0.022	0.857	0	1.2	1.3
60-100	0.48	8	0.76	32.5	1.2	0	0.03	0.793	0.1	1	1.4

2.1. The Details of the Levels of Each Factor

- Emitter type (A) with two types: A1 = Turbo, A 2= GR
- Water salinity (quality) (B) with two levels: B1 = Freshwater 0.55 dSm-1, B2 = Saline water 4.41 dSm^{-1}
- Deficit irrigation (C) with four levels: C1= 1.2 IF, where IF= full irrigation C2= 1 IF, C3= 0.75 IF C4= 0.5 IF

2.2. Evaporation from a Class A evaporation Pan (Epan), a Pan Coefficient (Kp), and Crop Coefficients were used to Determine How Much Water Would be Needed

Table 2. Physical and chemical properties of water quality.

Adjective	**Water quality**	
	Fresh water	**Saline water**
pH	7.7	8.1
EC $ds.m^{-1}$	0.55	4.41
Calcium meq/L	2.2	19.8
Magnesium meq/L	2.8	18.6
Potassium meq/L	0.01	0.06
Sodium meq/L	1.39	14.9
Biocarbon HCO_3	1.4	20
Chlorine meq/L	1.4	6.5
Turbidity NTU	1.5	6.4

2.3. Chemical Composition

2.3.1. Chlorophyll Content

The chlorophyll content in the leaves was measured at the rate of five leaves per plant and five plants per experimental unit with
SPAD -502, which was equipped by the (Japanese company Minolta Ltd). The SPAD-502 meter is a hand-held device, broadly used for the rapid, measurement of chlorophyll concentrations leaf in plant leaves. It is characterized by being a non-destructive method.

2.3.2. Proline Content $\mu mol.g^{-1}$

Proline was measured according to the procedure outlined by [19].
According to this procedure, 5g of fresh weight was taken and homogenized with sulfosalicylic acid and then infiltrated. Afterward, it was reacted with ninhydrin reagent. In the next step, Extraction was done to obtain chromophore dissolved in toluene. At the end the chromophore was measured spectophotometrically at a wavelength of 520 nm and the concentration of proline was determined in the sample after constructing a standard curve and applying the following formula:

$$\text{proline}(\mu mol.g^{-1}) = \text{proline ml} \times \text{toluene ml} \div 115.5 \div (\text{Sample Weight} \div 5) \quad (1)$$

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2.3.3. Total Sugar Content mg/100g

The sugar content was measured according to the method described by [20].Based on this procedure, 0.2 g of fresh sample was taken in a test tube and 10 ml perchloric acid HClO4 (1N) was added. Then the mixture was heated in a water batch for 60 minutes at 60 oC. Thereafter the mixture was centrifuged at 3000 RPM for 15 minutes and the clear solution was collected in a 100 ml-volumetric flask. This procedure was repeated 3 times and the flask was completed to the mark by adding distilled water. At the end, 1 ml of the extract was taken and mixed with 1 ml of phenol solution (5%) and 5 ml of concentrated sulfuric acid. The sample then was allowed to cool and the sugar content was measured by using the spectrophotometer Model (NV203) at a wavelength of 490 nm. Calculation of the total sugar content in (mg/100 g) was based on the following expression.

Total sugar (100 g/mg) =(100 x (the device reads))/((1000 x 0.134 x sample weight)) (2)

Figure 1. Laboratory analyses.

2.4. Studded Drip Irrigation System Indicators

2.4.1. Standard Deviation of Discharges (Lh^{-1})

According to the following equation, the standard deviation represents the emitter's capacity to regulate the right amount of water drainage on the field's soil across all regions: based on data from the American Society of Agronomists [21], and the calculation is conducted using the following statistical formula: [22].

$$SD=\sqrt{(qn-n(qm)^2)/(n-1)} \quad (3)$$

SD=Standard deviation of discharges (Lh^{-1})
qm = Average measured discharges (Lh^{-1})
q1, q2 = Emitter discharges ($L\ h^{-1}$)
qn = Sum of emitter discharges ($L\ h^{-1}$)
n = Number of drippers

2.4.2. Statistical Uniformity Coefficient Us(%)

Statistical uniformity was calculated by using an equation [23].

$$Us(\%) =(1-cv)*100 \quad (4)$$

2.4.3. Emitter Flow Uniformity (EU%)

When creating an irrigated network, the efficiency of water addition equals the efficiency of design water distribution as computed by the following formula equation [24,25]:

$$EU(\%)=100[(1-(1.27\times Cv)/(n))]\times(qn/qm) \quad (5)$$

EU = Design Emission Uniformity (%).
qn = The measured mean of the lowest 1/4 of the emitter discharge ($L\ h^{-1}$).
CV = Difference coefficient (%).

qm = Emitter discharge rate (L h^{-1}).
n = Number of drippers.

