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# Improvement of some Chemical Properties and Productivity of some Salt-affected Calcareous Soils

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DISTURBED soil columns experiment using two salt-affected calcareous soils was conducted to evaluate the effect of elemental sulphur (S) and farmyard manure (FYM) amendments as well as intermittent leaching using waters of different salinities on the improvement some chemical properties ,yield and nutrient uptake of barley (*Hordeum vulgare*) plant.

Results pertaining soil chemical properties indicated that, the salt removed by leaching the investigated soils was obviously pronounced. The electrical conductivity (ECe) values of the saturated extract of the untreated Maryout and Ras Sudr soils , after leaching with waters of different salinities were sharply reduced by 81 and 83%, respectively, indicating the high efficiency of leaching process. However, ECe values of the amended soils with S and FYM were fairly lower than that of control treatment by about 22 and 24% for Maryout soil and 13 and 17% for Ras Sudr soil, respectively. More or less, similar trend was obtained for the soluble ions with the height reduction for Cl- and Na+ ions on the other hand, an obvious reduction in the ESP value of the amended and leached Maryout soil turning it from saline sodic to non saline non sodic one.

The application of elemental sulphur and FYM to the investigated salt-affected calcareous soil sharply increased barley grain yield by about 94 and 76% for Maryout soil and 93 and 84% for Ras Sudr soil, over the control respectively. Almost, similar trend was found for barley straw dry weight. The total uptake of N, P and K increases markedly in all amended treatments. Such increase could be attributed to the increase in plant dry weigh rather than in nutrients concentrations.

**Keywords:** Salt-affected calcareous soil, Improvement, Elemental sulphur, Farmyard manure, Barley plant.

Salinization and alkalinization are the most common land degradation processes, particularly occurring in arid and semi-arid regions, whereas soluble salts are accumulated in the soil, influencing soil properties which cause lessening of the soil productivity (Szaboles, 1974 and Farifteh *et al.*, 2006). Moreover, the growing shortage of high quality water for irrigation has necessitated the use of saline water which, in turn, has caused considerable of some soil.

On the other hard, the calcareous soil occupy about 0.65 million acre from the desert region of Egypt.These soils are some what infertile due to their specific characteristics. The use of saline water for irrigation resulted in salinization build up (El-Sayed *et al.*, 2005 and Beheiry & Soliman, 2005) and vast areas turned to salt affected soils.Modification and improvement of the undesirable conditions of soils could be achieved through amendments application and adequate leaching.

A fair number of investigators indicated the advantage of using elemental sulphur and organic manure for retarding soil physical and chemical properties degradation (Yousry *et al.*, 1984; Alawi *et al.*, 1980; El-Maghraby, 2001 and El-Sayed *et al.*, 2005). The present investigation was carried out to evaluate the effect of elemental sulphur and farmyard manure amendments and leaching technique using the very high saline well water, that is available in Ras Sudr area and its dilution in improving some chemical properties and productivity of two salt-affected calcareous soils.

## Material and Methods

Two surface soil samples (0-30 cm depth) were collected from regions representing salt affected calcareous soils and having different amounts of $CaCO_3$ and total soluble salts content. The first one was *Typic torripsamments, Mixed, Hyperthermic*, saline calcareous sandy clay loam soil, Ras Sudr, South Sinai, while the later was *Typic Calciorthents,* saline sodic calcareous sandy clay loam soil, Maryout Area, South Alexandria. Some characteristics of these soils are shown in Table 1a. Soil routine analysis was conducted according to the standard methods outlined by Jakson (1967); Page *et al.* (1982) and Klute (1986).

A greenhouse experiment was carried out using disturbed soil columns (PVC of 50cm height and10.5cm internal diameter). Soil samples were mixed with the following amendments equivalent to: one ton elemental sulphur (S)/fed or 20 $m^3$/fed farmyard manure (FYM) of soil and straw bedding having EC of 2.0 $dS.m^{-1}$ in addition to control treatment (without amendments). The columns were packed with the amended soil samples to a height of 30cm and to give average bulk density of about 1.3 $kg/m^3$. The lower end of the column was supported by a plastic screen covered with filter paper. The treatments were replicated four times for each.

