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To cite this article: Sazan H Sabah *et al* 2023 *IOP Conf. Ser.: Earth Environ. Sci.* **1252** 012064

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Interactive effects of emitter type, water salinity, and deficit irrigation on of red cabbage (*Brassica oleracea L)* with evaluating drip irrigation system

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Abstract. Field research was carried out at Kirkuk Governorate (Altun Kopri district) near the village of Hasar Al- Kabeer for the agricultural season of 2022 to compare two types of GR and Turbo emitter and two levels of water salinity on yield (0.55 EC dSm-1), (4.40 EC dSm-1), with four levels of deficit irrigation (ETc 120%), (100% full irrigation) (75% ETc), and(0.50% Etc). The results were analyzed with a factorial split-split plot design, and the F-test and Duncan's test determined the differences between factories and averages. The system was evaluated at the beginning of the experiment in comparison between GR and turbo emitter performance. Results were shown to outperform the GR emitter on the Turbo emitter in four qualities: coefficient of manufactured variety (% CV), uniformity of emitter flow (% Eu), uniformity field emission F.EU%, and absolute uniformity field emission F.Eua% with results of 0.01% 9.45% %,99.09%and 99.87 % The system was also evaluated in the middle of the experiment in comparison between fresh water and saline water in same qualities parameter. The results were shown by the superiority of fresh water over saline water as the results were (0.0379%), (0.0932%), (98.83%), (97.16%),(98.28),(98.93), and(99.85),(99.87)respectively. The most important results showed the superiority of the GR emitter interference treatment with freshwater at water stress level (100% ETc) in the total yield Mg ha^{-1} and plant height cm for red cabbage were 26.50 Mg ha^{-1} and 35.00 cm. Turbo emitter with saline water at 50% water stress given the best value (24.20 leaf $plant^{-1}$).

Keywords: Drip irrigation, Emitter type, Water salinity, Deficit irrigation

1. Introduction

Drip irrigation systems, such as modern irrigation technologies, have become the newest agricultural method for farmers to grow crops [9]. A drip irrigation system typically improves crop yield by 25–30% and saves irrigation water by up to 50% [31]; [32]. Which has the ability to use limited but frequent water near the root zone of the plant through a network of tubing [12]. [8] showed that the uniformity of the distribution of water for drip irrigation systems is the result of a number of factors, including the pressure (head) of the pump and discharge of the pump, the friction losses inside pipes, and the diameter and length of pipes. [28] mentioned that the result rate of emitter variation flow is appropriate when it does not exceed 10% and is not acceptable when it exceeds 20%. Emitter variation of flow is employed to evaluate the operation, and the discharging standard of variation state of emitters discharge produces differences in the manufacture of these emitters. In a study that compared two types of emitters and two types of water quality. When GR emitters are one of the best emitters calculated in terms of efficiency, they are especially suitable for the cultivation of vegetable crops. At this emitter type, the farms are

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allowed to choose the spacing and flow rates that suit the needs of the crop. The nominal diameter of this emitter is 16 mm, the outer diameter is 15.5 mm–18 mm and above, and the dimension between the dots is a minimum of 20 cm and a maximum of 40 cm [17]. A turbo emitter is a pressure compensation emitter, also known as a DPJ emitter. allows for quick and easy on-site inspection and cleaning. The dimension between the dots depends on the distance between crops or trees [17]. The use of the drip irrigation system needs farmers to have a level of knowledge of how to use this modern system to irrigate vegetable crops, and this requires the workers of the agricultural extension apparatus to devote their effort and time to highlight the importance of using the drip irrigation system for farmers as a modern system that helps to rationalize the use of water in the cultivation of agricultural crops in general and vegetables in particular [14].

Water is the most important resource and a limiting factor in agricultural development; therefore, practices that lead to improving water use efficiency (WUE) and reducing the amount of added water are important for conserving water [7]. The scarcity of good-quality water forces growers to use water with moderate or high salinity levels. Irrigation with saline water leads to salt accumulation in the soil [6]. Saline water is an important resource in the semi-arid version with poor-quality groundwater resources, as poor-quality water poses serious losses in yield and plant growth [27]. Evaluating irrigation water quality is critical for optimum cultural practices and long-term productivity [15].