Table 3. Estimate values for Water distribution efficiency EU% and Statistical Uniformity Coefficient Us(%) According to the standard recommendations, according to the American Association (ASAE EP405.1FEB03) [21].

Criteria/ Classification	EU%	Us%
Excellent	94-100 %	90<%
Very Good	81-87%	90-80%
Good	68-75%	80-70%
Unacceptable	56-62%	70-60%

2.4.4. The Coefficient of Manufacture Variation (CV%)

The coefficient of manufacture variation of emitter discharge was computed using the following equation [26].

$$CV\ (\%) = (\ SD\ )/qm \quad (6)$$

CV = Coefficient of variation (%).
SD = Standard deviation of discharges (L h^{-1}).
qm = Emitter discharge rate (L h^{-1}).

Table 4. Emitters differential values of The Coefficient of Manufacture Variation(CV%)[26].

Criteria/ Classification	Values of variation manufacturing cv %
Excellent	Less than 0.05
Middle	0.07 -0.05
Below middle	0.11 - 0.07
Poor	0.15 -0.11
Unacceptable	More then 0.15

3. Results and Discussion

3.1. Phytochemical Qualities

3.1.1. Chlorophyll Content (mg/100g)

Figure 2 showed the effect of using of GR and Turbo emitter with different irrigation water quality (Freshwater, saline water) under four levels of water stress 1.2 %IF, 1% IF, 0.75%IF and 0.50%IF. where the results showed that the GR emitter with fresh water below the stress level 1.2 IF gave the highest value of (142.2mg/100g) for the characteristic of the leaf content of chlorophyll and this value decreased when using saline water under the same level of water stress 1.2 IF where it reached (112mg/100g). It also showed a decrease in these values sequentially when using fresh water with GR emitter compared to using the same dripper with saline water under 0.75% and 0.50%, 1% IF where it reached (135.7,128.5,121.7) and (110.8,97.3,97.7) mg/100 g respectively.

In the same figure, it appeared that when the Turbo emitter overlapped with the water quality under different levels of stress, chlorophyll values decreased with the use of saline water at levels of 0.75%IF,0.50%IF,1%IF compared to the Turbo emitter with fresh water in (131.5,128.2,121) and (110.4,99.4,98.3) respectively mg/100g, and this is what communicating with [27]and this may be attributed to the negative effect of water salinity in increasing osmotic pressure and decreasing nutrient absorption.

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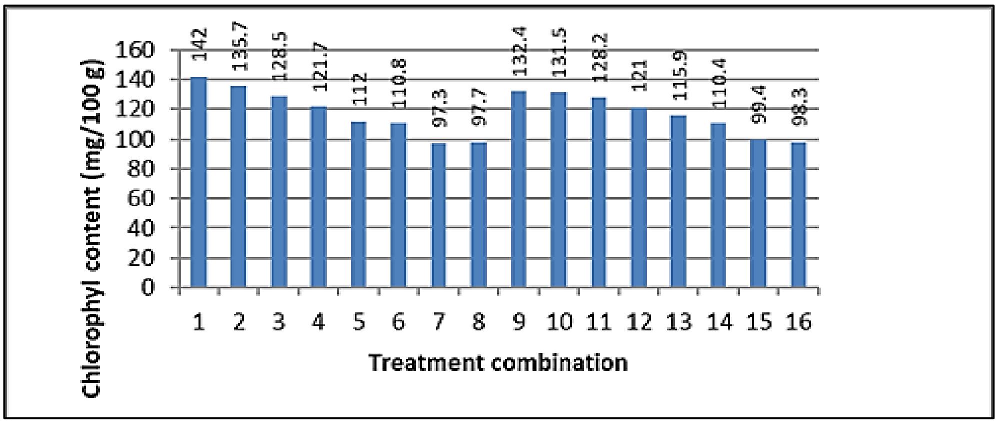

Figure 2. Effect the interactions among type of emitter, water quality and deficit irrigation level on leaf chlorophyll content of red cabbage.

