Improvement of a Salt Affected Soil on Bahr El-Bakar Area Using Certain Industrial Byproducts:
1. Effect on Physical and Chemical Characteristics

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Abstract: An equilibration experiment was conducted to assess and evaluate the effect of certain amendments i.e., byproduct-1, byproduct-2; from Citric Company; compost and gypsum on some characteristics of a salt affected soil, clay texture, Vertic Torrifuvents, at Bahr El-baker area, Sharkia Governorate Application of different amendments significantly improved the physical properties of the tested soil. Soil bulk density generally decreased, while available water content as well as hydraulic conductivity increased due to gypsum, byproduct-1, byproduct-2 and compost applications. Chemical properties of the studied soil were clearly improved due to amendments addition particularly after three or four months from application. Total soluble salts soil pH, soluble Na⁺, Cl⁻ and SAR values were significantly reduced, while soluble Ca²⁺ and SO₄²⁻ were significantly increased due to application of any amendment as compared with the control treatment. In addition, exchangeable Na as well as ESP were markedly reduced due to application of any amendment. The common parameters of saline sodic soil i.e. pH, EC, and ESP were clearly improved. The superiority in improving such soil parameters was resulted from byproduct-1 and 1/2 byproduct-1 combined with 1/2 byproduct-2) amendments as they removed sodist from the soil and reduced considerably its contents from soluble salts.

Keywords: Improvement- Salt affected soil - Industrial byproducts- Physical and chemical characteristics

INTRODUCTION

Total salt affected area in the world about 955 Mega ha¹ out of which 0.9 M ha in Egypt. The majority of salt-affected soils in Egypt are located in the northern-central part of the Nile Delta and on its eastern and western sides. However, fifty five percent of the cultivated lands of northern Delta region are salt-affected, twenty percent of the southern Delta and middle Egypt region and twenty five percent of the Upper Egypt region are salt-affected soils.

Many investigators such as³ used different soil conditioners e.g. organic manures, mineral fertilizers, sulfur and gypsum to avoid the risks of irrigation with drainage water on growing crops. Also the role of these conditioners on amelioration of some chemical and physical properties of different soils was investigated by many scientists such as⁴,⁵.

Abou-Baker and Omar⁶ found that application of organic compost alone or accompanied with NPK fertilizers caused a decrease in soil salinity when compared with the control treatment. Gypsum is used on these soils to improve soil structure but the responses are often short-lived and economically unsustainable⁷. While gypsum is an excellent kick-starter, gains in crop production and longer-term improvements in soil structure through amelioration of sodicity are possible if gypsum application and other soil management practices are combined. Moustafa⁸ also found that application of farm yard manure and gypsum reduced pH in the sodic soil with maximum decrease in the upper layer (0-20cm).

The present study was conducted to evaluate certain industrial byproducts in comparison with the usual conditioners i.e. gypsum and organic compost in improving some physical and chemical characteristics of a salt affected soil from Bahr Elbakar area.

MATERIALS AND METHODS

Equilibration experiment was carried out under greenhouse conditions to study the effect of some industrial byproducts namely byproduct-1 and byproduct-2 (waste products from Citric Company of 10⁸ of Ramadan City) as well as the usual conditioners, compost and gypsum on soil physical and chemical characteristics.
Surface soil samples were collected from Bahr El-Baqar area, Sharkia Governorate. Soil of this area is irrigated with drainage water and cultivated with crops suffering from problems of salinity. A survey study including soil, water and plants was carried on the studied area by the same authors (unpublished data). Some physical and chemical properties of this soil are shown in table 1. Soil samples were air-dried and ground separately and thereafter was packed in plastic pots (30-cm height and 17 cm diameter) with 2kg air dried soil for each.

The pot was vibrated during packing then, moisture content was brought to field capacity using tap water for irrigation. The pots were arranged in a randomized block design with three replicates for each treatment. Treatments were applied as follow: (1) Control, without any amendments. (2) Gypsum 14 g/pot, 7 ton/fed./15cm depth. (3) Byproduct-1 at a rate of 10.3 g/pot, 5.2 ton/fed./15cm depth. The amounts of byproduct-1 was calculated to be equivalent to calcium content in gypsum rate. (4) Compost, at a rate of 20 g/pot, 10ton/fed.. (5) Byproduct-2 at a rate of 19 g/pot, 9.5 ton/fed.. The amounts of byproduct-2 was calculated to equivalent organic matter content in the applied compost. (6) Half the used rate of byproduct-1 i.e. 5.2 g/pot, 2.6 ton/fed. and half the used rate of the compost i.e.10 g/pot, 5 ton/fed.. (7) Half the used rate of byproduct -1 and half the used rate of byproduct -2 i.e. 9.5g/pot, 4.8 ton/fed. Some characteristics of used conditioners are shown in table (2).