*Leaching of soil columns*

Waters of different salinity levels were used for leaching the columns having $EC_w$ values of 8 (W1), 4 (W2) and 0.4 (W3) dS/m. The second water (W2) was prepared by diluting the first water (W1) with tap water (W3). The saline water (W1) was artesian well water from Ras Sudr, South Sinai. W1 and W2 waters are considered very high saline (Richerds, 1954), or the use of such waters for irrigation would cause severe problems according to Ayers & Westcot (1985). Some characteristics of the three water used for leaching are shown in Table 1b. These waters were added to the appropriate soil columns at 2 days intervals to restore the soil to field capacity. The columns were maintained in a vertical position for 30 days, after which they were leached intermittently four times at 8 days intervals with water of the prescribed salinity level. Leaching volumes were equivalent to the water holding capacity plus 30 percent. The leaching was performed with three successive steps. Saline water (W1) was used in the first step. The next leaching step was carried out using the diluted saline water (W2), while the third step was performed with tap water (W3). Representative soil samples were taken for chemical analysis from the columns after leaching with waters (three sub samples were taken from each column ,0-10, 10-20 and 20-30 cm depth, to make a composite sample).

**TABLE 1a. Some physical and chemical characteristics of the studied soils.**

| Characteristics | Maryout soil | Ras Sudr soil |
|---|---|---|
| **Particle size distribution,%** | | |
| **Coarse sand** | 39.4 | 37.2 |
| **Fine sand** | 29.2 | 29.4 |
| **Silt** | 20.1 | 23.3 |
| **Clay** | 11.3 | 10.1 |
| **Texture** | Sandy clay loam | Sandy clay loam |
| **Field capacity,%** | 19.5 | 17.2 |
| **CaCO3,%** | 28.8 | 51.9 |
| **Organic matter,%** | 0.53 | 0.32 |
| **pH (1:2.5)** | 8 | 7.6 |
| **ECe, dS.m-1** | 19.5 | 10.8 |
| **Soluble ions, meq.l-1** | | |
| $Ca^{2+}$ | 37.2 | 29.8 |
| $Mg^{2+}$ | 30.7 | 18 |
| $Na^{+}$ | 114 | 55.6 |
| $K^{+}$ | 1.8 | 2.7 |
| $HCO_3^-$ | 7.7 | 3.3 |
| $Cl^-$ | 126 | 81.5 |
| $SO_4^{--}$ | 53.7 | 13.8 |
| **SAR** | 19.6 | 11.4 |
| **ESP, %** | 17.7 | 10.3 |

**TABLE 1b. Some characteristics of water used for leaching.**

| Leaching water | pH | ECw, dS/m | Soluble ions, meq / L | | | | | | | SAR |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | HCO3- | Cl- | $SO_4^{--}$ | |
| W1# | 8.4 | 8.0 | 160 | 13.6 | 57.3 | 2.40 | 20.5 | 46.8 | 20.7 | 14.9 |
| W2 | 8.2 | 4.0 | 9.10 | 3.15 | 25.8 | 2.20 | 4.84 | 28.6 | 6.65 | 10.3 |
| W3 | 7.1 | 0.4 | 1.44 | 0.64 | 1.84 | 0.16 | 0.88 | 2.80 | 0.40 | 1.80 |

#W1: Saline artesian well water, W2: Diluted well water using tap water and W3: Tap water, respectively.

*Barley cultivation*

The leached columns were fertilized with superphosphate by mixing with the top soil (0-5cm) at a rate of 20 kg $P_2O_5$/ fed. Ten grains of barley (*Hordeum vulgare,* Giza 125) were sowed in each column. The cultivated columns were supplied with urea and potassium sulphate at rates of 60 kg N/fed and 48 kg $K_2O$/fed 10days after sowing and the seedlings were thinned to 4 plants/column. The columns were irrigated with tap water up to field capacity by weighing every 3 days. The plants were cut 1 cm above soil surface and separated into grains and straw, oven dried at 70 and the dry weight was recorded, Then kept for N, P and K determination after digestion.

## Results and Discussion

The reclamation and improvement of salt-affected soils, particularly calcareous ones is mainly achieved through reducing their soluble salts and exchangeable Na contents to an acceptable levels. The soluble Ca required for the exchange reaction could be obtained through solubilization of the native calcium carbonate with acid or acidity producing materials such as elemental sulpher.

