

5. SUMMARY

This study deals mainly with the assessment of salt-affected soils and the role of the clay fraction in such assessment. Two natural soils, extremely differing in their texture, were selected from two locations in the south of Delta, Tukh district i.e. Moshtohor ($\approx 58\%$ clay) and Meet Kinana ($\approx 96\%$ sand) to develop the soil models needed for the study. Soil samples of both locations were treated with $\text{NaCl} + \text{CaCl}_2$ to obtain salinity grades corresponding to EC values of 2.75, 4, 8, 12, 16, 20 and 24 dSm^{-1} . Following to soil salinization, a sodication process was performed using NaOH solution to obtain seven levels of sodicity corresponding to ESP values of 10, 15, 20, 25, 30, 40 and 50, through each of the abovementioned grades of soil salinity. Therefore the three categories of salt-affected soils i.e. sodic and saline-sodic soils were represented through the prepared soil models.

The role of the clay fraction on the hazardous effects due to salinity and/or sodicity was evaluated in soil models derived from the aforementioned soils; by mixing each model derived from one soil, in increasing ratios, with the corresponding model of the other soil i.e. of the same salinity and sodicity levels. Accordingly, eight different grades of soil texture having clay content values of 2.32% (S1), 7.77% (S2), 16.12% (S3), 24.46% (S4), 32.82% (S5), 41.47% (S6), 49.52% (S7) and 57.98% (S8) were obtained through each grade of salinity (7) or sodicity (7).

Moreover, seventy samples representing the naturally salt-affected soils in Egypt were collected from different locations, adjacent to the bitter lakes in the east to the Delta and lakes of Manzala, Burullus, Edku and Mariut at Delta northern coasts.

Both prepared soil models and naturally salt-affected soils were subjected to the routine analyses; EC, exchangeable cations and CEC as well as ESP and hydraulic conductivity (K).

A greenhouse trial was carried out using both prepared and natural salt-affected soil samples as growth media, where barley plants (Giza 123) were grown for 45 days, thereafter dry matter yield, as well as plant content and uptake of N, P, K, Na, Ca and Mg were estimated.

The obtained data were subjected to statistical analyses and the different interrelationships describing the prepared soil models were established.

The validity of soil parameters and equations developed for the assessment of salt-affected soils was evaluated by computing the values of D.M. yield of barley plants predicted for the naturally salt-affected soils. Significance of differences were estimated between the values of predicted yield (calculated) and those of actual yield of naturally salt affected soils were estimated by means of "ANOVA" test.

The obtained results can be summarized in the following:

1- Soil salinity in relation to soil characteristics and productivity:

A. Hydraulic conductivity (K):

Results of (K) in tested soil models as affected by salinity and clay% reveal that:

1. Values of the relative hydraulic conductivity increased at a rate of about 1.70% per each unit of increase in soil salinity above EC 4 dSm⁻¹.
2. K values is negatively and significantly ($r=-0.913^{***}$) affected with increasing the clay content of soils.
3. The combined effect of soil salinity and clay content on K is described by the equation;

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

B. Soil pH (in 1:2.5 soil:water suspension):

pH values of tested models in relation to soil salinity and clay% reveal the following:

1. Soil pH was significantly ($r = -0.706^{***}$) reduced as the soil salinity increased (at a rate of about 0.03 pH unit for each E_{Ce} unit above of 4 dSm⁻¹).
2. Soil pH was significantly ($r = -0.587^{***}$) decreased with increasing the clay fraction%. Each increase of 1% in the clay content of the soil, above 2.32%, reduced soil pH by ≈ 0.01 unit.
3. The combined effect of the soil salinity and the the clay content on soil pH is represented by the equation;

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

C. Results of the elemental content of barley plants grown on tested saline models showed the following:

1. N-content of plants decreased with increasing soil salinity at all levels of soil salinity except those of E_{Ce} 16 and 20 dSm⁻¹, as compared by the control treatment.
2. N-content of plants slightly but gradually increased with increasing the soil content of clay.
3. P-content of plants decreased with increasing soil salinity.
4. Clay presence at any level tested, failed to affect clearly the P% of plants under the different levels of soil salinity.
5. K-content of plants was adversely and gradually affected with increasing soil salinity. Values of K-content were reduced, on average, from 4.4% to 2.5% for the highest level of salinity (EC 24 dSm⁻¹).
6. K-content of plants tended to increase steadily, with increasing the clay content of soil models.
7. Na-content of plants was positively affected by increasing soil salinity, but was progressively reduced by increasing the clay content.
8. Ca-content of plants consistently increased with increasing soil salinity as well as with increasing the clay content.
9. Mg-content of plants was positively affected by increasing soil salinity to more than E_{Ce} 8 and up to 24 dSm⁻¹, but did not show clear trend due to the increase in the clay fraction.