Also, [28] pointed that the most important negative salinity effects on the plant is the excessive production, which causes oxidation of the internal structures of chloroplasts and then the reduction of the size of the internal stromata's, which have most of the enzymes photosynthetic, and this results in reducing the plant content of chlorophyll. [29] indicated that the leaf value of chlorophyll decreases as salinity rises and is supported by [30,31].

3.1.2. Proline Content µmol/g

The results in Figure 3 showed a significant increase in the average values of the red leaf content of proline between 16 treatments when two types of emitter interfered with the use of irrigation water quality under four different levels of water stress 1%IF 1.2%IF, 0.75%IF, and 0.50%IF. Where the highest average proline was for the GR emitter overlaps with saline water under 0.50% IF, reaching (165.03 µmol/g), followed by the Turbo emitter with saline water under 0.50% IF, where this result confirmed the tolerance of red cabbage to stress conditions when this treatment was more than the rest of the treatments. In the same figure, an increase in the leaf content of proline when exposed to stress conditions showed 0.75% of total irrigation when using saline water compared to using the same treatment with fresh water, which showed the lowest value, which amounted to (144.07 µmol/g, 131.33 µmol/g) and (130.9 µmol/g,133.7 µmol/g) respectively. Also, it did not find differences with a significant effect when using two different types of the emitter with fresh water for the content of the leaves of proline, but the highest values of the Turbo emitter compared to the GR emitter when using 1% IF, where their values reached (134.67 µmol/g) and (137.4 µmol/g) respectively, [32] confirmed that the concentration of proline rises with high salinity concentrations.

The increase in the accumulation of proline is also due to the increased destruction of proteins and their transformation into amino acids, including proline, as this amino acid works to regulate the osmosis of plant tissue cells and reduce the ionic effect resulting from saline stress, as proline leads to the reorganization of osmosis of the plant to be able to overcome the osmosis of the soil solution and contribute to the restriction of toxic elements absorbed under saline conditions [33].

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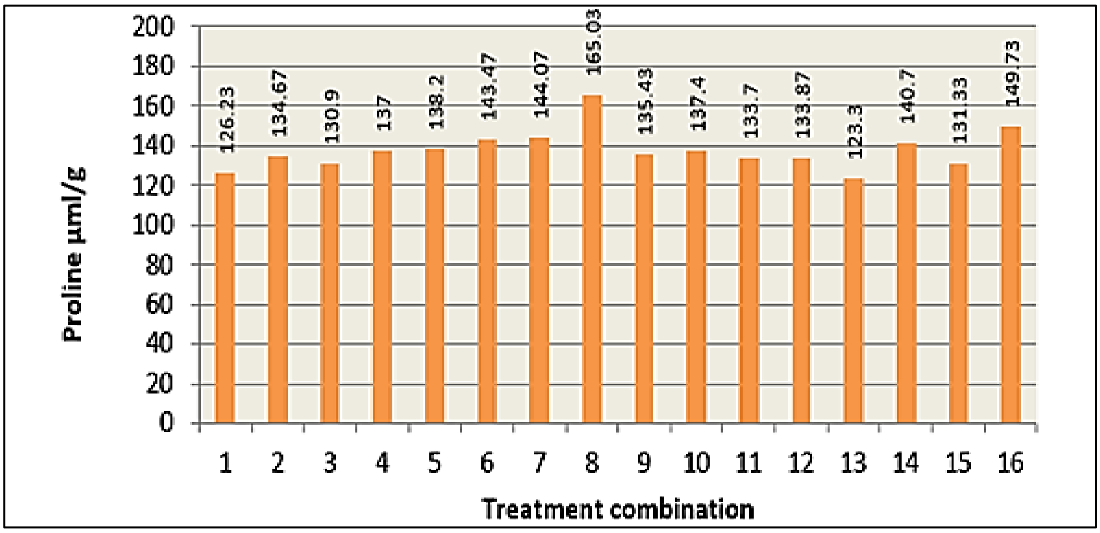

Figure 3. Effect the interactions of emitter type, water quality and deficit irrigation level on proline content of red cabbage.