*EC and SAR of soil leachates*

First, to elucidate the obtained results, it is worth to mention that through leaching process, the slightly soluble salts, mostly calcium sulphate, carbonate and bicarbonate supply the soil solution with an additional amount of Ca-ions which in turn exchange with $Na^+$ on the exchange complex. The total soluble salts and exchangeable Na removed during the leaching process were then undertaken (Kemper *et al.*,1975 and Khalifa *et al.*,1994).

Data in Table 2 show the changes in EC and SAR values of the leachates of the two amended soils after leaching with W1, W2 and W3 waters. The highest EC values of both studied soils leachates were obtained after leaching with saline water (W1), while the lowest ones were obtained after the final leaching with fresh water (W3). This is expected due to containing the investigated soils initial higher soluble salts prior to the first leaching ($EC_w$= 8 dS/m) compared to the fresh water that used for the final leaching ($EC_w$= 0.4 dS/m).

**TABLE 2. The detected EC and SAR values in the leachates of Maryout and Ras Sudr soils as affected by sulphur (S) and farmyard manure(FYM) amendments and leaching waters.**

| Leaching water | Maryout | | | Ras Sudr | | |
|---|---|---|---|---|---|---|
| | control | S | F YM | control | S | FYM |
| | | | ECw, dS/m | | | |
| W1# | 25.8 | 29.1 | 28.6 | 15.5 | 18.8 | 18.6 |
| W2 | 18.2 | 20.2 | 20.9 | 7.60 | 9.70 | 9.60 |
| W3 | 5.10 | 3.20 | 3.10 | 3.40 | 2.60 | 2.70 |
| | | | SAR | | | |
| W1 | 18.1 | 22.0 | 20.2 | 13.0 | 15.4 | 14.2 |
| W2 | 17.3 | 20.6 | 20.6 | 10.9 | 13.0 | 12.6 |
| W3 | 15.5 | 16.4 | 16.0 | 9.50 | 10.1 | 8.80 |

#W1, W2 and W3 mean leaching waters having 8, 4 and 0.4 dS/m, respectively.

Generally, the pattern of salt removal by leaching both soils with W1 and W2 waters appears to be increased due to elemental sulphur (S) or farmyard manure (FYM) application to Maryout and Ras Sudr soils. However, the final leaching of Maryout soil with fresh water (W3) resulted lower EC values of the leachate, due to S and FYM amendments, of 37 and 39% less than the untreated soil (control).

The corresponding effect of the applied S and FYM after leaching Ras Sudr soil with fresh water yielded 23 and 20% less than the control treatment, respectively. Increasing the total dissolved salts in the leachate of both amended soils after leaching with W1 and W2 waters as compared with the control could be attributed to the beneficial effect of FYM in improving the physical properties of soils, *i.e.*, total porosity and infiltration rate. However, the positive effect of S application could be explained that S was oxidized to $SO_4^{2-}$ by S-oxidizing soil microorganisms and the acidification enhanced the solubility and leachability of ions (Alawi *et al.*, 1980 and Yousry *et al.*, 1984).

The same table shows values of SAR of the amended soils leachates of the leaching with W1, W2 or W3 waters. Generally, elemental sulphur amendment resulted relatively higher SAR values as compared with the control treatment. This could be explained that S application enhanced $CaSO_4$ formation of the relatively higher solubility than $CaCO_3$ present in the investigated calcareous soils, beside the acidification effect on Ca release to the soil solution. Thus, more soluble Ca-ions could replace the excess of exchangeable $Na^+$ which in turn was leached out leading to SAR increase.

*Residual dissolved salts and ESP*

Data illustrated in Fig. 1 show some chemical changes of the amended and leached soils, *i.e.*, EC of the saturated extract, ESP and soil pH. As shown, the $EC_e$ of the untreated Maryout soil after leaching process was sharply reduced by about 81% from the soil initial $EC_e$, while those for Ras Sudr soil was about 83%. Amending the investigated soils with S or FYM reduced the $EC_e$ by about 86%, indicating the high efficiency of leaching process through the applied intermittent technique. This means that the residual salts in both soils were less than 20% of the initials. However, at the end of leaching process, $EC_e$ values of Maryout soil amended with S or FYM were fairly lower than that of control treatment by about 22 and 27%, respectively. The corresponding percentages for Ras Sudr soil were 13 and 18%, respectively.

