4. RESULTS AND DISCUSSION

4.1. Different relations of (non sodic) saline soils:

4.1.1. Soil salinity in relation to soil characteristics and soil productivity:

4.1.1.1. Soil salinity in relation to soil hydraulic conductivity:

Results, in Table (4) and illustrated in Fig. (1) show that values of the relative hydraulic conductivity of the tested soil models gradually increased by increasing the total soil salinity. It is obvious that the maximum rate of increase in relative hydraulic conductivity (from 19.72 to 32.79%) occurred as the EC_e of soil increased from 4 to 8 dSm^{-1}. The other increments in relative hydraulic conductivity values of tested soil models, amounted only to about 1.00 to 1.75% for each unit of increase in EC_e. However, the statistical analysis of EC_e values in relation to the hydraulic conductivity was insignificant. These results agree with those obtained by Oster and Schroer (1979), Rizk *et al.* (1990), Lima *et al.* (1990) and Abd-Allah (1988) who found that the hydraulic conductivity of tested alluvial soils generally increased by increasing salinity of irrigation water from EC 2 to 8 dSm^{-1}.

Concerning the role of the clay fraction on this relation, the obtained data reveal that the hydraulic conductivity of the tested soil models significantly decreased with increasing the clay content.

According to these results, it seems reasonable to state that although the soil hydraulic conductivity tends to respond positively to salinity in the tested soil models, this relation was more obvious but negative (r = -0.913***) versus log values of clay content in soil models. In other words, one may expect that increasing the clay content of soil will overcome the positive effect due to the salinity exhibiting a net negative close relation.

Such composited relation is reflected clearly through the multiple regression equation.

$$K = 9.67 + 0.0559\ EC - 6.61 \log clay \qquad (R = 0.921^{***})$$

Where the clay fraction was responsible for 84.91% of variations through hydraulic conductivity parameter meanwhile the EC_e parameters contributed only about 3.27% of that variation (Table, 5).

Table (4): Relative hydraulic conductivity (%) in relation to soil salinity (control 100).

Soil	EC (dSm^{-1})						
model	**4**	**8**	**12**	**16**	**20**	**24**	**Average**
S1	49.47	62.91	83.29	87.05	91.27	95.76	78.33
S2	43.42	57.17	62.30	66.58	79.92	87.92	66.21
S3	22.92	39.99	44.75	51.90	64.12	68.88	48.76
S4	13.05	30.20	31.70	38.45	53.67	57.03	37.35
S5	9.94	20.38	23.00	26.69	38.19	41.19	26.73
S6	6.89	19.85	19.92	20.38	22.75	23.13	18.82
S7	6.10	16.56	17.88	19.14	20.10	22.85	17.10
S8	5.71	14.29	16.00	18.43	19.75	22.39	16.06
Aver.	19.72	32.79	37.36	41.08	48.70	53.77	38.67

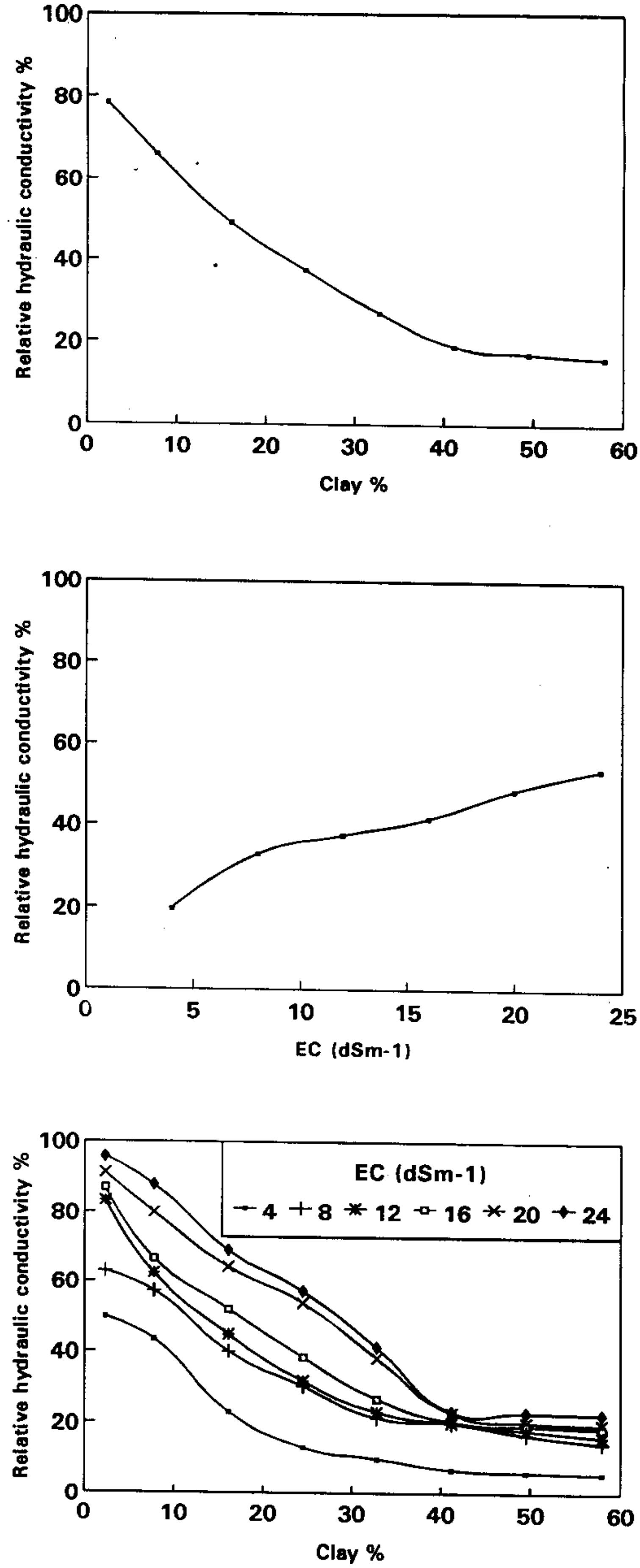


Fig (1) Relative hydraulic conductivity (%) in relation to soil salinity.

4.1.1.2. Soil salinity in relation to soil pH:

Data presented in Table (6) and graphically illustrated in Fig. (2) show that the pH of the tested soil models was significantly ($r = -0.706^{***}$) reduced (from 8.24 down to 7.61) with increasing the soil salinity from EC_e 4 up to 24 dSm^{-1}. The rate of reduction in soil pH was about 0.03 pH unit for each EC_e unit (above $EC_e = 4$ dSm^{-1}).

These results are in agreement with those obtained by Mac George (1938), USSLS (1954), Dregne (1976), Abrol *et al.* (1980), Khattak and Jarrell (1988), Abd-El-Nour (1989) and Khattak and Jarrell (1989) who found that the pH decreased with increasing soil salinity up to 18.0 dSm^{-1}. The decrease in soil pH with increasing soil salinity was related to the displacement of proton into the solution phase by Na^+ and Ca^{2+} (Doner *et al.*, 1982).

With regard to the role of the clay fraction, the pH of tested soils was significantly ($r = -0.587^{***}$) and gradually decreased (from 8.21 down to 7.61) with increasing the clay fraction (from 2.32 up to 57.98%). Each increase of 1.0% in the clay fraction of the soil (above 2.32%) reduced the pH by 0.011. Similar trends were obtained by Taha *et al.* (1969).

The combined effect of soil salinity and the clay fraction % in soil is described through the multiple regression equation developed for these parameters (Table 7) which state that:

$$pH = 8.62 - 0.034\ EC - 0.0104\ clay. \quad (R = 0.920^{***})$$

4.1.2. Soil salinity in relation to elemental utilization and soil productivity:

4.1.2.1. Soil salinity in relation to elemental content of barley plants:

*** N-content:**

Results obtained in Table (8) and illustrated in Fig. (3) indicate that increasing the soil salinity beyond EC_e 4 and up to EC_e 24 dSm^{-1} tended to inconsistently increase the nitrogen content of barley plants, where the maximum increase occurred at EC_e 16 dSm^{-1}. The obtained figures of N% ranged, on average, between 2.64 and 3.91%. However, the control treatment (of $EC \simeq 1.4$ dSm^{-1}) yielded average N% of about 3.40% which is higher than all the values of the higher salinity levels except those of EC_e 16 (3.91%) and 20 dSm^{-1} (3.61%).

Table (6): Soil pH in relation to soil salinity.

Soil model	Control	EC (dSm^{-1})						
		4	8	12	16	20	24	Average
S1	8.46	8.47	8.35	8.17	8.14	8.08	8.06	8.21
S2	8.35	8.35	8.21	8.94	7.91	7.88	7.86	8.03
S3	8.27	8.26	8.18	7.86	7.79	7.76	7.73	7.93
S4	8.24	8.24	8.10	7.81	7.67	7.59	7.57	7.83
S5	8.22	8.20	8.08	7.72	7.63	7.53	7.51	7.78
S6	8.20	8.16	8.04	7.51	7.47	7.45	7.43	7.68
S7	8.17	8.14	8.01	7.48	7.40	7.39	7.38	7.63
S8	8.12	8.10	8.00	7.45	7.39	7.38	7.33	7.61
Aver.	8.25	8.24	8.12	7.74	7.66	7.63	7.61	7.84

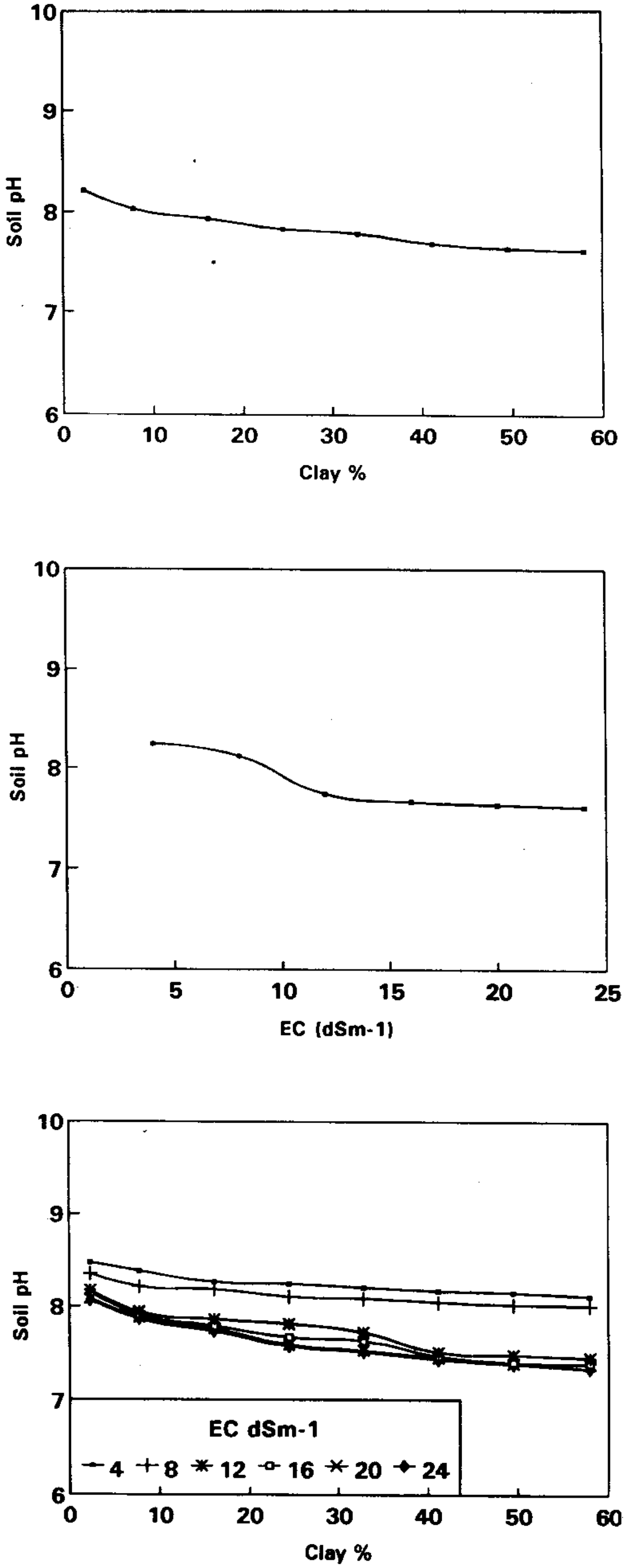


Fig. (2) Soil pH in relation to soil salinity.

Table (7): Soil pH in relation to soil salinity.

Type of relation	Equation	Correlation coefficient
Simple relation	$Y = 8.32 - 0.0339\ X_1$ $Y = 8.14 - 0.0104\ X_2$	-0.706^{***} -0.587^{***}
Multiple relation	$Y = 8.62 - 0.0340\ X_1 - 0.0104\ X_2$	0.920^{***}
Variables under study	Y = pH in 1:2.5 soil:water. X_1 = EC (dSm^{-1}). X_2 = Clay %.	
Contribution of factors	EC = 50.20% Clay = 34.57% Other factors = 15.23%	

*** = Significant at level of 0.001.

According to these results, it may be stated that soil salinity can induce or reduce the plant content of N, perhaps depending on the other controlling growth factors or the balance in between nutrients and chemical elements either in the growth media or in the plant tissues. Almost similar results were obtained by Shimose (1972), Panaullah (1980), Taha (1980), Wagenet *et al.* (1983) and Al-Sager (1991) who found that N-content of sorghum plants decreased (from 212 to 165 mg/100 g dry wt.) by increasing salt concentration from 500 to 5000 ppm.

As for the role of clay, results generally show an increasing tendency in N-content of barley plants due to increasing the clay content in soil models. However, this general trend was not always regular but it differed through the different categories of salinity in the tested soil models.

*** P-content:**

Results in Table (8) and shown in Fig. (3) generally reveal that P% in barley plants responded to soil salinity according to more than one trend as follows:

The highest average of P-content ($\simeq$0.708%) was shown by control soil models (having EC_e values of 1.4 and 1.5 dSm^{-1}).

Treating these control models with $CaCl_2$ and NaCl at 1:1.5 equivalent ratio, as mentioned before, to elevate their EC_e to 4 dSm^{-1}, reduced the average P-content in barley plants to 0.64%.

The next rate of soil salinity behaved quite differently as it induced p% of barley plants to reach a maximum value (0.67%) among all the tested salinity levels (EC 4-24 dSm^{-1}).

Further rates of salinity beyond EC_e = 8 and up to 24 dSm^{-1}, yielded a steadily decreasing trend of P% in barley plants. These results agree well with those obtained by Ashour *et al.* (1970), Kirti *et al.* (1976), Francois *et al.* (1988), Remison *et al.* (1988) and Francois *et al.* (1989) who found that phosphorus content of rye plants (cultivar of Bonel) slightly decreased from 79 to 74 mmol/kg dry wt. as the soil salinity increased from 5.8 to 15.9 dSm^{-1}.

Table (8): Nitrogen, phosphorus and potassium content (%) of barley plants in relation to soil salinity.

Soil model	Control	EC (dSm⁻¹)						
		4	8	12	16	20	24	Aver-age
Nitrogen								
S1	2.36	2.38	2.94	3.08	4.06	2.80	2.80	3.01
S2	3.40	2.80	2.94	2.94	4.06	3.80	2.80	3.22
S3	3.36	2.50	3.08	2.94	3.78	3.80	2.80	3.15
S4	3.36	2.52	3.08	2.94	3.50	3.80	2.94	3.13
S5	3.36	2.52	3.08	2.66	4.20	3.22	2.80	3.08
S6	3.36	2.80	3.08	2.66	3.92	3.92	3.36	3.29
S7	3.50	2.94	3.08	2.66	4.14	3.78	3.64	3.37
S8	3.50	2.66	3.22	2.80	4.06	3.78	3.78	3.38
Aver.	3.40	2.64	3.06	2.84	3.91	3.61	3.11	3.20
Phosphorus								
S1	0.71	0.55	0.58	0.53	0.46	0.56	0.45	0.52
S2	0.77	0.58	0.56	0.46	0.42	0.55	0.41	0.50
S3	0.70	0.53	0.64	0.45	0.44	0.44	0.42	0.49
S4	0.70	0.67	0.70	0.48	0.40	0.40	0.41	0.51
S5	0.70	0.67	0.74	0.49	0.47	0.40	0.40	0.54
S6	0.73	0.72	0.77	0.50	0.46	0.40	0.38	0.54
S7	0.67	0.71	0.71	0.53	0.46	0.47	0.39	0.55
S8	0.72	0.62	0.69	0.65	0.46	0.38	0.31	0.52
Ave.	0.71	0.64	0.67	0.51	0.45	0.45	0.40	0.52
Potassium								
S1	4.43	3.50	3.35	3.50	3.10	2.60	1.60	2.94
S2	4.40	3.70	3.30	3.10	3.35	2.87	1.80	3.02
S3	4.30	3.55	3.28	3.10	3.00	2.75	2.20	2.98
S4	4.30	3.50	3.30	3.10	3.12	2.90	2.60	3.09
S5	4.25	3.75	3.40	3.50	3.10	2.80	2.70	3.21
S6	4.55	4.00	3.50	3.00	3.00	2.50	3.10	3.18
S7	4.45	4.00	3.25	3.10	3.20	2.95	3.00	3.25
S8	4.50	4.00	3.30	3.50	3.10	3.10	3.20	3.37
Aver.	4.40	3.80	3.30	3.20	3.10	2.80	2.50	3.13

Concerning the role of clay, its presence at levels up to $\simeq$ 58% failed to affected materially the P% of barley plants grown on different salinized soil models, showing no distinict clear trend in this respect.

*** K-content:**

Data presented in Table (8) and illustrated in Fig. (3) show that K-content in barley plants was adversely and gradually affected with increasing the salinity of the tested soil models as the average value of K-content was reduced from 4.4% (control) in to 2.5% for the highest level of salinity (EC = 24 dSm^{-1}). These results are in harmony with those obtained by Francois *et al.* (1986 and 1988), Francois and Kleiman (1990), El-Raise (1991), Youssef and Saleh (1994) and El-Ghanam (1993) who found that K-content of corn plants was decreased (from 2.56 to 1.52% in case of sandy soil and from 3.48 to 2.34% in case of clay soil) with increasing the soil salinity from EC 4 up to 16 dSm^{-1} in both soils.

Concerning the effect due to the clay fraction, results show that values of K-content in barley plants tended to increase steadily, by increasing soil content of the clay fraction (up to about 58%).

*** Na-content:**

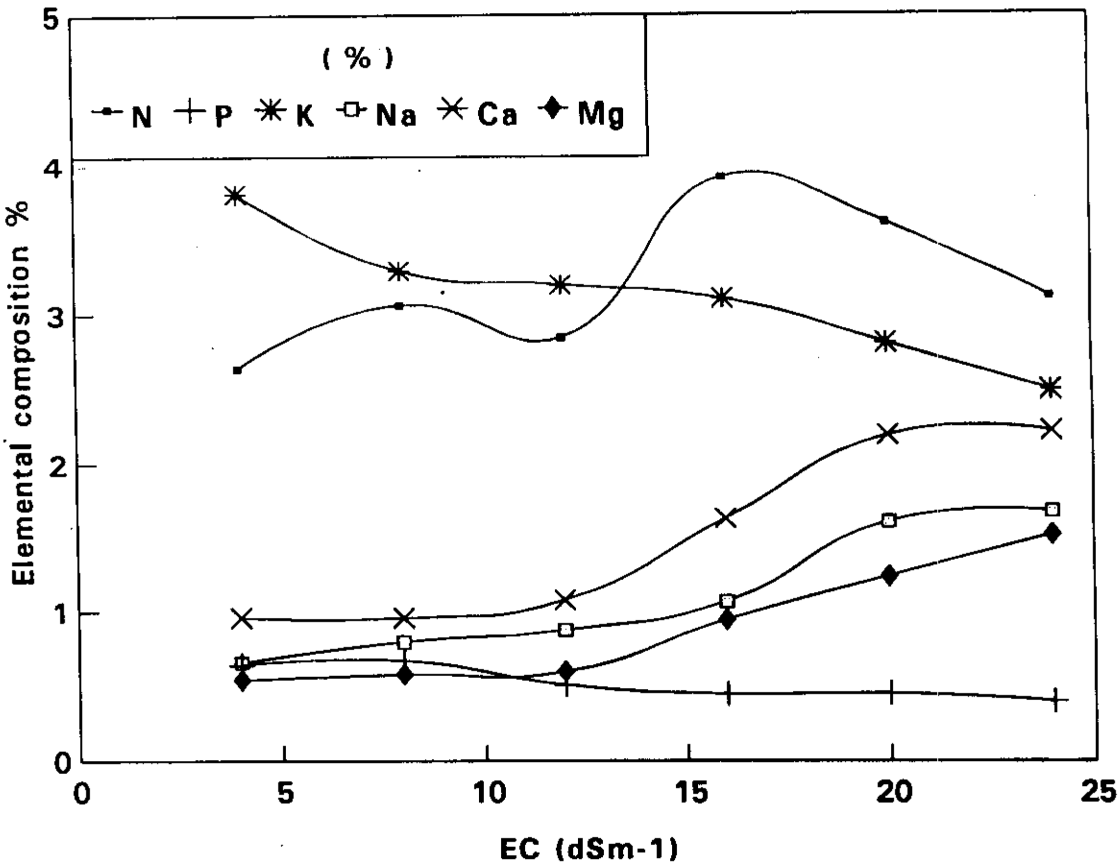
Data in Table (9) and Fig. (3) indicate that Na-content of barley plants was significantly and positively affected by increasing salinity in the tested saline soil models from (EC_e 4 up to 24 dSm^{-1}). The rate of the increase in Na%, corresponding to each unit of EC increase was about 0.05%.