Under irrigation, strategies are an appropriate way to increase water savings in irrigation by exposing crops to water stress and allowing only a marginal decrease in crop yield [16]. Before implementing any method of deficit irrigation, it is preferable to know the crop's response to water stress and its impact on the stages of crop growth to determine the possibility of applying the principle of water stress to the entire growing season [23]. [33] mentioned that exposing crops to water stress during specific growth stages does not cause any significant differences in plant production, and in this way, it is possible to save a quantity of water that can be exploited for agricultural expansion purposes.

Red cabbage (Brassica oleracea L) belongs to the family Brassicaceae and has a high nutritional value and is one of the richest sources of antioxidants; It is one of the most popular, palatable, and nutritious vegetable crops [4]. Fresh 100 g red cabbage contains 0.2% oil and 92% water, 8% dry matter, 1.3% protein, and 3.8 grams of carbohydrates [36]: [18]. One of the most important reasons for the decrease in production rates of this crop in Iraq compared to other producing countries is that the majority of farmers do not follow modern methods of production, as well as a lack of interest in good agricultural service operations such as irrigation and composting [1].

2. Materials and Methods

The experiment was carried out at Kirkuk governorate (Altun kopri district) near the village of Hasar Al- Kabeer on clay-loam soil from 2022/7/12 to 2022/12/7 to compare and evaluate two types of emitters with two types of water quality under a deficit irrigation system for red cabbage (Brassica oleracea L).

The seeds were grown on July 7, 2022, in plates after filling them with peat moss with a diameter of 4 cm at a rate of one seed in each chamber. The seeds were planted at the age of 37 days on August 8, 2022, with 5–6 leaves and 10-15 cm long, with spicing between seeds of 0.40 cm. The experiment was laid in a split-split plot design with 2 emitter types, two sub-treatment water quality, and 4 sub-sub treatments of deficit irrigation. As mentioned earlier, a field measuring 43.3 m x 3.60 m was selected for the experiment and this area was divided into three blocks of 14.43 m x 3.6 m. Each block consisted of 16 plots Each factor was replicated three times and a randomized complete block design was adopted. The experimental main plot was kept at 6 plots, the spacing between the main plots was 2 m, the spacing between subplots was 1.2 m, and the spacing between sub-sub plots was 1 m. For plants, the row-to-row and plant-to-plant spacings were 0.60 and 0.45 m, respectively [5], each plot has 8 rows of red cabbage with 9 plants in each row. The fertilizers have been added according to [3]. The data of plants was analyzed statistically by using Excel 2010 and SAS 2000 programs. The F-test and Duncan's test were performed to show the differences between the factors and averages.

2.1 The details of the levels of each factor are as follows:
1)Emitter type (A) with two types: A1 = Turbo, A 2= GR
2)Water quality(salinity) (B) with two levels: B1 = Freshwater, B2 = Saline water
3)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 Water requirement calculation was based on evaporation from class A evaporation pan (Epan), pan coefficient(Kp); crop coefficients for red cabbage during its growth (kc), and irrigation application efficiency(Ea). The calculations can be summarized as follows:
1.The evaporation pan was set up close to the experimental site for recording daily evaporation (mm/day).
2-The pan evaporation (Epan) was converted to potential evaporation(ETo) through

$$ETo = Epan \; x \; Kpan \qquad (1)$$

Kpan = pan coefficient =0.75
3- Establishment of crop coefficient (Kc)curve for red cabbage over the growing season (Fig.1).
4- The crop consumptive use was obtained from;

$$ETc = ETo \; x \; Kc \qquad (2)$$

5-The growth depth of applied water(dg) in mm was calculated from:

$$V = ETc/Ea \qquad (3)$$

6-The determination of the volume of applied water in liter/day /plant was based on the following expression:

$$V = ETc \; x \; WA \; x \; A \qquad (4)$$

where: WA = wetted area fraction or reduction factor (=0.5); A = area = Sp x Sr =0.40m x 0.6 m
The volume of applied water was based of cumulative evaporation for two and three days during the early stage and the period after this stage depending upon the intensity of external evaporative.

