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Effect of Salt in Irrigation Water on Some Physical and Chemical Properties of Lettuce Plant and Soil

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Knowledge of salt tolerance in vegetable plants is necessary to increase productivity and profitability of crop irrigated with saline waters. This research was carried out in Celal Bayar University, Alasehir vocational school glasshouse which is in Manisa, Alasehir located in the west part of Agean region. The purpose of the experiment is to determine salinity effects on some chemical and physical properties of lettuce plant and soil and some vegetative growth parameter of plant which is irrigated with water having different concentrations of salt (NaCl). The experiment was established in a randomized block design with four replications. Salinity levels are in five levels as 0-4-8-12-16 dSm^{-1} EC. Depending on increasing salt concentration in irrigation water, from the soil saturation extract values, especially Na^+ from cations and Cl^- from anions which are dominant compared to others (K^+, Mg^{2+}, SO_4^{2-}, HCO_3^-) and also increase of total soluble salt values have caused some negativeness in plant production. Different EC levels in irrigation water showed an important effect on K^+ and Na^+ content of soil and only Na^+ content of plant. Highest values were generally obtained at 4 dSm^{-1} EC for lettuce plant vegetative growing parameters such as dry and fresh head weight, head length and leaf number per plant. However, the increase in salt content of water (> 4 dSm^{-1} EC) affected negatively these vegetative growing parameters.

Key Words: Lettuce, *Lactuca sativa* L., Vegetative growth parameters, Salty irrigation water.

INTRODUCTION

Soil salinity and alkalinity is a problem in whole world especially in arid and semi arid regions which is an important bottleneck that increases global warming. A lot of crop plants are not grew properly if salinity is > 4 mmhos cm^{-1} in soil and > 2 mhos cm^{-1} in water[1].

When the salt concentration of the soil solution increases and the water potential decreases, the pressure potential of plant cell declines and cells ultimately cease to divide and elongate. Under water stress conditions, stomata close usually. This

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results in the reduction of photosynthesis. Protein breakdown is changed and plants ultimately show poor or negative growth and lose biomass[2,3]. NaCl salinity affects water and ion transport process in plants and these may change the nutritional status, ion balance and pH as well as may physiological, biochemical processes[1].

Besides the inappropriate use of cultural treatments, use of irrigation water unconsci-ously causes soil salinity. As a result, yield and quality loss occur in plant production and resistance to diseases are reduced[2,4]. In respect to salinity, lettuce in general is considered a moderately sensitive crop[5], although different authors report different levels of salt tolerance, probably depending on genotype (variety and cultivar) plant age and experimental conditions[4].

Lettuce (*Lactuca sativa* L.) is successfully grown in the open field and green-houses of almost all the regions with arid and semi-arid conditions of Turkey and its economic importance has gradually increased. Turkey has nearly 30,000 ha. greenhouse area, of which 96 % is used for vegetable growing for example pepper, eggplant, tomato and lettuce. In the areas that intensive vegetable production takes place, salinity is an important stress factor which must be considered[6].

This research was carried out in Manisa Celal Bayar University, Alasehir vocation school glasshouse, Turkey. The purpose of the experiment is to determine salinity effects on yield and some quality properties of lettuce (*Lactuca sativa* L.) irrigated with water which contains different concentrations of salt (NaCl). Second object is to determine salinity effects on plant vegetative growing parameters. In this experiment, effects of salty irrigation water on soil's physical and chemical properties were also examined.

EXPERIMENTAL

This research was conducted in Celal Bayar University Alasehir vocational school glasshouse which is in Manisa, Alasehir located in the west part of Agean region. Experimental material is Yedikule lettuce (*Lactuca sativa* L. cv.) variety which is commonly grown in the region. The experiment was arranged in 20 plastic cylinder flowerpots with the height of 225 mm, upper diameter by 290 mm and lower diameter by 220 mm (with 8.5 L volume). Soil as an examination material was taken from Alasehir city hall glasshouse and was weighed in the flowerpots of 5 kg each. The soil's physical and chemical properties are given in Table-1.