These results are in accordance with those ontained by Mc Lean (1956), El-Seewi *et al.* (1974), Wouters (1974), Panaullah (1980), Kriem and Abdou (1986), Abdel-Rahman and Mikkelson (1986), Fouda and Mohamed (1986) and Al-Sager (1991) who found that Na-content of sorghum plants increased from 33.20 to 44.97 mg/100 g with increasing salt concentration of the irrigation water from 500 to 5000 ppm.

Concerning the effect of clay % in soil on the Na-content in barley plants was gradually reduced from 1.78 down to 0.88% with increasing the clay fraction from 2.32 up to 57.98%. The rate of reduction in Na-content of plants, corresponding to each of 1% clay was about 0.016%.

Table (9): Sodium, calcium and magnesium content (%) of barley plants in relation to soil salinity.

Soil model	Control	EC (dSm⁻¹)						Aver-age
		4	8	12	16	20	24	
Sodium								
S1	0.57	0.80	0.80	1.05	1.75	2.50	3.50	1.78
S2	0.56	0.68	0.83	0.90	1.60	2.18	2.30	1.46
S3	0.53	0.59	0.82	0.95	0.90	2.10	1.90	1.24
S4	0.49	0.58	0.80	0.90	0.82	1.45	1.55	1.06
S5	0.47	0.67	0.87	0.85	0.80	1.50	1.25	1.04
S6	0.46	0.65	0.72	0.80	0.95	1.10	1.00	1.09
S7	0.44	0.67	0.75	0.82	0.87	1.05	0.96	0.90
S8	0.43	0.65	0.75	0.80	0.85	1.00	0.95	0.88
Aver.	0.49	0.66	0.80	0.88	1.07	1.61	1.68	1.18
Calcium								
S1	0.90	0.80	0.90	1.40	1.50	2.20	1.80	1.43
S2	0.90	0.80	0.80	1.07	1.80	2.10	1.80	1.40
S3	0.90	0.90	1.00	1.07	1.70	2.20	1.60	1.41
S4	1.00	1.00	1.00	1.10	1.70	2.00	2.20	1.50
S5	1.30	1.00	1.00	1.13	1.70	2.20	2.50	1.64
S6	1.40	1.00	1.10	1.00	1.60	2.40	2.70	1.65
S7	1.30	1.10	1.00	0.90	1.60	2.20	2.70	1.60
S8	1.30	1.10	0.90	1.00	1.50	2.30	2.60	1.57
Aver.	1.13	0.96	0.96	1.08	1.63	2.20	2.23	1.53
Magnesium								
S1	0.40	0.60	0.60	0.60	1.20	0.96	1.56	0.92
S2	0.50	0.60	0.70	0.60	1.10	1.32	1.56	0.98
S3	0.60	0.60	0.70	0.56	0.88	1.32	1.44	0.92
S4	0.60	0.48	0.53	0.60	0.89	1.32	1.44	0.88
S5	0.60	0.48	0.44	0.57	0.87	1.44	1.32	0.85
S6	0.60	0.48	0.57	0.60	0.84	1.44	1.68	0.96
S7	0.72	0.60	0.57	0.65	0.88	1.08	1.68	0.89
S8	0.72	0.48	0.55	0.63	0.92	1.08	1.56	0.87
Aver.	0.59	0.54	0.58	0.60	0.95	1.24	1.52	0.91



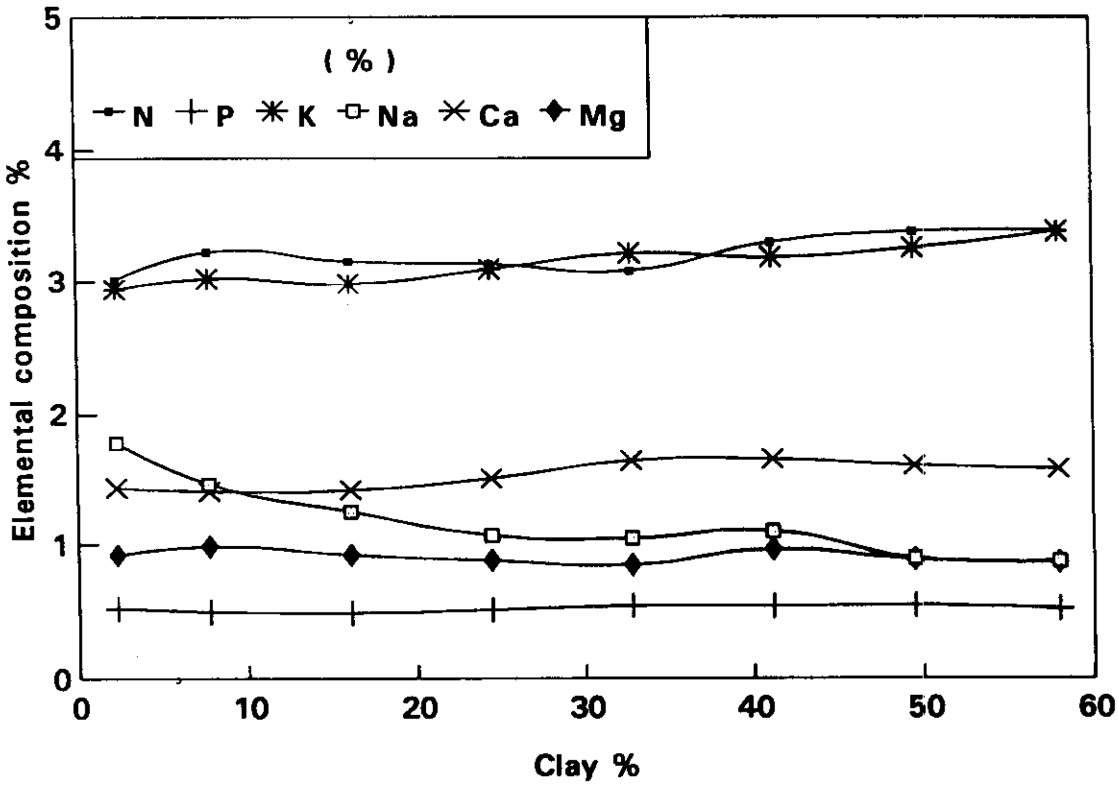


Fig (3) Elemental composition (%) of barley plants grown under saline condition.

*** Ca-content:**

Results in Table (9) and Fig. (3) show that the Ca-content of barley plants grown on the tested salinized soil models consitently increased (from 0.96 up to 2.23%), by increasing soil salinity (from EC_e 4 up to 24 dSm^{-1}). This increase could be attributed to an increase of Ca ions in soil solution due to the addition of calcium chloride through the prepartion of saline soil models.

These results are in agreement with those obtained by Francois *et al.* (1989), Francois and kleiman (1990), Al-Sager (1991) and Francois *et al.* (1986) who found that Ca-content in wheat plants increased from 142 to 207 mmol/kg dry wt. with increasing soil salinity from EC 3.5 up to 14 dSm^{-1}.

With respect to the effect of the clay fraction, Ca-content in barley plants positively responded to the increase in the clay content of soil models.

*** Mg-content:**

Data presented in Table (9) and illustrated in Fig (3) show that the Mg-content of barely plants grown on different soil models was positively affected by increasing soil salinity, beyond EC_e 8 to 24 dSm^{-1} as the corresponding values of Mg% in barley plants were, respectively, 0.48 and 1.52%. However, the Mg-content of barley plants grown on soil models of EC_e 8 dSm^{-1} i.e. (0.48%) was lower than that of plants in the models of Ec_e 4 (0.54%) as well as the control ones, of EC_e 1.4-1.5 dSm^{-1} (0.59%).

These results are in agreement with those obtained by Nath *et al.* (1982), Koszanski and Karczmarczyk (1985) and Al-Sager (1991) who found that Mg-content of sorghum plants grown on sandy soil was increased from 15.6 to 26.6 mg/100 g dry wt. with increasing salinity of irrigation water from 500 to 5000 ppm.

As for the role of the clay fraction, the obtained results exhibit no clear trend due to the increasing soil content of the clay fraction, on Mg content of barley plants while the Mg%, on average, varied between 0.92% and 1.00%.

4.1.2.2. Soil salinity in relation to elements uptake by barley plants:

*** N-uptake:**

Data presented in Table (10) and Fig. (4) indicate that the mean values of N-uptake by barley plants were reduced gradually (from 94.00 down to 28.90

mg/pot) with increasing soil salinity from EC_e 4 up to 24 dSm^{-1}. However this reduction in N-uptake was more pronounced with increasing the soil salinity beyond EC_e = 16 dSm^{-1}. At this limit of soil salinity, total N-uptake amounted to about 68 mg/pot and reduced to 42.9 and 28.9 mg/pot as the total salinity increased to 20 and 24 dSm^{-1}, respectively. The rate of reduction in N% averaged about 3.2 mg/pot for each unit of increase in EC above 4.0 dSm^{-1}.

These results are in harmony with those obtained by Hassan *et al.* (1970), Paliwal and Maliwal (1975) and Lotfy *et al.* (1987) and El-Laboudi *et al.* (1971) who reported a negative relationship between soil salinity and total uptake of most nutrient elements.

With respect to the role of the clay fraction, total N-uptake by barley plants was gradually increased (from 31.30 to 95.02 mg/pot) by increasing the clay fraction in the tested soil models (from 2.32 up to 57.98%), which give further evidence emphasizing the vital role of active surface-materials, like clay in N nutrition of plants.

The combined effect due the soil salinity and the clay content is represented (at a very high level of significancy), by the equation;

N-uptake = 83.20 - 3.45 EC + 1.12 clay (R = 0.960***)

This trend may suggest that the increasing abundance of the clay fraction in soil can dilute the adverse effect of soil salinity on N-uptake by plants grown on saline soils.

*** P-uptake:**

Results in Table (11) and in Fig (4) reveal that the P-uptake by barley plants was adversely affected with soil salinity. Increasing soil salinity beyond EC_e 4 dSm^{-1}, gradually up to 24 dSm^{-1}, resulted in corresponding gradually reduced values of P-uptake (from 23.2 down to 3.4 mg/pot). In other words increasing the total soil salinity by about 6 times (EC 24 dSm^{-1}) yielded corresponding reduction in total P-uptake by about 7 times.

These results are in harmony with those obtained by Rabie *et al.* (1985), Lotfy *et al.* (1987), Nour *et al.* (1989), Lal and Lal (1990), El-Ghanam (1993) and Dravid and Goswami (1986) who found that P-uptake by wheat plants significantly decreased as soil salinity increased up to 14.9 mmhos/cm.

Table (10) : Total uptake of nitrogen (mg/pot) by barley plants in relation to soil salinity.

Soil model	Control	EC (dSm^{-1}) 4	8	12	16	20	24	Average
S1	78.29	57.60	52.63	38.19	23.14	8.68	7.56	31.30
S2	92.48	69.16	55.86	49.69	34.92	27.36	15.12	42.01
S3	100.13	73.75	82.42	72.62	57.83	40.28	21.00	57.98
S4	107.18	90.97	91.78	81.44	63.35	46.74	23.81	66.34
S5	124.99	97.02	93.32	79.80	87.78	40.57	26.32	70.80
S6	133.73	111.72	113.34	89.91	88.20	54.10	40.66	82.98
S7	147.70	127.30	119.20	91.24	97.70	61.24	46.59	90.50
S8	152.60	124.49	132.99	107.52	91.35	63.88	49.90	95.02
Average	117.14	94.00	92.70	76.30	68.00	42.90	28.90	67.12

Table (11) : Total uptake of phosphorus (mg/pot) by barley plants in relation to soil salinity.

Soil modil	Control	EC (dSm^{-1}) 4	8	12	16	20	24	Average
S1	16.45	13.41	10.35	6.52	2.64	1.75	1.21	5.98
S2	20.89	14.28	10.56	7.77	3.59	3.97	2.22	7.06
S3	20.80	15.58	17.19	11.07	6.73	4.69	3.09	9.72
S4	22.01	24.19	20.86	13.35	7.28	4.90	3.30	12.36
S5	25.67	29.26	22.42	14.58	9.78	5.09	3.72	14.14
S6	28.97	28.81	28.48	16.76	10.40	5.49	4.60	15.75
S7	28.19	30.83	27.48	18.32	10.83	7.61	4.93	16.66
S8	31.18	29.10	28.50	24.88	11.24	6.39	4.14	17.37
Average	24.27	23.20	20.30	14.20	7.80	5.00	3.40	12.38

Concerning the effect of the clay fraction, P-uptake was significantly (r = 0.445**) increased as the clay fraction in soil models increased (from 2.32 up to 57.98%). It could be vital to observe that the rate of reduction in P-uptake was very much close to that observed with N-uptake. This trend is showing an almost constant N:P ratio (5.01 to 5.95:1).

The net combined effect of soil salinity and the clay fraction on P-uptake is discribed through the equation;

P-uptake = 21.40 - 1.09 EC + 0.215 clay (R = 0.937***)

*** K-uptake:**

The obtained results in Table (12) and Fig. (4) indicate that K-uptake by barley plants grown on salinized soil models decreased (at a VHL of significancy, r = -0.835***) with increasing soil salinity from EC_e 4 up to 24 dSm^{-1}. The decreasing trend was almost steady, where the rate of reduction in total K-uptake corresponding to each unit of increase in EC was about 5.48 mg/pot. These results are in accordance with those obtained by Sonnoveld and van Dan Ende (1967), Paliwal and Maliwal (1972), Chaudhary *et al.* (1974), Janardhan *et al.* (1979), Rabie *et al.* (1985), Nour *et al.* (1989), youssef and Saleh (1994) and also with El-Ghanam (1993) who found that K-uptake by corn plants was reduced from 80 to 5 mg/pot in the sandy soil and from 135 to 40 mg/pot in the caly one as the salinity increased from EC_e 4 to 16 dSm^{-1} in both soils.

As for the role of the clay fraction; K-uptake was high significantly correlated (r = 0.491***) with increasing the clay content (from 2.32 up to 57.98%) in soil models. The rate of increase in K-uptake, corresponding to each 1.0% of clay was about 1.23 mg/pot.

Such composited relation is reflected clearly through the equation ;

K-uptake = 116.00 - 5.59 EC + 1.20 clay (R = 0.968***)

*** Na-uptake:**

Data presented in Table (13) and shown in Fig. (4) indicate that the Na-uptake by barley plants was highly significant (-0.648***) reduced with increasing soil salinity of soil models from EC_e 4 up to 24 dSm^{-1}. Each unit increase in salinity above 12 dSm-1 reduced Na-uptake by 0.93 mg/pot. Similar results were obtained by Lashin and Atanasui (1972), Wouters (1974), Table (12) : Total uptake of potassium (mg/pot) by barley plants in relation to soil salinity.

Soil model	Control	EC (dSm^{-1}) 4	8	12	16	20	24	Average
S1	103.22	84.70	59.97	43.40	17.76	8.06	4.32	36.36
S2	119.68	91.39	62.70	52.39	28.81	20.66	9.72	44.27
S3	128.14	104.73	87.58	76.57	45.90	29.15	16.50	60.23
S4	137.17	126.35	98.34	85.87	56.47	35.67	21.06	70.62
S5	158.17	144.38	103.02	105.00	64.79	35.28	25.38	79.64
S6	181.09	159.60	128.80	101.40	67.50	34.50	37.51	88.21
S7	187.79	173.20	125.78	106.33	75.25	47.79	38.40	94.50
S8	196.20	187.20	136.29	134.40	87.12	52.39	42.24	105.10
Average	151.42	133.90	100.30	88.20	54.40	32.90	24.40	72.37

Table (13) : Total uptake of sodium (mg/pot) by barley plants in relation to soil salinity.

Soil model	Control	EC (dSm^{-1}) 4	8	12	16	20	24	Average
S1	13.28	19.36	19.33	13.02	9.98	7.75	9.45	13.14
S2	15.23	16.80	20.90	15.21	13.76	15.70	12.42	15.79
S3	15.79	17.41	26.70	23.47	13.77	22.26	14.25	19.64
S4	15.63	20.94	27.83	24.93	14.84	17.84	12.56	18.99
S5	17.48	25.80	34.85	25.50	16.72	18.90	11.75	22.25
S6	18.31	25.94	40.48	27.04	21.38	15.18	12.10	23.68
S7	18.57	29.01	38.70	28.13	20.53	17.01	12.29	22.61
S8	18.75	30.42	43.37	30.72	21.42	16.90	12.54	25.89
Average	16.63	23.30	31.50	23.40	16.60	16.40	12.20	19.12

Janardhan *et al.* (1979) and Lal and Lal (1990) who found that sodium uptake by wheat plants reduced with increasing salinity of irrigation water from EC 4 to 8 dSm^{-1}.

Concerning the effect of the caly fraction, Na-uptake, very high significantly (r = 0.549***) increased as the clay content increased in the tested soil models (from 2.32 up to 57.98%). The rate of increase in Na-uptake, corresponding to each 1.0% clay was about 0.21 mg Na/pot.

Such composited relation is reflected clearly through the multiple regression equation;

Na-uptake = 22.2 -0.596 EC + 0.185 caly (R = 0.849***)

*** Ca-uptake:**

Results obtained in Table (14) and Fig. (4) reveal that Ca-uptake by barley plants, significantly and gradually decreased (from 34.90 down to 21.20 mg/pot) with increasing soil salinity from EC_e = 4 up to 24 dSm^{-1}, that is because the main source of salinity was Na^+ (Na^+/Ca^{2+} equivalent ratio was 1.5/1.0). The rate of reduction in Ca-uptake by plants was 0.68 mg/pot for each unit of increase in soil salinity above 4 dSm^{-1}. Almost similar results were obtained by Dravid and Goswami (1986) and Lal and Lal (1990) who found that calcium uptake by wheat plants was significantly reduced as the soil salinity incraesed from EC 0.5 to 14.9 mmhos/cm.

With respect to the effect of the clay fraction on Ca-uptake under different levels of soil salinity, a very high significant positive (r = 0.811***) relation was achieved for Ca-uptake and soil content of the clay fraction. The rate of increase in Ca-uptake was 0.49 mg/pot for each 1.0% increase in soil content of clay above 2.32%.

The combined effect of soil salinity and clay fraction is described by the equation;

Ca-uptake = 23.20 - 0.591 EC + 0.484 clay (R = 0.888***)

*** Mg-uptake:**

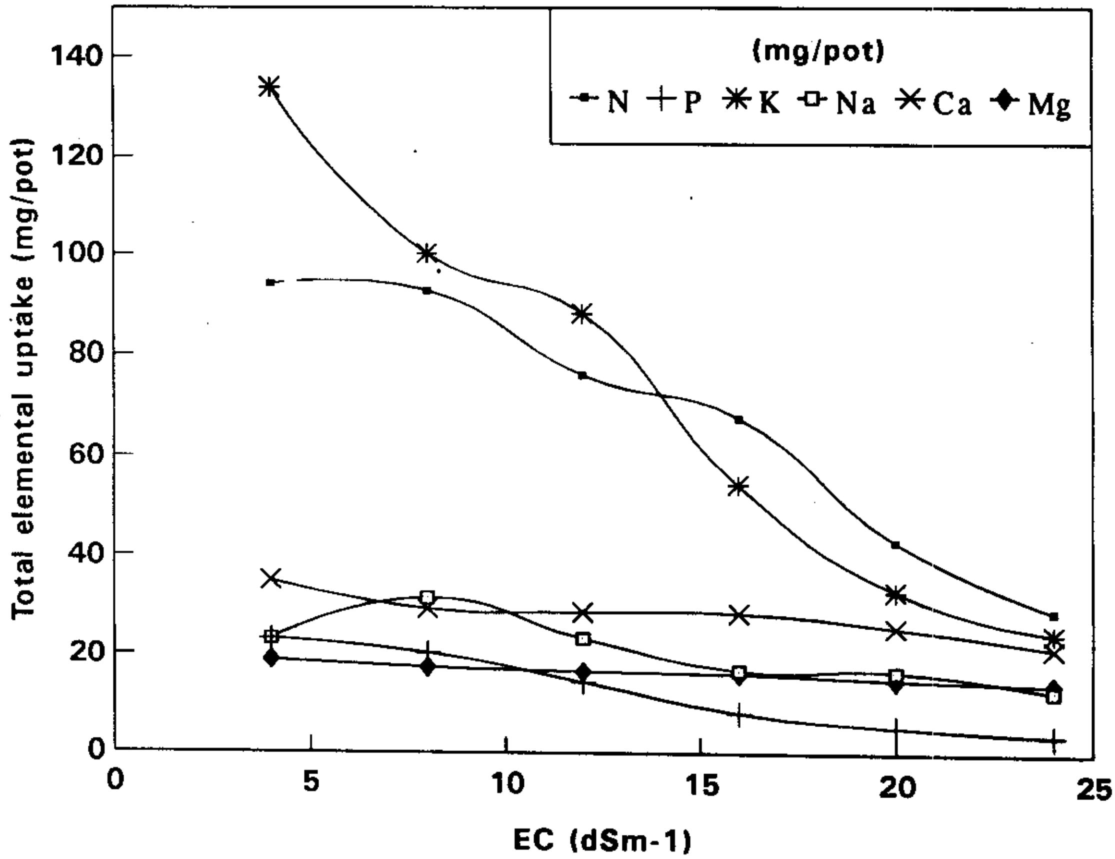
Data presented in Table (15) and illustrated in Fig. (4) show that the Mg-uptake by barley plants slightly decreased; from 18.80 down to 13.70 mg/pot, with increasing soil salinity from EC_e = 4 to 24 dSm^{-1}. Almost similar trends were obtained by Francois *et al.* (1986) and Dravid and Goswami (1986) who

Table (14) : Total uptake of calcium (mg/pot) by barley plants in relation to soil salinity.