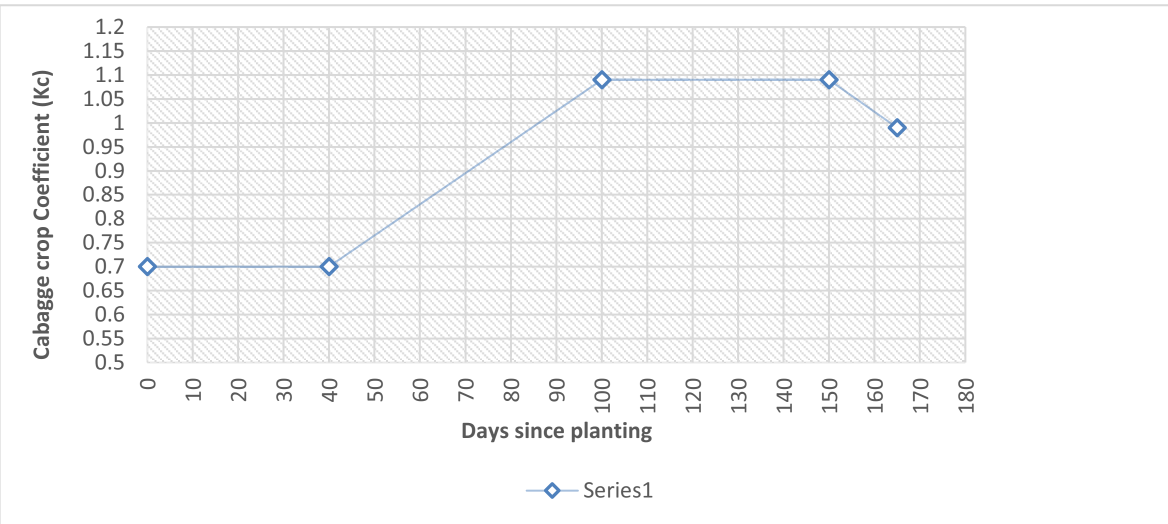

Fig 1Crop coefficient for red cabbage during its growing season

7-Time of operation (T in hours) was based on an irrigation interval of 3 days at the early stage of growth and 2 days thereafter. The formula takes the following form:

$$T = V/q \quad (5)$$

; where q = emitter discharge in L hr^{-1}.

The emitter discharge of each emitter was determined before the experimental setup and V=the average value for the discharge the emitters belonging to the same treatment was determined. The required irrigation water was provided from two storage tanks, one for the freshwater(S1) and the other for the saline water (S2). The sources for S1 and S2 were the lesser Zab tributary and a well south of Kirkuk respectively. Table 1. Portrays some characteristics of the applied waters, the soil sample was taken by the zig-zag method from three different depths (tables 2,3)

Table 1 Physical and chemical properties of water quality

Adjective	Water quality	
	Freshwater	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

Table 2 Chemical properties of soil.

Soil depth (cm)	Ec ds m^{-1}	PH	OM g %	$CaCo_3$ %	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

Table 3 Physical properties of soil

Soil depth (cm)	Soil particle size distribution %				Soil bulk density g cm^{-3}	Porosity %	Soil moisture content %
	Sand% (g kg^{-1})	Silt% (g kg^{-1})	clay% (g kg^{-1})	Textural class			
0-30 cm	555	140	306	Sandy clay loam	1.4839	44.00	3.86
30-60 cm	502	140	358	Sandy clay	1.5279	46.92	1.44
60-100 cm	255	420	325	Clay loam	1.5805	40.35	3.98

2.3 STUDDED INDICATORS OF DRIP IRRIGATION SYSTEMS.

2.3.1 THE DISCHARGE L h^{-1}

Discharge of emitters is calculated as mentioned by [34]

$$Q = V/T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (6)$$

Q= Dripper discharge L h^{-1}
T= Time for dripping discharge h
V= Water volume L

2.3.2 THE COEFFICIENT OF MANUFACTURE VARIATION (CV%):
Variation of emitter discharges due to the inability to produce comparable emitters, as a following equation [24]

$$CV\ \% = SD\ /qm \ldots\ldots\ldots\ldots\ldots.(7)$$

CV = Coefficient Of Manufacture Variation (%).
SD = Standard Discharges (L h^{-1})
Qm = Average discharges (L h^{-1})

Table 4: Emitters differential values of manufactured coefficient [10].

