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Effect of Different Concentrations of Irrigation Water Salinity and Potassium Humate on Vegetative Growth and Mineral Content of Prickly Pear Plants (*Opuntia ficus-indica* L.) (1)

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THIS study was conducted during two consecutive seasons of 2020 and 2021 on an orchard of prickly pear located at the Alumni villages area "Cairo-Alexandria desert", Egypt. The effects of water salinity levels (control (orchard irrigation water), 1000, 2000, 3000, 4000 and 5000 ppm), potassium humate (0, 50 and 100 g/tree /year) and their interactions on vegetative growth and cladodes minerals content of El-Shamia cactus pear plants were studied. Application with salinity levels and potassium humate as well as their interaction showed that, control (orchard irrigation water) with 100g potassium humate rate improved plant height, plant canopy volume, number of cladodes per plant, cladode area, cladodes relative turgidity, cladodes succulence grade, cladodes water potential, chlorophylls a and b, total chlorophyll, carotenoids, cladodes total carbohydrates content, and content of N, P, Mg, Fe, Mn and Zn of cladodes. On the other hand, reduced cladodes osmotic pressure, hard cladodes character, cladodes total sugars content, cladodes proline content, as well as Ca, Na and Cl contents. Thus, this treatment was proved to be the most efficient in enhancing growth and minerals content of cladodes of El-shamia cactus pear plants.

Keywords: Prickly pear, Salinity, Potassium humate, Vegetative growth, Mineral content, Pigment.

Introduction

The cactus pear (*Opuntia Ficus-indica* L.) belongs to the family Cactaceae and its common name is prickly pear. The cultivated area of prickly pear in Egypt amounted to 3395 feddens produced about 25391 tons of fruits according to the statistics of the Ministry of Agriculture, Egypt (2019). This plant is being introduced in similar production areas for alleviating soil erosion, animal feed, human consumption as a vegetable (young cladodes) or fruit and industrial purposes (Nefzaoui & Ben Salem, 2002 and Guovara et al., 2009).

Soil and water salinity are considered the main limiting factors of plant production. Soil salinization may occur because of climate change, overuse of groundwater (in the regions near the seas), use of low-quality water for irrigation, and over-irrigation (Machado and Serralheiro, 2017). In addition, with increasing temperatures and decreasing rainfall in arid lands, salt cannot be washed away, resulting in accumulations in the topsoil. This limits the growth of plant roots and causes abiotic challenges for plants (Dolarslan and Gul, 2012). Salinity buildup adversely affects plant growth and development through osmotic effects and the ionic supply of nutrients (Singh 2003). The edible cactus has a high potential for fodder and fruit production when grown in marginal lands with low-quality groundwater. Cactus pear has a lower tolerance to salinity at the survival stage but can sustain saline groundwater irrigation for optimum growth and production in later stages. Though the plant is moderately tolerant to salinity, it is sensitive to alkalinity and unable to perform at soil pH 9.8 (Gajenderg et al., 2014).

Humic acid is the most significant component of organic substances in aquatic systems. Humic acid is highly beneficial to both plants and soil; it

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is important for increasing microbial activity; it is considered a plant growth stimulant and effective soil enhancer; it promotes nutrient uptake as a chelating agent and improves vegetative characteristics, nutritional status and leaf pigments (Eissa et al., 2007). Potassium humate increases the production and quality of a crop and increases plant tolerance to drought stress, salinity, heat, cold, disease, and pests (Jalilm et al., 2013).

The application of potassium helps the plants cope with the hazardous effects of salinity by improving their morphological, physiological and biochemical attributes. Whereas, among various macronutrients, potassium (K+) occupies an important role in the survival of plants under salt-stressed conditions (Mengel et al., 2001 and Mahmood, 2011). Humic acid treatments (foliar and soil application) markedly increased the growth parameters (shoot length, number of leaves, shoot and leaf area) of the «Canino» apricot (Fathy et al., 2010 and Eissa 2003). Using potassium humate as a soil application at 75 g per tree followed by 100 g per tree gave the best results in the flowering and fruiting aspects of «Aggizi» olive trees. (Abo-Gabien et al., 2020).

Material and Methods

The present study was conducted during two successive seasons in 2020 and 2021 on a prickly pear cultivar, namely El-Shamia cactus pear plants (*Opunita ficus-indica L.*). The trees were about 9 years old, grown in an orchard at km 107 of the Alex Desert Road, namely the Alumni Villages, grown in a sandy soil about 6 x 2 m apart (about 350 plants per feeder), and subjected to irrigation with drip-salted irrigation water. Physical and chemical analyses of the experimental soil were shown in Table (1) and the chemical analysis of the used irrigation water is recorded in Table (2).

Fifty-four healthy plants, nearly uniform in shape, size, and productivity, were selected and they received the same horticultural practices. The experiment was designed as a randomized complete block design with three replicates for each treatment and each replicate was represented by one plant.

Drip irrigation system was designed with two drip lines, each one placed one meter from the trunk tree. Where trees were irrigated twice in February, March, April, May, June and July by 240 liters / tree / year. For traditional drip irrigation, a Gr dripper was used for 4 L/h/m of discharge, and four drippers for one tree were used for 20 liters per tree. Control irrigation uses the same rates as irrigation.

The present study was a factorial experiment with two factors. The first factor consisted of 3 rates of potassium humate (0, 50 and 100 g/plant) and the second factor involved 6 levels of salinity for irrigation water (NaCl) (orchard irrigation source: 1000, 2000, 3000, 4000 and 5000 ppm). The experiment was designed as a randomized complete block design with three replicates for each treatment and each replicate was represented by one plant.

TABLE 1. Analysis of experimental soil.

Soil Depth (cm)	Texture Class	pH Soil past	E.Ce (dSm^{-1})	Organic matter %	Soluble cations (meq/l)				Soluble anions (meq/l)			
					Ca^{++}	K^{+}	Na^{+}	Mg^{++}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}	$CO_3^{=}$
0-30	Sandy	7.3	1.7	0.21	7.1	0.5	6	3.4	6	7	4	-
30-60	Sandy	7.7	0.79	0.19	2.5	0.3	4	1.1	3.8	2.7	1.4	-

TABLE 2. Chemical analysis of water used for irrigation.

pH	E.C. dSm^{-1}	O.M %	Soluble cations (meq/l)				soluble anions (meq/l)			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
7.81	0.53	0.8	1.50	1.52	1.32	0.19	0.00	1.42	1.42	1.71

Vegetative growth

In the last week of September, the following parameters like plant height (m), plant canopy volume (m^3), the number of new cladodes per plant and cladodes area (cm^2) were measured and recorded.

Plant canopy volume (m^3)

Plant canopy volume (m^3) was calculated according to the formula:

Plant canopy volume = (π) (tree height) ($radius^2$).

Each tree's crown radius (m) was measured in eight directions (every 45 degrees) around the entire plant circumference, beginning with magnetic north. Radiuses were measured from the center of the trunk with a compass and a plummet was placed in the most external point of the profile for each considered direction (Smith et al., 1997). The resulting measurements were summed and tree canopy volume was determined.

Cladodes area (cm^2)

The cladode area was determined by adopting the methodology used by Barros et al. (2016).

Cladodes area (cm^2) = Cladode length (cm) x Cladode width (cm) x 0.693

Where: 0.693 = means correction factor for the ellipse shape of the cladode.