After 30 days, all the soil pots were leached with excess amounts of water (30 % of water holding capacity).thereafter, soil of the different treatments were sampled and prepared for analysis. The pots were leached again after two, three and four months from beginning of the experiment, then the soil samples, again, were collected. The collected samples were prepared for physical and chemical properties determination.

Physical and chemical properties of the soil as well as the used amendments were determined according to the standard methods \[ \text{[9,10]} \]. Values of pH of the different amendments were measured in 1:5 ratio (material : water) suspension. EC and soluble ions were determined in the extract of the suspension. Chemically available micronutrients were extracted by DTPA according to \[ \text{[11]} \] and measured using an atomic absorption spectrophotometer.

The compost and byproduct-2 were digested in concentrated H2SO4 and H2O2 at 400°C. Whereas, gypsum and byproduct-1 were digested in dilute HCl (1:3); Ca, Mg, Na, N, P, K, Fe, Mn, Zn and Cu were determined in the digested materials.

Analysis of variance was carried out for the data using the GLM procedure of SAS\[ \text{[12]} \].

### RESULTS AND DISCUSSIONS

Effect of the used different amendments on bulk density, hydraulic conductivity and available water content in the studied soil.

Data in figure (1) show that soil bulk density generally decreased by after four months from amendments application in comparison with the control treatment. It is clear that the treatment of 1/2 byproduct-1 combined with 1/2 byproduct-2 markedly reduced bulk density value of the studied soil after four months from its addition followed by byproduct-1 alone, 1/2 byproduct-1 combined with 1/2 compost and gypsum amendments. This effect may be related to the improvement of soil aggregates and soil porosity. Similar findings were also reported by \[ \text{[13,14]} \].

Soil hydraulic conductivity depends mainly on soil structure, soil texture and management processes. In general, addition of the different amendments clearly increased values of soil hydraulic conductivity in the studied soil, Fig. 1. The superiority of the treatment (1/2 byproduct-1+1/2 byproduct-2) in improving soil hydraulic conductivity is quite clear that it increased soil hydraulic conductivity by about 3.8 fold that of control treatment. This could be attributed to the production of high amounts of calcium from byproduct-1 and organic matter from byproduct-2, consequently increasing soil aggregation and the dynamic soil-water movement. The benefit effect of organic matter and /or gypsum in improving hydraulic conductivity of salt affected soils was also reported by \[ \text{[15]} \].