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

2.3.3 UNIFORMITY EMITTER FLOW (EU%):
The emitter flow uniformity was calculated using the following equation: [37]

$$EU\% = 100[(1 - 1.27Cv/n)] * Qn/Qm \ldots\ldots\ldots\ldots.(8)$$

EU = Uniformity emitter flow (%).
Qn = the lowest 1/4 quarter of the emitter discharge (L h^{-1}).
CV = Coefficient of Manufacture Variation (%).
Qm = Average discharges (L h^{-1}).
n = a number of drippers.

TABLE 5: Estimated values for uniformity emitter flow EU%, uniformity field emission F.EU % , and absolute uniformity field emission F.Eua % According to the standard recommendations the American Association [13]

Criteria/ Classification	EU%	F.EU %	F.EU a %
Excellent	94-100	More than 90%	94-100%
Very Good	81-87%	90-80%	81-87%
Good	68-75%	70-80%	68-75%
Unacceptable	56-62%	Less than 70%	56-62%

2.3.4 UNIFORMITY FIELD EMISSION F.EU %
The uniformity field emission was calculated by using the following equation: [19]

$$F.EU\ \% = 100\frac{Qn}{Qm} \ldots\ldots\ldots.(9)$$

F.EU % = Uniformity field emission
Qm = Average discharges (L h^{-1}).
Qn = the lowest 1/4 quarter of the emitter discharge (L h^{-1}).

2.3.5 ABSOLUTE UNIFORMITY OF FIELD EMISSIONS F. EUa %
The regularity value of F. Eua% Absolute Uniformity field emission (practically measured distribution in the field) is based on which the topical irrigation system can be assessed. It can be calculated by using the following formula equation: [22]

$$F.Eua\ \% = [\frac{Qn}{Qm} + \frac{Qm}{QX}] * 50 \ldots\ldots\ldots\ldots..(10)$$

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F.Eua % = Absolute Uniformity field emission %
Qm = Average discharges (L h^{-1}).
Qn = the lowest 1/4 quarter of the emitter discharge (L h^{-1}).
Qx=The mean of the highest 1/8 of emitter discharge measured (L h^{-1})

2.4PLANT INDICATORS:
2.4.1 -Plant height (cm) is calculated (at the harvest) using a ruler or tape meter from the ground's surface to the tops of the heads of the five homogeneous plants for each experimental unit, and then the rate is calculated for them [29].
2.4.2 -Number of the plant's external leaves (leaf plant -1) The number of exterior leaves (not wrapped for each selected plant was estimated and then corrected accordingly.
2.4.3 -Total fresh fruit yield (Mg ha^{-1}) The total result is calculated according to the following, as stated [4]

Fig *2* Field of experiment

3. Results and Discussion

3.1. Drip irrigation Assessment

Table 6 shows that there are significant differences in the Coefficient of manufacture variation and uniformity of flow emitter between GR and Turbo, where surpassed GR emitter values on Turbo emitter values were 0.0175, 0.0541, and 99.45 and 98.31, respectively, when the season first starts. Also, at the season's midpoint, the GR emitter gave the best value was (0.0519), (0.0792), (98.38), and (97.60), and this concurs with [20]. values were inconsistent for both GR and Turbo (point source emitters), possibly due to the fact that there can be no two emitters Two identical manufacturers unless there is a difference in the values of the manufacturing coefficient of variation, this is consistent with [26].

Table 6 Effect of emitter type on system-related characteristics during a different level in the season.

Measured characteristic	At the beginning of the season		At the middle of the season	
	Emitter type		Emitte type	
	GR	TURBO	GR	TURBO
Coefficient of Manufacture Variation Cv% *	0.0175	0.0541	0.0519	0.0792
design emission uniformity Eu% **	99.45 a	98.31 b	98.38	97.60

(*) The minimum value is the best
(**)A higher value is the best

Table 7 Effect of water salinity on system-related characteristics during different levels in the season.

Measured characteristic	At the beginning of the season	In the middle of the season

	Water quality		Water quality	
	Freshwater	Salin water	Freshwater	Salin water
Coefficient Of Manufacture Variation Cv% *	0.0341	0.0374	0.0379 b	0.09325 a
design emission uniformity Eu%**	98.93	98.83	98.83 a	97.16 b

(*) The minimum value is the best
(**) Higher value is the best

Table 7 results showed the impact of water quality on studied qualities when conducting evaluations of the system at the beginning and middle of the season, where freshwater was given the best values than saline water for the Coefficient of Manufacture variation (0.0341), (0.0374), and (0.0379), (0.0932), and where fresh water was given the highest value for the design emission uniformity (98.93), (98.83), and (97.16). A difference between the two types of emitters with the quality of water irrigation did not show a marked difference in results. This indicates the efficiency of the emitter on a good distribution of water and a positive effect on the studied qualities [2]. A difference in the manufacture, type of emitter and water salinity lead to a change in the water flow rate [25].