Cladodes physiological characteristics

Cladodes relative turgidity (C.R.T.): It was determined as follows: Discs about 1 cm in diameter were removed from each fresh leaf sample to determine their fresh weight (F.W.) immediately, then placed in a closed container (Petri dishes) until they became constant in weight (after 24 hours) at room temperature (20 + 2 0 C) in shade. The discs were surface dried with plotting paper and weighted for their turgid weight (Tr.W.). The dry weight (Dr.W) of each of the 10 discs was determined after 24 hours. Leaf relative turgidity (L.R.T.) was estimated according to the following equation described by Osman (2005).

$$L.R.T. = \frac{\text{Fresh wt. - Dry wt.}}{\text{Turgid wt. – Dry wt.}} \times 100$$

Cladodes succulence grade (C.S.G.): It was estimated according to the following equation Osman (2005):

$$L.S.G. = \frac{\text{Leaf water content (in g) *}}{\text{Leaf area (Dec)}^2} \text{(g) } H_2O/dec^2 \text{ of leaf}$$

Whereas, leaf water content (in g) =

$$\frac{\text{Total fresh weight – the total dry weight of the leaves at the end of experiments}}{\text{Total number of leaves at the end of experiments}}$$

According to Nomir (1994).

Cladodes water potential (C.W.P.) %: The method followed and the equation for the calculations have been suggested by Halma (1934) and confirmed by Draz (1986).

$$L.W.P. = \frac{\text{Fresh weight - dry weight}}{\text{Fresh weight}} \times 100$$

Cladodes osmotic pressure (bar): It was recorded after adequate fresh leaf samples were immediately frozen, and then the cell sap was extracted in the laboratory with a piston pressure when the frozen tissue had been thawed. The total soluble solids in the sap were determined by refractometer and the equivalent values of the osmotic pressure (in bars) were estimated according to Gusov (1960).

Hard cladodes character (H.C.C.): It was described according to the following equation:

$$H.L.C. = \frac{\text{The dry weight of leaf (g)}}{\text{Leaf area } (Dec^2)} = \text{dry matter g / Dec}^2.$$

Whereas, dry weight of leaf (in g) =

$$\frac{\text{The dry weight of the leaves at the end of the experiment}}{\text{No. of leaves at the end of experiment}}$$

This method was suggested by Youssef (1990), Hassan (1998) and Laz (1999).

Photosynthetic pigment

Chlorophylls A and B, as well as total chlorophyll carotenoids contents: The leaf contents of chlorophylls (A and B) as well as carotenoids were extracted, calculated according to the equation of Wettstien (1957), and expressed as mg/g fresh weight.

Cladodes total carbohydrates percentage (%)

Total carbohydrate percentage was determined in mature shoot dry samples (0.1 g) photometrically at 490 nm according to the method described by Dubois et al. (1956).

Cladodes total sugar content (%)

Total sugars were determined in shoot-dry samples (0.1 g) photometrically at 490 nm using the phenol method and using ethyl alcohol for 1 hour at 70 0C as described by Dubois et al. (1956).

Cladodes proline content (mg/100 g of fresh weight)

Proline content was determined in fresh leaves according to the method described by Batels et al. (1973) and confirmed by Draz (1986) and Osman (2005).

Cladodes mineral content

Leaf mineral content was determined as follows: Cladode samples were collected for the determination of the contents of macro and micronutrients in the tissue in the last week of September. 10 samples of cladodes were collected from the middle section of the plants per treatment. Samples were sliced, dried, ground and digested according to Parkinson and Allen (1975). Nitrogen was estimated by the micro-Kjeldahl method by (Bremner, 1965). According to Matt (1968), phosphorus was calorimetrically measured using a Spekol spectrophotometer wavelength 882 UV. Potassium was determined by flame-photometer according to Jackson (1958). Calcium and magnesium were determined by titration against the versenate solution (Na-EDTA) method as described by Chapman and Pratt (1961). Iron, Manganese and Zinc were estimated by using Atomic Absorption Spectrophotometer "Jarill - Ash 850". Sodium was determined by the method of the flame photometer according to the method of Brown and Lilleland (1946). Leaf chloride content was determined according to the Jackson (1958) method.

Statistical Analysis

Data recorded in both seasons were subjected to analysis of variance according to Clarke and Kempson (1997). The significant differences among means were determined by Duncan's multiple range test Duncan (1955).

Result and Discussion

Table 3 shows the effect of irrigation water salinity, potassium humate, and their interaction on prickly pear plant height and canopy volume during the 2020 and 2021 seasons.

Plant height

Concerning salinity levels, the control treatment as orchard irrigation water indicated higher significant values in plant height (2.16 and 2.13 m) than the other concentrations in both seasons. Regarding potassium humate treatments, it could be observed that the 100 g rates showed a higher significant value of plant height (1.93and 1.95 m) than the other concentrations (0 and 50 g) in both seasons. The interaction between the two study factors indicated that the control treatment using orchard irrigation water with potassium humate at 100 g gave the highest significant value of plant height (2.32 and 2.20 m) in both seasons.

Plant canopy volume

Regarding salinity levels, the control treatment using orchard irrigation water indicated the highest significant values of plant canopy volume (5.81 and 5.08 m^3) in both seasons. Regarding potassium humate, it could be noticed that the treatments with the 100 g rate recorded higher significant values for plant canopy volume (4.03 and 3.85 m^3) than the other rates (0 and 50 g) in both seasons. The interaction between the two study variables revealed that the control treatment, which used orchard irrigation water containing 100 g of potassium humate, produced the highest significant values of plant canopy volume (7.06 and 5.72 m^3) in both seasons.

Table 4 shows the effect of irrigation water salinity and potassium humate on the number of cladodes per plant and cladode area (cm^2) of prickly pear plants during the 2020 and 2021 seasons.

The number of cladodes

With respect to salinity levels, the orchard irrigation water control treatment recorded a higher significant value for the number of cladodes (36.11 and 38.89) than the other salinity levels in both study seasons. Additionally, in both research seasons, potassium humate treatments at 100 g/plant/year produced more cladodes per plant (30.28 and 31.00) than those at 0 g and 50 g. According to the interaction between salt levels and potassium humate rates, the control treatment plus 100 g of potassium humate produced the highest significant values of cladodes over the course of the two seasons.

Cladodes area

With regard to salinity levels, control treatment using irrigation water from orchards reported higher significant values for the cladodes area (440.21 and 456.47 cm^3) than all other concentrations in both seasons. Additionally, 100g potassium humate treatments had the largest cladodes areas (307.86 and 322.69 cm^3) in comparison to 0g and 50g potassium humate in both research seasons. According to the interaction between salt levels and potassium humate rates,