TABLE-1
SOME PHYSICAL AND CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOIL

pH	Total soluble salt (%)	$CaCO_3$ (%)	Organic matter (%)	Texture	Total N (%)
7.86	0.140	4.10	4.94	Sandy-Loam	0.165
Available (mg kg^{-1})					
P	K	Ca	Mg	Na	Fe	Zn	Mn	Cu
14.06	540	2900	858	125	6.51	0.75	1.30	3.63

Lettuce seedlings which are taken from Alasehir city hall glasshouse were put into flowerpots with two plants in each and were transported until the last week of November. The experiment was established in a randomized block design with four replications. The lettuce seedlings were irrigated 25 days after planting by the salty irrigation water which contains different concentrations of NaCl (EC = 0-4-8-12 and 16 dSm^{-1}). They were irrigated during the vegetation period. Tap water was used as control (EC_0 = 0.800 dSm^{-1}). After adding NaCl to tab water and obtaining different concentrations of salty water, salt concentrations were measured and determined in electrical conductivity meter (in 25 °C Ec_w)[5].

Chemical and physical analysis of tab water used in experiment are given in Table-2.

TABLE-2
PHYSICAL AND CHEMICAL PROPERTIES OF TAP WATER (CONTROL) USED IN EXPERIMENT

pH	EC dSm^{-1}	Cations (me L^{-1})			Total cations	Anions (me L^{-1})			Total anions	SAR
		Na^+	K^+	$Ca^{2+} + Mg^{2+}$		Cl^-	HCO_3^-	SO_4^{2-}		
7.19	0.800	0.79	0.19	7.40	8.38	0.50	7.55	0.36	8.41	0.41

Amount of water which would be given to flowerpots were weighed to 80 % of soil's water holding capacity. Harvest was made after the second week of February. The average of the two plants were taken and in each lettuce plant head length, leaf number, fresh and dry head weight, root diameter, root length, fresh and dry root weight such as vegetative growth parameters were measured.

Some salinity parameters (some extract values) (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-) of soil on which lettuce is grown with different EC levels were analyzed[7]. In addition, some physical and chemical properties of soils in beginning and at the end of experiment were determined[8,9].

The total amount of nitrogen in the leaf samples was measured using the modified Kjeldahl method, phosphorus in wet digested samples with coloritmetry, potassium, sodium and calcium with flame photometry and magnesium, iron, zinc, manganese and copper using AAS (atomic absorbsion spectrometry)[9]. Data were analyzed using the SPSS statistical software package[10].

RESULTS AND DISCUSSION

Effect of different EC levels in irrigation water on some chemical and physical properties of soils: Irrigation water containing five different levels of salt (0, 4, 8, 12, 16 dSm^{-1} EC) were applied to "Yedikule" Lettuce (*Lactuca sativa* L.) which is grown in flowerpots, in glasshouse along with control during the vegetation period.

In Table-3, the effect on salinity and alkalinity parameters of soils of salty (some extract values) irrigation water which is applied on four different EC levels is given. Data's would show that cations which are dominant in soil's saturation

extract are $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and anions are $Cl^- > SO_4^{2-} > HCO_3^-$. Increase in salt level in water has significantly affected Na^+ and K^+ amounts in soil's saturation extraction. In saturation extract, high Na content was 16 dSm^{-1} in EC level (22.15 me L^{-1}) according to control. K on the other hand, was determined in 4 and 8 dSm^{-1} EC level (3.57 me L^{-1}). The same influence was also recorded for Cl^- which is an anion in soil's saturation extract. Again in 16 dSm^{-1} EC level, the highest Cl^- content was found (26.93 me L^{-1}). For SO_4^{2-} an important increase was established compared to control at 4 dSm^{-1} in EC level but later no change occurred. Both total anion and cation values raised up as EC levels increased and when EC reached to its highest limit (16 dSm^{-1}), they were also highest values (Table-3). The researches have stated that applying salt (NaCl) to irrigation water and different cultivation media causes Na, a cation and Cl, an anion to become dominant which lead to important problems on soil usage and plant production[5,11-16]. As parallel to increase in salt content in irrigation water, increase in Na, K, Ca, Mg (cations) and Cl (anion) have been found statically important (Table-3).

TABLE-3
EFFECT OF DIFFERENT EC LEVELS ON VALUES OF SATURATION EXTRACT OF SOILS

EC levels (dsm^{-1})	Saturation extract of soils (me L^{-1})				Saturation extract of soils (me L^{-1})			
	Na^+	K^+	$Ca^{2+} + Mg^{2+}$	Total cation	Cl^-	SO_4^{2-}	HCO_3^-	Total anion
0	3.29 e	2.99 b	8.14	14.42 e	8.76 e	3.52 b	2.38	14.66 e
4	8.52 d	3.57 a	8.58	20.67 d	14.02 d	4.03 a	2.44	20.49 d
8	13.79 c	3.57 a	8.39	25.75 c	18.70 c	4.10 a	2.57	25.38 c
12	18.89 b	3.07 b	8.43	30.39 b	23.49 b	3.93 a	2.61	30.02 b
16	22.15 a	3.05 b	8.56	33.75 a	26.93 a	4.00 a	2.51	33.44 a
$LSD_{0.05}$	1.583	0.161	ns	1.631	1.803	0.331	ns	1.832

ns: non significant.