Soil model	Control	EC (dSm^{-1}) 4	8	12	16	20	24	Average
S1	20.79	19.36	16.11	17.36	8.55	6.82	4.86	12.18
S2	24.48	19.76	15.20	18.15	14.48	15.12	9.72	15.41
S3	26.28	26.55	26.70	26.50	26.01	23.32	12.00	23.51
S4	31.90	36.10	29.80	30.50	30.77	24.60	17.82	28.27
S5	48.36	38.50	30.30	34.00	35.77	27.72	23.50	31.36
S6	51.74	39.90	40.48	33.80	35.53	33.12	32.67	35.92
S7	54.86	47.36	38.70	30.87	36.00	35.64	34.56	37.23
S8	56.68	51.48	37.17	38.40	37.76	38.87	34.32	39.67
Average	39.48	34.90	29.30	28.70	28.50	25.65	21.20	27.98

Table (15) : Total uptake of magnesium (mg/pot) by barley plants in relation to soil salinity.

Soil model	Control	EC (dSm^{-1}) 4	8	12	16	20	24	Average
S1	9.32	14.52	10.74	7.44	6.84	2.98	4.21	7.79
S2	13.60	14.82	13.40	10.17	9.46	9.50	8.42	10.96
S3	17.88	17.70	15.82	13.84	13.52	13.99	10.80	14.28
S4	19.14	17.33	15.90	16.62	16.10	16.24	11.66	15.64
S5	22.32	18.48	16.54	17.00	18.25	18.14	12.41	16.80
S6	23.88	23.94	20.80	20.28	19.00	19.87	20.33	20.71
S7	30.38	20.78	21.93	22.15	20.70	17.50	21.50	20.76
S8	31.39	22.46	22.87	24.00	23.22	18.25	20.59	21.90
Average	20.99	18.80	17.25	16.43	15.89	14.60	13.70	16.10



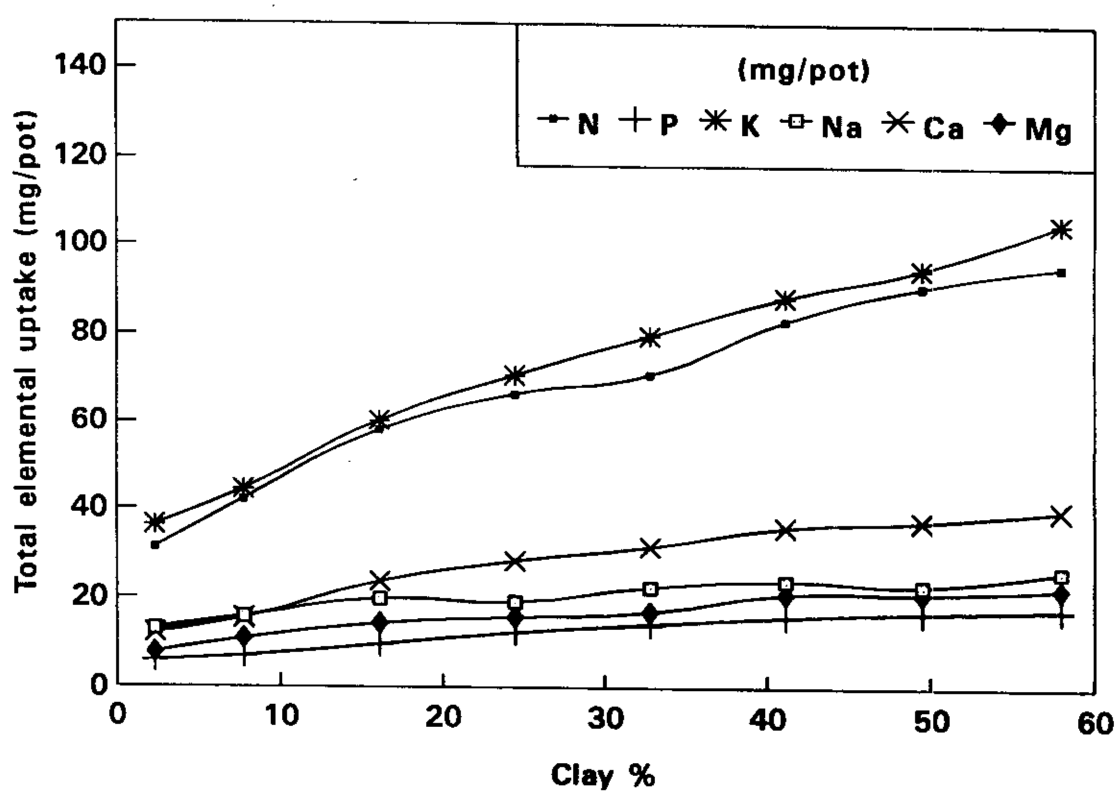


Fig (4) Total elemental uptake (mg/pot) by barley plants grown under saline condition.

reported that magnesium uptake by wheat plants significantly decreased with increasing soil, salinity up to 14.9 dS/m.

Concerning the role of the clay fraction on Mg-uptake by barley plants, Mg-uptake very high significantly (r = 0.786***) increased as the clay fraction increased (from 2.32 to 57.98%); according to the equation;

Mg-uptake = 11.40 - 0.155 EC + 0.243 clay (R = 0.807***)

Such reduction of element uptake under saline conditions could attributed to the decraese in dry matter accumulation and, to some extent, to the harmful effects of salinity that may be due to the toxicity of one or more specific ion present in higher concentration (Strogonov, 1964).

4.1.2.3. Hazardous effects due to soil salinity on dry matter yield of barley plants:

The hazardous effects due to soil salinity on soil productivity was evaluated using a series of saline soil models having ESP 10 and EC values from 4 up to 24 dSm^{-1} where salinity was developed through the application of $CaCl_2$ and NaCl at a constant aquivalent ratio (1:1.5).

The soil productivity was measured in terms of dry matter yield (g/pot) of barley plants grown on these soils. Data obtained are presented in Table (16) and illustrated in Fig. (5). Results indicate that the dry matter yield of barely grown on the tested soil models, gradually and significantly (r = -0.813***) decreased (from 3.54 down to 0.89 g/pot), by increasing soil salinity (from EC_e 4 up to 24 dSm^{-1}). The rate of reduction in dry matter yield of barley plants grown on the tested soil models, corresponding to each unit of increasing soil salinity was about 0.13 g/pot.

However, increasing the soil salinity from EC_e 4 up to 12 dSm^{-1} resulted in a reduction in the maximum yield, on average, by about 23%, meanwhile the next level of salinity (EC_e 16 dSm^{-1}), showed the most drastic reduction (about 51%), which may suggest that the critical level cultivar Giza 123 of soil salinity could be around EC 16 dSm^{-1}, with respect to barley (Giza 123).

These results are in agreement with those obtained by El-Bagouri (1980), Zwaik (1980), Grieve and Maas (1988), Francois and Kleiman (1990), El-Ghanam (1993), Bayoumi *et al.* (1994). Ball *et al.* (1984) who found that

Table (16): Dry matter yield of barley plants (g/pot) in relation to soil salinity.

Soil model	Control	EC (dSm^{-1})						
		4	8	12	16	20	24	Average
S1	2.23	2.42	1.79	1.24	0.57	0.31	0.27	1.10
S2	2.72	2.47	1.90	1.69	0.86	0.72	0.54	1.36
S3	2.98	2.95	2.67	2.47	1.53	1.06	0.75	1.90
S4	3.19	3.61	2.98	2.77	1.81	1.23	0.81	2.20
S5	3.72	3.85	3.03	3.00	2.09	1.26	0.94	2.36
S6	3.98	3.99	3.68	3.38	2.25	1.38	1.21	2.64
S7	4.22	4.33	3.87	3.43	2.36	1.62	1.28	2.81
S8	4.36	4.68	4.13	3.84	2.52	1.69	1.32	2.86
Aver.	3.44	3.54	3.01	2.73	1.75	1.16	0.89	2.13

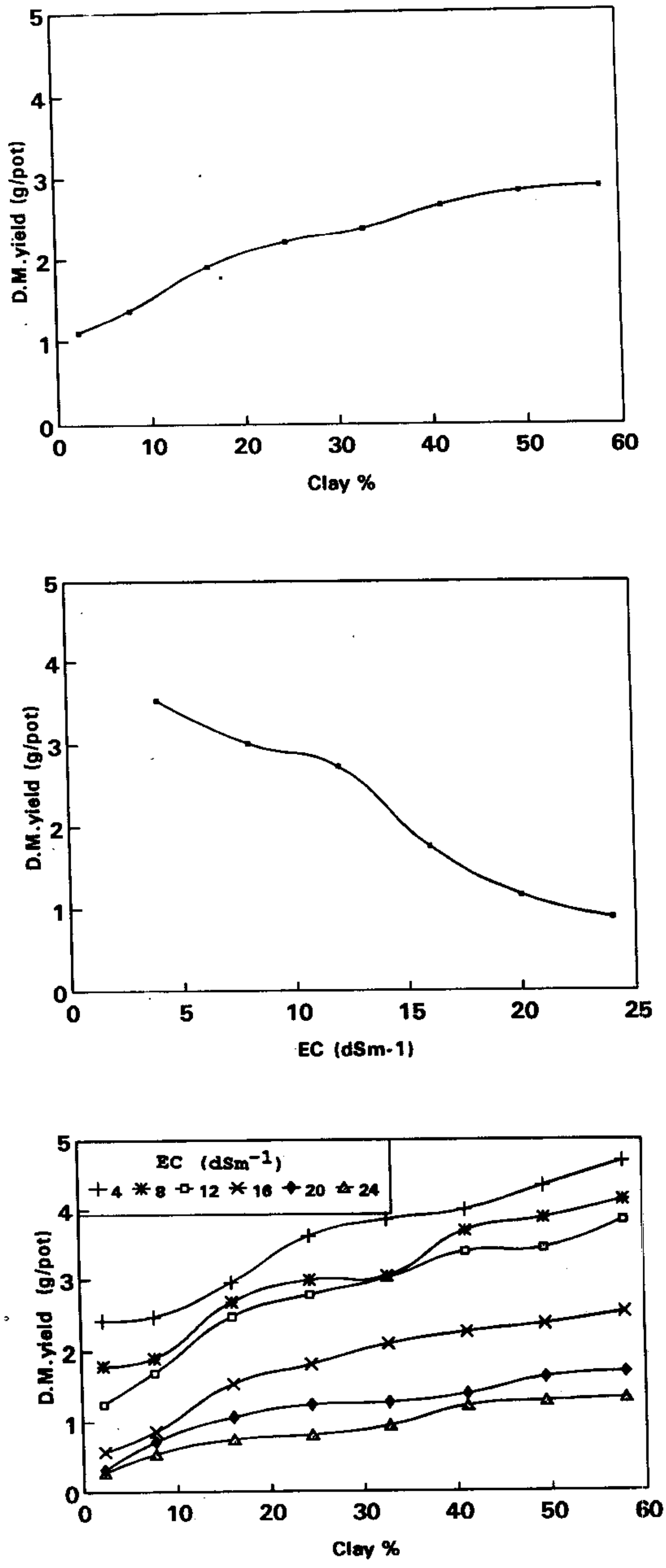


Fig. (5) Dry matter yield of barley plants (g/pot) in relation to soil salinty.

Table (17): Dry matter yield of barley plants (g/pot) in relation to EC (dSm^{-1}) and clay (%) of soil models.

Type of relation	Equation	Correlation coefficient
Simple relation	$Y = 4.16 - 0.141\ X_1$ $Y = 1.20 + 0.0338\ X_2$	-0.813^{***} 0.530^{***}
Multiple relation	$Y = 3.18 - 0.141\ X_1 + 0.0337\ X_2$	0.970^{***}
Variables under study	Y = D.M. yield of barley plants (g/pot). X_1 = EC (dSm^{-1}). X_2 = Clay %.	
Contribution of factors	EC = 69.87%. Clay = 29.74% Other factors = 0.39%	

*** = Significant at level of 0.001.

barley plants were grown economically till the EC of irrigation water reached 16 dSm^{-1}, where the average reduction in grain yield was 43% as compared to yield obtained under irrigation with water of EC 2.2 dSm^{-1}.

Concerning the role of the clay fraction, results show that it soundly lowered the adverse effect due to soil salinity on dry matter yield of barley plants and hence this yield was increased regularly under all the tested salinity levels, as the caly content increased. The dry matter yielded steadily increased (from 1.10 up to 2.86 g/pot) with increasing the caly content in tested soil models (from 2.32 up to 57.98%) i.e. at a rate of $\simeq$ 0.031 g/pot corresponding to each 1.0% increase in the clay fraction. Accordingly it may be concluded that the dry matter yield of soils is affected negatively by soil salinity and positively by the clay content.

Results show that the maximum increase in dry matter yield of barley plants due to the highest level of clay content (57.98%) amounted to about 93% and 388% under EC_e values of 4 and 24 dSm^{-1}, respectively, with a general average of about 160%.

This composited relation is reflected through the multiple regression equation developed for these parameters presented in Table (17) which state that:

$$\text{D.M. yield} = 3.18 - 0.141\ \text{EC} + 0.0337\ \text{clay} \qquad (R = 0.970^{***})$$

Finally, it is noteworthy to observe that the soil salinity level of EC_e 4 dSm^{-1} increased the dry matter yield of barley plants as compared with the control level of soil salinity (1.4 to 1.5 dSm^{-1}); regardless of the soil content of the clay fraction. Such results could be attributed to a unique behaviour restricted to salt-tolerant types of plants such as barley cultivar Giza 123.

4.2. Different relations of sodic soils:

4.2.1. Soil sodicity in relation to soil characteristics and soil productivity:

4.2.1.1. Soil sodicity in relation to soil hydraulic conductivity:

Data presented in Table (18) and illustrated in Fig. (6) show that values of relative hydraulic conductivity of the studied soil models were progessively reduced from 16.5 down to 2.48%, with increasing soil sodicity from ESP = 10 up to 50. This trend means that the relative hydraulic conductivity of tested soil

Table (18): Relative hydraulic conductivity (%) in relation to soil sodicity (control 100).

Soil model	ESP							Average
	10	15	20	25	30	40	50	
S1	48.70	40.52	40.52	25.97	21.87	20.56	17.390	30.79
S2	33.86	30.80	26.21	23.44	20.24	19.95	1.920	22.35
S3	20.79	16.60	9.40	5.09	5.03	2.54	0.370	8.55
S4	8.71	8.51	8.06	4.84	2.11	0.79	0.031	4.72
S5	6.92	6.73	6.10	4.26	1.88	0.58	0.026	3.79
S6	5.41	4.03	3.73	3.03	1.39	0.24	0.025	2.55
S7	4.02	3.95	3.39	2.91	1.20	0.20	0.025	2.24
S8	3.61	3.46	3.21	2.66	1.05	0.17	0.020	2.03
Average	16.50	14.33	12.58	9.03	6.85	5.60	2.480	9.63

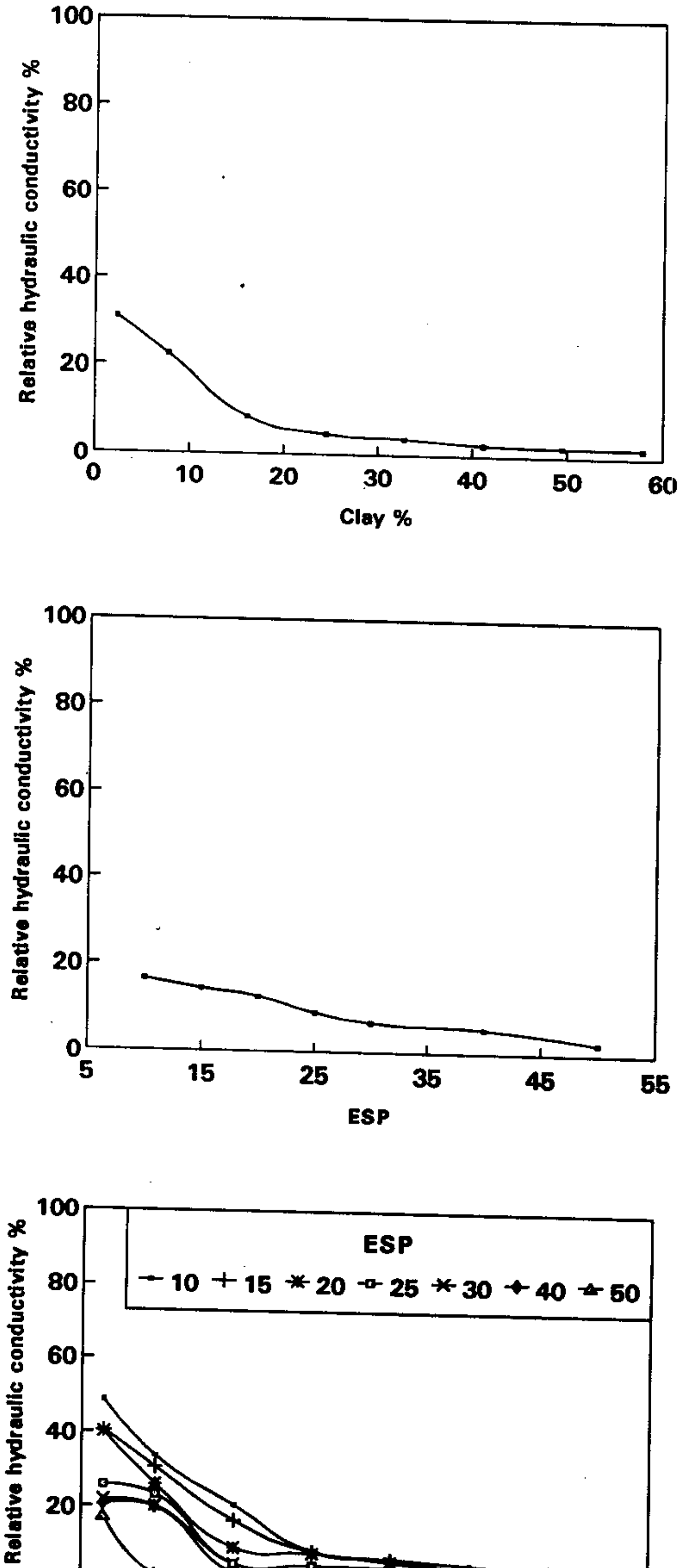


Fig (6) Relative hydraulic conductivity (%) in relation to soil sodicity.

Table (19): Hydraulic conductivity (cm/h) in relation to ESP and log of clay (%) in sodic soil models.

Type of relation	Equation	Correlation coefficient
Simple relation	$Y = 1.14 - 0.0184\,X_1$	$-0.179^{n.s.}$
	$Y = 3.95 - 2.54\,X_2$	-0.843^{***}
Multiple relation	$Y = 4.45 + 0.0184\,X_1 - 2.54\,X_2$	0.862^{***}
Variables under study	Y = Hydraulic conductivity. X_1 = ESP. X_2 = Log of clay %.	
Contribution of factors	ESP = 2.52% Clay = 84.88% Other factors = 12.60%	

n.s. = Non significant.
*** = Significant at level of 0.001.

models, on average, decreased at a rate of 0.35% for each ESP unit through the tested ESP range.

These results agree well with those obtained by Quirk and Schofield (1955), Mc Neal and Coleman (1966), Mc Neal *et al.* (1968), Varallay (1974), Schainberg *et al.* (1981) and Rizk (1986).

Regarding the role of the clay fraction, the relative hydraulic conductivity was depressed from 30.79 down to 2.03% with increasing the clay content of soil models from 2.32 up to 57.98% i.e. at a rate of 0.50% for each 1% of clay.

The reduction in hydraulic conductivity could be attributed to clay swelling, dispersion and the subsequent plugging of conducting pores by the dispersed clay and failure of soil aggregates (Quirk and Schofield, 1955).

These results are in accordance with those obtained by Frenkel *et al.* (1978), Pupisky and Shainberg (1979), Oster *et al.* (1980) and Alprovitch *et al.* (1985) who found that the relative hydraulic conductivity of wyoming montmorillonite-sand mixtures equilibrated with 10 mol/m^3 Na^+-Ca^{2+} solutions decreases as ESP increases.

Accordingly, one can expect that increasing the clay content of a given soil will induce the depressing effect due to soil sodicity on its hydraulic conductivity.

Such composited relation is reflected through the multiple regression equation developed for these parameters Table (19) which state that:

$$K = 4.45 - 2.54 \log clay - 0.0184\ ESP \quad (R = 0.862^{***}).$$

4.2.1.2. Soil sodicity in relation to soil pH:

The development of high pH in soil is influenced by Na^+ ions is one of the major problems associated with the management of soils in arid and semi-arid regions (USSLS, 1954 and Yaron *et al.*, 1973).

Data presented in Table (20) and graphically illustrated in Fig. (7) show that the pH of sodic soil models tested was significantly ($r = 0.877^{***}$) and gradually increased; from 8.39 up to 9.66, with increasing soil sodicity from

Table (20) : Soil pH in relation to soil sodicity.