Exchangeable sodium percentage (ESP) is considered as a good measure for soil sodicity beside soil pH. Values of ESP detected in the investigated soils either amended or not amended with S or FYM are shown in Fig. 1. An obvious reduction in the ESP of the leached Maryout soil that turned it from sodic soil to non sodic one with the highest effect for FYM amendment. However, ESP of Ras Sudr soil was improved showing a good response for S and FYM amendments as well as the applied leaching process. Similar trend was also found by Salem *et al.* (1990).

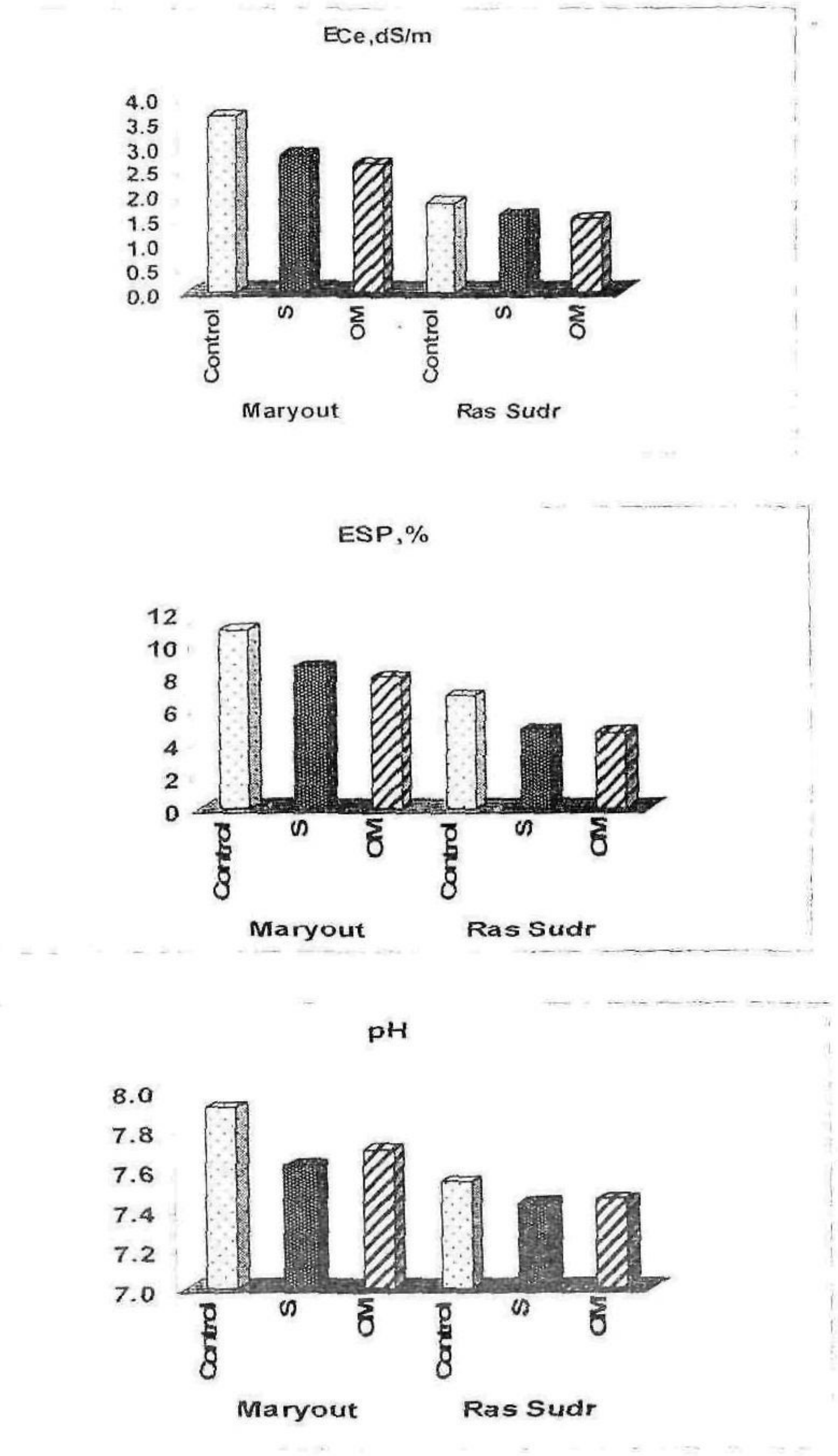


**Fig. 1. ECe, ESP and pH of the amended and leached Maryout and Ras Sudr soils.**

The initial pH values of both investigated soils did not exceed 8 and either the applied amendments or the used leaching technique slightly reduced pH values of such soils.