D- Results of the elemental uptake by barley plants grown on tested saline models reveal the following:

1. The total uptake of all the tested elements was high significantly decreased with increasing soil salinity due to its adverse effect on dry matter yield.
2. The total elemental uptake was positively affected by increasing the clay content according to the following equations:

$$\text{N-uptake} = 34.60 + 1.120 \text{ clay} \quad (r = 0.636^{***})$$

$$\text{P-uptake} = 6.11 + 0.216 \text{ clay} \quad (r = 0.445^{**})$$

$$\text{K-uptake} = 37.30 + 1.210 \text{ clay} \quad (r = 0.491^{***})$$

$$\text{Na-uptake} = 13.90 + 0.185 \text{ clay} \quad (r = 0.549^{***})$$

$$\text{Ca-uptake} = 14.90 + 0.484 \text{ clay} \quad (r = 0.811^{***})$$

$$\text{Mg-uptake} = 9.26 + 0.243 \text{ clay} \quad (r = 0.786^{***})$$

3. The combined effect of soil salinity and clay content on total elemental uptake can be described by the equations:

$$\text{N-uptake} = 83.20 - 3.45 \text{ EC} + 1.120 \text{ clay} \quad (R = 0.960^{***})$$

$$\text{P-uptake} = 21.40 - 1.09 \text{ EC} + 0.215 \text{ clay} \quad (R = 0.937^{***})$$

$$\text{K-uptake} = 116.00 - 5.59 \text{ EC} + 1.200 \text{ clay} \quad (R = 0.968^{***})$$

$$\text{Na-uptake} = 22.20 - 0.596 \text{ EC} + 0.185 \text{ clay} \quad (R = 0.849^{***})$$

$$\text{Ca-uptake} = 23.20 - 0.591 \text{ EC} + 0.484 \text{ clay} \quad (R = 0.888^{***})$$

$$\text{Mg-uptake} = 11.40 - 0.155 \text{ EC} + 0.243 \text{ clay} \quad (R = 0.807^{***})$$

E- Dry matter yield (D.M.) of barley plants grown on the tested soil models showed the following trends:

1. D.M. yield gradually and significantly decreased (by about 0.13 g/pot) for each unit of increase in EC more than 4 and up to 24 dSm⁻¹ according to the equation.

$$\text{D.M. yield} = 4.16 - 0.141 \text{ EC} \quad (r = -0.813^{***})$$

2. The clay fraction soundly decreased the adverse effect due to soil salinity on the D.M. yield which increased regularly under all the salinity levels, with increasing soil content of clay as described by the equations:

$$\text{D.M. yield} = 1.20 + 0.0338 \text{ clay} \quad (r = 0.530^{***})$$

$$\text{D.M. yield} = 3.18 - 0.141 \text{ EC} + 0.0338 \text{ clay} \quad (R = 0.970^{***})$$

II- Soil sodicity in relation to soil characteristics and productivity:

A. Hydraulic conductivity (K):

Results of the hydraulic conductivity (K) in the tested soil models as affected by sodicity and clay% reveal that:

1. The relative hydraulic conductivity was progressively reduced either as the soil sodicity or the clay content increased according to the equation;

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

B. Soil pH (in 1:2.5 soil:water suspension):

pH values of the tested soil models in relation to soil sodicity and clay% showed the following:

1. Soil pH significantly ($r = 0.877^{***}$) increased with increasing soil sodicity (by 0.03 pH unit for each ESP unit), according to the equation;

$$\text{pH} = 8.22 + 0.0307 \text{ESP} \quad (r = 0.877^{***})$$

2. The clay fraction significantly ($r = -0.427^{**}$), but negatively, correlated with soil pH, at a rate of about 0.011 unit versus each increase of 1% in clay (above 2.32%). This composited relation is represented the equation;

$$\text{pH} = 8.52 + 0.0307 \text{ESP} - 0.0105 \text{clay} \quad (R = 0.975^{***})$$