Soil model	Control	ESP 10	15	20	25	30	40	50	Average
S1	8.46	8.82	9.18	9.26	9.39	9.56	9.75	9.92	9.41
S2	8.35	8.62	8.99	9.16	9.28	9.47	9.62	9.80	9.28
S3	8.27	8.49	8.77	8.97	9.12	9.36	9.53	9.69	9.13
S4	8.24	8.39	8.71	8.86	9.05	9.21	9.44	9.66	9.05
S5	8.22	8.26	8.57	8.77	8.59	9.19	9.42	9.63	8.97
S6	8.20	8.21	8.54	8.66	8.92	9.10	9.33	9.58	8.91
S7	8.17	8.18	8.43	8.64	8.84	9.08	9.28	9.55	8.86
S8	8.12	8.13	8.39	8.60	8.75	9.00	9.22	9.45	8.79
Average	8.25	8.39	8.70	8.87	9.04	9.25	9.45	9.66	9.05

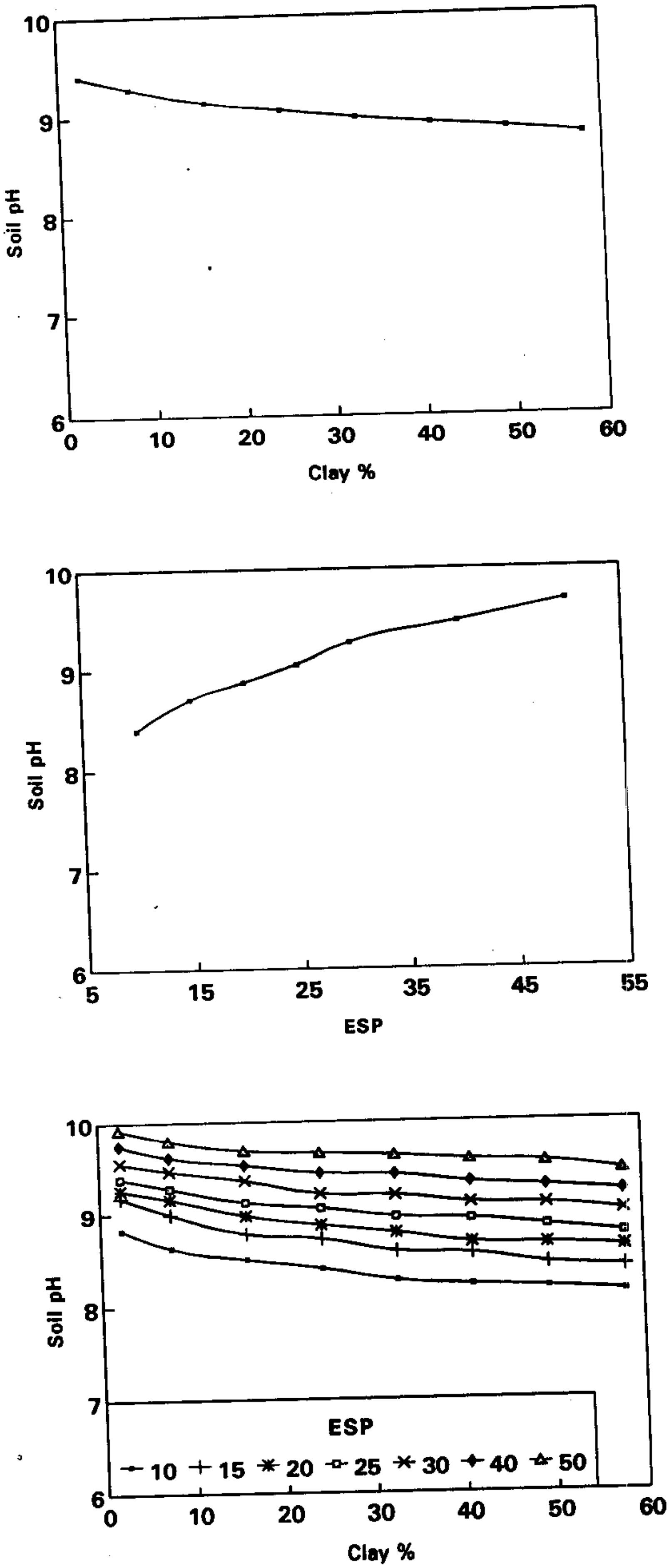


Fig. (7) Soil pH in relation to soil sodicity.

The net combined effect resulted from the simultaneous increases in ESP and clay content on plant N% is expressed through equation;

$$\text{N-content} = 2.54 + 0.0106 \text{ clay} - 0.00197 \text{ ESP} \quad (R = 0.621^{***})$$

This equation means that the abundance of the clay fraction in soils dilutes or reduces the effect due to soil sodicity on plant content of N in a highly significant relation.

*** P-content:**

Results obtained in Table (22) and Fig. (8) reveal that P-content in barley plants grown on the tested soil models was clearly and gradually reduced (from 0.714 down to 0.533%) by increasing soil sodicity (from ESP = 10 up to 50). The rate of reduction in P-content of plants, corresponding to each increasing ESP unit was, on average, about 0.004%. Almost similar results were obtained by Omar (1970) who found that P-content in barley plants decreased with increasing ESP from 15 up to 30 in the culture media.

With respect to the role of the clay fraction, it tended also to reduce the P% of plants steadily, but at a rate of 0.0008% P per each 1% clay.

According to these results, it may be concluded that the increasing presence of the clay fraction in Delta soils slightly induce the adverse effect of soil sodicity on P% of barley plants, according to the equation;

$$\text{P\%} = 0.799 - 0.000509 \text{ clay} - 0.00464 \text{ ESP} \quad (R = 0.663^{***})$$

*** K-content:**

Data in Table (22) and shown in Fig. (8) indicate that K-content in barley plants grown on the tested soil models sharply and consistently decreased i.e. from 3.70 down to 1.50% by increasing soil sodicity from ESP 10 up to 50.

The rate of reduction in K-content in plants, corresponding to each ESP unit was about 0.055%. These results are in accordance with those obtained by Martin and Bingham (1954), Bernstein and Pearson (1956), El-Ghanam (1993) and Omar (1970) who found that K-content of barley plants was reduced by increasing the ESP values from 5 up to 40 in the culture media.

Concerning the effect due to the clay fraction, on K-content of plants, this content positively and gradually responded to the abundance of clay, as it

Table (23): Sodium, calcium and magnesium content (%) of barley plants in relation to soil sodicity.

Soil model	Control	ESP				
		10	20	30	50	Average
Sodium						
S1	0.57	0.80	1.25	1.70	2.60	1.59
S2	0.56	0.76	1.20	1.65	2.55	1.54
S3	0.53	0.73	1.10	1.70	2.65	1.55
S4	0.49	0.62	1.05	1.60	2.45	1.43
S5	0.47	0.61	1.06	1.65	2.35	1.42
S6	0.46	0.63	1.05	1.60	2.30	1.40
S7	0.44	0.63	1.05	1.55	2.25	1.37
S8	0.43	0.64	1.00	1.50	2.20	1.34
Average	0.49	0.68	1.09	1.62	2.41	1.45
Calcium						
S1	0.90	0.70	0.70	0.50	0.31	0.55
S2	0.90	0.70	0.70	0.60	0.40	0.60
S3	0.90	0.70	0.80	0.60	0.40	0.63
S4	1.00	0.80	0.80	0.80	0.50	0.73
S5	1.30	0.80	0.90	0.80	0.60	0.78
S6	1.40	1.00	1.00	0.80	0.60	0.85
S7	1.30	1.10	1.00	0.90	0.70	0.93
S8	1.30	1.10	1.00	0.90	0.70	0.93
Average	1.13	0.86	0.83	0.71	0.53	0.75
Magnesium						
S1	0.40	0.36	0.48	0.36	0.24	0.36
S2	0.50	0.36	0.48	0.36	0.24	0.36
S3	0.60	0.48	0.48	0.48	0.36	0.45
S4	0.60	0.60	0.48	0.48	0.30	0.46
S5	0.60	0.60	0.36	0.48	0.30	0.45
S6	0.60	0.50	0.48	0.36	0.36	0.43
S7	0.72	0.60	0.48	0.36	0.36	0.45
S8	0.72	0.60	0.48	0.36	0.36	0.45
Average	0.59	0.54	0.47	0.41	0.31	0.43

*** Mg-content:**

Results in Table (23) and Fig. (8) indicate that Mg-content in barley plants grown on the tested soil models was clearly and consistently reduced (from 0.54 down to 0.31%) as the soil sodicity increased from ESP = 10 up to 50. The rate of reduction in Mg-content corresponding to each ESP unit was about 0.005%. Similar results were obtained by Martin and Ervin (1957) and Omar (1970) who found that Mg-content in barley plants markedly decreased with increasing the ESP from 10 to 50.

As for the effect of the clay fraction, the Mg-content of barley plants gradually increased; from 0.36 up to 0.45% with incresaing the clay content in the tested soil models from 2.32 up to 57.98%.

The combined effect of soil sodicity and clay content in soils is described by the equation;

$$Mg\% = 0.555 + 0.00103 \text{ clay} - 0.00558 \text{ ESP} \qquad (R = 0.826^{***})$$

4.2.2.2. Soil sodicity in relation to elemental uptake by barley plants:

*** N-uptake:**

Data presented in Table (24) and graphically illustrated in Fig. (9) indicate that N-uptake by barley plants grown on the tested soil models sharply decreased (from 106.32 down to 64.68 mg/pot) by increasing the soil sodicity from ESP 10 up to 50, i.e. at a rate of 1.04 mg N versus each ESP unit.

These results are in accordance with those obtained by El-Shakweer and Barakat (1984), Omar (1970) and El-Ghanam (1993) who found that N-uptake by corn plants was reduced with increasing soil sodicity from ESP 10 up to 25.

Concerning the effect of clay content, results show that N-uptake by barley plants was positively affected with increasing the caly content in soil (up to 57.98%), i.e. at a rate of 1.28 mg N per 1% clay.

The combined effect due to the soil sodicity and clay content is represented by the equation;

$$\text{N-uptake} = 78.7 - 1.04 \text{ ESP} + 1.29 \text{ clay} \qquad (R = 0.989^{***})$$

This trend may suggest that the existence of the clay fraction in the soil can improve the adverse effect of soil sodicity on N-uptake by plants.

Table (24): Total uptake of nitrogen, phosphorus and potassium (mg/pot) by barley plants in relation to soil sodicity.

Soil model	Control	ESP				
		10	20	30	50	Average
Nitrogen						
S1	78.29	71.40	64.12	55.33	23.74	53.65
S2	92.48	77.62	72.80	61.29	36.57	62.07
S3	100.13	82.61	80.26	65.00	50.83	69.68
S4	107.18	96.14	89.01	78.96	61.88	81.50
S5	124.99	113.84	91.84	86.37	73.15	91.30
S6	133.73	124.43	103.60	94.36	76.34	99.68
S7	147.70	142.22	123.48	113.78	91.17	117.66
S8	152.60	142.32	134.90	119.70	103.78	125.18
Average	117.14	106.32	95.00	84.35	64.68	87.59
Phosphorus						
S1	16.45	20.60	17.72	14.66	5.60	14.65
S2	20.89	19.27	19.66	15.98	10.92	16.57
S3	20.80	18.83	20.28	18.00	14.63	17.94
S4	22.01	23.41	21.96	20.40	15.08	20.21
S5	25.67	24.01	25.06	22.03	11.77	20.72
S6	28.97	27.47	25.75	19.48	15.77	22.12
S7	28.19	33.70	25.79	28.44	12.67	25.15
S8	31.18	32.00	29.52	29.45	18.67	27.41
Average	24.27	24.91	23.22	21.06	13.14	20.60
Potassium						
S1	103.22	91.80	76.03	47.84	13.25	57.23
S2	119.68	95.57	80.60	52.21	19.40	61.95
S3	128.14	101.16	91.46	63.75	27.63	71.00
S4	137.17	114.45	93.93	81.49	35.10	72.47
S5	158.10	138.96	105.62	75.50	38.78	89.72
S6	181.09	151.10	111.00	77.51	40.18	94.95
S7	187.79	161.63	134.40	112.23	59.20	116.87
S8	196.20	176.80	146.73	115.71	82.96	130.55
Average	151.42	128.90	103.80	78.30	39.60	86.84

*** P-uptake:**

The obtained results in Table (24) and Fig. (9) reveal that P-uptake by barley plants grown on the tested soil models was adversely affected with increasing soil sodicity from ESP = 10 up to 50. The rate of reduction in P-uptake was about 0.29 mg P/pot per each unit increase in ESP above 10. Similar results were obtained by El-Ghanam (1993) and Omar (1970) who found that the P-uptake by barley plants decreased with increasing ESP values from 10 up to 40 in the culture media.

With respect to the effect of clay content, results show that P-uptake by barley plants was significantly affected with increasing the clay content. The rate of incraese in P-uptake, corresponding to each 1% clay was 0.23 mg P/pot. This combined relation is represented by the equation;

P-uptake = 21.6 - 0.296 ESP + 0.231 clay (R = 0.926***)

*** K-uptake:**

Data obtained in Table (24) and Fig. (9) show that the K-uptake by barley plants grown on the tested soil models was sharply depressed (from 128.90 to 39.60 mg/pot) by increasing the soil sodicity from 10 uo to 50, i.e. at a rate of about 2.23 mg K/pot corresponding to each ESP unit.

These results are in agreement with those of El-Gabaly (1955), Martin *et al.* (1961), El-Ghanam (1993) and Omar (1970) who found that increasing ESP values from 10 to 40% decreased K-uptake by barley plants.

Concerning the effect of the clay fraction, K-uptake by barley plants was significantly increased (from 57.23 up to 130.55 mg/pot) with increasing the caly content in soil models (from 2.32 to 57.98).

The combined effect of soil sodicity and the clay fraction is described by the equation;

K-uptake = 111.0 - 2.23 ESP + 1.30 clay (R = 0.983***)

*** Na-uptake:**

Results in Table (25) and shown in Fig. (9) indicate that Na-uptake by barley plants was significantly (r = 0.827***) increased (from 23.20 up to 59.27 mg/pot) with increasing soil sodicity from ESP 10 up to 50. The rate of increase in Na-uptake by plants, corresponding to each unit of ESP was about 0.9

mg/pot. These results are in harmony with those obtained by Bower and Wadleigh (1948), El-Gabaly (1955), Martin *et al.* (1961), Anter (1967) and Omar (1970) who found that Na-uptake by barley plants was progressively increased with increasing ESP up to 40.

Concerning the role of the clay content in soil models, Na-uptake by barley plants gradually increased (from 30.11 up to 52.40 mg/pot) with increasing the clay content (from 2.32 up to 57.98%).

This compoisted relation is described by the equation;

Na uptake = 5.29 + 0.896 ESP + 0.395 clay (R = 0.946***)

*** Ca-uptake:**

Studies of salt-affected soils have shown that increasing the exchangeable Na^+ abundance in soil, was accompanied by decreases in exchangeable Ca^{2+} which may result in ion imbalance that adversely affect plant growth and nutrient uptake (Cramer *et al.*, 1986).

Data obtained in Table (25) and graphically shown in Fig. (9) indicate that Ca-uptake by barley plants was adversely and consistently decraesed (from 31.14 down to 13.82 mg/pot) with increasing the soil sodicity (from ESP 10 up to 50). The rate of reduction in Ca-uptake, corresponding to each ESP unit was about 0.43 mg/pot. Similar trends were obtained by Bower and Wadleigh (1948), Martin and Ervin (1957) and Omar (1970) who found that the Ca-uptake by barley plants was markedly decreased with increasing ESP from 10 up to 40.

As for the effect of the caly fraction, Ca-uptake by plants was significantly (r = 0.778***) and gradually increased (from 11.87 up to 37.41 mg/pot) with increasing the clay content in soil (from 2.32 up to 57.98%). The rate of Ca-uptake reduction, corresponding to each 1% of clay content was about 0.46 mg Ca/pot.

The combined effect of soil sodicity and the caly fraction is described by the multiple regression equation;

Ca-uptake = 22.2 - 0.441 ESP + 0.466 clay (R = 0.973***)

Table (25): Total uptake of sodium, calcium and magnesium (mg/pot) by barley plants in relation to soil sodicity.

Soil model	Control	ESP				Average
		10	20	30	50	
Sodium						
S1	13.28	20.04	28.63	35.36	36.40	30.11
S2	15.23	20.06	28.92	37.47	40.55	31.75
S3	15.79	20.51	30.03	42.50	58.57	37.90
S4	15.63	20.27	30.35	44.96	63.70	39.82
S5	17.48	23.55	34.77	49.83	64.63	43.20
S6	18.31	25.45	38.85	53.92	66.01	46.06
S7	18.57	27.15	43.99	59.99	66.60	49.43
S8	18.75	28.29	43.80	59.85	77.66	52.40
Average	16.63	23.20	34.92	48.00	59.27	41.33
Calcium						
S1	20.79	17.85	16.03	10.40	3.18	11.87
S2	24.48	18.48	18.20	13.62	6.36	14.17
S3	26.82	19.67	21.84	15.00	8.84	16.34
S4	31.90	26.16	23.12	22.48	13.00	21.19
S5	48.36	30.88	29.52	24.16	16.50	25.27
S6	51.74	40.04	30.70	26.96	17.22	28.73
S7	54.86	47.41	40.20	27.09	20.72	33.86
S8	56.68	48.62	40.38	35.91	24.71	37.41
Average	39.48	31.14	27.50	21.95	13.82	23.60
Magnesium						
S1	9.32	9.18	10.99	7.49	2.54	7.55
S2	13.60	12.67	12.48	8.17	3.82	9.29
S3	17.88	16.86	13.10	12.00	7.96	12.48
S4	19.14	19.62	13.87	13.49	7.80	13.70
S5	22.32	23.16	11.81	14.50	8.25	14.43
S6	23.88	20.20	17.76	12.13	10.33	15.11
S7	30.38	25.86	20.16	13.93	10.66	17.65
S8	31.39	26.52	21.02	14.36	12.71	18.65
Average	20.99	19.26	15.15	12.01	8.01	13.61

*** Mg-uptake:**

The obtained data in Table (25) and Fig. (9) reveal that total uptake of magnesium by barley plants grown on the tested soil models sharply decreased (from 19.26 down to 8.01 mg/pot) with increasing soil sodicity (from ESP 10 up to 50) i.e. at a rate of 0.28 mg Mg/pot corresponding to each unit of ESP. Almost similar trends were obtained by Bower and Wadleigh (1948), Martin and Ervin (1957) and Omar (1970).

With respect to the role of the clay fraction, Mg-uptake significantly increased (from 7.55 to 18.65 mg/pot) with increasing the clay fraction existence (from 2.32 to 57.98%). The rate of increase in Mg-uptake, corresponding to each 1% of clay was about 0.2 mg Mg/pot.

In conclusion, the overall effects of soil salinity and sodicity in presence of different levels of clay fraction on Mg-uptake by barley plants, could be described as follows:

$$\text{Mg-uptake} = 15.7 - 0.275\ \text{ESP} + 0.187\ \text{clay\%} \quad (R = 0.933^{***})$$

4.2.2.3. Hazardous effects due to soil sodicity on dry matter yield of barley plants:

Plant growth is adversely affected in sodic soils due to one or more of the following factors:

i) Excess exhangeable sodium in sodic soils has a marked influence on the physical soil properties. As the proportion of exchangeable sodium increases, the soil tends to become more dispersed which results in the breakdown of soil aggregates and lowers the permeability of the soil to air and water. Dispersion also results in the formation of dense, impermeable surface crusts that hinder the emergence of seedlings.

ii) A second effect of excess exchangeable sodium on plant growth is through its effect on soil pH. Although high pH of sodic soils has no direct adverse effect on plant growth, it frequently results in lowering the availability of some essential plant nutrients.

iii) Accumulation of certain elements in plants at toxic levels may result in plant injury or reduced growth and even death. Elements more commonly toxic in sodic soils include sodium, molybdenum and boron.

Data presented in Table (26) and illustrated in Fig. (10) show that values of the dry matter yield of barley plants grown on the tested sodic soil models, were gradually and significantly (r = -0.478**) reduced (from 3.49 down to 2.44 g/pot) with increasing soil sodicity from ESP 10 up to 50). The rate of reduction in dry matter yield per each increasing ESP unit, was about 0.03 g/pot. However, increasing the soil sodicity (from ESP 10 up to 30) resulted in, on average, a reduction in the dry matter yield by 14%, meanwhile the next rate of sodicity (ESP 50) showed the most sharp reduction (i.e. about 30%). Such trend may suggest that the critical level of soil sodicity for barley cultivar Giza 123 could be around ESP value of 50.

Concerning the role of clay content, data show that the clay content lowered the adverse effect of soil sodicity on dry matter yield of barley plants and consequently the dry matter yield of barley plants grown on the tested sodic soil models, significantly increased from (2.00 up to 4.08 g/pot) with increasing the clay content in the tested soil models (from 2.32 up to 57.98%). The rate of increase in dry matter yield of barley plants, corresponding to each 1.0% clay was about 37 mg/pot.

These results are in agreement with those obtained by Omar (1970), Omer and Aziz (1982) and El-Ghanam (1993) who found that the dry matter yield of corn plants grown on sand and clayey soils was decreased from 2.74 down to 0.60 g/pot, and from 3.93 to 1.74 g/pot, respectively, as the soil sodicity incresaed from ESP 10 to 25. The unfavorable affect of high ESP levels on plant growth and dry matter yield can be due among other things, to sodium toxicity, due to the increase in its concentration in plants (Kelly and Thomas, 1928).

