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Effect of salinity level of irrigation water on cowpea (Vigna Unguiculata) growth

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ABSTRACT : *A field experiment was carried out to study the effect of different levels of saline water on some cowpea characteristics by using randomized complete block design with three replicates. Plant growth, nutrient concentration and protein content were studied. In addition, some soil chemical properties were investigated. Three levels 0, 2500 and 3500 ppm of saline water (sodium chloride) were used for irrigation in two types of soil. Results indicated that increasing salinity levels significantly decreased plant height, number of leaves, nutrients uptake, protein yield of cowpea, and ions concentration in the soil after harvesting. Vegetative growth was affected by increasing salinity levels of irrigation water. Increase in salinity of irrigation water above 3500 ppm reduced plant height and number of leaves by 38% and 66% respectively in Khabat soil. On the other hand, the result shows that the ions accumulated significantly in soil with increasing water salinity levels. A rapidly increase in chloride concentration was observed with increasing water salinity levels but other ions gradually increase in both soils.*

Keywords - *salinity, water quality, vigna unguiculata, protein content, Iraqi Kurdistan.*

I. INTRODUCTION

A considerable part of the world's soil and irrigated water resources are affected by salinity. This problem restricts yield on almost 40 million hectares of irrigated land, which is approximately one third of the irrigated land on earth (Norlyn and Epstein, 1984). Irrigation- water quality may have a profound impact on crop production. All irrigation water contains dissolved mineral salts, but the concentration and composition of the dissolved salts vary depending on source of the irrigation water (Stephen R. G., 2002). On the other hand, due to increasing world's population and food needs, it is recommended to use available soil and water resources optimally; as well as, using ignored resources such as saline water. In addition, researchers should investigate to increase plants resistant to salinity, particularly legume plants that have important role in supplying of vegetable protein.

However, plant growth includes a series processes such as photosynthesis, nutrition and water-plant relationships, and salinity stress will affect all these processes. The first reaction of plants against salinity stress is reduction of leaf growth due to osmotic pressure (Curtis P.S, et al, 1987). Also, reducing photosynthetic process diminishes dry weight. In addition, nutrient availability in the soil solution will be reduced by salinity conditions due to the high concentration of sodium and chlorine ions. In addition, salinity conditions cause nutrient imbalances and disruptions in plant nutrient. Thus, the role of proper nutrition is important in contributing of nutrient balance and plant growth.

Two parameters should be determined to adequately define the salt tolerance of a crop (Maas and Hoffman, 1977). They are: 1) the mean value of salinity in the root zone which, if exceeded, results in reduced yield, and 2) rate of yield decline as root zone salinity increases beyond this threshold value.

Salts dissolve in water and form positive ions (cations) and negative ions (anions). The most common cations are calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^{+}) while the most common anions are chloride (Cl^{-}), sulfate ($SO4^{2-}$), and bicarbonate (HCO^{3-}). The ratios of these ions vary from one water supply to another. Potassium (K^{+}), carbonate ($CO3^{2-}$), and nitrate (NO^{3-}) also exist in water supplies, but the concentrations of these constituents are comparatively low.

Salinity and sodication will destroy soil structure and can cause unsuitable physical properties in the soil. Swelling and dispersion of clays, which occur due to the high exchangeable sodium percentage, are two major factors to reduce the permeability and soil hydraulic conductivity. However, this case is not occurring in calcareous soils, because sometimes it is found in high amounts in gypsum; and soil solution concentrations reach above 3 meq/l. Furthermore, high concentrations of sodium would cause deficiency of other elements such as potassium and calcium in plants; whereas, high amounts of calcium can reduce the negative effects of sodium chloride (Cramer G.R., et al, 1986). However, when saline water is used, the salt tolerance of plants in different growth stages should be considered. These plant growth stages include; vegetative, reproduction, senescence and the dormancy, and salinity tolerance increases from first to last stage respectively. However, the tolerance of plants to salinity may not be considered accurate guide, as it is affected by various factors such as temperature, relative humidity, irrigation scheme, soil fertility and planting method.

