INTRODUCTION

Calcareous saline sodic soils dominated farmlands in Saudi Arabia (Al-Omran et al., 2005). This soil affected many problems to cultivate vegetable crops, such as low in soil nitrogen (N), phosphorus (P), potassium (K), and organic matter (OM) and high in soil electric conductivity (EC) and pH. In the other hand, dry land condition on this are added more problems, such as scarcity of irrigation water, low irrigation water quality, high salinity of water and soil, and poor soil fertility. Squash crop is one of the most widespread and important vegetable crops in Saudi Arabia. It is a sensitive crop to water and soil salinity (Al-Omran et al., 2005). Consequently, need a proper method to enhance the soil quality on this are for producing squash with the high yield. There are many studies have been conducted on the reclamation of saline sodic soils, but only some of them have been focused on calcareous soils (Qadir and Oster, 2004; Li and Keren, 2009). Some researcher reported some effects of salinity and sodicity on soil physical properties (Tejada et al., 2006), soil chemical properties (Ferreras et al., 2006) and also on plant growth (Gill et al., 2008; Ammari et al., 2008). This study focused on the effect of sulphur as soil chemical amendment to reclaim the calcareous saline sodic soil and increase squash yield.

MATERIALS AND METHODS

The present study conducted at the Agriculture Experimental Station belongs to King Abdulaziz University (KAU) located at Hada Alsham, 90 km northeast of Jeddah city. This experiment carried out during two successive seasons of winter and spring (2012 and 2013) to study the effect of sulphur as soil chemical amendment to reclaim this soil and produce squash crop. A split plot design with three replications used on this experiment. This made nine plots (2x3 m/plot) corresponding to three sulphur amendment levels (SAL) with (0 (control), 4, and 6 ton/ha) was applied to study its effect on reclamation of this soil and produce squash crop during 2 successive seasons of winter and spring (2012-2013). The contents of soil nitrogen (N), phosphorus (P), potassium (K), pH, electric conductivity (EC), and organic matter (OM) in 2 soil depths (0-15) cm and (15-30) cm was measured as the efficacy parameters of the soil reclamation. The results indicated that SAL 6 ton/ha gave the best results and significantly decreased soil EC (57.54% and 51.51%) and pH (4.67% and 2.83%) respectively in (0-15) and (15-30) cm soil depth compared with the control. Moreover, the contents of N, P, K, and OM of the soil increased (16.0% and 68.50%), (29.20% and 26.29%), (14.61% and 15.85%), and (3.99% and 7.60%) respectively in (0-15) and (15-30) cm soil depth. These results affected in increasing of squash yield significantly 9.39 ton/ha in winter and 6.11 ton/ha in spring.

REFERENCES

Al-Omran, S., et al., 2005. Some effects of salinity and sodicity on soil physical properties. *Soil Reclamation; Soil Chemical Characteristics; Soil Reclamation; Squash yield.*

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perchloric and nitric acids. Soil content of P was determined using Spectrophotometer at light wave 640 nanometer. Soil content of potassium (K) was determined using VARIAN (ICP-Optical Emission Spectrometer). After the harvesting of squash crop, soil samples in each treatment collected again at the different depths (0-15 cm and 15-30 cm). Each sample placed in a plastic bag and thoroughly mixed to make the sample homogenized for testing. Each sample was analyzed for soil pH, EC, OM%, total and available N, P, and K. Methods of analysis was done exactly the same as those used for the initial soil analysis. The squash yield in each plot recorded in harvesting time, then converted into ton/ha unit. The collected soil analysis was done exactly the same as those used for the initial soil, control, 4 ton/ha, and 6 ton/ha sulphur doses. For the deeper layer, soil phosphor content decreased in the control treatment. Then continuously increased by using 4 ton/ha and 6 ton/ha of sulphur. Applied sulphur with doses 4 ton/ha and 6 ton/ha increased the soil phosphor content. It indicated that adding sulphur fertilizer increased soil phosphor content (Chabra et al., 1976; Singh et al., 1995) found the same result with this experiment. They explained that increasing soil phosphor content will increasing activity of mycobacterial and decomposed inaccessible phosphor to be accessible phosphor. Initial soil K content in deeper layer higher than upper layer. Nevertheless, the soil K content in upper layer higher than deeper layer after experiment (Figure 1). Soil K content after experiment increased according to the increasing sulphur doses in both layers. Qi et al. (2004) was in agreement with this result. They found that applied sulphur fertilizer in the salt condition increased potassium content of the soil.