TABLE 3. Effect of irrigation water salinity, potassium humate and their interaction on plant height and canopy volume of prickly pear plants during 2020 and 2021 seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Plant height (m)							
Control	2.01 c*	2.13 b	2.32 a	2.16 A	2.11 b	2.10 b	2.20 a	2.13 A
1000	1.96 cd	1.94 def	1.95 de	1.95 B	1.81 ef	1.94 d	2.05 c	1.94 B
2000	1.90 efg	1.84 hij	1.91 ef	1.89 C	1.73 g	1.94 d	2.05 c	1.91 C
3000	1.80 jk	1.85ghi	1.89 fgh	1.85 D	1.71 g	1.83 e	1.91 d	1.82 D
4000	1.81 ijk	1.78 k	1.80 ijk	1.79 E	1.65 h	1.79 f	1.82 ef	1.76 E
5000	1.69 l	1.65 l	1.69 l	1.68 F	1.60 i	1.63 hi	1.70 g	1.64 F
Mean	1.86 B	1.87 B	1.93 A	-	1.77 C	1.87 B	1.95 A	-
	Plant canopy volume (m^3)							
Control	4.85 c	5.50 b	7.06 a	5.81 A	4.46 c	5.06 b	5.72 a	5.08 A
1000	3.87 d	3.75 de	3.74 de	3.79 B	3.23 g	3.79 e	4.34 d	3.78 B
2000	3.25 fg	3.38 fg	3.98 d	3.54 C	2.70 i	3.27 g	4.30 d	3.43 C
3000	2.25 ij	3.15 g	3.51 ef	2.97 D	2.44 j	3.42 f	3.74 e	3.20 D
4000	1.98 j	2.59 h	3.29 fg	2.62 E	2.02 l	2.36 j	2.85 h	2.41 E
5000	1.61 k	2.36 hi	2.61 h	2.19 F	1.45 m	1.91 l	2.16 k	1.84 F
Mean	2.97 C	3.46 B	4.03 A	-	2.72 C	3.30 B	3.85 A	-

* Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

TABLE 4. Effect of irrigation water salinity, potassium humate and their interaction on the number of cladodes/ plant and cladodes area of prickly pear plants during 2020 and 2021 seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Number of cladodes/Plant							
Control	32.33 de	36.00 bc	40.00 a	36.11 A	37.34 b	37.33 b	42.00 a	38.89 A
1000	31.67 e	33.00 cde	38.00 ab	34.22 B	30.67 E	33.00 d	36.00 c	33.22 B
2000	25.00 fg	28.00 f	35.33 bcd	29.44 C	30.66 e	27.00 g	35.00 c	30.89 C
3000	20.00 hi	26.00 fg	28.00 f	24.67 D	26.33 g	26.00 g	29.00 f	27.11 D
4000	12.33 k	17.00 ij	23.00 gh	17.44 E	13.00 j	22.00 h	22.00 h	19.00 E
5000	11.33 k	14.00 jk	17.33 i	14.22 F	12.33 j	18.00 i	22.00 h	17.45 F
Mean	22.11 C	25.67 B	30.28 A	-	25.06 C	27.22 B	31.00 A	-
	Cladodes area (cm^2)							
Control	390.57 c	416.72 b	513.33 a	440.21 A	328.28 c	423.61 b	617.52 a	456.47 A
1000	247.91 g	264.21 fg	360.51 d	290.88 B	292.75 de	301.43 d	331.49 c	308.55 B
2000	213.10 h	275.59 ef	292.68 e	260.46 C	245.98 gh	260.61 f	291.75 de	266.11 C
3000	204.95 hi	247.18 g	265.52 fg	239.21 D	205.16 i	236.00 h	286.21 e	242.46 D
4000	200.71 hi	204.40 hi	219.47 h	208.20 E	190.64 j	217.20 i	248.40 fgh	218.75 E
5000	183.80 ij	165.60 j	195.65 hi	181.68 F	183.09 j	252.63 fg	160.76 k	198.82 F
Mean	240.17 C	262.28 B	307.86 A	-	240.98 C	281.91 B	322.69 A	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

the control treatment plus 100 g of potassium humate had the greatest significant values of cladodes area during both research seasons.

Table 5 shows the effect of irrigation water salinity, potassium humate, and their interaction on cladodes relative turgidity (%), cladodes succulence grade, and cladodes water potential (%) of prickly pear plants during the 2020 and 2021 growing seasons.

Cladodes relative turgidity

Referring to salinity levels, orchard irrigation water utilized as a control treatment had the greatest significant value of cladodes relative turgidity (91.24 and 91.43%) in both seasons. Regarding potassium humate treatments, the data showed that the 100 g rate demonstrated greater significant values of cladodes relative turgidity (82.99 and 84.71%) than the other concentrations (0 g and 50 g) in both seasons. The interaction between the two parameters showed that utilizing orchard irrigation water as a control treatment with potassium humate at 100 g generated the greatest significant value of cladodes relative turgidity (94.07 and 93.03%) in both seasons.

Cladodes succulence grade

Regarding salinity treatments, it was observed that orchard irrigation water utilized as a control treatment showed the highest significant cladodes succulence grade in both seasons (24.99 and 22.51%). According to the findings on potassium humate treatments, the 100g rate recorded the greatest significant cladodes succulence grades (21.65 and 20.08%) in both seasons. Orchard irrigation water (control treatment) with potassium humate at 100 g recorded the highest significant cladodes succulence grade (27.06 and 24.56%) in both seasons, according to the interaction between two study components.

Cladodes water potential

With regard to salinity levels, it could be observed that orchard irrigation water used as a control treatment had the highest significant cladodes water potential (93.62 and 93.34%) in both seasons. Regarding potassium humate treatments, the data indicated that a 100g rate showed the highest significant cladodes water potential (89.68 and 91.31%) in both seasons. The interaction between the two studies factory indicated that orchard irrigation water used as a control treatment with potassium humate at 100 g gave the highest significant cladodes water potential (94.43 and 93.03%) in the first season, while orchard irrigation water used as a control treatment with potassium humate at 50 g and 100 g were similar and also had the highest significant cladodes water potential in the second season compared with other treatments.

Table 6 shows the effect of irrigation water salinity, potassium humate, and their interaction on cladodes osmotic pressure and hard cladodes character of prickly pear plants during the 2020 and 2021 seasons**.**

Cladodes osmotic pressure

Concerning salinity levels, the results indicated that the control treatment showed the lowest significant cladodes osmotic pressure (0.234 and 0.249 bar) in both seasons. Regarding potassium humate treatments, the data showed that a 100 g rate recorded the lowest significant cladodes osmotic pressure (0.271 and 0.292 bar) in both seasons as compared with other applied treatments. The interaction between the two studied factors indicated that the control (orchard irrigation water) with potassium humate at 100 g had the lowest significant cladodes osmotic pressure in both seasons.

Hard cladodes character

In terms of salinity, the control treatment (orchard irrigation water) had the lowest significant cladodes hard cladodes character in both seasons (1.621 and 1.482%).Regarding potassium humate treatments, the 100g rate had the lowest significant hard cladodes character in both seasons (2.033 and 2.028%). According to the interaction between two study parameters, potassium humate at 100 g in the control treatment (orchard irrigation water) produced the least significant hard cladodes character (1.500 and 1.236%) in both seasons.

The data in Table 7 demonstrated the effect of irrigation water salinity, humate potassium, and their interaction on chlorophyll A, chlorophyll B, and total chlorophyll of prickly pear plants during the 2020 and 2021 seasons.

Chlorophyll A

Concerning salinity treatments, the data showed that the control treatment (orchard irrigation water) indicated the highest significant value of chlorophyll A (2.058 and 2.078 mg/g fresh weight) in both seasons. Regarding potassium humate treatments, the results indicated that the 100g rate recorded the highest chlorophyll A in the first season, while 50g and

100g rates were similar and recorded the highest significant chlorophyll A (1.762, 1.740 and 1.818 mg/g fresh weight, respectively), compared to the other levels. The interaction between two study factors resulted in the control treatment (orchard irrigation water) with potassium humate at 100 g in the first season and with potassium humate at 50 g and 100 g in the second season recording the highest significant chlorophyll A (2.11, 2.08, and 2.20 mg/g fresh weight, respectively) relative to other treatments.