II. MATERIALS AND METHODS

This study was carried out at experimental field of Khabat Agriculture Technical Institute under greenhouse conditions, where is 30 km western Erbil (Figure1). The experimental design was randomized complete block design with three replicates. Black-eyed Variety of cowpea was sown in three holes in plastic pots containing 8 Kg soil. Three seeds were planted in each hole. After two weeks from sowing, seedlings were thinned to one plant per hole. Fertilizers were applied at the following rates: 100 kg P/ha, 50 kg K/ha and 30 ton peatmoss/ha. Two types of soil (*Aski Kalak and Khabat*) were sampled and analyzed as shown in (Table 1).

Figure1. The experience location map

Salinity irrigation water treatments were applied as NaCl solution by three levels which were 0, 2500 and 3500 ppm. Then, the treatments were converted to ds/m including; distilled water (EC=0), (EC=3.91) and (EC=5.47). In addition, to obtain NaCl solution by mg/l, the results of electrical conductivity should be multiplied 0.51. Afterwards, the pots were irrigated by the treatments 15 days after sowing, and the irrigation was continued twice per a week.

Samples were taken at flowering stage for plant growth measurements and determine of plant height and leaves number. Also, samples were taken at ripening stage to determine nutrient contents and chemical properties. Leaves and seeds were collected after harvest to determine seed protein percentage and total N by using Kejldahl method; as well as, other elements such as Na, Cl, Ca, Mg, P, and K (table 2). SAR (sodium adsorption ratio), Adj.SAR, and Adj.RNa were calculated according to (Richards, 1954), (Ayers and Westcott, 1976) and (Suarez, 1981), respectively. Also, Residual sodium carbonates was calculated by [RSC= (CO_3^{2-} +HCO^{3-}) - (Ca^{2+}+Mg^{2+})] equation. Data were analyzed using SPSS 18 statistical package. The least significant difference (TUKEY`S HSD) at 1% level was used to compare the means of treatments.

Table 1: Analysis of soil samples before sowing

Soil Name	Sand	Silt	Clay	OM	pH	EC	N	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	Cl^-
	%					$dS.m^{-1}$	%	$mg.g^{-1}$	$mmolic.L^{-1}$				
Soil I (Aski Kalalk)	33	26	41	0.8	7.9	1.6	0.16	4.15	0.14	7.28	2.96	3.58	1.28
Soil II (Khabat)	6	50	44	1.1	7.5	1.3	0.27	3.76	0.22	6.57	3.98	4.08	0.92

III. RESULTS AND DISCUSSION

Physiological impacts: Analysis of variance shows that application of irrigation water salinity significantly decreased plant height and number of leaves in cowpea at flowering stage compared to control treatment (Table 2). The results indicate that the minimum height of plant was observed at (S_1, EC_2) treatment which was 10.3 cm, while plant height was 16.7 cm in control treatment in soil I. Similarly, at (S_2, EC_2) treatment was 11.7 cm while plant height was 16.5 cm compared to control for soil II (Figure 2). The decrease in the shoot length might have been caused by suppression in cell elongation and cell division under salt stress (Atta Ullah et al, 1981). Also, the results show that the maximum number of leaves was observed at (S_1, EC_0) treatment which was 13.7 in soil I, and was 13.1 at (S_2, EC_0) treatment for soil II (Figure 3). Furthermore, number of leaves was reduced to 7.3 and 4.4 by salinity level of (S_1, EC_2) and (S_2, EC_2), respectively. However, all treatments had significant effects ($P < 0.01$).