The amount of available soil moisture significantly increased by application of different amendments. The highest effect was recorded due to application of 1/2
Table 2: Some characteristics of the amendments used for soil improvement.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Byproduct-1</th>
<th>Gypsum</th>
<th>Byproduct-2</th>
<th>Compost</th>
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<tbody>
<tr>
<td>pH (1:5)</td>
<td>3.12</td>
<td>4.09</td>
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<td>EC, dS/m (1:5)</td>
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<td>2.55</td>
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<td>9.22</td>
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<td>Moisture content</td>
<td>35</td>
<td>25</td>
<td>40</td>
<td>15</td>
</tr>
<tr>
<td>Solubility point, g/100 g</td>
<td>1.76</td>
<td>0.92</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
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<td>Bulk density, g/cm³</td>
<td>0.39</td>
<td>0.82</td>
<td>0.25</td>
<td>0.45</td>
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<td>Organic carbon, %</td>
<td><strong>n.d.</strong></td>
<td>n.d.</td>
<td>53.9</td>
<td>36.2</td>
</tr>
<tr>
<td>Organic matter, %</td>
<td>n.d.</td>
<td>n.d.</td>
<td>93.0</td>
<td>62.4</td>
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<td>Soluble cations and anions, mg/kg</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>2050</td>
<td>1560</td>
<td>2390</td>
<td>2040</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>73</td>
<td>157</td>
<td>67</td>
<td>195</td>
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<tr>
<td>Na⁺</td>
<td>173.5</td>
<td>815</td>
<td>119.5</td>
<td>7705</td>
</tr>
<tr>
<td>K⁺</td>
<td>13.65</td>
<td>37.05</td>
<td>242</td>
<td>296.5</td>
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<td>Cl⁻</td>
<td>710</td>
<td>1570</td>
<td>2800</td>
<td>8675</td>
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<tr>
<td>HCO₃⁻</td>
<td>610</td>
<td>915</td>
<td>1220</td>
<td>3965</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>4150</td>
<td>3260</td>
<td>1800</td>
<td>7270</td>
</tr>
<tr>
<td>CO₃⁻</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d</td>
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<tr>
<td>Chemically available nutrients, mg/kg</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>45.2</td>
<td>32.0</td>
<td>987</td>
<td>913</td>
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<td>P</td>
<td>4.52</td>
<td>2.89</td>
<td>481</td>
<td>441</td>
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<td>K</td>
<td>15.5</td>
<td>10.2</td>
<td>626</td>
<td>749</td>
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<td>Fe</td>
<td>2.48</td>
<td>1.12</td>
<td>312</td>
<td>215</td>
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<td>Mn</td>
<td>1.64</td>
<td>0.97</td>
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<td>Zn</td>
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<td>0.50</td>
<td>185</td>
<td>125</td>
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<tr>
<td>Cu</td>
<td>0.12</td>
<td>0.08</td>
<td>136</td>
<td>96.2</td>
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<td>Total content of macronutrients, %</td>
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<td></td>
<td></td>
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<tr>
<td>Ca</td>
<td>18.3</td>
<td>9.96</td>
<td>5.71</td>
<td>7.24</td>
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<td>Mg</td>
<td>3.60</td>
<td>2.43</td>
<td>0.40</td>
<td>0.32</td>
</tr>
<tr>
<td>N</td>
<td>0.08</td>
<td>0.03</td>
<td>4.18</td>
<td>2.16</td>
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<tr>
<td>P</td>
<td>0.02</td>
<td>0.01</td>
<td>0.86</td>
<td>0.71</td>
</tr>
<tr>
<td>K</td>
<td>0.36</td>
<td>0.18</td>
<td>1.92</td>
<td>2.83</td>
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<tr>
<td>Total content of micronutrients, mg/kg</td>
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<td></td>
<td></td>
<td></td>
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<td>Fe</td>
<td>328</td>
<td>215</td>
<td>150</td>
<td>919</td>
</tr>
<tr>
<td>Mn</td>
<td>45.2</td>
<td>32.1</td>
<td>65.2</td>
<td>408</td>
</tr>
<tr>
<td>Zn</td>
<td>21.5</td>
<td>15.6</td>
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<td>Cu</td>
<td>18.9</td>
<td>9.48</td>
<td>31.8</td>
<td>93.4</td>
</tr>
</tbody>
</table>

* (1:5) = amendment; water ratio and ** n.d. = not detected
byproduct-1 combined with 1/2 byproduct-2 followed
by 1/2 byproduct-1 combined with 1/2 compost
amendments. Improving some physical properties
of soil such as soil structure, soil aggregates and soil
porosity, data reveal that the applied amendments
were the main factor in increasing available water of the
studied soil.

Effect of the Used Different Amendments on pH,
Salinity, Soluble Ions and SAR value: Basically,
reclamation or improvement of sodic soils requires
the removal of part or most of the exchangeable sodium
and its replacement by the more favourable calcium
ions in the root zone. This can be accomplished in
many ways, the best dictated by local conditions,
available resources.

Data in table (3) show, irrespective of the source
of amendment, that application of any amendment to
the soil causes slight decline in the pH values
compared to the control treatment. After 120 days,
such decrease reaches 0.38 unit with application of
(1/2 byproduct-1+1/2 compost) meanwhile, byproduct-1
or compost treatment alone reduced soil pH by 0.2 or
0.12 unit, respectively. However, soil pH was reduced
by 0.25 unite after application of the treatment (1/2
byproduct-1+ 1/2 byproduct-2). The decrease in soil pH
values could be attributed to the low amounts of
soluble and exchangeable sodium and high contents of
both soluble and exchangeable calcium of the different
amendments applied. The highest effect in lowering pH
values may be attributed to increasing organic acids
from compost decomposition as well as citric acid from
byproduct-1. Byproducts from Citric Acid Company
may increase quantities of exchangeable hydrogen on
clay surface and therefore have an acidic reaction.
Also, release of organic acids and CO₂ during the
decomposition process and thus decreased precipitation
of Ca and CO₂ ions which should lead to decreasing
exchangeable Na percentage (ESP) and subsequently
increasing the removal of Na ions in the drainage water.
Similar finding was found by[16].