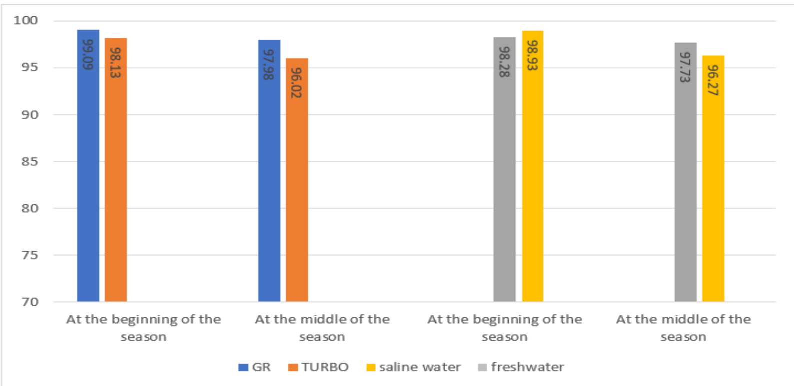

Fig 3 the impact of two types of emitters with two types of water quality on Uniformity field emission F.EU % at the beginning and middle of the season.

Fig 3 showed that The GR emitter gave the highest value compared to the Turbo emitter of the Uniformity field emission F.EU% at the beginning of the season, where it reached (99.09) and (98.13) respectively. In the middle of the season, despite a significant decrease in the regular values of Uniformity field emission F.EU%, the GR emitter also outperformed the Turbo emitter by (97.98), (96.54), which indicates a better consistency of water distribution at the GR emitter, which corresponds to [35] [21].

Also, Fig 3 shows the effect of two types of water quality Uniformity field emission F.EU% at the beginning and middle of growth season, where saline water at the beginning of growth season given the best value compared to fresh water, which amounted to (98.93) and (98.28). The regularity of field emission was affected in the middle of growth season, where fresh water gave the highest value compared to saline water were (97.73) and (96.27) respectively.

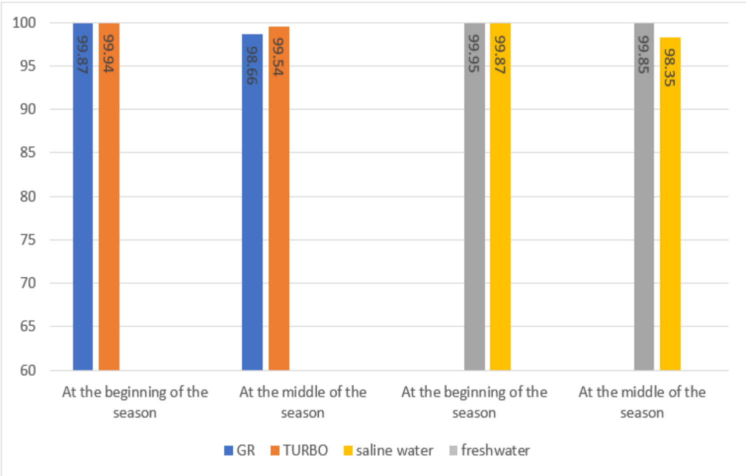

Fig 4 the impact of two types of emitters with two types of water quality on Absolute Uniformity field emission F. EUa % at the beginning and middle of the season.

Figure 4 showed that the Turbo emitter gave the highest value for Absolute Uniformity field emission F. EUa% compared to the GR emitter at the beginning and middle of the season when it reached (99.87), (99.94) and (99.54),(98.66). Also, Fig. 4 shows the effect of two types of water quality for Absolute Uniformity field emission F. EUa% at the beginning and middle of the growing season, fresh water gave the best value compared to saline water, which was (99.95), (99.87)and (99.85)(98.35).