Table 2: Effect of water salinity level on some physiological properties at flowering stage of cowpea

Soil type	Treatments	Plant height, cm	Number of leaves
Aski kalak	S_1, EC_0	16.7	13.7
	S_1, EC_1	12.7	8.7
	S_1, EC_2	10.3	7.3
Khabat	S_2, EC_0	16.5	13.1
	S_2, EC_1	13.6	5.1
	S_2, EC_2	11.7	4.4
	Tukey's HSD	0.50	0.56

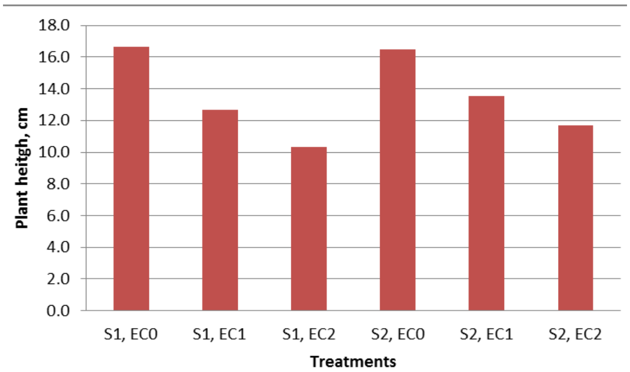

Figure 2. Effect of salinity level of irrigation water on plant height at flowering stage in cowpea

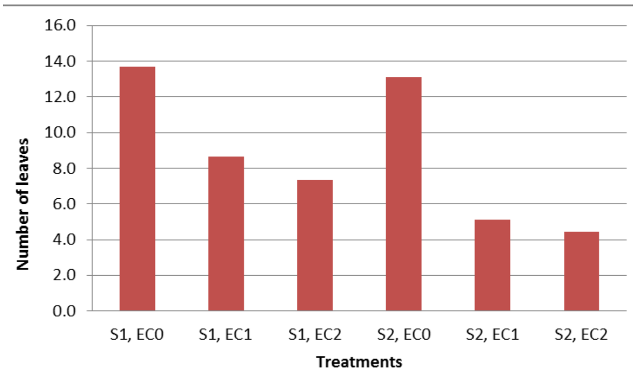

Figure 3. Effect of water salinity level on number of leaves at flowering stage in cowpea

Nutrient concentration: The study results show that application of saline water had different effects on nutrient concentration in cowpea (Table 3). The results of plant analyzed in both soil types indicate that sodium and chloride concentrations were increased greatly by increasing salinity, whereas calcium and magnesium ions were increased normally; but phosphorus and potassium were reduced (Figure 4). So, salinity caused a significant increase in sodium and chloride concentrations, while it reduced the accumulation of phosphorus and potassium. Moreover, the ratio of K^+/Na^+ was decreased significantly by salinity level. (Kuiper, 1984) noted that plants accumulate Na^+ at the expense of Ca^{2+} and K^+ in saline conditions. According to (Greenway and Munns, 1980), the reduction in potassium concentration could inhibit growth by reducing the capacity for osmotic adjustment and turgor maintenance or by adversely affecting metabolic functions.

Table 3: Effect of water salinity level on nutrient concentration in cowpea in two soil types

Soil type	Treatments	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	Cl^-	K^+/Na^+
		mg.g^{-1}						
Aski kalak	S_1, EC_0	3.2	22.2	3.20	2.32	2.10	1.40	10.57
	S_1, EC_1	3.1	19.5	2.73	2.37	3.96	2.64	4.92
	S_1, EC_2	2.9	18.7	2.14	3.02	5.47	3.25	3.42
Khabat	S_2, EC_0	3.0	20.9	3.45	2.54	2.22	1.80	9.41
	S_2, EC_1	2.7	18.3	2.66	2.62	3.20	2.23	5.72
	S_2, EC_2	2.6	16.6	2.98	3.27	6.12	4.08	2.71
Tukey's HSD		0.369	0.305	0.956	0.208	0.273	0.683	-