Chlorophyll B

With regard to salinity treatment results declared that, the control treatment (orchard irrigation water) provided the highest significant value of chlorophyll B (4.055 & 2.681 mg/ g fresh weight) than the other concentrations in both seasons,. Regarding potassium humate treatments, it was observed that the 100g rate in both seasons recorded the most significant chlorophyll B levels (3.135 and 2.601 mg/g fresh weight, respectively). The interaction between the two studied factors showed that, when compared

TABLE 5. Effect of irrigation water salinity, potassium humate and their interaction on cladodes relative turgidity, cladodes succulence grade and cladodes water potential of prickly pear plants during 2020 and 2021 seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Cladodes relative turgidity (%).							
control	90.59 b*	89.06 b	94.07 a	91.240 A	89.81 c	91.47 b	93.03 a	91.43 A
1000	85.25 c	86.44 c	88.95 b	86.88 B	86.92 e	87.94 de	89.01 cd	87.96 B
2000	82.38 d	84.96 c	85.88 c	84.41 C	81.15 ij	82.75 gh	82.99 g	83.31 C
3000	79.64 e	80.65 de	82.39 d	80.89 D	80.51 j	84.52 f	84.90 f	82.29 D
4000	73.43 fg	73.72 fg	74.18 f	73.77 E	77.85 k	80.69 j	81.85 hi	80.13 E
5000	70.67 h	71.66 gh	72.47 fgh	71.60 F	73.88 m	74.46 m	76.45 l	74.93 F
Mean	80.33B	81.08B	82.991A	-	81.69 C	83.64 B	84.71 A	-
	Cladodes succulence grade (%).							
control	23.02 c	24.91 b	27.06 a	24.99A	20.34 d	22.62 b	24.56 a	22.51 A
1000	19.99 ef	21.54 d	21.70 d	21.18 B	19.50 g	19.96 e	20.63 c	20.03 B
2000	20.85 de	21.24 d	21.46 d	21.08 B	19.16 h	19.49 g	19.64 f	19.43 C
3000	17.67 h	19.85 efg	21.21 d	19.57 C	18.64 j	18.63 j	18.89 i	18.72 D
4000	15.81 i	19.12 fg	19.20 fg	18.05 D	18.33 lm	18.38 kl	18.46 k	18.39 E
5000	15.05 i	17.24 h	18.88 g	17.06 E	18.06 o	18.23 n	18.28 mn	18.19 F
Mean	18.73 C	20.65 B	21.65 A		19.00 C	19.55 B	20.08 A	
	Cladodes water potential (%).							
control	92.99 c	93.42 b	94.43 a	93.62 A	92.39 b	93.68 a	93.97 a	93.34 A
1000	88.37 g	89.77 e	90.79 d	89.65 B	91.04 de	92.19 bc	92.57 b	91.93 B
2000	86.70 j	88.87 f	88.12 g	87.89 C	90.20 fg	90.22 f	91.56 cd	90.66 C
3000	85.82 k	87.33 hi	88.95 f	87.36 D	89.98 fgh	90.05 fgh	90.38 ef	90.14 D
4000	85.33 l	87.25 i	88.14 g	86.91 E	89.51 gh	89.79 fgh	89.88 fgh	89.72 E
5000	84.63 m	87.09 i	87.67 h	86.46 F	88.68 i	88.74 i	89.49 h	88.97 F
Mean	87.31 C	88.96 B	89.68 A	-	90.30 C	90.78 B	91.31 A	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level

TABLE 6. Effect of irrigation water salinity, potassium humate and their interaction on cladodes osmotic pressure and hard cladodes character of prickly pear plants during 2020 and 2021 seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Cladodes osmotic pressure (bar)							
Control	0.252 fg*	0.239 gh	0.212 i	0.234 E	0.237 l	0.264 j	0.245 k	0.249 F
1000	0.298 e	0.232 ghi	0.216 hi	0.249 E	0.15 e	0.271 i	0.265 j	0.284 E
2000	0.314 e	0.249 fg	0.242 fg	0.269 D	0.317 e	0.283 h	0.276 i	0.292 D
3000	0.346 cd	0.306 e	0.265 f	0.305 C	0.324 d	0.295 g	0.306 f	0.308 C
4000	0.355 bc	0.343 cd	0.321 de	0.340 B	0.345 b	0.328 cd	0.325 d	0.333 B
5000	0.394 a	0.374 ab	0.367 bc	0.378 A	0.354 a	0.345 b	0.332 c	0.344 A
Mean	0.327 A	0.290 B	0.271 C	-	0.316 A	0.297 B	0.292 C	-
	Hard cladodes character (%)							
Control	1.753 i	1.610 j	1.500 k	1.621 F	1.860 jk	1.350 m	1.236 n	1.482 F
1000	2.260 e	2.167 f	1.956 h	2.128 E	1.887 ij	1.830 k	1.773 l	1.830 E
2000	2.347 d	2.267 e	1.967 h	2.193 D	1.976 h	1.926 i	1.866 jk	1.923 D
3000	2.393 c	2.240 e	2.060 g	2.231 C	2.460 cd	2.237 g	2.316 f	2.337 C
4000	2.413 c	2.347 d	2.250 e	2.337 B	2.500 c	2.416 de	2.373 e	2.430 B
5000	2.487 a	2.430 bc	2.466 ab	2.461 A	2.746 a	2.636 b	2.606 b	2.663 A
Mean	2.275 A	2.176 B	2.033 C	-	2.238 A	2.066 B	2.028 C	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

TABLE 7. Effect of irrigation water salinity, potassium humate and their interaction on chlorophyll A, chlorophyll B and total chlorophyll of prickly pear plants during 2020 and 2021 seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Chlorophyll A (mg/g fresh weight).							
Control	2.010 c*	2.053 b	2.110 a	2.058 A	1.953 bc	2.083 ab	2.200 a	2.078 A
1000	1.600 hi	1.720 e	1.873 d	1.731 B	1.720 def	1.810 cde	1.903 bcd	1.811 B
2000	1.513 k	1.670 g	1.686 fg	1.623 C	1.476 gh	1.710 def	1.800 cde	1.662 C
3000	1.453 m	1.613 h	1.700 f	1.589 D	1.426 ghi	1.733 c-f	1.756 c-f	1.638 CD
4000	1.477 l	1.566 j	1.616 h	1.553 E	1.356 hi	1.566 fgh	1.643 efg	1.522 DE
5000	1.093 n	1.550 j	1.590 i	1.411 F	1.206 i	1.536 fgh	1.610 efg	1.451 E
Mean	1.524 C	1.695B	1.762 A	-	1.523 B	1.740 A	1.818 A	-
	Chlorophyll B (mg/g fresh weight).							
Control	2.780 e	4.240 b	5.146 a	4.055 A	2.526 bc	2.386 cd	3.130 a	2.681 A
1000	2.843 d	2.546 k	2.746 f	2.740 B	2.050 fgh	2.193 d-g	2.683 b	2.308 B
2000	2.683 h	2.626 j	2.910 c	2.712 C	1.973 gh	2.233 def	2.540 bc	2.248 BC
3000	2.473 m	2.513 l	2.726 g	2.571 D	1.876 h	2.133 efg	2.356 cde	2.186 BC
4000	1.583 q	2.443 n	2.650 i	2.236 E	1.826 hi	2.230 def	2.503 bc	2.122 C
5000	1.733 p	2.346 o	2.630 j	2.225 F	1.610 i	2.346 cde	2.393 cd	2.116 C
Mean	2.349 C	2.786 B	3.135 A	-	1.977 C	2.253 B	2.601 A	-
	Total chlorophyll (mg/g fresh weight)							
control	4.793 d	6.246 b	7.200 a	6.080 A	4.480 bc	4.473 bc	5.333 a	4.762 A
1000	4.440 f	4.270 h	4.846 c	4.518 B	3.773 gh	4.006 d-g	4.583 b	4.121 B
2000	4.196 i	4.296 g	4.600 e	4.364 C	3.450 hi	3.940 efg	4.340 bcd	3.910 C
3000	3.926 l	4.126 j	4.423 f	4.158 D	3.300 i	3.863 efg	4.116 def	3.760 CD
4000	3.063 n	4.010 k	4.266 h	3.780 E	3.183 i	3.800 fg	4.146 cde	3.710 D
5000	2.823 o	3.893 m	4.220 i	3.645 F	2.813 j	3.883 efg	4.006 d-g	3.567 D
Mean	3.873 C	4.473 B	4.926 A	_-	3.500 C	3.994 B	4.421 A	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