According to such results, it may be reasonable to state that the dry matter yield of barley plants is affected negatively by soil sodicity on one hand and positively by the clay content on the other hand.

This composited relation is represented by the multiple regression equation developed for these parameters (Table, 27) which state that:

$$\text{D.M. yield} = 2.68 - 0.0262\ \text{ESP} + 0.0374\ \text{clay} \quad (R = 0.983^{***})$$

Table (26): Dry matter yield of barley plants (g/pot) in relation to soil sodicity.

Soil model	Control	ESP				
		10	20	30	50	Average
S1	2.33	2.55	2.29	2.08	1.06	2.00
S2	2.72	2.64	2.60	2.27	1.59	2.28
S3	2.98	2.81	2.73	2.50	2.21	2.56
S4	3.19	3.27	2.89	2.81	2.60	2.89
S5	3.72	3.86	3.28	3.02	2.75	2.23
S6	3.98	4.04	3.70	3.37	2.87	3.50
S7	4.22	4.31	4.20	3.87	2.96	3.59
S8	4.36	4.42	4.38	3.99	3.53	4.08
Average	3.44	3.49	3.26	2.99	2.44	3.02

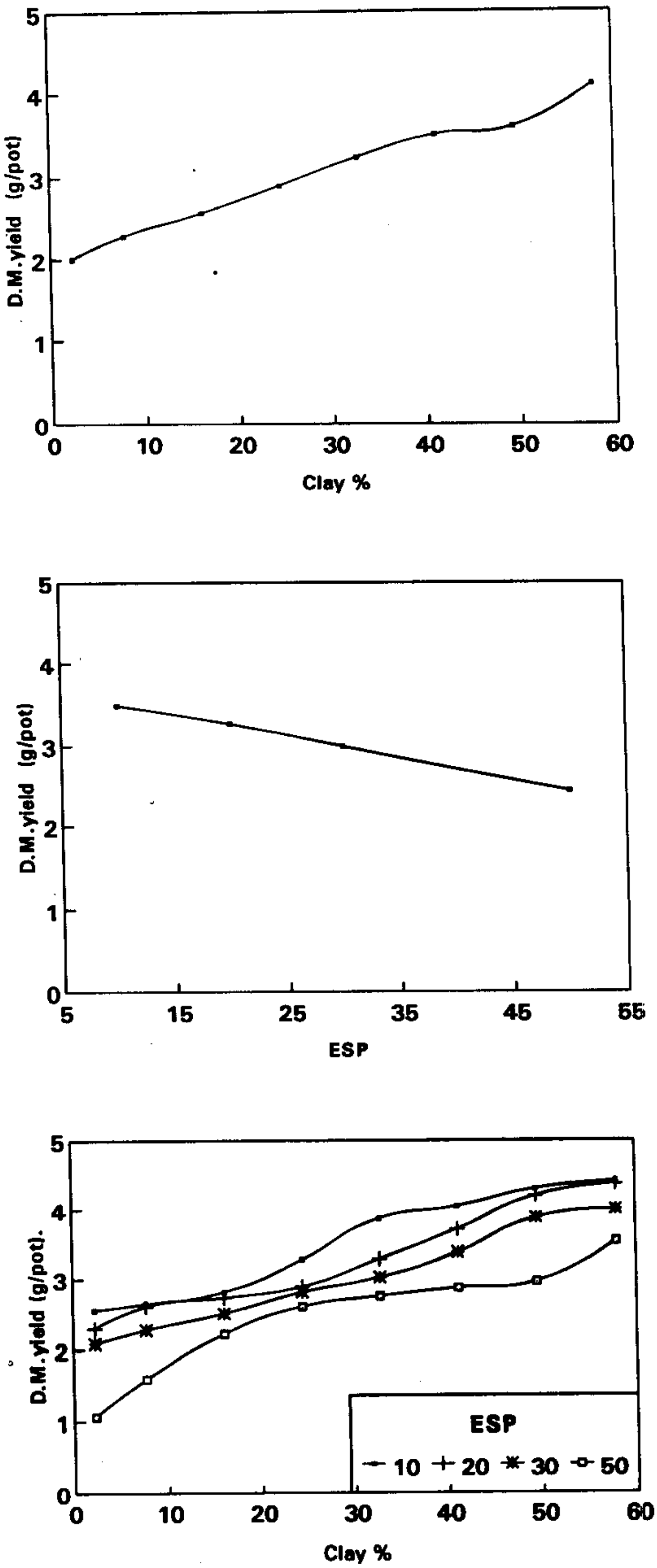


Fig (10) Dry matter yield of barley plants (g/pot) in relation to soil sodicity.

Table (27): Dry matter yield of barley plants (g/pot) in relation to ESP and clay (%) of soil models.

Type of relation	Equation	Correlation coefficient
Simple relation	$Y = 3.77 - 0.0262\ X_1$ $Y = 1.96 + 0.0374\ X_2$	-0.478** 0.858***
Multiple relation	$Y = 2.68 - 0.0262\ X_1 + 0.0374\ X_2$	0.983***
Variables under study	Y = D.M. yield of barley plants (g/pot). X_1 = ESP. X_2 = Clay %.	
Contribution of factors	ESP = 32.97%. Clay = 53.28% Other factors = 13.75%	

** = Significant at level of 0.01.
*** = Significant at level of 0.001.

4.3. Different relations of soil salinity combined with soil sodicity:

4.3.1. Combined effect of soil salinity and sodicity on soil characteristics and soil productivity:

4.3.1.1. Combined effect of soil salinity and sodicity on soil hydraulic conductivity:

Data presented in Table (28) and graphically illustrated in Fig. (11) show that the relative soil hydraulic conductivity clearly and gradually increased, on average, from 10.78 up to 31.32% with increasing soil salinity from EC_e = 4 up to 24 dSm^{-1}. The rate of the increase in relative hydraulic conductivity under saline-sodic conditions was about 1.03% per each unit increase in salinity above 4 dSm^{-1}. Similar trends were obtained by Zein EL-Abdine *et al.* (1968), Russo and Bresler (1977), Oster and Schroer (1979), Abd-Allah (1988), Lima *et al.* (1990) and Rizk *et al.* (1990) who found that the relative hydraulic conductivity increased with increasing salt concentration.

With regard to the effect of soil sodicity on hydraulic conductivity, the relative hydraulic conductivity clearly decreased with increasing soil sodicity from ESP 15 up to 50 at the different levels of EC although the relative hydraulic conductivity was increased with increasing soil salinity under the different levels of ESP. Similar trends were obtained by Qurik and Schofield (1955), Mc Neal and Coleman (1966), Mc Neal *et al.* (1968), Shalhevet and Kamburov (1976) and Bresler *et al.* (1982).

Concerning the role of the clay fraction the relative hydraulic conductivity clearly and gradually decreased (from 58.10 down to 6.94%) and (from 36.05 down to 9.51%) with increasing the clay fraction content in soils (from2.32 to 57.98%) and soil sodicity from ESP 15 up to 50.

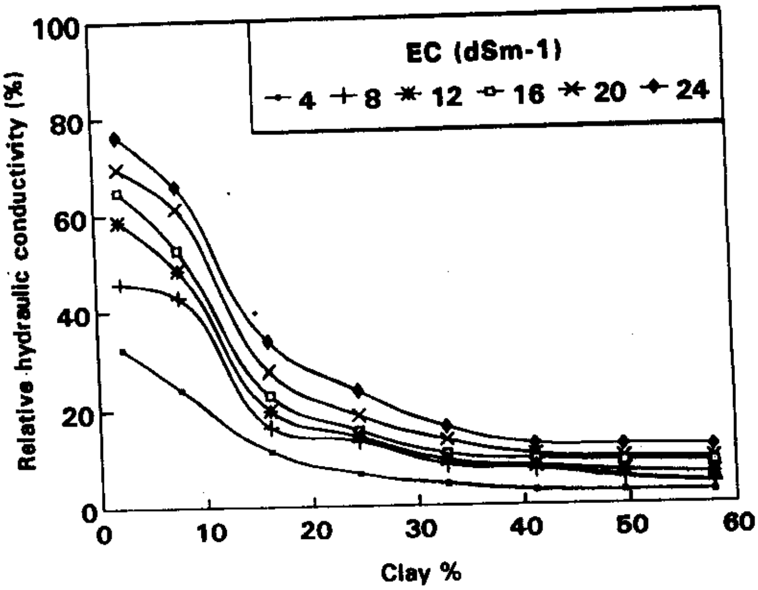
Values of the relative hydraulic conductivity clearly and consistently increased (from 10.78 up to 31.32%) with increasing soil salinity (from EC 4 up to 24 dSm^{-1}) under the tested levels of ESP and clay content. Similar trends were obtained by Mc Neal and Coleman (1966), Mc Neal *et al.* (1968), Russo and Bresler (1977), Abd-Allah (1988), Lima *et al.* (1990) and Rizk *et al.* (1990).

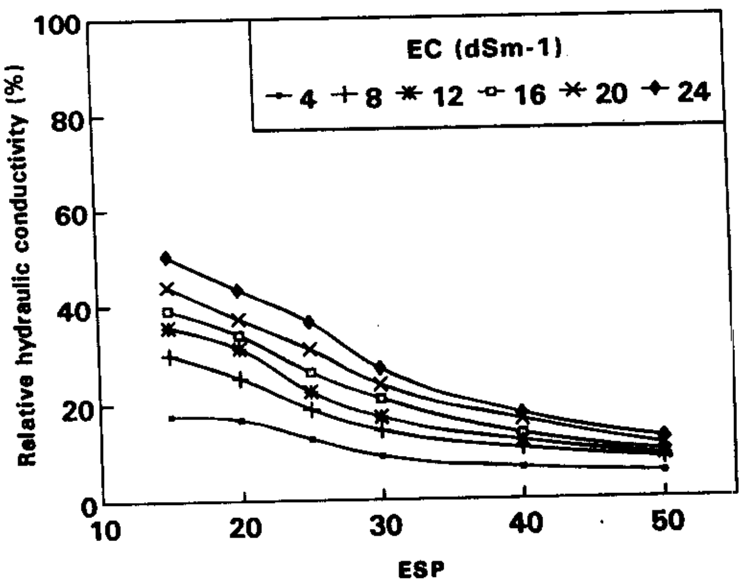
The net combined effect due to the simulitaneous increases of EC, ESP and clay contents on hydraulic conductivity is expressed through the multiple regression equation;

$$K = 7.12 + 0.0749\ EC - 0.0165\ ESP - 4.90 \log clay\ (R = 0.874^{***})$$

Table (28): Relative hydraulic conductivity (%) in relation to combined salinity and sodicity in soils (control 100).

Soil model	EC (dSm^{-1})	ESP 15	20	25	30	40	50	Average
S1		42.71	41.21	31.60	29.76	24.84	22.96	32.18
S2		41.51	39.18	30.38	23.97	21.83	18.39	24.14
S3		20.60	20.00	13.05	8.29	3.16	1.17	11.04
S4	4	11.73	11.13	9.33	4.29	1.47	0.32	6.38
S5		8.08	7.79	6.28	2.80	0.65	0.10	4.28
S6		5.76	5.11	4.65	1.87	0.25	0.07	2.95
S7		5.41	4.98	4.23	1.49	0.21	0.06	2.73
S8		5.14	4.86	3.71	1.14	0.18	0.06	2.51
Average		17.62	16.78	12.90	9.20	6.57	5.39	10.78
S1		60.98	53.42	46.68	42.40	39.47	35.01	46.32
S2		56.54	52.23	41.97	40.08	37.89	29.02	42.96
S#		30.33	28.63	20.57	12.19	4.10	1.41	16.21
S4	8	26.68	22.32	16.31	10.15	1.71	0.50	12.95
S5		19.61	15.40	8.84	3.21	0.76	0.34	8.03
S6		18.82	13.20	6.13	2.94	0.68	0.18	6.99
S7		14.11	8.14	5.27	2.86	0.62	0.16	5.19
S8		12.00	8.00	5.14	2.80	0.57	0.15	4.78
Average		29.88	25.17	18.86	14.58	10.73	8.35	17.93
S1		81.89	75.28	59.73	52.17	44.50	38.82	58.73
S2		61.28	59.73	50.71	49.16	42.86	30.11	48.98
S3		41.40	36.67	21.57	12.44	4.53	1.58	19.70
S4	12	29.72	23.27	17.14	11.12	1.82	0.57	13.94
S5		21.80	17.10	8.85	3.72	1.35	0.46	8.88
S6		19.20	14.40	7.39	3.17	1.23	0.32	7.62
S7		15.01	12.05	6.95	3.04	1.18	0.30	6.42
S8		13.57	10.71	6.43	2.96	1.14	0.29	5.85
Average		35.48	31.15	22.35	17.22	12.33	9.06	21.23
S1		86.17	77.08	70.50	60.53	51.96	43.87	65.02
S2		65.07	64.78	57.71	53.44	44.86	32.25	53.02
S3		46.60	40.50	24.28	18.66	4.96	1.69	22.78
S4	16	33.89	24.81	18.16	12.70	1.89	0.72	15.36
S5		24.18	17.32	11.63	5.98	1.80	0.44	10.23
S6		20.00	16.10	10.01	5.83	1.74	0.40	9.01
S7		18.63	15.43	9.22	5.17	1.73	0.38	8.43
S8		17.71	15.18	9.14	5.13	1.71	0.38	8.21
Average		39.03	33.90	26.33	20.93	13.83	10.02	24.01
S1		89.92	84.16	79.22	65.60	55.51	45.27	69.95
S2		74.59	73.13	65.44	61.42	52.27	40.49	61.22
S3		50.65	43.45	31.96	24.59	12.16	1.87	27.45
S4	20	42.61	26.63	22.81	13.30	5.26	0.88	18.58
S5		35.02	18.05	14.99	7.93	2.11	0.73	13.14
S6		21.13	17.40	12.14	6.10	1.98	0.68	9.91
S7		18.78	17.21	10.77	5.80	1.94	0.58	9.18
S8		18.20	17.10	10.36	5.29	1.82	0.57	8.89
Average		43.86	37.14	30.96	23.75	16.63	11.38	27.29
S1		93.47	92.77	87.67	74.76	61.71	48.01	76.40
S2		86.18	80.94	65.15	61.88	56.97	44.77	65.98
S3		66.45	52.12	41.46	22.17	12.46	5.39	33.34
S4	24	53.90	39.69	30.14	13.36	2.78	1.14	23.50
S5		38.87	23.19	18.76	11.68	2.60	1.02	16.02
S6		22.17	19.32	17.06	11.04	2.39	0.88	12.14
S7		21.38	19.00	16.68	10.85	2.08	0.74	11.79
S8		21.15	18.83	15.43	10.29	2.03	0.73	11.41
Average		50.45	43.23	36.54	27.00	17.88	12.84	31.32





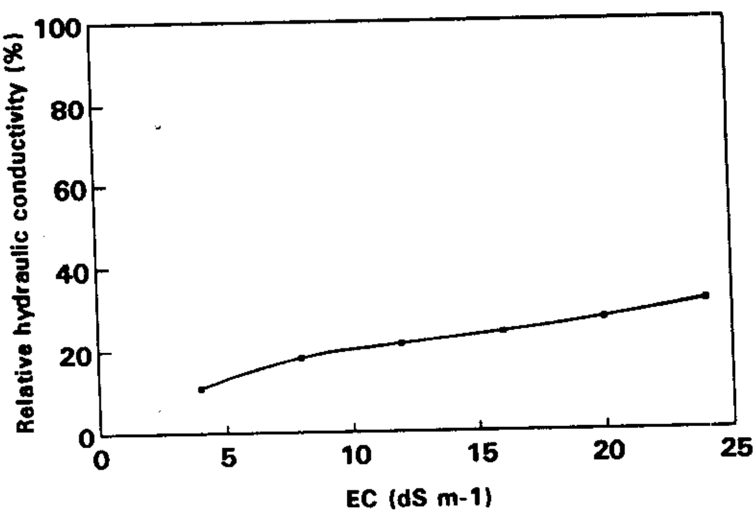


Fig (11) Relative hydraulic condutivity (%)in relation to combined soil salinity and sodicity.

Data in Table (29) may suggest that the hydraulic conductivity parameter could be predicted in a satisfactorily degree of accuracy by introducing the EC and clay% parameter (R = 0.873***). Introducing the third excluded parameter (ESP) resulted in a very slight improvement in this relation (R = 0.874***).

4.3.1.2. Combined salinity and sodicity in soils in relation to soil pH:

Results in Table (30) and graphically shown in Fig. (12) reveal that soil pH significantly decreased (from 8.84 down to 8.08) with simultaneous increases in soil salinity and sodicity (from EC 4 up to 24 dSm^{-1} and ESP values from 15 to 50. The rate of reduction in soil pH was about 0.04 per each unit increase in salinity above EC 4 dSm^{-1}, while the soil sodicity increased the soil pH from 7.95 to 8.98 i.e. at a rate of 0.03 pH unit versus each ESP unit above 15 and up to 50. Similar results were obtained by USSLS (1954), Brown and Miller (1971), Abrol *et al.* (1980), Gupta *et al.* (1983) and Abd-El-Nour (1989).

Concerning the role of the clay fraction, under the saline-sodic conditions in soils, the pH values were significantly decreased (on average, from 8.81 to 8.17) with increasing the soil clay fraction (from 2.32 up to 57.98%).

The combined effect of soil salinity, soil sodicity and the clay content on soil pH is described through the multiple regression equation developed for these parameters (Table, 31) which state that:

$$pH = 9.23 - 0.0462\,EC + 0.0054\,ESP - 0.0109\,clay \quad (R = 0.638^{***})$$

4.3.2. Combined salinity and sodicity of soils in relation to elemental utilization by plants and soil productivity:

4.3.2.1. Combined salinity and sodicity of soils in relation to elemental content of barley plants:

This part of study was conducted using saline (EC_e 4-24 dSm^{-1}) sodic (ESP 20-50) soil models containing values of clay fraction ranging from 2.32 to 57.98%.

Each of these above mentioned factors (soil salinity, sodicity and clay content) will be discussed from the view point of its effect on elemental content of barley plants individually at first and thereafter in combination with the other ones through the multiple regression equations developed.

Table (30): Soil pH in relation to combined salinity and sodicity in soils.

Soil model	EC (dSm-1)	Control	ESP 15	20	25	30	40	50	Average
S1		8.46	8.87	8.92	9.18	9.27	9.32	9.46	9.17
S2		8.35	8.52	8.78	8.97	9.01	9.19	9.24	8.95
S3		8.27	8.48	8.62	8.86	8.92	9.14	9.20	8.87
S4	4	8.24	8.43	8.58	8.78	8.91	9.11	9.18	8.83
S5		8.22	8.40	8.54	8.67	8.85	9.01	9.15	8.77
S6		8.20	8.38	8.51	8.65	8.83	8.98	9.09	8.74
S7		8.17	8.35	8.46	8.60	8.78	8.95	9.03	8.70
S8		8.12	8.30	8.41	8.56	8.74	8.92	8.98	8.65
Average		8.25	8.47	8.60	8.78	8.89	9.08	9.17	8.84
S1		8.46	8.48	8.75	8.82	8.96	9.00	9.44	8.91
S2		8.35	8.39	8.63	8.65	8.94	8.98	9.23	8.80
S3		8.27	8.31	8.55	8.58	8.90	8.93	9.15	8.74
S4	8	8.24	8.24	8.50	8.53	8.82	8.85	9.00	8.66
S5		8.22	8.22	8.48	8.50	8.65	8.74	8.94	8.59
S6		8.20	8.17	8.41	8.44	8.58	8.70	8.89	8.53
S7		8.17	8.15	8.32	8.42	8.53	8.68	8.84	8.49
S8		8.12	8.13	8.21	8.34	8.50	8.63	8.70	8.42
Average		8.25	8.26	8.48	8.54	8.74	8.81	9.02	8.64
S1		8.46	8.24	8.33	8.57	9.06	9.20	9.42	8.80
S2		8.35	8.06	8.20	8.49	8.93	8.99	9.22	8.65
S3		8.27	7.92	7.96	8.42	8.74	8.93	9.09	8.51
S4	12	8.24	7.81	7.91	8.34	8.66	8.85	9.00	8.43
S5		8.22	7.78	7.88	8.24	8.53	7.78	8.90	8.35
S6		8.20	7.62	7.78	8.23	8.51	8.76	8.82	8.29
S7		8.17	7.56	7.71	8.17	8.44	8.72	8.76	8.23
S8		8.12	7.51	7.70	8.06	8.36	8.61	8.70	8.16
Average		8.25	7.81	7.93	8.32	8.65	8.86	8.99	8.43
S1		8.46	8.20	8.31	8.52	9.02	9.21	9.40	8.78
S2		8.35	8.02	8.19	8.47	8.89	9.00	9.19	8.63
S3		8.27	7.87	7.91	8.39	8.70	8.92	9.03	8.47
S4	16	8.24	7.76	7.90	8.28	8.62	8.80	8.98	8.39
S5		8.22	7.72	7.81	8.19	8.50	8.74	8.90	8.31
S6		8.20	7.57	7.75	8.18	8.42	8.63	8.79	8.22
S7		8.17	7.54	7.66	8.12	8.34	8.51	8.72	8.15
S8		8.12	7.48	7.63	8.04	8.30	8.46	8.66	8.10
Average		8.25	7.77	7.90	8.27	8.60	8.78	8.96	8.38
S1		8.46	8.12	8.20	8.51	8.64	9.00	9.40	8.65
S2		8.35	7.97	8.10	8.28	8.52	8.96	9.10	8.49
S3		8.27	7.85	7.97	8.06	8.40	8.88	9.00	8.36
S4	20	8.24	7.74	7.78	7.98	8.33	8.60	8.91	8.22
S5		8.22	7.63	7.64	7.84	8.18	8.47	8.82	8.10
S6		8.20	7.54	7.59	7.80	8.05	8.35	8.70	8.01
S7		8.17	7.49	7.57	7.72	8.02	8.24	8.59	7.94
S8		8.12	7.44	7.52	7.66	7.95	8.20	8.57	7.89
Average		8.25	7.72	7.80	7.98	8.26	8.59	8.89	8.21
S1		8.46	8.11	8.19	8.39	8.47	8.65	9.30	8.52
S2		8.35	7.94	8.00	8.20	8.22	8.56	9.07	8.33
S3		8.27	7.80	7.90	8.01	8.07	8.47	8.92	8.20
S4	24	8.24	7.67	7.77	7.91	7.88	8.44	8.87	8.09
S5		8.22	7.60	7.68	7.77	7.81	8.29	8.77	7.99
S6		8.20	7.49	7.60	7.69	7.73	8.22	8.63	7.89
S7		8.17	7.42	7.52	7.62	7.67	8.15	8.55	7.82
S8		8.12	7.35	7.48	7.57	7.63	8.11	8.50	7.77
Average		8.25	7.67	7.77	7.90	7.94	8.36	8.83	8.08