3.1.3. Total Sugar Content g/100 g

Figure 4 showed the effect of the interaction of two types of drippers with the use of different water quality under four different levels of stress on the content of red head on total sugars for 16 treatments separately, where the results showed that the percentage of total sugars when two types of emitter with the fresh water decreased under 0.75%IF and 0.50%IF compared to 1.2%IF and 1%IF where their values were (3.2g/100g, 2.96g/100g)(3.3g/100,3.8g/100g) and (3.74g/100g, 3.18g/100g) (3.34g/100g, 3.64g/100g) respectively.

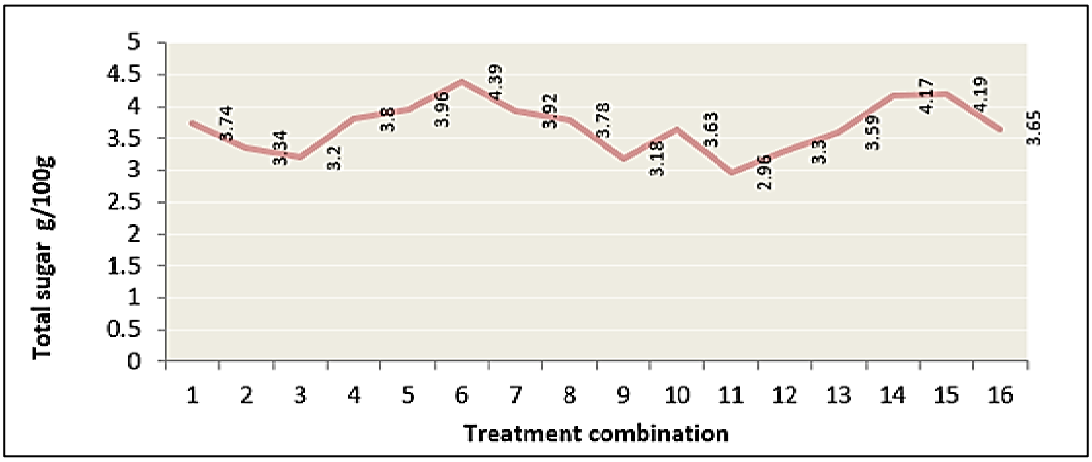

Figure 4. Effect the interactions of emitter type, water quality and deficit irrigation level on total suger content of red cabbage.

It also showed an increase in the level of total sugars when the GR emitter overlapped with saline water under 1.2%IF and 1%IF where the highest value of this trait was recorded (4.39g/100g, 3.96g/100g) and the lowest value (3.92g/100, 3.78g/100) was under 0.50%IF and 0.75%IF for the same treatment. When using the type of Turbo emitter with saline water, it was found that the value of total sugars at 0.75%IF and 1%IF showed the highest value, reaching (4.17g/100, 4.19g/100g), and the lowest value was at 1.2% IF and 0.50%IF amounted to (3.59g/100g, 3.65g/100g), and this is what was agreed with what was brought by [34,35].

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Bernstein et [36]explained that in the presence of salinity, residual carbohydrates accumulate in high concentration because plants growing under normal conditions quickly reduce the carbohydrate level in their tissues for use in the formation of new cells.

3.2. Drip Irrigation Assessment

3.2.1. Standard Deviation of Discharges(SDLh^{-1})

It is noted from Table 5 that the average GR emitter significantly exceeded the Turbo emitter at the beginning of the season, where it reached (0.06781), and (0.215) respectively, and these values decreased at the middle of the season to (0.1957) and (0.3088) respectively, in the same table that there was no significant difference in the average water quality that used at the beginning of the season, where the freshwater was the least difference for the plant (0.1349) compared to saline water, as it gave us the highest difference (0.148), and the values of this characteristic decreased for the average water quality at the middle of the season and found a significant difference where the freshwater was less different than the saline water as it amounted to (0.1495) and(0.3551).
The same table shows a significant difference when the emitter overlap with the water irrigation quality at the beginning and at the middle season, where the GR emitter with fresh and saline water had the least difference compared to the Turbo emitter with fresh and saline water, which gave the highest difference as the values were (0.0751), (00605), (0.0982), (0.2933), (0.7947), (0.2364), (0.2009), (0.4169) respectively.

Table 5. The effect of factorial treatment and their interaction on Standard Deviation of Discharges(Lh^{-1})at the beginning of the season and middle of the season.