to other treatments, the control treatment (orchard irrigation water) with potassium humate at 100 g had the highest significant chlorophyll B levels during the two seasons of the study (5.146 and 3.130 mg/g fresh weight, respectively).

Total chlorophyll

Regarding salinity treatments, the data revealed that control treatments (orchard irrigation water) had the highest significant total chlorophyll (6.080 and 4.762 mg/g fresh weight, respectively) in both seasons. Regarding potassium humate treatments, it could be found that a 100g rate recorded the highest significant total chlorophyll in both seasons (4.926 and 4.421 mg/g fresh weight). The interaction between the two studied factors showed that the control (orchard irrigation water) with potassium humate at 100 recorded the highest significant total chlorophyll (7.200 and 5.333 mg/g fresh weight, respectively) in both seasons.

Table 8 shows the effect of irrigation water salinity, potassium humate, and their interaction on the carotenoids and cladodes total carbohydrates contents of prickly pear plants during the 2020 and 2021 seasons.

Carotenoids

Regarding salinity treatments, the data revealed that the control treatment (orchard irrigation water) gave the highest significant carotenoids (2.023 and 1.475 mg/g fresh weight) in both seasons. In terms of potassium humate treatments, 50g and 100g rates yielded the highest significant carotenoids in the first season, while 100g yielded the highest significant carotenoids in the second. The interaction of the two factors under investigation revealed that the control treatment with potassium humate at 50 and 100 g was comparable and produced the highest significant levels of carotenoids in the first season, while the control treatment at 100 g produced the highest significant levels of carotenoids in the second.

Cladodes total carbohydrates percentage

According to the findings of the salinity treatments, the control treatment (orchard irrigation water) had the greatest significant cladodes total carbohydrates percentages (36.213 and 36.743%) in both seasons. Regarding potassium humate treatments, it was noticed that a 100g rate produced the highest significant cladodes total carbohydrate percentages (33.918 and 32.238%) in both seasons. The results of

TABLE 8. Effect of irrigation water salinity, potassium humate and their interaction on carotenoids and cladodes total carbohydrates contents of prickly pear plants during 2020 and 2021 seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Carotenoids (mg/g fresh weight).							
Control	1.340 bcd	2.330 a	2.400 a	2.023 A	1.280 c	1.393 b	1.753 a	1.475 A
1000	1.333 bcd	1.353 bcd	1.396 b	1.361 B	0.933 ij	1.253 c	1.413 b	1.200 B
2000	1.326 bcd	1.343 bcd	1.380 bc	1.350 B	0.960 hi	1.213 d	1.213 d	1.128 C
3000	1.153 cd	1.226 bcd	1.270 bcd	1.216 C	0.956 hij	1.176 ef	1.193 de	1.108 D
4000	0.740 e	1.170 bcd	1.253 bcd	1.054 D	0.930 j	1.106 g	1.150 f	1.062 E
5000	0.736 e	1.143 d	1.240 bcd	1.040 E	0.790 k	0.983 h	1.086 g	0.953 F
Mean	1.105 B	1.427 A	1.490 A	-	0.975 C	1.187 B	1.301 A	-
Cladodes total carbohydrates content (%)								
Control	34.767 e	35.123 c	38.747 a	36.212 A	33.947 c	36.820 b	39.463 a	36.743 A
1000	31.343 k	35.140 c	35.583 b	34.022 B	31.233 h	33.130 f	33.567 d	32.643 B
2000	29.627 l	33.863 f	34.983 d	32.824 C	30.517 i	32.440 g	33.307 e	32.088 C
3000	27.533 o	32.793	33.597 g	31.308 D	28.297 o	29.543 k	29.963 j	29.268 D
4000	26.913 p	31.643 j	31.750 i	30.102 E	25.477 q	28.453 m	28.767 l	27.566 E
5000	26.110 q	27.910 n	28.847 m	27.622 F	22.963 r	27.877 p	28.363 n	26.401 F
Mean	29.382 C	32.746 B	33.918 A	-	28.739 C	31.377 B	32.238 A	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

the interaction between the two factors under investigation revealed that the control treatment (orchard irrigation water) containing potassium humate at a concentration of 100 g produced the highest significant percentages of Cladodes total carbohydrates (38.747 and 39.463%), respectively, in both seasons.

The data in Table 9 demonstrated the effect of irrigation water salinity, potassium humate, and their interaction on cladodes total sugar percentage and cladodes proline content in prickly pear plants during the 2020 and 2021 seasons.

Cladodes total sugars percentage

In the case of salinity levels, it was observed that the control (orchard irrigation water) produced the lowest percentages of cladodes total sugars (1.519 and 1.331%) in both seasons. According to the findings on potassium humate treatments, the 100g rate recorded the lowest significant cladodes total sugar percentages (1.725 and 1.410%) in both seasons. The interaction between the two parameters under investigation revealed that the control treatment using 100 g of potassium humate recorded the lowest significant values of cladodes total sugars (1.221 and 1.291%) in both seasons.

Cladodes proline content

Concerning salinity levels, the results showed that the control (orchard irrigation water) recorded the lowest significant cladodes proline contents (0.129 and 0.128 mg/g fresh weight). Regarding potassium humate treatments, the data indicated that the 100g rate recorded the lowest significant cladodes proline contents (0.251 and 0.246 mg/g fresh weight) in both seasons. The interaction between the two studied factors revealed that control treatment