3.2 Growth characters for vegetative:

3.2.1 Plant height (cm)

The result in Table 8 shows an overlapping interaction effect between emitter type and water salinity under different water stress levels for plant height cm. The highest plant height measured was 35.00 cm from a GR emitter with fresh water at 100% irrigation without stress, and the lowest plant height was 28.50 cm from a Turbo emitter with impact and saline water at 100% irrigation without stress. Where we note that the deficit irrigation and the use of saline water did not cause noticeable negative effects on the characteristics of vegetative growth and was agreed with [30].

Table 8 overlapping effect of emitter type and water salinity under different water stress levels for plant characteristics.

Characteristic treatment			Plant height cm **	Leaves No/plant **	Total yield Mg ha $^{-1}$ **
Emitter type	Water quality	Deficit irrigation			
GR	Fresh water	1.2 IF	33.47 ^{cab}	15.40 ^{h}	22.65 ^{ab}
		1 IF	35.00 ^{a}	16.20 ^{hg}	26.50^{ab}
		0.75 IF	31.80^{cedb}	16.67 ^{fhg}	20.16^{ab}
		0.50 IF	31.87^{cedb}	16.80 ^{efhg}	21.97^{ab}
	Saline water	1.2 IF	33.73^{cedb}	17.07 ^{efhg}	25.45^{ab}
		1 IF	32.00 ^{ab}	17.40^{edfhg}	24.08^{ab}
		0.75 IF	30.27^{cedb}	18.13^{edfcg}	22.52^{ab}
		0.50 IF	29.47 ^{edf}	19.47 ^{dc}	17.01 ^{b}
TURBO	Fresh water	1.2 IF	33.53 ^{ef}	17.60^{edfcg}	23.93 ^{ab}
		1 IF	32.47 ^{cab}	17.87^{edfcg}	24.58 ^{ab}
		0.75 IF	32.00^{cabd}	19.00 ^{edc}	21.75 ^{ab}
		0.50 IF	30.20^{cedb}	19.53 ^{dc}	22.68 ^{ab}

	Saline water	1.2	28.50 f	19.80 bc	22.87 ab
		1 full irrigation	30.73cedf	18.67edfc	21.60 ab
		0.75	31.80cedb	21.60 b	19.93 ab
		0.50	31.0cedbf	24.20 a	18.01 b

(**) A higher value is the best

3.2.2 Number of leaves (leaf plant $^{-1}$)

The results of Table 8 showed significant differences when the triple overlap between two types of the emitter with two types of irrigation water on four different levels of water stress, where the highest value of this characteristic was given to the GR emitter with salt water below the water stress level (50%) amounted to (19.47) compared to the interference of GR emitter with fresh water at the stress level (120%), which gave the lowest value of (15.40), When the Turbo emitter overlapped with the marinade at the water stress level (50%), it was given a value compared to fresh water at the water stress level (120%), the lowest value was purified, reaching (24.20) and (17.60) respectively, and this is consistent with what was communicated [30] . [38] also show that the degree of foliar induction is one of the morphological responses to plant salt tensions.

3.2.3 Total yield Mg ha^{-1}

Table 8 shows The highest yield with (26.50 Mg ha^{-1}) was obtained by use of GR emitter with fresh water at (100%) water stress, also participated in a moral with GR and turbo with saline and fresh water at (100%),(75%)(50%)water stress . And the lowest yield with (17.01 Mg ha^{-1}) and (18.01 Mg ha^{-1}) were for using GR and Turbo emitter with saline water at (50%) water stress. The possible reason of obtaining highest yield in Gr emitter with fresh water for full irrigation maybe that irrigation water was applied almost uniformly and controlled for all plants and plants were taken from their root zone depths equally [4].

4. Conclusion

1- The GR emitter outperforms the Turbo emitter also superior of fresh water and saline water in terms of Coefficient of Manufacture Variation (Cv%), design emission uniformity (Eu%), Uniformity field emission F.EU% and Absolute Uniformity field emission F. EUa%

2- Treatment with more water developed larger plants at 100% and 75% water stress levels on plant Hight cm and total yield Mg ha^{-1}.

3- According to the result of this study, it is fair to propose that red cabbage be irrigated with a maximum of 4400 ppm saline water.

4- Turbo emitter significantly outperformed GR emitter when interfering with the salinity of irrigation water under different levels of water stress) in the characteristic of the number of leaves (leaf plan^{-1}).

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