Concerning the soluble cations in Maryout soil, the residual $Ca^{2+} + Mg^{2+}$ reached 34.2, 36.9 and 32.6% of the initial values under the control, S and FYM treatments, respectively (Table 3). This means that about 66-68% of the soluble $Ca^{2+} + Mg^{2+}$ were removed during leaching process as well as S or FYM amendments. The remained $Na^+$ values were generally lower compared with $Ca^{2+} + Mg^{2+}$ indicating that the soluble $Na^+$ was much affected by leaching. Moreover, S or FYM amendments reduced the soluble $Na^+$ remained in the studied soils to about 20% of the initial value. While, those for control were 30 and 37% for Maryout and Ras Sudr soils, respectively. The elemental sulphur and FYM reduced the residual $Na^+$ amounts values by about 37 and 31% for Maryout soil and 43 and 41% for Ras Sudr soil less than control treatment, respectively.

**TABLE 3. The soluble ions remained in Maryout and Ras Sudr amended and leached soils as percentage from the initial ones.**

| Soluble ions | Maryout soil | | | Ras Sudr soil | | |
|---|---|---|---|---|---|---|
| | Control | S | FYM % | Control | S | FYM |
| $Ca^{2+}+Mg^{2+}$ | 34.2 | 36.9 | 32.6 | 40.3 | 41 | 35.9 |
| $Na^+$ | 30.0 | 18.8 | 20.7 | 37.6 | 21.2 | 22 |
| $HCO_3^-$ | 35.0 | 29.3 | 33.4 | 39.4 | 32.4 | 35.8 |
| $Cl^-$ | 25.8 | 15.8 | 14.1 | 30.1 | 25.0 | 23.2 |
| $SO_4^{=}$ | 39.4 | 35.1 | 29.6 | 44.6 | 38.4 | 39.8 |

Concerning the soluble anions, the removed soluble $HCO_3^-$, $Cl^-$ and $SO_4^{2-}$ were 65, 74.2 and 60.6%, 60.6, 69.9 and 55.4% for Maryout and Ras Sudr not amended soils, respectively. The higher amounts of the removed $Na^+$ and $Cl^-$ indicate that the soluble salts leached from the soils were mainly NaCl. Amending the studied soils with either S or FYM increased the amounts of removed anions, *i.e.*, $Cl^-$, $HCO_3^-$ and $SO_4^{2-}$ due to, as have been previously mentioned, the favorable effect of S on increasing acidification and ions leachability and/or the influence of organic manure on improving the soil structure with consequently dominant salt movement. Such findings agree with those obtained by Mohamedin *et al.* (2005) and Ahmed (2007).

The influence of the applied treatments on barley yield as well as total uptake of N, P and K are shown in Table 4. It is clear that grain yield increased by about 94 and 76% over the control for Maryout soil and 93 and 84% for Ras Sudr soil due to S and FYM application, respectively. The corresponding increases in straw dry weight were 65 and 57% for Maryout soil and 71 and 68% for Ras Sudr soil, respectively. Such increases over the control treatment may be due to the beneficial effect of the applied sulphur on improving soil physical properties as well as playing an important role through the relative reduction of soil pH which in turn may increase nutrients availability to the growing plants as have been reported by Salem *et al.* (1990). On the other hand, the favorable effects of organic manure on decreasing soil pH due to organic and inorganic acids formed during organic manure decomposition as well as improving the structure of the studied calcareous soils and consequently decreasing soil salinity was also reported by Beheiry & Soliman (2005). Accordingly, the growing plants will have better environmental conditions with relatively low stress on growth.

The total uptake of N, P and K increased progressively in all amended treatments. It is worth to mention that accumulation of N, P and K in both grains and straw of barley plant which amended with S or FYM could be attributed to the increase in dry weight rather than in nutrients concentrations. This is could be due to the favorable conditions for plant growth after the removal of most of soluble salts and exchangeable Na from the investigated soils. The obtained findings are in a good agreement with the results of Salem *et al.* (1990); Sakr *et al.* (1992) and El-Maghraby (2001).