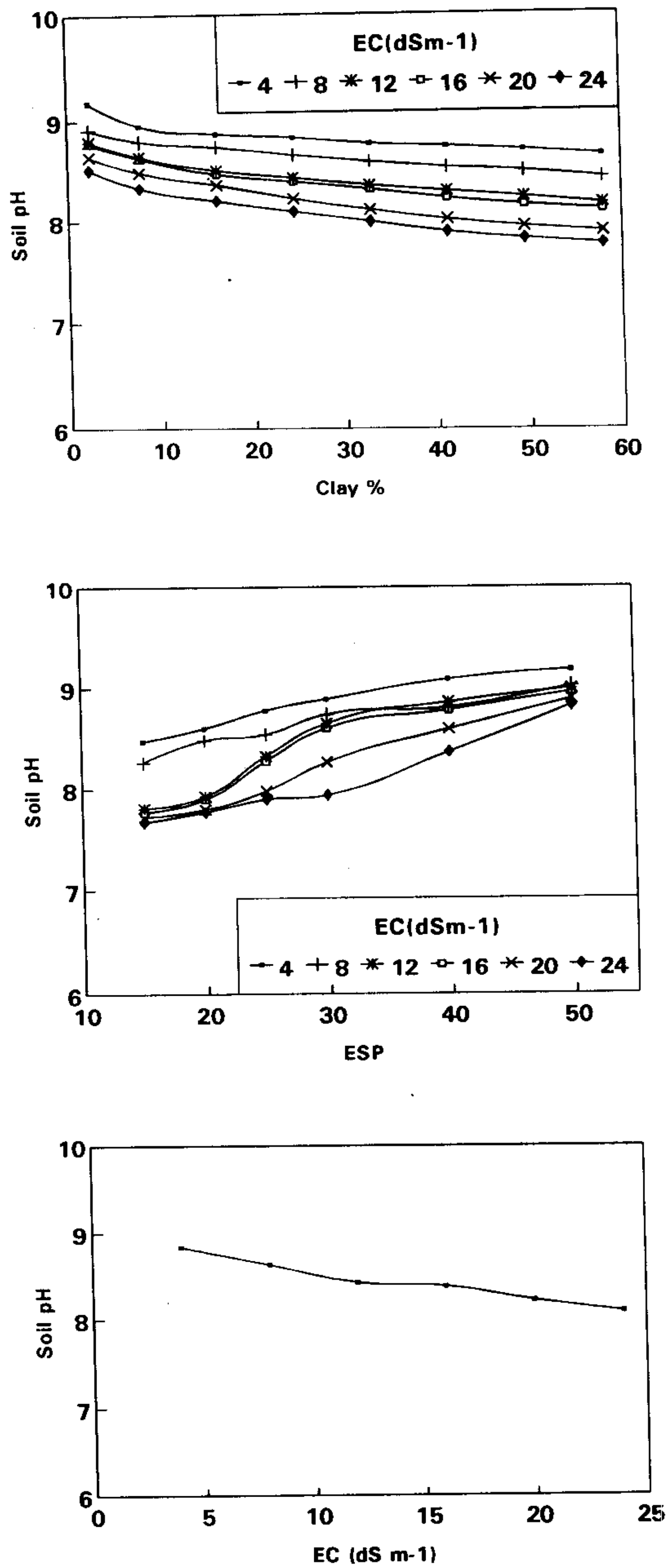


Fig (12) pH in relation to combined soil salinity and sodicity.

Table (31): Combined soil salinity and soil sodicity in relation to soil pH.

Type of relation	Equation	Correlation coefficient
Simple relation	$Y = 8.84 - 0.0336\ X_1$	-0.460^{***}
	$Y = 8.92 + 0.0185\ X_2$	0.442^{***}
	$Y = 8.66 - 0.0102\ X_3$	-0.379^{***}
Multiple relation	$Y = 8.75 - 0.0598\ X_1 - 0.0153\ X_2$	0.466^{***}
	$Y = 9.14 - 0.0337\ X_1 - 0.0102\ X_3$	0.597^{***}
	$Y = 9.22 - 0.0185\ X_2 - 0.0102\ X_3$	0.582^{***}
	$Y = 9.23 - 0.0462\ X_1 - 0.0054\ X_2 - 0.0109\ X_3$	0.638^{***}
Variables under study	Y = pH. X_1 = EC (dSm^{-1}). X_2 = ESP. X_3 = Clay%.	
Contribution of factors	EC = 37.94% ESP = 23.94% Clay = 16.22% Other factors = 21.90%	

*** = Significant at level of 0.001.

*** N-content:**

Data presented in Table (32) and Fig. (13) reveal that the nitrogen content of barley plants grown on saline sodic soils tended to be inconsistently increased with increasing soil salinity from EC 4 up to 24 dSm^{-1}, where the maximum increase occurred at EC of 16 dSm^{-1}. The obtained figures of N% ranged, on average, between 2.61 and 3.57%. However, the control treatment (EC $\simeq$ 1.4 dSm-1) yielded average N% of about 3.40% which is higher than all of those yielded by the higher salinity levels except those of EC_e 16 dSm^{-1} (3.57% N) and 20 dSm^{-1} (3.50% N). Almost similar results were obtained by Chhipa and Lal (1978), El-Sheweikh (1980), Chauhan *et al.* (1991) and Al-Sager (1991) who found that N-content of sorghum plants grown on sandy soil was decreased from 212 to 165 mg/100 g dry wt. with increasing the salinity of irrigation water from 500 to 5000 ppm.

Concerning the ESP effect on N% of barley plants, the N% in plants was slightly reduced (from 3.15 to 3.00%) with increasing soil ESP (from 20 to 50 at the tested levels of EC). These results agree with those obtained by Omar (1970), El-Shakweer and Barakat (1984) and El-Ghanam (1993) who found that the N-content of corn plants slightly decreased with increasing soil sodicity from ESP 12 to 18 under the tested levels of EC.

With respect to the role of the clay fraction, the N-content of barley plants grown on the tested soil models clearly and gradually increased from 2.77 up to 3.24% with increasing the clay fraction from 2.32 up to 57.98% under the tested levels of soil salinity and sodicity.

*** P-content:**

Results obtained in Table (33) and Fig. (13) declare that P-content of barley plants decreased from 0.69 down to 0.36% with increasing soil salinity from 4 to 24 dSm^{-1}, at different levels of ESP. These results are in accordance with those obtained by Ashour *et al.* (1970), Kirti *et al.* (1976), El-Sheweikh (1980) and Francois *et al.* (1986) who reported that phosphorus content of wheat plants was decreased, from 93 to 69 mmol/kg dry wt. with increasing soil salinity from EC 3.5 to 14.0 dS/m.

As for the ESP effect on P% of barley plants, values of P% slightly decreased (from 0.52 to 0.50%), with increasing soil sodicity up to ESP 50, at the tested levels of soil salinity.

Concerning the role of the clay content, no clear trend could be detected for P% due to increasing the clay fraction in saline-sodic soil models. Almost similar results were obtained by Omar (1970) and El-Ghanam (1993) who found that P% of corn plants grown on a clay soil slightly decreased as the soil sodicity increased from ESP 12 to 18 at levels of EC varying from 4 to 16 dSm^{-1}.

*** K-content:**

Data presented in Table (34) and graphically shown in Fig. (13) reveal that the K-content of barley plants clearly and gradually decreased (from 2.90 down to 2.03%) with increasing soil salinity (from EC 4 to 24 dSm^{-1}) at tested levels of ESP; 20 to 50). Similar trends were obtained by Larson and Pierre (1953), Montasir *et al.* (1966), Francois *et al.* (1988), Francois and Kleiman (1990), El-Raise (1991) and El-Ghanam (1993).

With regard to the effect of soil sodicity on K-content of barley plants, at different levels of soil salinity, the K% was adversely affected with increasing soil sodicity (from ESP 20 up to 50), under tested levels of soil salinity.

Concerning the role of the clay content, the K% in barley plants grown on saline sodic soil models was increased from 1.71 up to 2.91% with increasing the clay fraction from 2.32 up to 57.98.

*** Na-content:**

Results in table (35) and Fig. (13) indicate that Na-content of barley plants clearly and consistently increased from 1.84 up to 2.66% with incraesing the soil salinity from EC 4 up to 24 dSm^{-1} under tested levels of soil sodicity. These results are in harmony with those obtained by Mc Lean (1956), El-Seewi *et al.* (1974), Francois *et al.* (1988), Maas and Poss (1989) who found that Na% in wheat plants was increased exponentially with increasing salinity ($NaCl:CaCL_2$, 2:1 molar) in the media from EC 1.4 to 28 dSm^{-1}.

With respect to the effect of soil sodicity, the Na% of plant was progressively increased (from 1.71 to 2.68%) as the soil sodicity increased from ESP 20 to 50, under tested levels of soil salinity. Almost similar observations were recorded by Bower and Wadleigh (1948), El-Gabaly (1955), Martin *et al.* (1953) and Omar (1970).

Table (34): Potassium content (%) of barley [illegible]

Soil model	Con.	EC (dSm^{-1}) 4			8			12			16			20			24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	4.43	3.18	2.25	1.15	3.35	1.35	1.10	2.80	1.00	0.90	3.00	1.85	0.85	2.45	1.35	0.90	1.35	1.35	0.70	1.71
S2	4.40	3.40	2.65	2.00	2.70	1.95	1.35	2.80	2.50	2.00	2.80	2.55	1.00	2.40	2.45	1.40	1.45	1.60	1.35	2.07
S3	4.30	3.35	2.50	2.50	3.10	2.55	2.00	2.20	2.45	2.05	3.40	3.20	2.20	2.70	2.55	2.20	1.80	1.80	1.40	2.46
S4	4.40	3.20	2.60	2.60	3.25	3.35	2.00	2.80	2.90	2.05	3.40	3.20	2.45	2.45	2.60	2.30	2.30	2.55	2.30	2.68
S5	4.25	3.55	2.55	2.40	3.55	3.50	2.20	2.50	2.75	2.20	2.98	3.40	2.55	2.55	2.70	2.30	2.40	2.50	2.30	2.71
S6	4.55	3.50	3.50	2.49	3.50	3.85	2.90	3.35	2.70	2.00	2.95	3.10	2.30	2.45	2.45	2.40	2.60	2.65	2.35	2.83
S7	4.45	3.60	3.20	2.75	3.50	3.85	2.80	3.40	2.95	1.95	2.95	3.20	2.30	2.35	2.55	2.35	2.75	2.50	2.30	2.84
S8	4.50	3.65	3.60	2.70	3.50	2.70	3.20	3.35	2.90	2.45	3.20	3.30	2.45	2.70	2.60	2.40	2.80	2.55	2.45	2.91
Ave.	4.40	3.50	2.90	2.30	3.30	2.60	2.10	3.00	2.50	2.00	3.10	3.00	2.00	2.50	2.40	2.40	2.10	2.10	1.90	2.35
Ave.		2.90			2.47			2.50			2.70			2.43			2.03			

Con.= Control Ave.= Average

Table (35): Sodium content (%) of barley plants in relation to combined salinity and sodicity in soils.

Soil model	Con.	EC (dSm^{-1}) 4			8			12			16			20			24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	0.57	1.59	2.20	2.55	1.75	2.28	2.30	2.40	2.60	3.30	2.05	3.25	4.05	4.00	4.05	4.30	4.20	4.25	4.33	3.10
S2	0.56	1.32	1.80	2.25	1.65	2.15	3.00	1.35	1.95	3.20	1.65	2.45	3.25	2.45	2.80	3.65	3.00	4.00	4.00	2.55
S3	0.53	1.28	1.56	2.30	1.58	1.88	2.05	1.25	1.80	2.65	1.25	1.50	2.50	2.40	2.60	3.15	2.30	2.97	3.20	2.06
S4	0.49	1.27	1.58	2.15	1.56	1.95	2.09	1.20	1.78	2.55	1.26	1.50	2.40	2.05	2.50	3.15	2.40	2.62	2.65	2.05
S5	0.47	1.25	1.50	2.20	1.50	1.90	2.08	1.25	1.60	2.50	1.20	1.50	2.35	1.95	2.30	2.45	1.65	2.20	2.15	1.81
S6	0.46	1.53	1.92	2.35	1.40	1.85	2.05	1.30	1.60	2.85	1.25	1.45	2.35	1.50	1.75	2.45	1.55	1.95	2.20	1.79
S7	0.44	1.48	1.95	2.20	1.65	1.87	2.05	1.20	1.80	2.50	1.30	1.50	2.26	1.40	1.70	2.20	1.70	2.10	2.20	1.82
S8	0.43	1.28	1.85	2.25	1.50	2.05	2.00	1.25	1.60	2.20	1.20	1.50	2.30	1.30	1.60	2.00	1.55	1.85	2.15	1.74
Ave.	0.49	1.45	1.79	2.28	1.60	1.99	2.33	1.39	1.83	2.71	1.40	1.83	2.68	2.13	2.43	3.22	2.29	2.82	2.86	2.12
Ave.		1.84			1.97			1.97			1.97			2.59			2.66			

Con.= Control Ave.= Average

Concerning the role of the clay fraction, the Na% of plant clearly and progressively decreased (from 3.10 to 1.74%) with increasing the clay content of the tested soil models.

*** Ca-content:**

Data presented in Table (36) and in Fig. (13) show that values Ca% in barley plants, slightly but gradually increased from (0.61 up to 1.14%) as the soil salinity increased from EC 4 up to 24 dSm^{-1} under increasing tested levels of soil sodicity (from ESP 20 to 50). Almost similar obervations were recorded by Koszanski and Karczmarczyk (1985), Francois *et al.* (1986), Maas and Poss (1989) stated that Ca% of wheat plants increased exponentially with incresaing salinity, ($NaCl$:$CaCl_2$, 2:1 molar) in the media from EC 1.4 to 28 dSm^{-1}.

With regard to the effect of soil sodicity at tested levels of soil salinity on Ca% of barley plants, the Ca-content of plant was clearly and progressively reduced (from 1.06 to 0.56%) with increasing soil sodicity from ESP 20 up to 50, at the different levels of soil salinity (from EC 4 to 24 dSm^{-1}). Similar trends were obtained by Omar (1970) and Dravid and Goswami (1986).

With respect to the effect of the clay fraction, the Ca% of plants slightly but gradually increased from (0.62 up to 1.00%) as the clay content of the tested soils increased.

*** Mg-content:**

Results in Table (37) and Fig. (13) indicate that the Mg-content of barley plants grown under tested saline-sodic conditions, slightly but gradually increased (from 0.46 up to 0.75%) as the soil salinity increased from 4 up to 24 dSm^{-1}. Almost similar observations were recorded by Koszanski and Karczmarczyk (1985), Al-Sager (1991) and Nath *et al.* (1982) who found that magnesim content of wheat grain and straw increased by increasing soil salinity from EC 2 to 20 mmhos/cm.

Concerning the effect of ESP, the Mg-content of barley plants was clearly and consistently reduced (from 0.66 down to 0.49%) with increasing soil sodicity (from ESP 20 to 50) under the tested levels of soil salinity. Similar results were obtained by Omar (1970) and Dravid and Goswami (1986).

Table (36): Calcium cntent (%) of barley plants in relation to combined salinity and sodicity in soils.

Soil model	Con.	EC (dSm^{-1}) 4			8			12			16			20			24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	0.90	0.40	0.40	0.60	0.58	0.47	0.50	0.61	0.70	0.40	0.90	0.50	0.40	1.30	0.40	0.40	1.20	1.00	0.40	0.62
S2	0.90	0.60	0.50	0.50	0.65	0.54	0.50	0.80	0.70	0.40	1.20	0.60	0.40	1.30	1.10	0.50	1.20	1.20	0.40	0.73
S3	0.90	0.60	0.50	0.50	0.66	0.51	0.50	0.66	0.64	0.50	1.50	0.80	0.50	1.30	1.30	0.50	1.20	1.30	0.50	0.78
S4	1.00	0.60	0.60	0.50	0.70	0.58	0.52	0.73	0.75	0.50	1.40	1.00	0.50	1.36	1.40	0.60	1.60	1.50	0.50	0.85
S5	1.30	0.70	0.60	0.50	0.80	0.73	0.59	0.76	0.82	0.50	1.30	0.90	0.50	1.40	1.40	0.50	1.60	1.50	0.60	0.87
S6	1.40	0.70	0.70	0.50	0.73	0.80	0.55	0.80	0.80	0.50	1.30	0.90	0.50	1.50	1.40	0.50	1.60	1.40	0.70	0.88
S7	1.30	0.80	0.80	0.60	0.87	0.87	0.64	0.89	0.90	0.60	1.30	1.00	0.80	1.50	1.40	0.80	1.70	1.50	0.70	0.98
S8	1.30	0.80	0.80	0.60	0.90	0.90	0.70	0.92	0.90	0.60	1.20	1.00	0.80	1.60	1.40	0.90	1.65	1.60	0.70	1.00
Ave.	1.13	0.66	0.63	0.54	0.73	0.68	0.56	0.77	0.77	0.50	1.26	0.84	0.55	1.41	1.22	0.64	1.50	1.37	0.56	0.84
Ave.		0.61			0.66			0.68			0.88			1.09			1.14			

Con.= Control Ave.= Average

Table (37): Magnesium content (%) of barley plants in relation to combined salinity and sodicity in soils.

Soil model	Con.	EC (dSm^{-1}) 4			8			12			16			20			24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	0.40	0.36	0.24	0.36	0.36	0.36	0.48	0.48	0.36	0.36	0.48	0.36	0.36	0.60	0.48	0.48	0.72	0.70	0.48	0.45
S2	0.50	0.60	0.48	0.48	0.48	0.48	0.36	0.60	0.48	0.36	0.48	0.36	0.36	0.70	0.56	0.60	0.80	0.70	0.48	0.52
S3	0.60	0.60	0.48	0.36	0.48	0.48	0.36	0.72	0.48	0.48	0.56	0.60	0.48	0.70	0.84	0.48	0.84	0.72	0.48	0.56
S4	0.60	0.60	0.36	0.48	0.60	0.48	0.36	0.72	0.60	0.36	0.60	0.72	0.48	0.82	0.84	0.72	0.84	0.80	0.50	0.60
S5	0.60	0.48	0.36	0.36	0.48	0.36	0.48	0.60	0.72	0.36	0.72	0.48	0.48	0.84	0.72	0.72	0.95	0.75	0.55	0.58
S6	0.60	0.60	0.48	0.36	0.41	0.36	0.46	0.60	0.65	0.48	0.85	0.60	0.48	0.87	0.72	0.72	0.95	0.86	0.60	0.61
S7	0.72	0.48	0.48	0.48	0.36	0.36	0.47	0.60	0.60	0.48	0.84	0.72	0.48	0.90	0.84	0.60	0.97	0.84	0.72	0.61
S8	0.72	0.48	0.60	0.48	0.60	0.36	0.47	0.60	0.60	0.36	0.97	0.84	0.48	0.90	0.86	0.60	0.98	0.84	0.72	0.65
Ave.	0.59	0.53	0.43	0.42	0.47	0.40	0.47	0.61	0.56	0.41	0.68	0.58	0.45	0.79	0.73	0.62	0.89	0.78	0.57	0.57
Ave.		0.46			0.45			0.53			0.57			0.71			0.75			

Con.= Control Ave.= Average

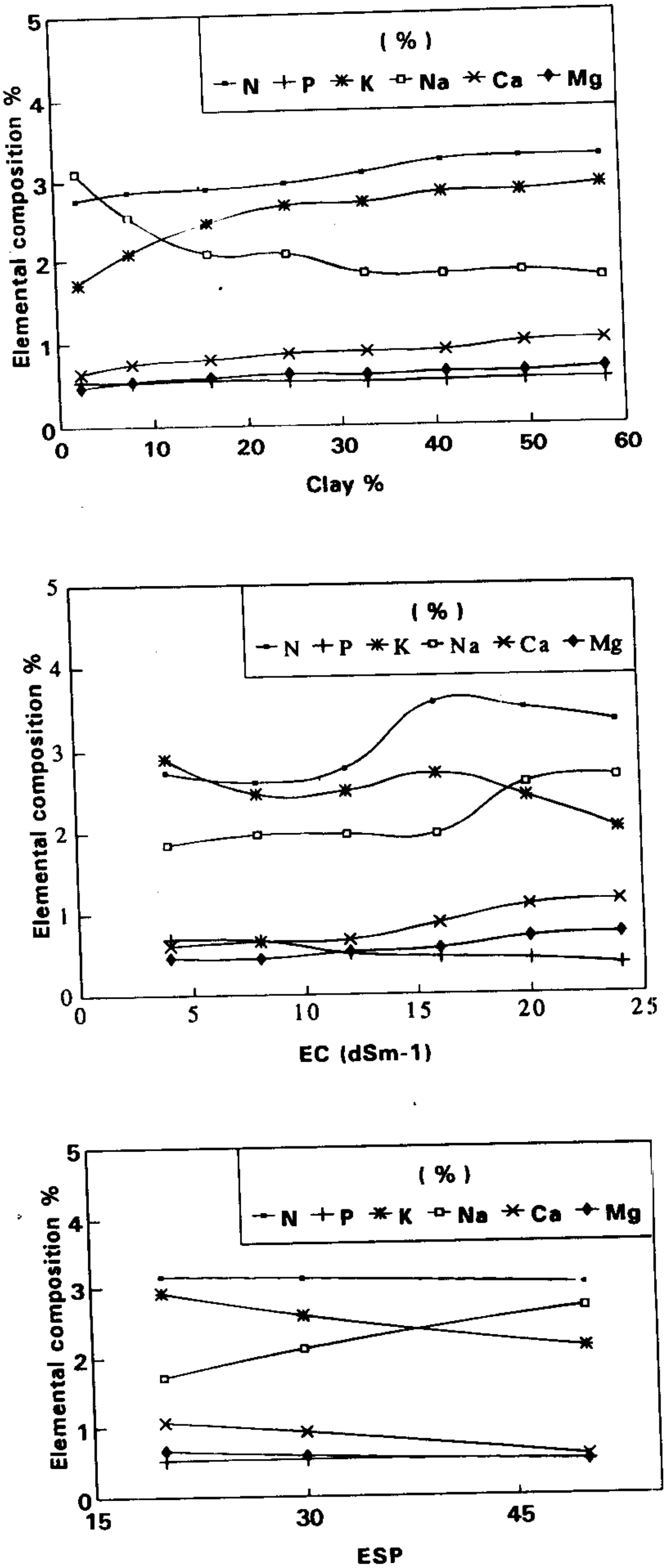


Fig (13) Elemental composition (%) of barley plants grown under saline-sodic condition.