When the effect of different EC levels on some physical effects of lettuce growing soils were examined (Table-4), it was determined that only total soluble salt amount was higher depending on the increase of salt levels in irrigation water. This relation which was also found statistically significant did not show same level of importance in other features of soil. At the end of the research, it was determined that the soils which were irrigated with water containing different concentrations of salt were found to be slightly alkaline reaction, poor in lime, just exceed salinity limit level and light texture (sandy loam, loamy sand) (Table-4). Soil being light texture is an important advantage in lettuce production because lettuce is a plant which is moderately sensitive to salt.

Irrigation water containing different EC levels causes changes in lettuce planted soil's primary and secondary elements (N, P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu). Different EC levels of irrigation water have a major effect on only K and Na contents in soil. According to control, K^+ reaches its highest limit (616 mg kg^{-1}) at 8 dSm^{-1} EC

TABLE-4
EFFECT OF DIFFERENT EC LEVELS ON SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOILS

EC levels (dsm^{-1})	pH	Total soluble salt (%)	$CaCO_3$ (%)	Sand (%)	Silt (%)	Clay (%)	Texture	Organic matter (%)
0	7.94	0.145 c	4.06	74.24	20.00	5.76	Sandy-Loam	4.92
4	7.95	0.203 b	4.05	76.91	17.33	5.76	Loamly-Sand	5.06
8	7.92	0.213 b	4.06	76.91	17.33	5.76	Loamly-Sand	5.06
12	7.90	0.227 ab	4.05	75.57	18.67	5.76	Loamly-Sand	5.24
16	7.91	0.242 a	4.04	76.24	18.00	5.76	Loamly-Sand	5.04
$LSD_{0.05}$	ns	0.025	ns	ns	ns	ns		ns

ns: non significant.

and Na^+ (552 mg kg^{-1}) at 16 dSm^{-1} EC. This increase of sodium content in soil was also proven with statistical relation (Table-5).

K and Na levels in lettuce growing soils are pointed out higher values compared to criterions of previous workers[17-19].

TABLE-5
EFFECT OF DIFFERENT EC LEVELS ON PRIMARY AND SECONDARY ELEMENT CONTENTS OF SOILS

EC levels (dsm^{-1})	N (%)	(mg kg^{-1})								
		P	K	Ca	Mg	Na	Fe	Zn	Cu	Mn
0	0.156	14.00	527 c	2864	846	123 c	5.85	0.71	3.60	1.24
4	0.170	14.25	611 a	2915	955	303 b	5.09	0.72	4.30	1.53
8	0.188	14.31	616 a	2880	959	429 ab	4.39	0.80	4.35	1.62
12	0.190	14.76	593 ab	2880	943	516 a	5.66	0.83	4.99	2.20
16	0.177	14.47	555 bc	2840	867	552 a	4.42	0.72	4.44	1.79
$LSD_{0.05}$	ns	ns	55.04	ns	ns	141.60	ns	ns	ns	ns

ns: non significant.

Effect of different EC levels in irrigation water on plant primary and secondary element contents and vegetative growing parameters of lettuce plant: Effects of different EC levels on primary and secondary elements (N, P, K, Ca, Mg, Fe, Zn, Mn, Cu) of lettuce plant have been given in Table-6. Only Na content of lettuce plant was found to be considerably affected from different EC levels. Sodium contents of lettuce plant increased in parallel to enhanced salt concentration in irrigation water and reached up to its highest level (1.34 % Na) at 16 dSm^{-1} level (Table-6). If the amount of primary and secondary elements in lettuce plant leaves were compared to the reference values suggested[20,21], N and Ca contents would be insufficient; both P, K and Mg content and secondary elements (Fe, Zn, Mn, Cu) would be adequate. In many researches made on various plants by adding NaCl to irrigation water and different culture media, it was determined that NaCl increases Na and Cl levels in leaves, but decreases or unbalances N, K, Ca, Mg contents and K\Na value[2,13-15,22-26]. An excess of Na^+ and to an even greater extent, excess Cl^- in

the protoplasm leads to disturbances in the ionic balance (K^+ and Ca^{2+} to Na^+) as well ion-specific effects on enzyme protein and membranes. However, excessive amount of Na^+ taken by plant competes with K^+, which has the same ionic diameter and electrical charge, so intake is inhibited[1].