RESULTS AND DISCUSSION

Soil Chemical Characteristics

Analysis of variance (ANOVA) in Table (1) showed Sulphur significantly (p < 0.01) affected to the soil N, P, and K in both soil depths.

Table 1. ANOVA of soil macronutrient under sulphur doses

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Replication</th>
<th>Sulphur (a)</th>
<th>Error “a”</th>
</tr>
</thead>
<tbody>
<tr>
<td>df</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>N (ppm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15 cm</td>
<td>0.00</td>
<td>23.38</td>
<td>** 0.05</td>
</tr>
<tr>
<td>15-30 cm</td>
<td>0.00</td>
<td>17.19</td>
<td>** 0.05</td>
</tr>
<tr>
<td>P (mg/l)</td>
<td>0.01</td>
<td>70.26</td>
<td>** 0.08</td>
</tr>
<tr>
<td>0-15 cm</td>
<td>0.00</td>
<td>60.60</td>
<td>0.15</td>
</tr>
<tr>
<td>15-30 cm</td>
<td>0.91</td>
<td>1134.50</td>
<td>** 1.87</td>
</tr>
<tr>
<td>K (%)</td>
<td>0.41</td>
<td>1208.31</td>
<td>** 2.58</td>
</tr>
</tbody>
</table>

Table 2. ANOVA of soil pH, EC and OM under sulphur doses

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Replication</th>
<th>Sulphur (a)</th>
<th>Error “a”</th>
</tr>
</thead>
<tbody>
<tr>
<td>df</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-15 cm</td>
<td>7.47</td>
<td>3547.66</td>
<td>** 2.98</td>
</tr>
<tr>
<td>15-30 cm</td>
<td>2.65</td>
<td>2444.00</td>
<td>** 0.96</td>
</tr>
<tr>
<td>EC (mS)</td>
<td>596.08</td>
<td>221658.21</td>
<td>** 282.51</td>
</tr>
<tr>
<td>0-15 cm</td>
<td>2.53.15</td>
<td>111742.56</td>
<td>** 10.72</td>
</tr>
<tr>
<td>OM (%)</td>
<td>1988.85</td>
<td>1833546.07</td>
<td>** 724.01</td>
</tr>
</tbody>
</table>

Soil EC, pH, and OM

The effect of sulphur doses to soil EC, pH, and OM presented in variance analysis. Sulphur significantly affected to the soil EC, pH and OM in both soil depths (p < 0.01), except the soil OM in 0-15 cm soil depth with p < 0.05 (Table 2).

Figure 1. Effect of sulphur doses on soil macronutrient

N content in soil surface (0-15 cm soil depth) decreased after experiment and significantly increased in 15-30 cm soil depth (Figure 1). In the control, N content in the upper layer was decreased and in the deeper layer was increased after experiment. It showed that the availability of N in soil surface washed by the water irrigation and accumulated in the deeper layer. N content under 4 ton/ha and 6 ton/ha of sulphur respectively was higher than control in both layers. It indicated that adding sulphur in the soil increased N content of the calcareous soil. (Yin et al., 2007; Abdelgadir et al., 2010) found the same results that applied sulphur increasing soil nitrogen content and increasing soil fertility. The highest soil phosphor content presented by sulphur with the dose 6 ton/ha (Figure 1). Soil phosphor content in upper layer increased respectively from the initial soil, control, 4 ton/ha, and 6 ton/ha sulphur doses. For the deeper layer, soil phosphor content decreased in the control treatment. Then continuously increased by using 4 ton/ha and 6 ton/ha of sulphur. Applied sulphur with doses 4 ton/ha and 6 ton/ha increased the soil phosphor content. It indicated that adding sulphur fertilizer increased soil phosphor content (Chabra et al., 1976; Singh et al., 1995) found the same result with this experiment. They explained that increasing soil fertilizer will increasing activity of mycobacterial and decomposed inaccessible phosphor to be accessible phosphor. Initial soil K content in deeper layer higher than upper layer. Nevertheless, the soil K content in upper layer higher than deeper layer after experiment (Figure 1). Soil K content after experiment increased according to the increasing sulphur doses in both layers. Qi et al. (2004) was in agreement with this result. They found that applied sulphur fertilizer in the salt condition increased potassium content of the soil.