C. Plant contents of elements showed the following trends:

1. The N, P, K, Ca and Mg in barley plants significantly and gradually decreased, but Na increased with increasing soil sodicity.
2. Plant content of N, K, Ca and Mg increased with increasing soil content of clay, while P% and Na% slightly decreased.
3. The combined effect of soil sodicity and clay% on elemental content of plants can be described by the equations:

$$\text{N\%} = 2.540 + 0.0106 \text{clay\%} - 0.0020 \text{ESP} \quad (R = 0.621^{***})$$

$$\text{P\%} = 0.799 - 0.0006 \text{clay\%} - 0.0046 \text{ESP} \quad (R = 0.663^{***})$$

$$\text{K\%} = 3.970 + 0.0090 \text{clay\%} - 0.0540 \text{ESP} \quad (R = 0.973^{***})$$

$$\text{Na\%} = 0.372 - 0.0044 \text{clay\%} + 0.0439 \text{ESP} \quad (R = 0.995^{***})$$

$$\text{Ca\%} = 0.786 + 0.0064 \text{clay\%} - 0.0088 \text{ESP} \quad (R = 0.946^{***})$$

$$\text{Mg\%} = 0.555 + 0.0010 \text{clay\%} - 0.0056 \text{ESP} \quad (R = 0.826^{***})$$

D- Results of total elemental uptake by barley plants grown on the tested sodic soil models reveal the following:

1. Plant Uptake of N, P, K, Ca and Mg sharply decreased with increasing soil sodicity, while Na-uptake significantly increased as the soil sodicity increased.
2. Elemental uptake of barley plant was positively affected with increasing the clay content.
3. The combined effect due to the soil sodicity (ESP) and clay content (%) on elemental uptake is represented by these equations;

$$\text{N-uptake} = 78.70 - 1.040 \text{ ESP} + 1.290 \text{ clay} \quad (R = 0.989^{***})$$

$$\text{P-uptake} = 21.60 - 0.296 \text{ ESP} + 0.231 \text{ clay} \quad (R = 0.926^{***})$$

$$\text{K-uptake} = 111.00 - 2.230 \text{ ESP} + 1.300 \text{ clay} \quad (R = 0.983^{***})$$

$$\text{Na-uptake} = 5.29 + 0.896 \text{ ESP} + 0.395 \text{ clay} \quad (R = 0.846^{***})$$

$$\text{Ca-uptake} = 22.20 - 0.441 \text{ ESP} + 0.466 \text{ clay} \quad (R = 0.973^{***})$$

$$\text{Mg-uptake} = 15.70 - 0.275 \text{ ESP} + 0.187 \text{ clay} \quad (R = 0.933^{***})$$

E. Dry matter yield (D.M.):

Results of D.M. yield of barley plants grown on sodic soil models showed the following trends:

1. D.M. yield was significantly ($r = -0.478^{**}$) reduced with increasing soil sodicity, at rate of about 0.03 g/pot for each ESP unit. The relationship between D.M. yield and soil sodicity is described by this equation:

$$\text{D.M. yield} = 3.77 - 0.0262 \text{ ESP} \quad (r = -0.478^{**})$$

2. The clay fraction presence diluted the adverse effect of soil sodicity on D.M. yield of barley plants and consequently increased regularly this yield. at a significantly ($r = 0.858^{***}$) increased with increasing the clay content, at a rate of about 37 mg/pot for each 1% of the clay content.

3. The relationship between D.M. yield and the clay content is described by the equation:

$$\text{D.M. yield} = 1.96 + 0.0374 \text{ clay} \quad (r = 0.858^{***})$$

4. The composited relation of D.M. yield with ESP and clay% is represented by the equation:

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

III- Combined effect of soil salinity and sodicity of soils on their characteristics and productivity:

A. Hydraulic conductivity (K):

The obtained trends for hydraulic conductivity under saline-sodic conditions are summarized in the following:

1. Values of the relative hydraulic conductivity were increased at a rate of about 1.03% per each unit of increase in soil salinity above EC 4 dSm⁻¹.
2. Relative hydraulic conductivity values decreased with increasing soil sodicity, but increased with increasing soil salinity.
3. Relative hydraulic conductivity values gradually decreased with increasing the soil content of clay and the levels of soil sodicity as well, but tended to increase with increasing soil salinity under the tested levels of ESP and clay%.
4. The net combined effect due to soil salinity (EC), soil sodicity and clay content on hydraulic conductivity (K) is expressed by the equation;