Emitters	**Water quality**		**A Effect**
	Fresh water(B1)	**Salinewater(B2)**	
GR (A1)	0.0751 b	0.0605 b	0.0678 a
Turbo(A2)	0.1947 a	0.2364 a	0.2156 a
B Effect	0.1349 a	0.1484 a	
At the middle of season			
Emitters	Water quality		A Effect
	Fresh water(B1)	Saline water(B2)	
GR (A1)	0.0982 a	0.2933 ab	0.0957 a
Turbo(A2)	0.2009 bc	0.4169 a	0.3088 a
B Effect	0.1495 b	0.3551	

3.2.2. Statistical Uniformity Coefficient US%

Statistical uniformity coefficient US% is used to estimate the consistency of emitter flow rates in all parts of the irrigation system [37]. In Table 6, significant differences were found based on statistical analysis
at the beginning of the season and in the middle of the season at two types of the emitter, where the GR emitter had the best value compared to the Turbo emitter with their values of (98.25) (94.59) and (94.81) (92.07) respectively. In the middle of the season, it found a significant difference in the quality of water, where freshwater gave the highest value of (96.21) compared to saline water, which recorded the lowest value for this trait, reaching (90.67).

Table 6. The effect of factorial treatment and their interaction on Statistical uniformity coefficient US% at the beginning of the season and middle of the season.

Emitters	**Water quality**		**A Effect**
	Fresh water(B1)	**Saline water(B2)**	
GR (A1)	98.07 ab	98.43 a	98.25 a
Turbo(A2)	95.11 ab	94.08 b	94.59 b
B Effect	96.59 a	96.26 a	
At the middle of the season			

Emitters	**Water quality**		**A Effect**
	Fresh water(B1)	**Saline water(B2)**	
Emitters	Water quality		A Effect
	Fresh water(B1)	Saline water(B2)	
GR (A1)	97.47 a	92.13 ba	94.81 a
Turbo(A2)	94.95 ab	89.12 b	92.07 b
B Effect	96.21a a	90.67 b	

It confirmed in Table 3 that the interference of the emitter with the quality of irrigation water at the beginning of the season and in the middle of the Season had high moral effects, where the highest value of the GR emitter with saline water was recorded (98.43) and the lowest value was for the Turbo emitter with saline water, where it reached (94.08) at the beginning of the season, but in the middle of the season the highest value of the GR emitter with fresh water amounted to (97.47) and the lowest value was for the Turbo emitter with saline water, where it was recorded (89.12).

3.2.3. The Coefficient of Manufacture Variation (CV%)

Fig.5 Effect of Overlap of Two Types of Emitter with Irrigation Water Quality on The Coefficient of Manufacture Variation (CV%) at the Beginning and Middle of the Season

Fig.5 shows that there are significant differences in the Coefficient of manufacture variation between GR and Turbo with fresh and saline water, where surpassed GR emitter with fresh water on Turbo emitter with fresh water were 0.0193, and 0.0488 respectively when the season first started. Also, at the season's midpoint, the GR emitter with fresh and saline water gave the best value was (0.0253), (0.0786) and this concurs with [38]. Values were inconsistent for both GR and Turbo (point source emitters), possibly due to the fact that there can be no two emitters and Two identical manufacturers unless there is a difference in the values of the manufacturing coefficient of variation, this is consistent with [39].