With regard to the role of clay fraction, the Mg-content of barley plants was slightly incraesed (from 0.45 up to 0.65%) as the clay content of soil models increased (from 2.32 up to 57.98%) under the tested levels of soil salinity and sodicity.

4.3.2.2. Combined salinity and sodicity of soils in relation to elemental uptake by barley plants:

*** N-uptake:**

Data presented in Table (38) and graphically illustrated in Fig. (14) show that the N-uptake by barley plants grown under tested saline sodic conditions significantly and drastically decreased (from 79.97 down to 18.03 mg/pot) as the soil salinity increased (from EC 4 up to 24 dSm^{-1}). The rate of reduction in N-uptake was about 3.10 mg/pot for each unit of EC increase above EC 4 dSm^{-1}.

With regard to the combined effect of soil salinity and sodicity on N-uptake by barley plants, the N-uptake by plants gradually and significantly reduced (from 59.82 to 42.50 mg/pot) with increasing soil sodicity (from ESP = 20 to 50) under tested levels of soil salinity (EC 4 to 24 dSm^{-1}).

Concerning the role of the clay fraction, the N-uptake by barley plants grown on saline sodic soil models significantly ($r = 0.595^{***}$) increased from (22.14 up to 78.43 mg/pot) with increasing the clay fraction of the tested models from 2.32 up to 57.98%.

The combined effect of the soil salinity, soil sodicity and the clay fraction of the tested soil models is described through the multiple regression equation;

$$\text{N-uptake} = 64.40 - 4.30\ EC + 0.159\ ESP + 1.02\ clay\ (R = 0.923^{***})$$

*** P-uptake:**

Data presented in Table (39) and graphically illustrated in Fig. (14) show that the P-uptake by barley plants grown on saline sodic soils was sharply decreased (from 20.27 down to 1.84 mg/pot) with increasing soil salinity (from EC_e 4 up to 24 dSm^{-1}) within levels of soil sodicity; ranging from ESP 20 to 50. With each unit of EC increase above 4 dSm^{-1}, the P-uptake by plants was decreased by 0.92 mg/pot.

Table (38): Total uptake of nitrogen (mg/pot) by barley plants in relation to combined salinity and sodicity in soils.

Soil modil	Con.	EC (dSm^{-1}) 4			8			12			16			20			24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	78.60	53.73	47.08	35.28	47.32	34.27	31.89	25.47	26.87	21.42	17.47	14.35	8.40	9.80	6.47	3.15	6.44	5.88	3.23	22.14
S2	92.48	67.48	56.84	39.27	58.80	44.98	31.81	43.12	38.92	24.96	28.35	26.60	19.80	22.54	22.30	7.00	12.05	10.03	8.01	31.28
S3	100.13	61.88	58.25	50.46	67.76	51.17	37.13	60.20	54.32	34.51	49.70	37.80	25.56	26.37	22.44	12.60	15.29	14.78	8.11	38.25
S4	107.18	73.78	70.76	79.67	77.91	68.89	84.41	55.45	56.84	53.20	62.61	45.22	29.40	30.91	27.20	15.68	20.94	19.29	9.24	46.96
S5	124.99	84.92	75.60	84.97	91.78	72.32	49.14	68.78	72.62	59.92	76.44	60.37	47.60	37.13	31.33	17.93	27.59	21.70	10.16	55.01
S6	133.73	103.21	102.76	95.48	104.66	87.78	83.50	103.80	79.24	65.17	82.71	62.97	50.05	42.34	38.00	23.31	29.85	29.01	14.64	66.58
S7	147.70	111.54	104.27	108.51	104.16	93.37	96.10	109.84	98.36	77.56	82.40	64.80	50.23	46.49	40.82	28.66	36.04	29.86	16.66	71.90
S8	152.60	116.51	117.32	119.62	114.95	96.56	99.18	118.17	106.26	84.28	96.60	67.14	61.44	49.52	44.60	37.04	37.10	25.37	20.16	78.43
Av.	117.14	84.10	79.10	76.70	83.40	68.70	59.60	73.00	66.70	52.60	62.00	47.70	36.60	33.20	29.10	18.20	23.20	19.60	11.30	
Av.			79.97			70.57			64.10			48.67			26.38			18.03		

Con. = Control Av. = Average

Table (39): Total uptake of phosphorus (mg/pot) by barley blants in relation to combined salinity and sodicity in soils.

Soil model	Con.	EC (dSm^{-1}) 4			8			12			16			20			24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	16.45	14.14	11.26	9.18	10.48	9.73	6.81	5.37	5.23	4.81	2.37	1.80	1.37	1.45	1.28	0.53	0.92	0.89	0.47	4.89
S2	20.89	16.00	14.90	11.06	13.69	11.26	6.02	6.16	7.37	4.68	3.68	3.51	2.67	3.43	3.01	0.99	1.66	1.27	0.99	6.24
S3	20.80	24.96	17.30	13.25	14.81	14.84	14.28	8.77	10.79	7.74	6.28	4.22	3.17	4.15	2.84	1.61	1.97	1.96	1.02	8.55
S4	22.01	17.17	17.72	18.54	16.59	15.63	13.29	12.30	9.70	10.60	7.81	6.66	4.10	4.19	3.60	1.89	2.60	2.15	1.02	9.53
S5	25.67	24.66	19.50	16.01	21.61	22.53	13.99	14.16	13.39	10.79	8.31	6.65	6.45	4.26	4.29	1.97	2.41	2.24	1.04	10.76
S6	28.97	27.08	25.10	20.00	25.99	24.88	25.13	14.49	14.89	11.91	8.65	8.03	5.85	3.98	3.96	2.36	2.61	2.71	1.18	12.67
S7	28.19	33.10	24.93	23.59	29.09	27.38	24.80	18.36	17.40	14.13	9.42	9.97	6.40	4.06	3.91	2.68	3.05	2.80	1.57	14.53
S8	31.18	32.41	29.58	25.28	29.79	22.36	28.49	17.84	17.63	16.68	11.32	12.38	8.91	4.66	4.05	3.90	3.54	2.76	1.98	15.19
Ave.	24.27	23.70	20.00	17.10	20.30	18.58	16.60	12.20	12.05	10.20	7.20	6.70	4.90	3.90	3.40	2.00	2.30	2.09	1.12	
Ave.			20.27			18.49			11.48			6.27			3.10			1.84		

Con. = Control Ave. = Average

With respect to soil sodicity, the P-uptake by barley plants grown on saline sodic soils was reduced from 11.60 down to 8.65 mg/pot as thesoil sodicity increased from ESP 20 up to 50, at the different levels of soil salinity.

Concerning the role of the clay fraction, the P-uptake by barley plants grown on saline sodic soils was significantly increased (on average from 4.89 up to 15.19 mg/pot) as the clay fraction increased from 2.32 up to 57.98%.

The combined effect of both soil salinity, soil sodictity and the clay fraction is described through the equation;

P-uptake = 18.0 - 1.10 EC + 0.0703 ESP + 0.186 clay (R = 0.920***)

*** K-uptake:**

Results obtained in Table (40) and Fig. (14) reveal that the K-uptake by barley plants grown on saline sodic soil models high significantly (r = -0.720***) decreased (from 87.70 down to 12.15 mg/pot) by increasing soil salinity (from EC_e 4 up to 24 dSm^{-1}).

With regard to soil sodicity, K-uptake by barley plants grown on saline sodic soils was progressively reduced (on average) from 62.92 down to 34.02 mg/pot) with increasing soil sodicity from ESP 20 up to 50.

Concerning the role of clay content, the K-uptake by barley plants grown on saline sodic soils was high significantly (r = 0.881***) increased (from 16.10 up to 77.17 mg/pot) with increasing the clay fraction from 2.32 up to 57.98%.

The combined effect of soil salinity, soil sodicity and the % of the caly fraction in reducing such hazardous effect, is described through the multiple regression equation:

K-uptake = 69.70 - 4.29 EC + 0.257 ESP + 1.06 clay (R = 0.884***)

*** Na-uptake:**

Data obtained in Table (41) and Fig. (14) indicate that the Na-uptake by barley plants grown on saline sodic soils was high significantly (r = -0.813***) decreased (from 52.23 down to 11.92 mg/pot) as the soil salinity increased from (EC 4 up to 24 dSm^{-1}).

Table (40): Total uptake of potassium (mg/pot) by barley plants in relation to combined salinity and sodicity in soils.

Soil model	Con.	EC 4 (dSm^{-1})			EC 8			EC 12			EC 16			EC 20			EC 24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	103.22	64.24	39.83	16.10	56.61	20.66	14.74	29.96	10.10	8.10	14.40	7.59	2.55	6.62	2.97	1.35	3.11	2.70	0.77	16.10
S2	119.68	81.94	53.80	33.00	56.70	36.86	19.17	43.12	34.75	20.80	22.68	19.38	5.50	16.80	14.46	5.50	5.95	5.12	2.97	26.58
S3	128.14	87.10	54.75	53.00	75.02	54.83	40.80	68.80	47.53	29.73	48.28	32.00	15.62	22.41	16.83	9.9	9.36	7.92	3.64	37.64
S4	137.17	99.20	69.16	70.46	86.13	86.77	39.52	65.24	58.87	38.95	58.48	38.08	20.58	23.52	20.80	12.88	15.64	13.52	6.90	45.80
S5	158.10	119.64	76.50	69.36	105.08	100.45	59.40	72.52	67.93	47.08	58.11	52.36	34.68	26.01	24.03	14.04	17.52	15.50	7.59	53.75
S6	181.09	135.08	128.45	77.19	124.60	94.05	82.36	112.90	76.41	49.00	62.25	53.63	32.89	27.44	24.50	17.52	21.32	19.61	8.93	63.82
S7	187.79	150.84	125.44	92.68	130.20	100.04	87.36	115.60	85.85	54.02	64.31	62.08	35.88	28.91	27.54	20.92	27.23	19.75	11.27	68.88
S8	196.20	159.87	150.84	96.12	136.85	98.01	103.04	122.95	100.05	73.75	73.60	71.94	74.04	35.37	30.68	23.52	29.68	21.17	14.70	77.17
Av.	151.42	112.30	87.30	63.50	96.40	74.00	55.80	78.90	60.20	40.20	50.30	42.13	24.30	23.40	20.20	13.20	16.20	13.16	7.10	
Av.		87.70			75.40			59.77			38.91			18.93			12.15			

Con. = Control Av. = Average

Table (41): Total uptake of sodium (mg/pot) by barley plants in relation to combined salinity and sodicity in soils.

Soil model	Con.	EC 4 (dSm^{-1})			EC 8			EC 12			EC 16			EC 20			EC 24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	13.28	39.39	38.94	35.70	29.58	34.88	44.22	25.68	26.26	36.00	9.84	13.32	12.15	10.80	9.13	6.45	9.66	8.50	4.76	21.95
S2	15.23	31.81	36.54	37.13	34.65	40.64	42.60	20.79	27.11	33.28	13.37	18.62	17.88	17.15	16.52	9.13	12.30	12.80	8.80	23.95
S3	15.79	33.28	34.16	48.76	38.24	40.42	41.82	26.88	34.92	38.43	17.75	15.00	17.75	19.92	17.16	14.18	11.96	13.08	8.32	26.22
S4	15.63	39.37	42.03	58.27	46.49	50.51	51.62	27.96	36.12	48.45	21.67	17.58	20.16	19.68	20.00	17.64	16.32	13.90	7.95	30.88
S5	17.48	42.13	45.00	63.58	44.70	54.53	56.16	36.13	40.76	53.50	23.40	23.10	31.96	19.89	20.47	14.59	12.05	13.64	7.10	32.94
S6	18.31	59.36	70.46	72.85	49.48	61.05	58.22	43.81	45.28	69.83	26.38	25.09	33.61	16.80	17.50	17.86	12.71	14.43	8.36	39.06
S7	18.57	62.01	76.44	74.14	61.38	65.71	63.96	40.80	52.38	69.25	28.34	29.10	35.26	17.22	18.36	19.58	16.83	16.59	10.78	42.11
S8	18.75	56.06	77.52	80.10	58.65	74.42	64.40	47.00	55.20	66.22	27.60	32.70	44.16	17.03	18.88	19.60	16.43	15.36	12.90	43.56
Ave.	16.63	45.30	52.60	58.80	45.40	52.80	52.90	33.60	39.80	51.90	21.00	21.80	26.60	17.30	17.30	14.90	13.50	13.66	8.60	
Ave.		52.23			50.37			41.77			23.13			16.50			11.92			

Con. = Control Ave. = Average

With respect to soil sodicity, the Na-uptake by barley plants grown on saline sodic soil models increased (from 29.35 up to 42.28 mg/pot) with increasing soil sodicity from ESP 20 up to 50.

Concerning the effect due to the clay fraction on Na-uptake by barley plants under saline sodic conditions, it was increased (from 21.95 to 43.56 mg/pot) as the clay fraction increased from 2.32 up to 57.98% at the tested levels of salinity and sodicity.

This combined relation is described through the equation;

Na-uptake = 46.30 - 2.58 EC + 0.304 ESP + 0.427 clay (R = 0.923***)

*** Ca-uptake:**

Results obtained in Table (42) and shown in Fig. (14) show that the Ca-uptake by barley plants grown on saline sodic soils decreased (from 18.50 down to 6.78 mg/pot) as the soil salinity increased from EC_e 4 up to 24 dSm^{-1}.

With respect to soil sodicity, Ca-uptake by barley plants grown on saline sodic models, progressively decreased (from 18.22 down to 8.44 mg/pot) with increasing soil sodicity (from ESP 20 up to 50).

Concerning the role of the clay fraction, the Ca-uptake by barley plants grown on these saline sodic soils, was consistently increased (from 4.57 up to 22.73 mg/pot) as the clay fraction increased (from 2.32 up to 57.98%).

The combined effect of salinity and sodicity and the role of the clay content on Ca-uptake by barley plants, is described through the equation;

Ca-uptake = 13.20 - 0.758 EC + 0.0908 ESP + 0.309 clay (R = 0.787***)

*** Mg-uptake:**

Data presented in Table (43) and graphically shown in Fig. (14) indicate that the Mg-uptake by barley plants grown on saline sodic soils, was reduced from 13.80 down to 4.24 mg/pot with increasing soil salinity from EC 4 up to 24 dSm^{-1}.

With regard to soil sodicity the Mg-uptake by barley plants consistently decreased (from 12.09 down to 6.65 mg/pot) as the soil sodicity increased from ESP 20 up to 50.

Table (42): Total uptake of calcium (mg/pot) by barley plants in relation to combined salinity and sodicity in soils.

Soil model	Con.	EC (dSm^{-1}) 4			8			12			16			20			24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	20.97	8.08	7.08	8.40	9.83	7.18	6.70	6.56	7.07	3.60	4.32	2.05	1.20	3.51	0.88	0.60	2.76	2.00	0.44	4.57
S2	24.48	14.46	10.15	8.25	13.70	10.23	7.10	12.32	9.73	4.16	9.72	4.56	2.20	9.10	6.49	1.25	4.92	3.84	0.88	7.39
S3	26.82	15.60	10.95	10.60	15.94	11.00	10.24	14.20	12.46	7.25	21.30	8.00	3.55	10.79	8.58	2.25	6.24	5.72	1.30	9.77
S4	31.90	18.60	15.96	13.55	18.55	15.13	12.82	17.00	15.27	9.50	24.08	11.90	4.20	13.06	11.20	3.36	8.32	7.95	1.50	12.32
S5	48.36	23.59	21.00	14.45	23.82	20.83	15.90	22.10	20.23	10.70	25.35	13.86	6.80	14.28	12.46	3.05	12.41	9.30	1.98	14.62
S6	51.74	27.16	25.69	15.50	26.04	26.40	15.72	29.80	22.64	12.25	27.43	15.57	7.15	16.80	14.00	3.65	13.12	10.36	2.66	17.33
S7	54.86	33.52	31.36	20.22	32.48	30.59	19.96	30.10	26.19	16.62	28.34	19.40	12.48	18.45	15.12	7.12	16.83	11.85	3.43	20.78
S8	56.68	35.04	33.52	21.36	35.19	32.67	22.54	33.70	31.05	18.06	27.60	21.80	15.36	20.96	16.52	8.82	17.49	13.28	4.20	22.73
Ave.	39.84	22.00	19.50	14.00	21.97	19.25	13.87	20.72	18.04	10.30	21.00	12.10	6.60	13.37	10.70	3.80	10.26	8.04	2.05	
Ave.		18.50			18.36			16.35			13.23			9.29			6.78			

Con. = Control Ave. = Average

Table (43): Total uptake of magnesium (mg/pot) by barley plants in relation to combined salinity and sodicity in soils.

Soil model	Con.	EC (dSm^{-1}) 4			8			12			16			20			24			Average
		ESP 20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	9.32	7.27	4.25	5.04	10.74	5.51	6.43	5.14	3.64	3.24	2.30	1.48	1.08	1.62	1.06	0.72	1.66	1.40	0.53	3.51
S2	13.60	14.46	9.74	7.92	11.40	9.07	5.11	9.24	6.67	3.74	3.89	2.74	1.98	4.90	3.30	1.50	3.28	2.24	1.06	5.68
S3	17.88	15.60	10.51	7.63	12.82	10.13	7.34	15.48	9.31	6.96	7.95	6.00	3.41	5.81	5.54	2.16	4.37	3.17	1.25	7.52
S4	19.14	18.60	9.58	13.01	14.30	12.43	8.89	16.78	12.18	6.84	10.32	8.57	4.03	7.87	6.72	4.03	5.71	4.24	1.50	8.59
S5	22.32	16.18	10.80	10.40	14.45	10.33	12.96	17.34	17.48	7.70	14.04	7.39	6.53	8.57	6.41	4.39	6.94	4.65	1.82	9.91
S6	23.88	23.28	17.62	11.16	14.66	11.88	13.04	20.22	18.36	11.67	17.94	10.38	6.86	9.74	7.20	5.26	7.79	6.36	2.28	11.98
S7	30.38	20.11	18.82	16.18	13.93	12.64	14.72	20.40	17.46	13.30	18.31	13.97	5.62	11.07	9.07	5.34	9.60	6.64	3.53	12.81
S8	31.39	21.02	25.14	17.09	14.87	13.07	15.10	22.02	20.70	10.84	22.31	18.31	6.91	11.79	10.15	5.88	10.39	6.97	4.32	13.16
Ave.	20.99	17.00	13.30	11.10	13.70	10.60	10.45	15.82	13.23	8.00	12.13	8.60	4.60	7.67	6.18	3.70	6.22	4.46	2.04	
Ave.		13.80			11.58			12.35			8.44			5.85			4.24			

Con. = Control Ave. = Average

Concerning the role of clay fraction, the Mg-uptake by barley plants grown on saline sodic models increased, on average (from 3.51 up to 13.16 mg/pot) with increasing the clay content (from 2.32 up to 57.98).