**TABLE 4. Dry weight and N, P and K uptake of grains and straw of barely grown on Maryout and Ras Sudr amended and leached soils.**

| Amendment | Dry weight g/ column (4plants) | | Nutrients uptake , mg/4plants | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grain | Straw | Grain | | | Straw | | |
| | | | N | P | K | N | P | K |
| | | | **Maryout soil** | | | | | |
| Control | 2.52 | 6.96 | 32.5 | 7.6 | 35.8 | 73.8 | 12.5 | 129 |
| S | 4.90 | 11.5 | 75.5 | 20.6 | 73.1 | 136 | 34.5 | 226 |
| FYM | 4.76 | 10.9 | 71.9 | 19.1 | 64.3 | 134 | 35.9 | 239 |
| | | | **Ras Sudr soil** | | | | | |
| Control | 2.91 | 7.16 | 47.1 | 11.6 | 36.1 | 62.3 | 18.6 | 146 |
| S | 5.62 | 12.23 | 80.9 | 24.7 | 91 | 117 | 21.9 | 275 |
| FYM | 5.35 | 12.06 | 77.1 | 24.7 | 88.1 | 135 | 36.3 | 279 |

Comparing the obtained results of salinity and sodicity status as well as barley yield and its nutrient content for the two investigated soils reveal that, Ras Sudr soil is better than Maryout soil. This could be due to that Maryout soil contains higher salinity and sodicity (ECe=19.5 dS/m and ESP=17.7%) comparing those of Ras Sudr soil (ECe=10.8 dS/m and ESP=10.3%). Although Ras Sudr soil contains higher amounts of CaCO3, about two fold that of Maryout one, but the higher salinity and sodicity of Maryout soil showed more depressive effect on the detected soil and plant growth parameters.

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## تحسين بعض الخواص الكيميائية وإنتاجية بعض الأراضي الجيرية المتأثرة بالأملاح

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أقيمت تجربة أعمدة تربة باستخدام أرضين جيريتين متاثرتين بالاملاح لتقييم تاثير معاملة التربة بكل من الكبريت العنصري ، السماد البلدي جنبا الي جنب مع الغسيل المتقطع للتربة بمياه مختلفة في درجات ملوحتها علي تحسين بعض الخواص الكيميائية والمحتوي العنصري وانتاجية محصول الشعير ٠

دلت النتائج علي تحسن خواص الاراضي الكيميائية تحت الدراسة حيث أدت عملية غسيل أعمدة التربة- الغير معاملة – الي حدوث انخفاض شديد لقيم التوصيل الكهربي لارضي مريوط ، ورأس سدر تقدر بحوالي ٨١ ٪ ، ٨٣٪ علي الترتيب مقارنة بتلك الغير مغسولة ، مما يدل علي كفاءة عملية الغسيل. وقد أدت معاملة كلا الارضين بالكبريت أو السماد البلدي الي نقص واضح في قيم التوصيل الكهربي - مقارنة بتلك الغير معاملة – قدر بحوالي ١٣ ، ١٧ ٪ لأرض مريوط و ٢٢ ، ٢٤٪ ، لأرض رأس سدر على الترتيب .

أظهرت الايونات الذائبة سلوكا مقاربا خاصة الكلوريد والصوديوم ٠ ومن جهة أخري انخفضت قيم النسبة المئوية للصوديوم المتبادل (ESP) نتيجة المعاملة بأي من الكبريت أو السماد البلدي مع غسيل أعمدة التربة بصورة واضحة أدت الي تحول أرض مريوط الملحية القلوية الي أرض غير ملحية وغير قلوية٠

ازدادت قيمة الوزن الجاف من الحبوب لمحصول الشعير نتيجة معاملة الاراضي تحت الدراسة بأي من الكبريت أو السماد البلدي وقدرت الزيادة بحوالي ٩٤ ، ٧٦٪ ، في حالة أرض مريوط بينما كانت الزيادة ٩٣ ، ٨٤ ٪ في حالة أرض رأس سدر علي الترتيب وكانت هناك زيادة مشابهة في الكميات الكلية الممتصة من عناصر النيتروجين ، الفوسفور و البوتاسيوم .