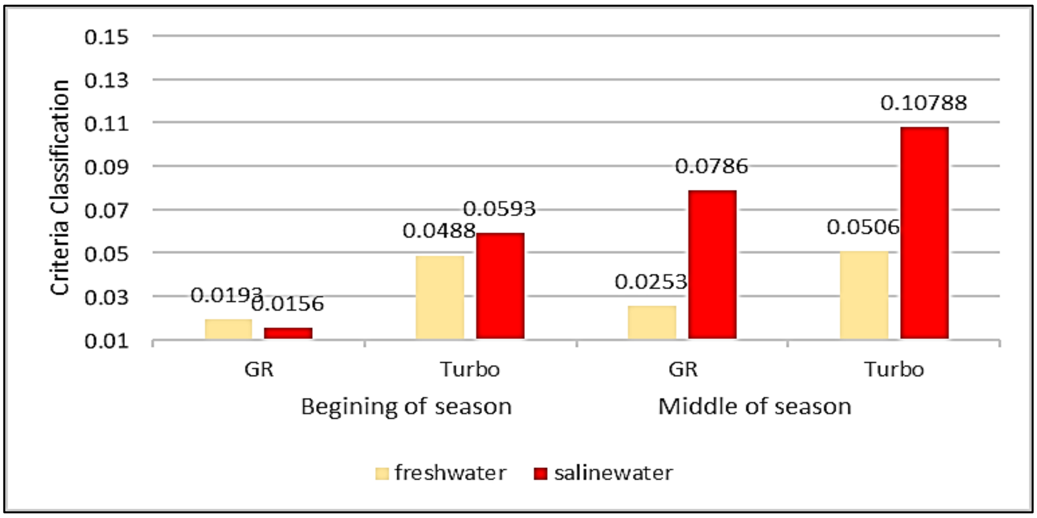

Figure 5. Effect of Overlap of Two Types of Drippers with Irrigation Water Quality on The Coefficient of Manufacture Variation (CV%) at the beginning and middle of the season.

3.2.4. Design Emission Uniformity (EU%)

Fig 6 shows overlapping between types of the emitter with different levels of irrigation water, we note that the GR emitter with saline water achieved the best value in the efficiency of adding water if it was recorded (99.51%) and the Turbo emitter with saline water was less efficient at the beginning of the season, where it reached (98.15%), and this value decreased at the middle of the season, where the GR emitter with fresh water given The highest efficiency of adding water reached (99.21%), and the lowest efficiency of adding water was for the Turbo emitter with saline water, where it was recorded (96.76%). All the values of this characteristic (Design emission uniformity EU%) are within the required limits according to Table 3.

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The reason for the differences between the values was low irrigation rates were more effective in increasing the efficiency of adding water than high irrigation rates, and where the results indicate the extent of the efficiency of the emitter in the distribution of good water and its positive impact on the studied qualities and in increasing the yield and quality qualities, and this is what agreed with what was stated by [25,40,41].

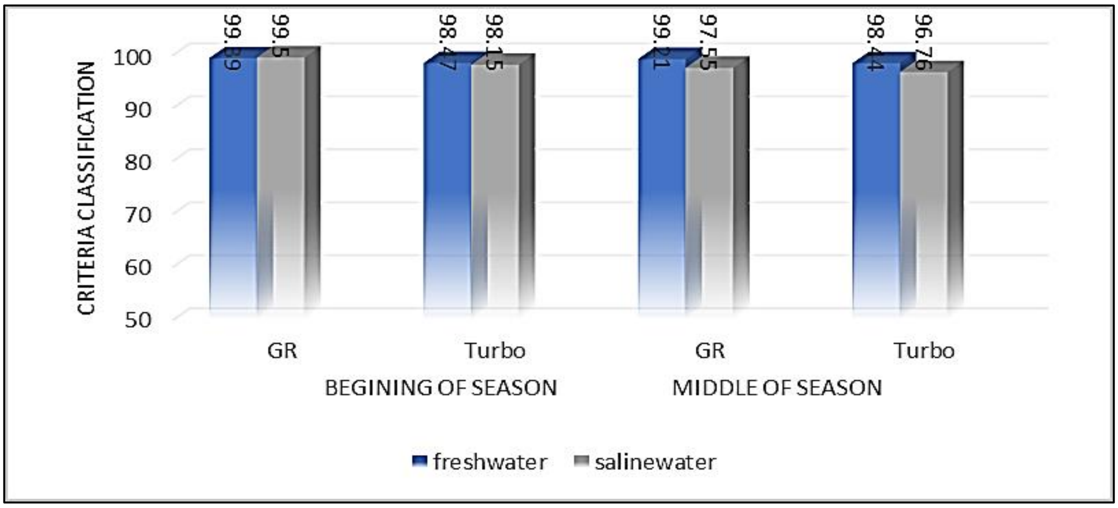

Figure 6. Effect of Overlap of Two Types of Drippers with Irrigation Water Quality on Design Emission Uniformity (EU%) at the beginning and middle of the season.

Conclusion

- Deficit irrigation at 0.75%IF < 0.50%IF with saline water (4.41 dSm-1) had high influence on leaf content of chlorophyll.
- Exposure of red cabbage to deficit irrigation leads to an increase in the rate of proline synthesis.
- Saline water affects the chemical properties of mineral content in plants, a total sugar content increased with the saline water under 1%IF and 1.2% IF.
- GR emitter achieved superiority over the Turbo emitter at Standard Deviation of Discharges, Statistical uniformity coefficient, The Coefficient of Manufacture Variation, and Design Emission Uniformity.
- The best combination of GR with fresh water was the most studied characteristic.

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