TABLE 9. Effect of irrigation water salinity, potassium humate and their interaction on cladodes total sugars content and cladodes proline content of prickly pear plants during 2020 and 2021seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Cladodes total sugars percentage (%)							
Control	1.744 l	1.593 m	1.221 n	1.519 F	1.359 i	1.345 i	1.291 j	1.331 E
1000	1.991 de	1.913 h	1.771 k	1.892 E	1.527 cde	1.364 hi	1.363 i	1.418 D
2000	2.005 d	1.925 gh	1.810 j	1.913 D	1.534 cd	1.483 f	1.399 gh	1.472 C
3000	2.097 c	1.938 g	1.824 j	1.953 C	1.547 c	1.485 f	1.419 g	1.483 C
4000	2.125 b	1.963 f	1.856 i	1.981 B	1.612 b	1.500 def	1.493 ef	1.535 B
5000	2.215 a	1.977 ef	1.868 i	2.020 A	1.945 a	1.505 def	1.495 ef	1.648 A
Mean	2.029A	1.885 B	1.725 C	-	1.587 A	1.447 B	1.410 C	-
Cladodes proline content (mg/100g fresh weight)								
Control	0.144 l	0.131 o	0.113 q	0.129 F	0.114 q	0.145 n	0.125 p	0.128 F
1000	0.192 k	0.131 o	0.127 p	0.151 E	0.111 r	0.157 m	0.143 o	0.137 E
2000	0.232 j	0.140 m	0.136 n	0.169 D	0.267 h	0.184 k	0.158 l	0.203 D
3000	0.438 f	0.246 h	0.241 i	0.308 C	0.347 f	0.255 i	0.239 j	0.280 C
4000	0.646 b	0.460 e	0.354 g	0.487 B	0.571 b	0.378 e	0.326 g	0.425 B
5000	0.763 a	0.571 c	0.531 d	0.621 A	0.649 a	0.548 c	0.489 d	0.562 A
Mean	0.403 A	0.280 B	0.251 C	-	0.343 A	0.278 B	0.246 C	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

TABLE 10. Effect of irrigation water salinity, potassium humate and their interaction on nitrogen, phosphorus and potassium contents of prickly pear plants during 2020 and 2021seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Nitrogen (%)							
Control	0.776 c*	0.810 b	0.890 a	0.825 A	0.820 c	0.876 b	0.920 a	0.872 A
1000	0.710 e	0.760 d	0.816 b	0.762 B	0.763 d	0.766 d	0.803 c	0.777 B
2000	0.656 i	0.680 g	0.716 e	0.684 C	0.663 fg	0.723 e	0.773 d	0.720 C
3000	0.616 j	0.666 h	0.693 f	0.658 D	0.640 gh	0.676 f	0.710 e	0.675 D
4000	0.543 m	0.546 m	0.576 k	0.555E	0.586 i	0.626 h	0.653 fg	0.622 E
5000	0.463 o	0.506 n	0.566 l	0.512 F	0.510 j	0.533 j	0.596 i	0.546 F
Mean	0.627 C	0.661 B	0.710 A	-	0.663 C	0.700 B	0.742 A	-
	Phosphorus (%)							
Control	0.290 c	0.336 b	0.352 a	0.326 A	0.262 c	0.287 b	0.322a	0.291 A
1000	0.272 g	0.288 d	0.290 c	0.283 B	0.251 f	0.255 e	0.258 d	0.254 B
2000	0.259 h	0.273 f	0.278 e	0.270 C	0.237 i	0.242 h	0.247 g	0.242 C
3000	0.238 k	0.245 j	0.251 i	0.244 D	0.197 l	0.231 k	0.224 j	0.211 D
4000	0.176 n	0.195 m	0.219 l	0.196 E	0.174 o	0.183 n	0.191 m	0.182 E
5000	0.124 q	0.132 p	0.148 o	0.134 F	0.155 q	0.156 q	0.159 p	0.157 F
Mean	0.226 C	0.245 B	0.256 A	-	0.212 C	0.223 B	0.233 A	-
	Potassium (%)							
Control	1.991 c	2.434 b	2.719 a	2.381 A	1.783 c	1.978 b	2.362 a	2.041 A
1000	1.706 f	1.784 e	1.816 d	1.769 B	1.661 f	1.681 e	1.753 d	1.698 B
2000	1.533 i	1.557 h	1.595 g	1.562 C	1.570 i	1.588 h	1.611 g	1.590 C
3000	1.485 l	1.516 k	1.531 j	1.510 D	1.504 l	1.527 k	1.536 j	1.522 D
4000	1.226 p	1.344 n	1.370 m	1.313 E	1.323 o	1.374 n	1.390 m	1.362 E
5000	0.962 r	1.112 q	1.240 q	1.105 F	1.158 r	1.179 q	1.184 p	1.173 F
Mean	1.484 C	1.642 B	1.712 A	-	1.500 C	1.554 B	1.639 A	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

The optimum level of Nitrogen in cactus pear cladode = 0.79 %, Phosphorus = 0.26 % and Potassium = 3.75 % (Salama, et al., 2021)

with potassium humate at 100 g gave the lowest significant cladodes proline contents (0.113 and 0.125 mg/g fresh weight) in both seasons, respectively.

Data in Table 10 showed the effect of the sae linity of irrigation water, potassium humate and their interaction on nitrogen (%), phosphorus (%) and potassium (%) of prickly pear plants during the 2020 and 2021 seasons.

Nitrogen

According to the results about salinity treatments, the control treatment (orchard irrigation water) showed the greatest significant nitrogen concentrations (0.825 and 0.872%) in both seasons. Regarding potassium humate treatments, it was noted that 100 g rate recorded the highest significant nitrogen levels (0.710 and 0.742%) in both seasons. The interaction between the two components under investigation demonstrated that the control treatment using 100 g of potassium humate produced the highest levels of nitrogen (0.890 and 0.920%) in the two seasons, respectively.

Phosphorus

In case of salinity treatments, the data showed that the control treatment (orchard irrigation water) had the highest significant phosphorus percentages (0.326 and 0.291%) in both seasons compared to the other concentrations. Concerning potassium humate treatments, it could be found that 100 g of potassium humate recorded the highest significant phosphorus contents (0.256 and 0.233%) in both seasons. The interaction between the two studied factors revealed that potassium humate at 100 g with the control treatment showed the highest significant values of phosphorus (0.352 and 0.322 %) in both seasons, respectively.

Potassium

Regarding treatments for salinity levels, the data revealed that the control treatment (orchard irrigation water) indicated the greatest significant potassium percentages (2.381 and 2.04%1) in both seasons. In the case of potassium humate treatments, it was seen that 100 g rate recorded the greatest significant potassium contents (1.712 and 1.639%) in both seasons. The interaction between the two study variables revealed that the control treatment, which contained 100 g of potassium humate, produced the highest significant potassium values (2.719 and 2.362 %) in both seasons, respectively.

Table 11 shows the effect of irrigation water salinity, potassium humate, and their interaction on calcium and magnesium percentages of prickly pear plants during the 2020 and 2021 seasons.

Calcium

Concerning salinity levels, the data showed that the control (orchard irrigation water) recorded the lowest significant calcium (5.802 and 5.511%) in both seasons, respectively. Regarding potassium humate treatments, it could be found that 100 g of potassium humate gave the lowest significant calcium percentages (6.849 and 6.263%) in both seasons. The interaction between the two study factors indicated that the control treatment with potassium humate at 50 g had the lowest significant values of calcium (5.193 and 5.290%) in both seasons, respectively.

Magnesium

With regard to salinity treatments, it could be seen that the control treatment (orchard irrigation water) had the greatest significant magnesium concentrations (0.893 and 0.951%) in both seasons. With respect to potassium humate treatments, the data revealed that 100 g of rate recorded the greatest significant magnesium percentages (0.729 and 0.821, respectively) during the two study seasons. Regarding the interaction of two study variables, magnesium levels in the control treatment with 100 g of potassium humate revealed the highest significant values (0.971 and 0.984%) in both seasons, respectively.