The obtained data in table (3) indicate also that
application of the different amendments caused an
appreciated reduction in the ECₑ values. However, the
different amendments caused a clear decline in the ECₑ
values with increasing time. The ECₑ values decreased
by about 1.81, 1.20, 2.96, 2.11, 2.50 and 2.15Dś/m by
application of gypsum, compost, byproduct-1,
byproduct-2, 1/2 byproduct-1 combined with 1/2
byproduct-2) and 1/2 byproduct-1 combined with
1/2 compost after four months from their applications
compared to the control, respectively. It's clear that
byproduct-1 was the most effective in reducing ECₑ
value of the studied soil after four months from its
addition followed by the treatment of 1/2 byproduct-1
combined with 1/2 byproduct-2. This effect may be
related to the improvement of soil porosity as well as
the down movement of irrigation water which enhanced
leaching of soluble and exchangeable Na⁺ from the
soil. Abou El-Defan[17] studied that application of
farmyard manure, gypsum and mix of them on some
soil characteristics and found that, both EC and ESP
values significantly decreased with different treatments,
especially with application of farmyard manure mixed
with gypsum.

Application of different amendments to the soil
significantly increased soluble Ca²⁺ and the same time,
significantly decreased Na⁺, and slightly effected both
Mg²⁺ and K⁺ after 30 days from application table (3).
After 120 days, the most pronounced was increasing
Ca²⁺ and decreasing Na⁺ due to added different
amendments was pronounced. The highest effect was
obtained from application of byproduct-1 followed by
1/2 byproduct-1 combined with 1/2by-product-2 and 1/2
byproduct-1 combined with 1/2compost treatments.
Such increases recorded 3.80, 3.04 and 2.54 fold,
respectively compared with the control treatment.
These findings are logically expected due to the
production of high amounts of calcium from byproduct-
1, which contain high amounts from soluble calcium
that replaced Na and Mg, which were then leached
from the soil pots. Soluble potassium relatively
increased with application of different amendments and
this could be due to its low initial concentration in
either soil or added conditioners.

Application of gypsum, compost, byproduct-1,
byproduct-2, 1/2 byproduct-1 combined with
1/2byproduct-2 and 1/2 byproduct-1 combined with
1/2compost to the soil decreased Cl ions by 62.6,
41.7, 87.9, 68.9, 81.6 and 72.6 % respectively
compared to the control treatment. The highest decrease
in chloride ions concentration was obtained after four
months from the addition of byproduct-1 to the soil.
On the other hand, SO₄²⁻ and HCO₃⁻ ions in the soil
extract were significantly increased due to application
of gypsum, compost, by-product-1, by-product-2, 1/2
byproduct-1 combined with 1/2by-product-2 and 1/2
byproduct-1 combined with 1/2compost to the soil. The
increases in SO₄²⁻ reached 4.5, 2.6, 5.2, 4.3, 4.8 and
4.4 fold above the control treatment. This finding is
expected since SO₄²⁻ ions are one of the major
products of added gypsum, byproduct-1 and
byproduct-2