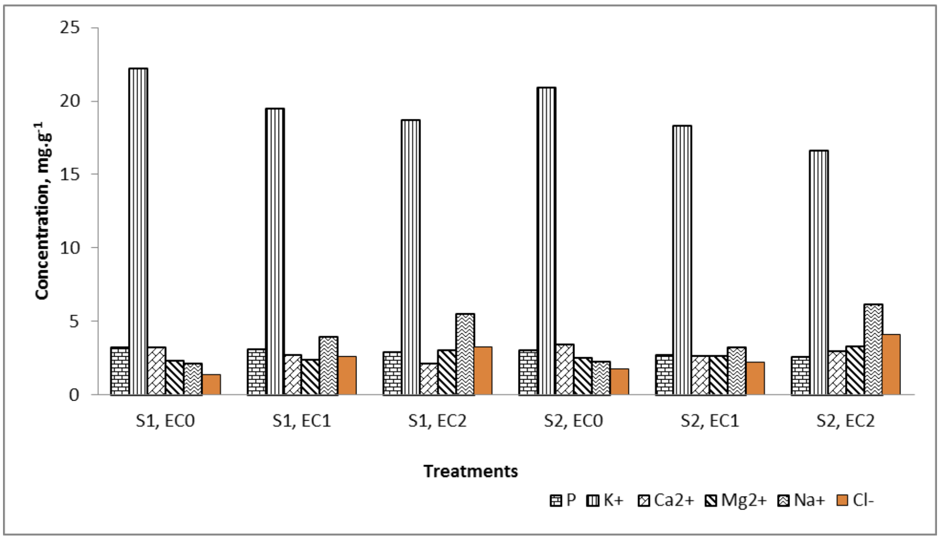

Figure 4: Effect of water salinity level on nutrient concentration in cowpea in two soil types

Protein percentage of seed: Analysis of variance shows that increasing salinity had negative effect on protein percentage in cowpea seeds (Table 4). Protein percentage was suppressed by increasing salinity levels compared to control 24.4% in the *Aski kalak* soil which was reduced to 22.1% at (3.91 ds/m) and to 18.5% at (5.47 ds/m). Similarly, in *Khabat* soil, protein percentage was reduced to 23.2% at (0 ds/m), 21.3% at (3.91 ds/m), and to 17.7% at (5.47 ds/m).

However, the result studies of (Cordovilla et al., 1995; Veatch et al., 2004) explain that the depressive effect of salt stress on N_2 fixation by legumes is directly related to the salt induced decline in dry weight and N content in the shoot. The salt induced distortions in nodule structure could also be reasons for the decline in the N_2 fixation rate by legumes subject to salt stress (Zahran and Abu-Gharbia, 1995). Reduction in photosynthetic activity might also affect N_2 fixation by legumes under salt stress (Georgiev and Atkias, 1993). On the other hand, Salinity diminished chlorophyll content of cowpea leaves. It is attributed to a salt-induced weakening of protein-pigment-lipid complex (Strogonove et al., 1970) or increased chlorophyllase enzyme activities (Stivesev et al., 1973).

Table 4: Effect of water salinity level on protein percentage in cowpea in two soil types

Soil name	Treatments	Protein percentage of seed
Aski kalak	S_1, EC_0	24.4
	S_1, EC_1	22.1
	S_1, EC_2	18.5
Khabat	S_2, EC_0	23.2
	S_2, EC_1	21.3
	S_2, EC_2	17.7
Tukey's HSD		1.05

Effect on soil chemical properties: As shown in Table 5 after experiment, soil chemical properties were changed:

Soil Salinity: EC measured values in both soils after harvesting are illustrated in Table 5. EC values significantly were increased in both soil, but it was higher in *Khabat* soil than the *Aski kalak* soil. Increasing water salinity levels caused to increase gradually in electrical conductivity values in both soil.