TABLE 11. Effect of irrigation water salinity, potassium humate and their interaction on calcium and magnesium percentages of prickly pear plants during 2020 and 2021seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Calcium (%)							
Control	6.736 l	5.193 p	5.476 o	5.802 F	5.836 m	5.290 o	5.406 n	5.511 F
1000	6.873 k	6.566 m	6.336 n	6.592 E	6.123 j	6.030 k	5.856 l	6.003 E
2000	7.263 i	6.926 j	6.876 k	7.022 D	6.563 g	6.480 h	6.423 i	6.488 D
3000	7.436 f	7.360 h	7.266 i	7.354 C	6.780 d	6.566 g	6.433 i	6.593 C
4000	7.663 d	7.456 e	7.416 g	7.512 B	6.843 b	6.753 e	6.700 f	6.765 B
5000	7.723 c	7.800 b	7.936 a	7.820 A	6.976 a	6.803 c	6.760 e	6.846 A
Mean	7.318 A	6.883 B	6.849 C	-	6.520 A	6.320 B	6.263 C	-
	Magnesium (%)							
Control	0.812 c	0.897 b	0.971 a	0.893 A	0.914 c	0.956 b	0.984 a	0.951 A
1000	0.784 f	0.787 e	0.790 d	0.787 B	0.879 d	0.850 ef	0.854 e	0.861 B
2000	0.697 i	0.711 h	0.716 g	0.708 C	0.831 f	0.841 ef	0.849 ef	0.840 C
3000	0.616 n	0.646 k	0.653 j	0.637 D	0.764 h	0.797 g	0.802 g	0.787 D
4000	0.592 p	0.618 m	0.626 l	0.612 E	0.728 i	0.737 i	0.746 hi	0.737 E
5000	0.573 q	0.609 o	0.618 m	0.599 F	0.681 j	0.692 j	0.695 j	0.689 F
Mean	0.678 C	0.711 B	0.729 A	-	0.799 B	0.812 A	0.821 A	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

The optimum level of Calcium in cactus pear cladode = 6.08 %, and Magnesium = 0.93% (Salama et al., 2021)

TABLE 12. Effect of irrigation water salinity, potassium humate and their interaction on iron, manganese and zinc contents of prickly pear plants during 2020 and 2021 seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Iron (ppm)							
Control	50.633 c	53.193 b	53.837 a	52.554 A	48.607 c	48.973 b	49.273 a	48.951 A
1000	49.283 j	50.267 e	50.480 d	50.010 B	46.927 f	47.207 e	47.343 d	47.159 B
2000	48.670 n	49.563 g	50.237 f	49.490 C	46.510h	46.760 g	46.807 g	46.692 C
3000	48.523 o	49.307 i	49.410 h	49.080 D	45.830 j	46.427 i	46.570 h	46.276 D
4000	46.910 p	49.130 l	49.260 k	48.433 E	44.760 n	45.690 k	45.773 j	45.408 E
5000	45.930 q	48.673 n	48.860 m	47.821 F	44.523 o	44.963 m	45.503 l	44.997 F
Mean	48.325 C	50.022 B	50.347 A	-	46.193 C	46.670 B	46.878 A	-
	Manganese (ppm)							
Control	447.39 e	485.82 b	506.90 a	480.04 A	512.97 c	548.01 b	572.82 a	544.60 A
1000	426.92 h	458.57 d	426.57 c	449.35 B	484.19 f	494.70 e	496.81 d	491.90 B
2000	395.30 j	436.47 g	443.05 f	424094 C	462.51 i	462.64 h	473.51 g	464.16 C
3000	371.52 n	426.19 h	413.58 i	403.76 D	428.40 m	436.50 k	445.16 j	436.69 D
4000	357.49 o	386.42 k	395.37 j	379.76 E	418.41 n	427.53 m	432.17 l	426.03 E
5000	336.82 p	376.01 m	381.74 l	364.86 F	397.48 q	403.30 p	412.35 o	404.38 F
Mean	389.24 C	428.25 B	433.87 A	-	449.66 C	462.08 B	472.14 A	-
	Zinc (ppm)							
Control	17.227 c	18.760 b	18.970 a	18.319 A	18.433 e	18.733 c	18.973 a	18.713 A
1000	16.580 f	16.793 e	16.903 d	16.759 B	18.163 g	18.653 d	18.833 b	18.550 B
2000	15.863i	16.203 h	16.357 g	16.141 C	17.827 j	18.267 f	18.430 e	18.174 C
3000	15.390 m	15.743 j	15.860 i	15.664 D	17.527 l	17.863 i	18.087 h	17.826 D
4000	15.163 o	15.407 l	15.590 k	15.387 E	17.183 p	17.503 m	17.643 k	17.443 E
5000	14.690 q	15.113 p	15.237 n	15.013 F	16.807 q	17.283 o	17.357 n	17.149 F
Mean	15.819 C	16.337 B	16.486 A	-	17.657 C	18.051 B	18.221 A	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

The optimum level of Iron in cactus pear cladode = 47.90ppm, Manganese = 810.45 ppm, Zinc = 20.35 ppm. (Salama et al., 2021)

Data in Table (12) showed the effect of the salinity of irrigation water, potassium humate and their interaction on the iron, manganese and zinc contents of prickly pear plants during the 2020 and 2021 seasons.

Iron

Concerning salinity treatments, the data showed that the control treatment using orchard irrigation water recorded the highest significant contents of iron (52.554 and 48.951 ppm) in both seasons of study. Regarding potassium humate treatments, it could be noticed that 100 g of potassium humate treatment recorded the highest iron contents (50.347 and 46.878 ppm) in both seasons of the study. The interaction between potassium humate rates and salinity levels revealed that control treatment combined with 100 g of potassium humate gave the highest significant values of iron (53.837 and 49.273 ppm) in both seasons.

Manganese

Regarding salinity treatments, the data showed that the control treatment utilizing orchard irrigation water recorded the highest significant values of manganese (480.04 and 544.60 ppm) in both seasons of the study. Regarding potassium humate treatments, it was seen that 100 g of this substance produced the highest manganese concentrations (433.87 and 472.14 ppm) in both seasons. The combination of the control treatment and 100 g of potassium humate produced the highest significant manganese readings (506.90 ppm and 572.82 ppm, respectively) in both seasons.

Zinc

Concerning salinity treatments, the results revealed that the control treatment (orchard irrigation water) recorded the highest significance contents of zinc (18.319 and 18.713 ppm) in both study seasons. Regarding potassium humate treatments, the data showed that 100 g of potassium humate treatment recorded the highest zinc values (16.486 and 18.221 ppm) in both seasons. The interaction between potassium humate rates and salinity levels indicated that control treatment

With 100 g of potassium humate showed the highest significant values of zinc (18.970 and 18.973 ppm) in both seasons.

Table 13 shows the effect of irrigation water salinity, potassium humate, and their interaction on sodium and chloride percentages of prickly pear plants during the 2020 and 2021 seasons**.**

Sodium

With regard to salinity levels, the data revealed that the control treatment (orchard irrigation water) had the lowest significant sodium values (0.159 & 0.208%). Regarding potassium humate treatments, the data showed that 100 g of potassium humate produced the lowest significant sodium values (0.274 and 0.331%) in both seasons. The interaction between two parameters mentioned that the control treatment, which contained 100g of potassium humate, had the lowest significant sodium values (0.071 and 0.107%) in both seasons, respectively.