Sodium adsorption ratio (SAR) values that
calculated from soluble Na, Ca and Mg ions are shown
in table (3). The relatively high mobility and
leachability of Na from soil due to the applied
amendments as compared with Ca²⁺ and Mg²⁺, resulted
in lower values of SAR hence, the SAR values of
the treated soil were sharply decreased with increasing time
Table 3: Effect of different amendments on some chemical characteristics of the studied soil.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH (1:2.5)</th>
<th>EC, dS/m paste</th>
<th>Soluble ions, meq/L</th>
<th>SAR</th>
<th>After 30 days</th>
<th>After 60 days</th>
<th>After 90 days</th>
<th>After 120 days</th>
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</thead>
<tbody>
<tr>
<td>Control</td>
<td>8.14</td>
<td>8.91</td>
<td>5.90</td>
<td>9.97</td>
<td>98.5</td>
<td>1.74</td>
<td>106</td>
<td>1.02</td>
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<td>9.97</td>
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<td>1.84</td>
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<td>9.10</td>
<td>6.15</td>
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<td>94.6</td>
<td>1.93</td>
<td>89.9</td>
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<td>B1**</td>
<td>8.13</td>
<td>8.83</td>
<td>8.23</td>
<td>9.55</td>
<td>89.2</td>
<td>1.86</td>
<td>74.3</td>
<td>6.14</td>
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<td>B2***</td>
<td>8.14</td>
<td>9.01</td>
<td>7.03</td>
<td>9.13</td>
<td>93.1</td>
<td>1.83</td>
<td>81.7</td>
<td>7.86</td>
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<tr>
<td>1/2B1+1/2 B-2</td>
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<td>8.90</td>
<td>9.14</td>
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<td>88.4</td>
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<td>78.4</td>
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<td>91.9</td>
<td>1.95</td>
<td>81.8</td>
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<td>0.57</td>
<td>0.62</td>
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<td>After 30 days</td>
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<td>6.88</td>
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*aControl mean without amendment, **B1 and ***B2 mean byproduct-1 and byproduct-2 from Citric Acid Company, respectively.*
### Table 4: Effect of some amendments on exchangeable cations and ESP of the studied soil.

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<tr>
<th>Treatment</th>
<th>Exchangeable cations, meq/100g soil</th>
<th>ESP</th>
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<td>Mg(^{2+})</td>
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<td>18.0</td>
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<tr>
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<td>B2(^{2})</td>
<td>19.4</td>
<td>16.7</td>
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<tr>
<td>1/2B1+1/2 B-2</td>
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<td>17.5</td>
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<td>B1(^{1})</td>
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<td>1/2B1+1/2 B-2</td>
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</table>

*Control mean without amendment, ** B1 and *** B2 mean byproduct-1 and byproduct-2 from Citric acid Company, respectively.
Fig. 1: Effect of different amendments on bulk density, hydraulic conductivity and available water content of the studied soil.

of incubation. The studied soil highly responded to the added amendments especially byproduct-1 followed by 1/2 byproduct-1 combined with 1/2byproduct-2 treatments. The highest decreases in SAR values after four months from incubation were attained due to application of byproduct-1 and 1/2 byproduct-1 combined with 1/2byproduct-2 and recorded 75.6 and 66.8 %, respectively compared with the control treatment.

From the aforementioned results, it can be concluded that the amended soil under study became almost, more free from alkalinity and salinity as indicated by lowering pH, EC, Na+, Cl and SAR as well as increasing Ca²⁺ and SO₄²⁻ ions after 90-120 days from byproduct-1, 1/2 byproduct-1 combined with 1/2by-product-2 and 1/2 byproduct-1 combined with 1/compost additions.

Effect of the Used Different Amendments on Exchangeable Cations: Data listed in table (4) show the effect of different amendments on the exchangeable cations of the investigated soil after different times of incubation. Generally, exchangeable Ca²⁺ values were clearly increased due to any amendment applied after any time of incubation. Similarly exchangeable K⁺ showed noticeable increase. Meanwhile, exchangeable
Na' as well as ESP values were sharply decreased. It is worthy to mention that application of byproduct-1 resulted in the highest effect on increasing exchangeable Ca\textsuperscript{2+} as well as decreasing exchangeable Na' and ESP values after any time of incubation. Maximum effects were recorded after four months from incubation. The benefit effect of byproduct-1 treatment could be attributed to its relatively higher amounts from Ca ions, (table, 1). The ESP values were reduced from 31.2 (control treatment) to 13.4, 18.9, 2.90, 13.2, 7.50 and 11.3 at the end of the experiment due to gypsum, compost, byproduct-1, byproduct-2, 1/2 byproduct-1 combined with 1/2 byproduct-2 and 1/2 byproduct-1 combined with 1/2 compost additions to the soil, respectively. The highest beneficial effects seemed to be due to byproduct-1 followed by 1/2 byproduct-1 combined with 1/2 byproduct-2 therefore, these treatments are appreciated for application in cultivating wheat crop under conditions of saline-sodic soils.

It can be concluded that application of different amendments improved the soil of Brh Elbaker area which is classified as saline soil (EC\textsubscript{e} > 4 and ESP<15) except for compost treatment which did not change the soil class. So, it seems that such soil needs further leaching requirements, particularly fresh or high quality water to be classified as non saline soil.

REFERENCES