Figure 2. Effect of sulphur doses on soil pH, EC and OM

Figure (2) showed that increasing the doses of sulphur decreased the soil EC. The highest soil EC occurred on the
control and the lowest soil EC happened on the 6 ton/ha sulphur dose. This result is in agreement with (Mass et al., 1988; Hoffman et al., 1989). They explained that Sulphuric acid formed from higher levels of sulphur not only removed sodium from the soil complex but also calcium and both could be percolated from the soil by leaching. Figure (2) showed that increasing sulphur doses to the soil reduced the soil pH. The lowest pH resulted by the highest doses of sulphur and the highest soil pH given by the lowest doses of sulphur. The same results reported by (Ashraf, 2001). Sulphur increased the activity of some mycorrhizae that played a role in preventative Na and Ca element to make salt formation in the soil. In particular form, Na and Ca was no dangerous for plant. Increasing the doses of sulphur doses increased the soil OM. Figure (2) showed that the soil OM is very small in the control. The opposite result occurred in the highest doses of sulphur, which resulted the highest soil OM. (Marschner and Bredow, 2002) reported the same result with this experiment. They explained that increasing soil OM caused by the function of sulphur to build the salt in particular plant.

**Squash Yield**

The ability of sulphur to increase the soil quality in calcareous saline sodic soil evidenced by increasing squash yield. Sulphur significantly affected to the squash yield (p < 0.01) in both seasons (Table 3).

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Replication</th>
<th>Sulphur (a)</th>
<th>Error &quot;a&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (ton/ha) - Winter</td>
<td>7.47</td>
<td>3547.66</td>
<td>** 2.98</td>
</tr>
<tr>
<td>Yield (ton/ha) - Spring</td>
<td>2.65</td>
<td>2444.00</td>
<td>** 0.96</td>
</tr>
</tbody>
</table>

*Not significant, ** significant at p = 0.05 and p < 0.01 of probability respectively

![Figure 3. Effect of sulphur doses on squash fruit yield](image_url)

The highest squash yield resulted by 6 ton/ha of sulphur (Figure 3). This treatment increased squash yield significantly 9.39 ton/ha in winter and 6.11 ton/ha in spring. The effect models of sulphur doses to the squash yield are $y = 0.6882x^2 + 1.9432x + 6.2744$ with $R^2 = 100\%$ in winter and $y = 0.9271x^2 - 0.6441x + 8.3151$ with $R^2 = 100\%$ in spring. This result might be caused by the ability of sulphur to decrease soil EC and pH and increase soil N, P, K and OM. Guzys et al. (2005) reported the same result with this experiment. They found that increasing sulphur increased the yield of some vegetable crops. They expressed that increasing the sulphur improve the soil macronutrient content and the capability of squash to uptake water and nutrient from the soil. The other roles of sulphur are as a catalyst for certain enzyme activity (Kopriva and Rennenberg, 2004), increasing the plant to uptake nutrient from the soil (Schnug et al., 1993) and increasing photosynthesis (Capon, 2010).

**Conclusions**

Sulphur as a soil chemical amendment significantly reclaimed the soil chemical properties in calcareous saline sodic soil with 6 ton/ha sulphur dose as the best treatment. The results indicated that 6 ton/ha sulphur dose significantly decreased EC (57.54% and 51.51%) and pH (4.67% and 2.83%) respectively in (0-15) and (15-30) cm soil depth compared with the control. Moreover, the contents of N, P, K, and OM of the soil increased (16.0% and 68.50%), (29.20% and 26.29%), (14.61% and 15.85%), and (3.99% and 7.60%) respectively in (0-15) and (15-30) cm soil depth. These results affected in increasing squash yield significantly 9.39 ton/ha in winter and 6.11 ton/ha in spring.

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