TABLE-6
EFFECT OF DIFFERENT EC LEVELS ON PRIMARY AND SECONDARY ELEMENT CONTENT OF LETTUCE PLANT (IN DRY MATTER)

EC levels (dsm^{-1})	N	P	K	Ca	Mg	Na	Fe	Zn	Cu	Mn
	(%)						(mg kg^{-1})			
0	2.82	0.51	6.16	0.88	0.75	0.47 d	567.47	66.67	11.73	76.80
4	3.30	0.52	6.35	0.90	0.75	0.67 cd	549.73	68.67	12.47	72.32
8	3.42	0.58	6.53	1.42	0.82	0.90 bc	416.73	79.67	12.47	92.80
12	3.81	0.50	6.30	0.95	0.81	1.00 b	388.87	69.17	12.47	82.56
16	3.83	0.52	6.25	1.03	0.82	1.34 a	323.00	66.50	11.73	67.84
$LSD_{0.05}$	ns	ns	ns	ns	ns	0.254	ns	ns	ns	ns

ns: non significant.

Effects on different EC levels of irrigation water to lettuce plant's vegetative growing parameters (head fresh and dry weight per plant, plant head length, leaf number, root length, root diameter, dry and fresh weight of the root) were examined (Table-7).

Important effects of salt amount in irrigation water were observed on head dry and fresh weight, plant head length and leaf number for each lettuce plant when Table-7 was considered.

This stated four vegetative growing parameters (head fresh and head dry weight, plant head length and leaf number) were given as the highest values (184.13 g; 3.25 g; 24.50 cm; 21.67 per plant) in the level of 4 dSm^{-1} EC. It is noted that as the level of EC increases, these parameters decrease (Table-7). It can be said that irrigation water salt level in this research is 4 dSm^{-1} EC, if soil properties and ecological characteristics are taken into consideration. The results obtained from present research show similarity to the other researchers who have worked in this field[2,5,13,14,16,27-29].

TABLE-7
EFFECT OF DIFFERENT EC LEVELS ON VEGETATIVE GROWTH PARAMETERS OF LETTUCE PLANT (PER PLANT)

EC levels ($ds\ m^{-1}$)	Head fresh weight (g $plant^{-1}$)	Head dry weight (g $plant^{-1}$)	Plant head lengh (cm)	Leaf No.	Root lengh (cm)	Root diameter (cm)	Root fresh weight (g $plant^{-1}$)	Root dry weight (g $plant^{-1}$)
0	185.67 a	3.00 a	18.83 c	18.33 b	12.73	1.64	13.43	1.29
4	184.13 a	3.25 a	24.50 a	21.67 a	11.77	1.73	15.59	2.29
8	148.33 b	2.76 a	22.00 b	20.67 a	13.67	1.70	15.24	1.95
12	140.33 b	2.68 ab	18.33 c	18.00 b	12.07	1.65	12.71	1.47
16	110.67 c	2.03 c	15.67 d	17.33 b	12.57	1.61	12.57	1.22
$LSD_{0.05}$	25.477	0.655	2.408	1.694	ns	ns	ns	ns

ns: non significant.

In whole vegetables, lettuce plant shows growing performance in a decreasing ratio with respect to electrical conductivity degree of soil's saturation extract. When EC (dSm^{-1}) is 2.0, the growing ratio is 81 %; if it is 4.0, the ratio is 80 %; in 6.0, it comes as 44 % and if it happens to be 6.0 a 35 % of growth is obtained. When EC is 10 dSm^{-1}, no growth is observed[30].

In general, outstanding results were obtained for Na and Cl values of soil's saturation extract depending on increasing EC levels of irrigating water (Na and Cl determine soil's salinity and alkalinity). Some of the physical properties of lettuce grown soils, only total soluble salt amount have increased along with enhanced salt content in irrigation water. Different EC levels have had an important effect to K and Na content of soil and Na content of the plant. However, different concentrations of salty water applications have not caused important problems on primary and secondary elements in soil and on lettuce plant. But, vegetative growth parameters of lettuce plant such as head fresh weight, head dry weight, head length and leaf number reached highest levels when EC was 4 dSm^{-1}, but as EC level goes up (> 4 dSm^{-1} EC) it was observed that these parameters were negatively effected. As a result in most of the places in world and in Turkey which arid and semi-arid climate prevail, it would be difficult to find high qualified irrigation water, related to global warming in future. So having to take advantage of relatively salty irrigation waters would be a solution. Therefore, this research is extremely important for producers in this respect.

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