The combined effect due to salinity, sodicity and clay% on Mg-uptake by plants is represented by the equation;

Mg-uptake = 9.38 - 0.427 EC + 0.0344 ESP + 0.200 clay (R = 0.740***)

Finally, results reveal that the total uptake of N, P, K, Na, Ca and Mg by barley plants significantly decraesed as the soil salinity increased from EC 4 to 24 dSm^{-1} at the different levels of soil sodicity (ESP 20 to 50). Similar observations were reported by Hassan *et al.* (1970), Janardhan *et al.* (1979), Rabie *et al.* (1985), Lotfy *et al.* (1987), Nour *et al.* (1989), Lal and Lal (1990), El-Ghanam (1993) and El-Laboudi *et al.* (1971) concluded that a negative relationship occurs between soil salinity and total uptake of most nutrient elements. Such reduction of element uptake under saline conditions could be attributed to the decrease in the dry matter yield accumulation, to the disturbances in ion absorption as have been previously mentioned, and to the harmful effect of salinity that may be due to the toxicity of one or more specific ion present in higher concentration (Strogonov, 1964).

Concerning the effect of soil sodicity under saline conditions on the uptake of N, P, K, Ca and Mg by barley plants, a pronounced decrease was observed with increasing soil sodicity from ESP 20 to 50 at the different levels of soil salinity from EC 4 to 24 dSm^{-1}, while Na-uptake was increased. Almost similar results were obtained by EL-Gabaly (1955), El-Shakweer and Barakat (1982), El-Ghanam (1993) and Omar (1970) who found that the total uptake of N, P, K, Ca and Mg by barley plants was decreased with increasing soil sodicity from ESP 10 to 40.

4.3.2.3. Combined salinity and sodicity in soils in relation to dry matter yield of barley plants:

Data obtained for the effects due to soil salinity combined with sodicity in the presence of different clay contents on the dry matter yield of barley plants, are presented in Table (44) and graphically illustrated in Fig. (15 & 16).

Results reveal that the dry matter yield of barley plants grown on saline sodic soil models was decreased from 2.92 down to 0.53 g/pot as the salinity

Table (44): Dry matter yield of barley plants (g/pot) in relation to combined soil salinity and sodicity.

Soil model	Con.	EC (dSm^{-1})																		Average
		4			8			12			16			20			24			
		ESP																		
		20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	20	30	50	
S1	2.33	2.02	1.77	1.40	1.69	1.53	1.34	1.07	1.01	0.90	0.48	0.41	0.30	0.27	0.22	0.15	0.23	0.20	0.11	0.84
S2	2.72	2.41	2.03	1.65	2.10	1.89	1.42	1.54	1.39	1.04	0.81	0.76	0.55	0.70	0.59	0.25	0.41	0.32	0.22	1.12
S3	2.98	2.60	2.19	2.12	2.42	2.15	2.04	2.15	1.94	1.45	1.42	1.00	0.71	0.83	0.66	0.45	0.52	0.44	0.26	1.41
S4	3.19	3.10	2.66	2.71	2.65	2.59	2.47	2.33	2.03	1.90	1.72	1.19	0.84	0.96	0.80	0.56	0.68	0.53	0.30	1.67
S5	3.72	3.37	3.00	2.89	2.98	2.87	2.70	2.89	2.47	2.14	1.95	1.54	1.36	1.02	0.89	0.61	0.73	0.62	0.33	1.91
S6	3.98	3.88	3.67	3.10	3.56	3.30	2.84	3.37	2.83	2.45	2.11	1.73	1.43	1.12	1.00	0.73	0.82	0.74	0.38	2.17
S7	4.22	4.19	3.92	3.37	3.72	3.51	3.12	3.40	2.91	2.77	2.18	1.94	1.56	1.23	1.08	0.89	0.99	0.79	0.49	2.34
S8	4.36	4.38	4.19	3.56	3.91	3.63	3.22	3.67	3.45	3.01	2.30	2.30	1.92	1.31	1.18	0.98	1.06	0.83	0.60	2.52
Ave.	3.44	3.24	2.93	2.60	2.88	2.68	2.39	2.55	2.25	1.96	1.62	1.34	1.08	0.93	0.68	0.58	0.68	0.56	0.34	1.75
Ave.		2.92			2.65			2.25			1.35			0.73			0.53			

Con.= Control Ave.= Average

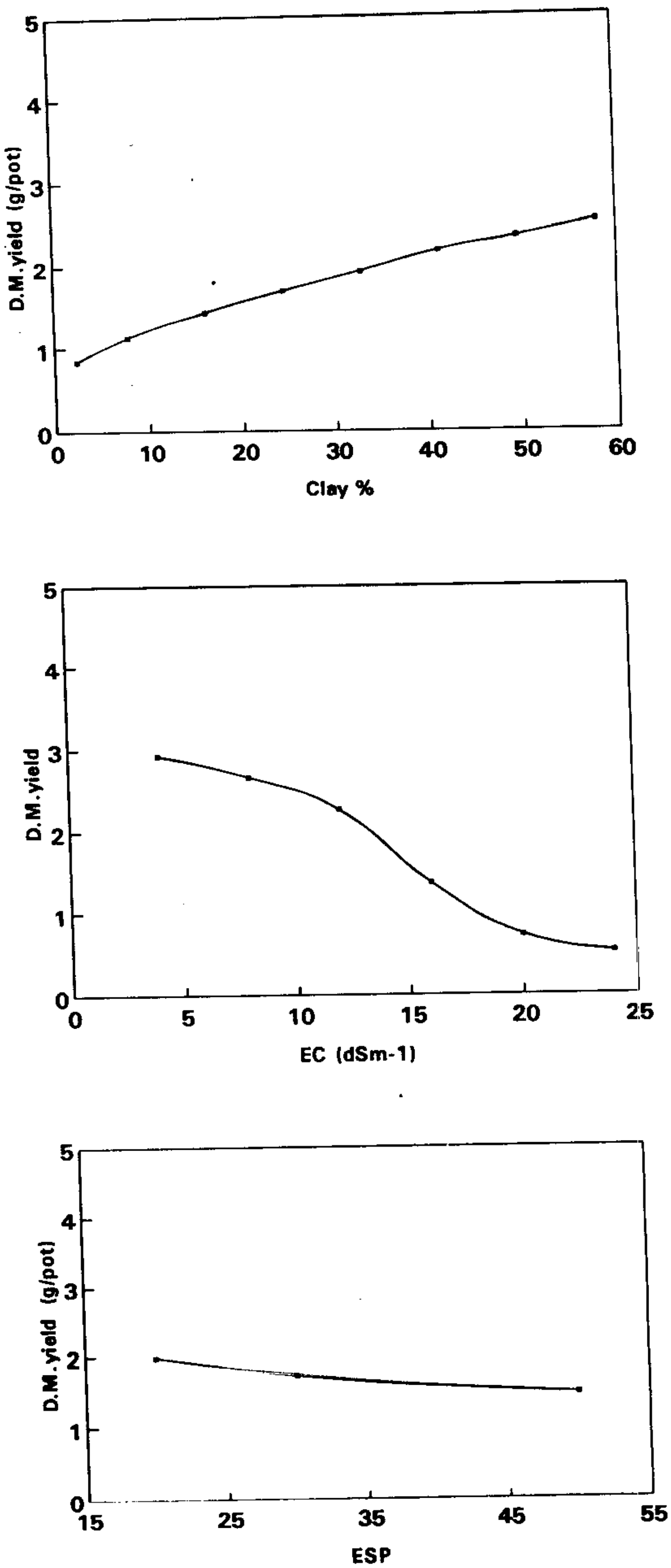


Fig. (15) Dry matter yield of barley plants (g/pot) in relation to combined soil salinty and sodicty.

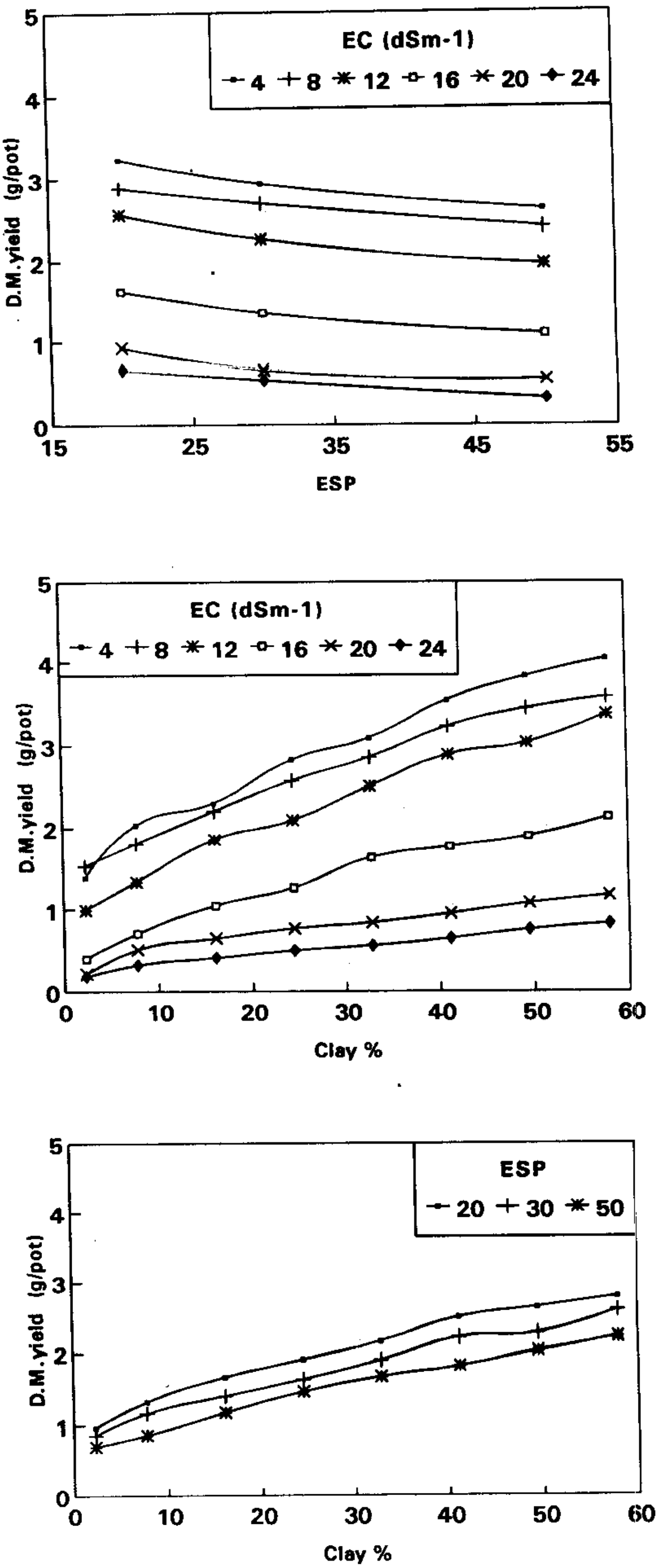


Fig. (16) Dry matter yield of barley plants (g/pot) in relation to combined soil salinty and sodicty.

increased from 4 up to 24 dSm^{-1} at tested levels of soil sodicity, i.e. each unit of soil salinity above 4 dSm^{-1} reduced the dry matter yield by 0.12 g/pot. These results are in accordance with those obtained by Ball *et al.* (1984), Grieve and Maas (1988), Francois and Kleiman (1990), El-Sager (1991), Francois *et al.* (1994) and El-Ghanam (1993) who found that the dry matter yield of corn plants was decreased from 2.93 to 0.33 g/pot in sandy soil and from 3.31 to 1.55 g/pot in the clay soil with increasing soil salinity from EC_e 4 to 16 dSm^{-1} at levels of soil sodicity varying from ESP 12 to 18 in both soils.

With regard to the sodicity effect, the dry matter yield of barley plants was reduced (from 1.98 down to 1.49 g/pot) with increasing soil sodicity (from ESP 20 to 50). The rate of reduction in dry matter yield was about 0.016 g/pot for each unit of ESP above 20. Almost similar trends were obtained by El-Gabaly (1955), Omar (1970), El-Shakweer and Barakat (1984) and El-Ghanam (1993) who found that the dry matter yield of corn plants grown on sandy and clayey soils was decreased from 1.61 to 1.22 g/pot and from 2.75 to 2.22 g/pot, respectively as the soil sodicity increased from ESP 12 to 18 at levels of soil salinity differeing from EC 4 to 16 dSm^{-1} in both soils.

Concerning the role of the clay fraction, the dry matter yield of barley plants grown on saline sodic soil samples increased from 0.84 up to 2.52 g/pot with increasing the clay content in the tested soil models from 2.32 to 57.98%. The rate of increase in the dry matter yield was about 0.03 g/pot for each 1% of clay.

The overall effect of soil salinity, soil sodicity and clay% is reflected clearly through the equation for these parameters, presented in Table (45) which state that:

D.M. yield = 2.45 - 0.144 EC + 0.0137 ESP + 0.0295 clay (R = 0.952***)

4.4. Validity of equations developed for assessment of soil salinity and sodicity:

The validity of the main equations (Table, 46) developed "through this work" for the assessment of salt affected soils was evaluated as follows:

Values of dry matter yield of barley plants grown on both prepared salt affected soil models and naturally salt affected ones were estimated.

The equations developed from prepared salinized and sodicated soil models were used to compute the dry matter yield of plants that could be gain (predicted yield, Y) from natural soils where plants were grown under the same conditions.

The relation between predicted values of yield "Y" and those obtained actually (Y) was investigated using "ANOVA" test (Table, 47) where the absence of significant difference between the two variables ensure the validity of the equations developed for these variables.

According to the abovementioned basis, the obtained results reveal the validity of the following parameters:

1- The "EC" parmeter is reliable or valid for assessment saline, saline sodic and salt affected soils, in general (noteworthy reffering that this parameter was not computed for sodic soil models).
2- Introducing the clay content of soils (the suggested parameter) beside the "EC" parameter improved the reliability of the "EC" parameter for assessment all the abovedmentioned types of salt affected soils. This result is clear from the increasing values of probability due to introducing clay % beside the EC for the estimation of predicted yield.
3- The "ESP" parameter was valid only in case of "saline sodic soils" while introducing the "clay content" parameter beside the "ESP" exhibited more validity in both sodic and saline sodic soils.
4- Results reveal the validity of equations based on the "EC" and "ESP" parameters for assessing only the saline sodic soils, while introducing the clay % parameter improved this relation which became valid in both saline sodic soils and salt affected soils, in general.
5- It may be of vital importance to refer that the general equation including the "EC", "ESP" and clay % realized the highest degree of validity for assessment of salt affected soils, in general. Fig. (17) reveal no significant difference between actual yield of barley plants and that predicted for the naturally salt affected soils. Accordingly the use of this general equation is proposed for assessment soil salinity or sodicity in salt affected soils and predicting the productivity of such soils.

Table (46): Regression equations developed for assessment of salinized soil models (SSM) and naturally salt affected soils (NSS) where Y = dry matter yield, X_1 = EC, X_2 = ESP and X_3 = clay%.

No.	Salinized soil models		Naturally salt affected soils	
	Equations	Co.O. "r or R"	Equations	Co.C. "r or R"
1	$Y = 3.59 - 0.126 X_1$	-0.794 ***	$Y = 2.59 - 0.0162 X_1$	-0.700 ***
2	$Y = 2.53 - 0.0186 X_2$	-0.230 **	$Y = 3.45 - 0.0667 X_2$	-0.692 ***
3	$Y = 1.10 + 0.0316 X_3$	0.496 ***	$Y = 0.882 + 0.0521 X_3$	0.532 ***
4	$Y = 4.10 - 0.126 X_1 - 0.0186 X_2$	0.828 ***	$Y = 3.15 - 0.0096 X_1 - 0.0375 X_2$	0.744 ***
5	$Y = 2.68 - 0.126 X_1 + 0.0315 X_3$	0.935 ***	$Y = 1.69 - 0.0141 X_1 + 0.0378 X_3$	0.793 ***
6	$Y = 1.61 - 0.0186 X_2 + 0.0316 X_3$	0.547 ***	$Y = 2.42 - 0.059 X_2 + 0.039 X_3$	0.793 ***
7	$Y = 3.19 - 0.126 X_1 - 0.0186 X_2 + 0.0315 X_3$	0.964 ***	$Y = 2.24 - 0.0081 X_1 - 0.0342 X_2 + 0.0363 X_3$	0.836 ***

Co.C.: Correlation coefficient.
r: Simple correlation coefficient.
R: Multiple correlation coefficient.

Table (47): Anova of actual and predicted values of dry matter yield of barley plants grown on naturally salt affected soils.

Soil category	Anova table	EC	ESP	Clay	EC & ESP	EC & clay	ESP & clay	EC, ESP & clay
Saline	Significant level	N.S.	N.C.	**	N.C.	N.S.	N.C.	N.C.
	probability	0.133	N.C.	0.008	N.C.	0.431	N.C.	N.C.
Sodic	Significant level	N.C.	**	N.S.	N.C.	N.C.	N.S.	N.C.
	probability	N.C.	0.004	0.927	N.C.	N.C.	0.441	N.C.
saline- sodic	Significant level	N.S.	N.S.	*	N.S.	N.S.	N.S.	N.S.
	probability	0.510	0.243	0.030	0.110	0.133	0.143	0.170
salt-affected soils	Significant level	N.S.	*	***	*	N.S.	***	N.S.
	probability	0.488	0.003	0.000	0.048	0.343	0.000	0.374

* : Significant at level of 0.05.
** : Significant at level of 0.01.
*** : Significant at level of 0.001.
N.S. : Non significant
N.C. : Non computed.

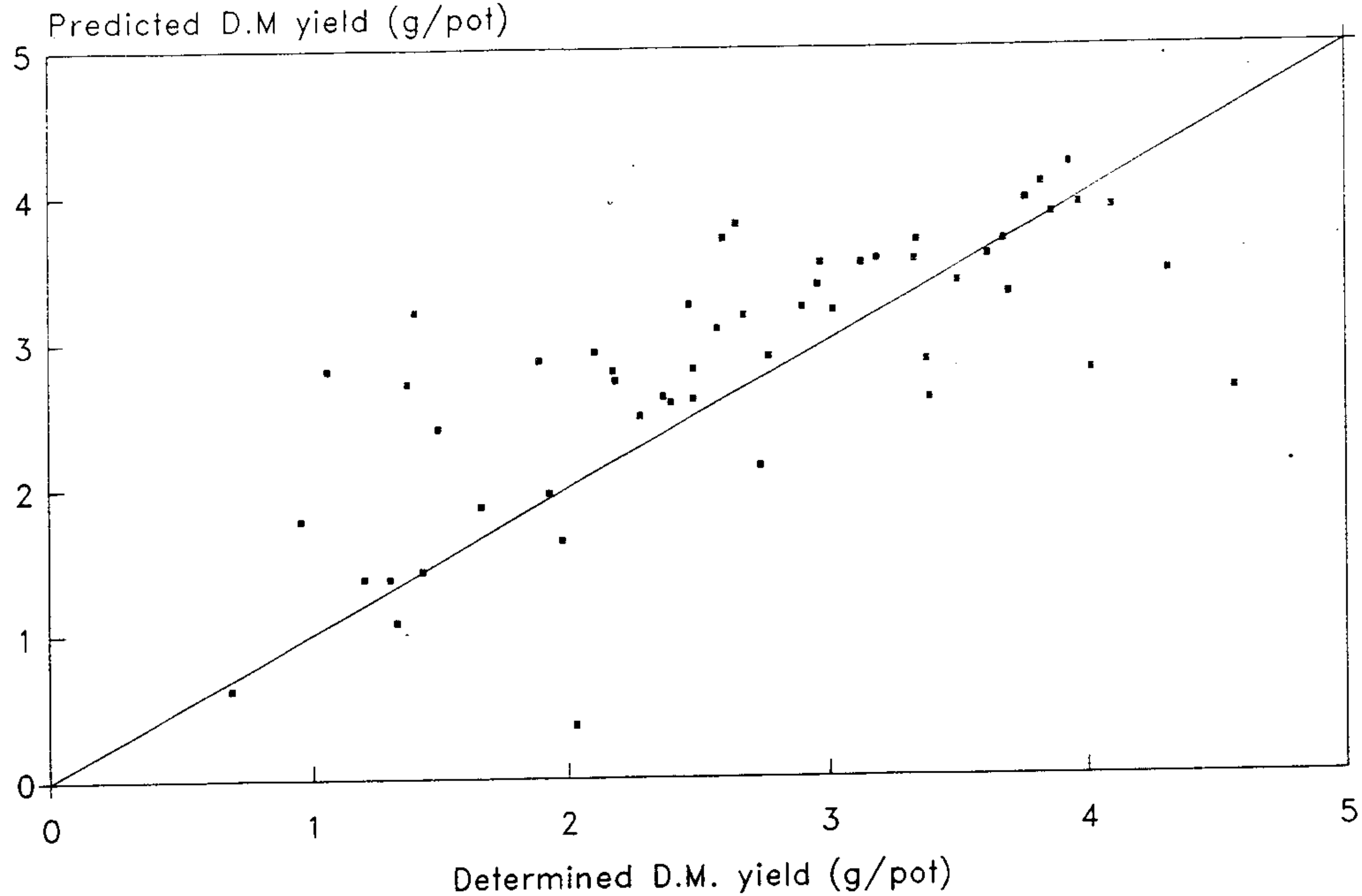


Fig. (17): Comparison between determined and predicted dry matter yield of barley plants, for the proposed equation.