Table 5: Analysis of soil samples after harvesting

Soil name	Treatments	EC $dS.m^{-1}$	Concentration.$mmolc.L^{-1}$						SAR	RSC	Adj.SAR	Adj.RNa	Mg^{2+}/Ca^{2+}	Na^{+}/Ca^{2+}
			Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Cl^{-}	HCO_3^{-}						
Aski kalak	S_1, EC_0	1.8	7.1	2	0.5	4.1	1.5	1.8	1.92	-7.3	3.84	2.11	0.28	0.58
	S_1, EC_1	4.4	11.7	2.8	0.62	12	44	2.3	4.46	-12.2	10.03	5.39	0.24	1.03
	S_1, EC_2	5.9	16.4	7.9	0.8	17	65	5	4.88	-19.3	13.41	6.50	0.48	1.04
Khabat	S_2, EC_0	1.5	7.5	3.1	0.67	5	1.2	2.3	2.17	-8.3	4.78	2.51	0.41	0.67
	S_2, EC_1	5.1	12.3	5.8	0.71	14.5	48	3.1	4.82	-15	12.77	5.89	0.47	1.18
	S_2, EC_2	7.3	20.1	10.1	0.77	22	69	6.2	5.66	-24	16.42	7.78	0.50	1.09

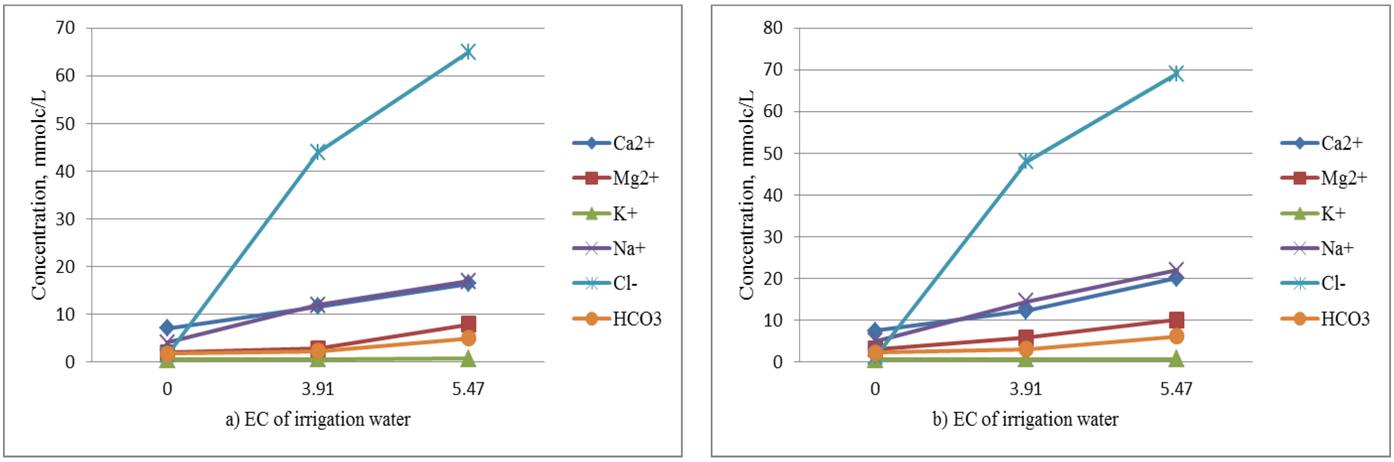

Figure 5. Effect of water salinity on ions concentration in *a) Aski kalak soil* and, *b) Khabat soil* after harvesting

The ions concentration: Saline water had different effects on the measured ions in both soil types, and is graphically illustrated by Figure 5. A rapid increase in chloride concentration was observed by increasing water salinity levels in both soils. Chloride does not affect chemical reactions in soil, but it will accumulate and can be considered as a good indication for accumulating salts in soils. On the other hand, the results show a gradual increase in sodium, calcium, magnesium and bicarbonate, but potassium was increased slightly by increasing water salinity levels in both soils.

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