Chloride

The results for salinity levels showed that the control treatment (orchard irrigation water) had the lowest significant values of chloride (0.042 and 0.051%) in comparison to other levels. According to the results on potassium humate treatments, the 100 g rate recorded the lowest significant levels of chloride (0.053 and 0.062%) in both seasons. The interaction between the two parameters under

TABLE 13. Effect of irrigation water salinity, potassium humate and their interaction on sodium and chloride percentages of prickly pear plants during 2020 and 2021 seasons.

Salinity levels of irrigation water (ppm)	2020				2021			
	Potassium humate							
	0	50	100	Mean	0	50	100	Mean
	Sodium (%)							
control	0.226 n*	0.181 p	0.071 q	0.159 F	0.303 o	0.213 p	0.107 q	0.208 F
1000	0.284 l	0.243 m	0.217 o	0.248 E	0.384 j	0.328 l	0.306 n	0.339 E
2000	0.372 f	0.351 i	0.321 j	0.350 D	0.418 g	0.370 k	0.326 m	0.371 D
3000	0.395 d	0.367 g	0.361 h	0.374 C	0.447 d	0.426 f	0.394 i	0.422 C
4000	0.428 c	0.385 e	0.360 h	0.391 B	0.481 b	0.436 e	0.415 h	0.444 B
5000	0.463 a	0.437 b	0.308 k	0.403 A	0.505 a	0.459 c	0.436 e	0.467 A
Mean	0.361 A	0.327 B	0.274 C	-	0.423 A	0.372 B	0.331 C	-
	Chloride (%)							
control	0.045 j	0.042 k	0.037 l	0.042 F	0.054 hi	0.052 i	0.046 j	0.051 F
1000	0.53 h	0.048 i	0.044 j	0.0487 E	0.063 g	0.055 h	0.053 hi	0.057 E
2000	0.058 f	0.054 g	0.053	0.055 D	0.067 f	0.064 g	0.062 g	0.064 D
3000	0.066 d	0.059 f	0.054 g	0.060 C	0.076 d	0.068 ef	0.063 g	0.069 C
4000	0.077 b	0.066 d	0.061 e	0.068 B	0.086 b	0.075 d	0.070 e	0.077 B
5000	0.086 a	0.073 c	0.067 d	0.075 A	0.095 a	0.082 c	0.076 d	0.084 A
Mean	0.064 A	0.057 B	0.053 C	-	0.073 A	0.066 B	0.062 C	-

*Means having the same letter (s) in each row, column or interaction are insignificantly different at the 5% level.

investigation showed that the control treatment, which consisted of 100 g of potassium humate, produced the lowest significant values of chloride (0.037 & 0.046%) in both seasons.

These results were in a harmony with those found by Amri et al. (2011), who found that saline water in irrigation reduced the length and leaf area of pomegranate. Moreover, humic acid treatments (foliar and soil applications) increased the growth parameters (shoot length, number of leaves / shoot and leaf area) of the "Canino" apricot (Fathy et al., 2010; Eissa, 2003). Singh (2003) found that salinity buildup adversely affects plant growth and development through osmotic effects and the ionic supply of nutrients. Furthermore, Franco-Salazar and Veliz (2007) worked on *Opuntia ficus-indica* Mill. in hydroponic culture with different concentrations of sodium chloride (NaCl) and observed that salinity affected the plant growth, reducing both the shoots and roots. Hayward and Wadleigh (1949) reported that the tolerance of the plant to salt depends on its ability to regulate the intake of ions to affect the increase in osmotic pressure without excessive accumulation of such absorbed ions. Slatyer (1961) and Bernstein (1975) found that when plants are exposed to osmotic substances, a sufficient amount of the substrate is absorbed to increase the internal osmotic pressure by an amount equal to the increase in the substrate. Stevens and Harvey (1990) proved that increasing salinity caused a decline in the leaf water potential of grapevines. El-Hefnawi (1986) discovered on guava seedlings and Nomir (1994) discovered on kaki plants that increasing salt concentration in irrigation water decreased leaf succulence grade significantly. Madlen (2006) revealed that all three investigated saline solutions (2000, 4000 and 6000 ppm) resulted in an obvious increase in the values of hard leaf character (H.L.C.) of three pomegranate cultivars. Use of humic substances for removing negative effects of elements in toxic quantities and effects on plant growth of wheat (*Triticum durum cv. Salihli*) under conditions of water shortage and salt level (Asik et al., 2009) The humic substance is essential in soil organic matter; in addition, the natural stability of these substances affects carbon and nitrogen cycles and carbon sequestration. Furthermore, it can reduce the negative effect of salt on plant gross and nutrient uptake in cucumber (Cucmis sativus L.) Demir et al. (1999) and Casierra-Pisada et al. (2009).

Conclusion

Finally, irrigation with water less than 1,000 ppm salinity and 100 g potassium humate could be recommended as the most appropriate treatment for reducing the detrimental effects of salt in "El-Shamia" prickly pears. This treatment improved vegetative growth (plant height, plant canopy volume, number of cladodes per plant and cladode area), cladodes physiological characteristics (cladodes relative turgidity, cladodes succulence grade and cladodes water potential), photosynthetic pigment (chlorophylls a and b, carotenoids and cladodes total carbohydrates content), as well as cladodes mineral content of N, P, Mg, Fe, Mn and Zn in cladodes. On the other hand, this treatment reduced cladodes osmotic pressure, hard cladodes character, cladodes total sugars content, cladodes proline content as well as contents of Ca, Na and Cl. This treatment was proven to be the most efficient in enhancing growth and mineral content.

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Conflicts of interest

Authors have declared that no conflicts of interest.

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تأثير تركيزات مختلفة من ملوحة ماء الري وهيومات البوتاسيوم على النمو الخضرى والمحتوى المعدنى لنباتات التين الشوكى

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أجريت هذه الدراسة خلال موسمى٢٠٢٠ و ٢٠٢١ على نباتات التين الشوكى صنف الشامية المنزرع بقرى الخريجين طريق مصر – إسكندرية الصحراوى الكيلو ١٠٧ من القاهرة.

لدراسة تأثير هيومات البوتاسيوم بتركيزات صفر و٥٠و١٠٠ جرام/للشجرة/سنة ومستويات ملوحة ماء الرى (الكنترول و ١٠٠٠و٢٠٠٠و٣٠٠٠و٤٠٠٠و٥٠٠٠ جزء فى المليون) والتفاعل بينهما على النمو الخضرى والمحتوى المعدنى لألواح التين الشوكى صنف الشامية.

وأوضحت الدراسة إلى أن التركيز ١٠٠جرام/للشجرة/سنة من هيومات البوتاسيوم مع معاملة الكنترول (نظام رى المزرعة) أدى الى تحسين طول النبات وحجم النبات وعدد الألواح على النبات و مساحة اللوح والتصلب النسبى للألواح وغضاضة الألواح وقوة شد المياة فى الألواح وكلوروفيل أ و ب و الكلورفيل الكلى والكاروتينات والسكريات الكلية وبعض العناصر مثل النيتروجين والفوسفور والبوتاسيوم والمغنيسيوم والحديد والمنجنيز والزنك.

و قللت المعاملة الضغط الإسموزى فى الألواح وصلابة الألواح والبرولين والكالسيوم والصوديوم والكلور.

وقد أثبتت أن هذه المعاملة هي الأكثر كفاءة فى تحسين النمو الخضرى والمحتوى المعدنى للألواح فى التين الشوكى صنف الشامية.