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

B. Soil pH (in 1:2.5 soil:water suspension):

The following trends for soil pH under saline-sodic conditions were obvious:

1. The soil pH negatively correlated with soil salinity, at a rate of about 0.04 pH unit reduction per each unit of increase in EC above 4 dSm⁻¹. The soil sodicity increased the soil pH at a rate of about 0.03 pH unit versus each ESP unit above 15.
2. Soil pH decreased, on average, (from 8.81 to 8.17) with increasing the clay content of the soil from 2.32 up to 57.98%.
3. The combined effect of soil salinity, soil sodicity and clay content on soil pH is described by the equation:

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

C. Elemental content of barley plant:

The following trends of elemental content of barley plants under saline-sodic conditions are obvious:

1. N, P and K contents decreased with increasing soil salinity under all the ESP levels, while N-content at EC 16 and 20 dSm⁻¹ increased. Na, Ca and Mg contents increased as the soil salinity increased, but the rate of increase in Ca and Mg was slight, under all the ESP levels.
2. Plant content of N, P, K, Ca and Mg was adversely affected with increasing soil sodicity, while Na-content was progressively increased under all the levels of soil salinity.
3. N, K, Ca and Mg contents of plants were positively affected, while Na⁺% was negatively affected as the soil content of clay increased. P% showed no clear trend due to increasing the clay fraction content in soil.

D. Total elemental uptake by barley plants:

Results of total elemental uptake by barley plants grown on saline-sodic soils reveal the following:

1. Uptake of N, P, K, Na, Ca and Mg by plants was significantly reduced as the soil salinity increased at different levels of ESP.
2. Uptake of N, P, K, Ca and Mg soundly decreased with increasing soil sodicity, while Na-uptake was increased.
3. Uptake of N, P, K, Na, Ca and Mg significantly increased as the clay content increased.
4. The combined effect of soil salinity, soil sodicity and the clay content of the tested soil models on plant uptake of N, P, K, Na, Ca and Mg is described by the equations:

$$\text{N-uptake} = 64.40 - 4.30 \text{ EC} + 0.1590 \text{ ESP} + 1.02 \text{ clay} \quad (R = 0.923^{***})$$

$$\text{P-uptake} = 18.00 - 1.10 \text{ EC} + 0.0703 \text{ ESP} + 0.186 \text{ clay} \quad (R = 0.920^{***})$$

$$\text{K-uptake} = 69.70 - 4.29 \text{ EC} + 0.2570 \text{ ESP} + 1.06 \text{ clay} \quad (R = 0.884^{***})$$

$$\text{Na-uptake} = 46.30 - 2.58 \text{ EC} + 0.3040 \text{ ESP} + 0.427 \text{ clay} \quad (R = 0.923^{***})$$

$$\text{Ca-uptake} = 13.20 - 0.758 \text{ EC} + 0.0908 \text{ ESP} + 0.309 \text{ clay} \quad (R = 0.787^{***})$$

$$\text{Mg-uptake} = 9.38 - 0.427 \text{ EC} + 0.0344 \text{ ESP} + 0.200 \text{ clay} \quad (R = 0.740^{***})$$

E- Dry matter yield (D.M.):

Results of the D.M. yield of barley plants grown on saline-sodic soil models showed the following trends:

1. D.M. yield of tested soil models was decreased by about 0.12 g/pot for each unit (EC) of increase in soil salinity above EC 4.

2. D.M. yield decreased with increasing soil sodicity at different levels of soil salinity, at a rate of 0.016 g/pot for each unit of increase in ESP above 20.
3. D.M. yield significantly increased with increasing the clay content, the rate of the increase was about 0.03 g/pot per each 1% of clay.
4. The net effect of soil salinity, soil sodicity and the clay content of the tested soil models on D.M. yield is expressed by this equation:

$$\text{D.M. yield} = 2.45 - 0.144 \text{ EC} + 0.0137 \text{ ESP} + 0.0295 \text{ clay} \quad (R = 0.952^{***})$$

Finally, it should be referring that this investigation represent a preliminary study only restricted to the conditions prevailing in soils of "Delta" in Egypt and barley (var. Giza 123) as an indicator plant. However, it could be profitable for assessment the salt affected soils under other conditions and other crops by developing specific new equations, in the same way that could be more suitable for such conditions.