RECLAMATION OF CALCAREOUS SALINE SODIC SOIL WITH SOIL AMENDMENT “POZZOLAN” IN SAUDI ARABIA

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Abstract: This study investigate the pozzolan as a soil amendment to reclaim the calcareous saline sodic soil and produce squash crop in Saudi Arabia. A field experiment was conducted during winter and spring (2012-2013) with a split plot design. Four pozzolan placements (PP) with 5 cm thickness in different soil depths (surface, 10 cm, 20 cm, and control (no pozzolan)) was replicated three times. The efficacy parameters are squash yield and the contents of soil nitrogen (N), phosphorus (P), potassium (K), pH, electric conductivity (EC), and organic matter (OM). The collected data in each experiment was statistically analyzed using the analysis of variance procedures and mean separation using least significant difference (LSD) test. The results indicated that PP in the soil surface gave the best soil reclamation. Compared with the control, it significantly decreased soil EC from 2715 to 2268 dS.m⁻¹ and pH from 7.57 to 7.23 respectively. Moreover, the soil N, P, K, and OM increased from 549 to 794 ppm, 33.20 to 53.91 ppm, 0.79 to 0.93%, and 0.3401 to 0.3684% respectively. These results significantly affected in increasing squash yield by 9.91 ton.ha⁻¹ in winter and 9.27 ton.ha⁻¹ in spring season.

Keywords: Squash, yield, soil, chemical, properties

INTRODUCTION

The sustainability of crop productivity is primarily a function of various environmental stress factors, such as high temperature, cold, drought, salinity or biotic factors [1] and is also associated with the fertility status of soil [2]. Soil fertility is adversely affected by salinity, which has emerged as one of the most serious factors limiting plant growth and productivity and soil health [3]. It is expected to result in the loss of up to 50% fertile land by the middle of the 21st century [1].

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 [4, 5]. Generally, calcareous saline...
sodic soils are limited in macronutrients availability, therefore reclamation of such soils is important for improving soil fertility and plant production. Some effects of salinity and sodicity on physical [6] and chemical [7] properties of soils and also on plant growth [8, 9] have been reported in the literature.

Soil salinity and sodicity are main concerns on land degradation especially in world arid and semiarid regions [9]. In Jeddah, south part of Saudi Arabia, most farmlands are on calcareous saline sodic soils and irrigated with saline water [10]. Poor quality of irrigation water together with saline sodic soil has reduced plants yields over recent years[9]. On the other hand, sandy soil also suffer from soil physical problem with high infiltration and hot weather completed the problems with increasing high evapotranspiration [11]. Under these conditions, no crops could grow well.

One of the recommended method to improve the production under these conditions is using pozzolan to reclaim soil physical and chemical characteristics, especially soil water content and reclaiming soil chemical properties. This study focused on the effect of pozzolan as soil amendment to reclaim the calcareous saline sodic soil with its physical and chemical characteristics. Efficacy parameter of this experiment is tested by the squash yield.

**MATERIALS AND METHODS**

The present study conducted at the Agriculture Experimental Station belongs to King Abdulaziz University (KAU) located at HadaAlsham, 90 km northeast of Jeddah city for two successive seasons of winter and spring (2012 and 2013). The aim of this study is to know the effect of pozzolan as soil amendment under 2000 mg.L\(^{-1}\) water salinity levels to improve squash yield.

A split plot design with three replications used on this experiment. This made 12 plots (2x3 m/plot)corresponding to 4 pozzolan placements (PP) (1. Soil surface; 2. 10 cm in soil depth; 3. 20 cm in soil depth and 4. Control) with 5 cm thickness of pozzolan. The physical properties of pozzolan characterized by bulk density (0.78), particle density (2.87) and porosity (63%). Pozzolan chemical properties consists of 70.55% (SiO\(_2\)), 12.24% (Al\(_2\)O\(_3\)), 0.89% (FeO\(_3\)), 2.36% (CaO), 0.1% (MgO), 0.03% (SO\(_3\)), 4.21% (K\(_2\)O), 3.49% (Na\(_2\)O), 5.51% (Loss on ignition) and 0.61% undetermined. A salinity level with 2000 mg.L\(^{-1}\) of irrigation water applied to irrigate the squash crop. Fertilization applied using phosphorus fertilizer (P\(_2\)O\(_5\): 100 Kg.Ha\(^{-1}\)), potassium fertilizer (K\(_2\)O: 75 Kg.Ha\(^{-1}\)) and nitrogen fertilizer (N: 200 Kg.Ha\(^{-1}\)). Phosphorus and potassium fertilizer applied with the single dose before planting. Nitrogen fertilizers applied in 4 times (15, 30, 45 and 60 days after planting) with the same doses.

Allsoil samples were collected from the open experimental field at different depths; 0-15 cm and 15-30 cm. Samples were prepared and analyzed to determinate nitrogen (N), phosphorus (P), potassium (K), pH, electric conductivity (EC), and organic matter (OM). After the harvesting of squash crop, soil samples in each treatment collected 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 homogeneous 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.

Soil pH and EC was determined in 1:1 soil suspension and extraction using pH and EC meter. Total OM percentage in the soil was also determined using the methods that described by [12]. Total soil nitrogen content was measured by Kjeletec Auto 1030 analyzer using the methods.
that described by [12]. Total phosphorous (P), potassium (K) was measured using the extraction digestion method with 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). The squash yield in each plot recorded at harvesting time, then converted into ton/ha unit.

The collected data in each experiment statistically analyzed using the analysis of variance procedures after applying the ANOVA assumptions then the treatment means separated and tested using LSD test according to [13] using SAS program.

RESULTS AND DISCUSSION

Soil Chemical Characteristics

Effect of pozzolan on soil macronutrient was presented in Table (1). Pozzolan significantly affected on soil N, P, and K in both soil depths with the levels of probability 99%. Then, pozzolan also significantly affected on the soil EC, pH and OM in both soil depths with the levels of probability 99%, except soil OM in 15-30 cm soil depth with 95% of probability levels (Table 2).

Table 1: ANOVA of soil N, P and K under the Effect of Pozzolan Placement

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>dF</th>
<th>N (ppm)</th>
<th>Mean Squares</th>
<th>K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0-15 cm</td>
<td>15-30 cm</td>
<td>0-15 cm</td>
</tr>
<tr>
<td>Replications</td>
<td>2</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Pozzolan (a)</td>
<td>3</td>
<td>114.26 **</td>
<td>92.52 **</td>
<td>113.28 **</td>
</tr>
<tr>
<td>Error &quot;a&quot;</td>
<td>6</td>
<td>0.05</td>
<td>0.05</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Ns: Not significant and *, **: significant at p < 0.05 and p < 0.01 levels of probability respectively

Means comparison of pozzolan effects on soil chemical characteristics presented in Figure (1a - 1f). Results showed that the control increased the N content in 15-30 cm soil depth and decreased the N content in 0-15 cm soil depth (Figure 1a). Decreasing N content in 0-15 cm soil depth might be washed by irrigation water to the deeper layer, so N content in 15-30 cm soil depth was increased.

Placing pozzolan in the soil surface resulted the highest N content in both layers. On this treatment, N content in the upper layer higher than the deeper layer and might be caused by the ability of pozzolan to hold the water from infiltration. Higher N content in the soil enhanced the growth condition for squash plant.

N content under placing pozzolan in 10 cm and 20 cm soil depth respectively decreased compared with pozzolan in soil surface in both layers. Pozzolan in 10 cm soil depth retained the irrigation water in deeper layers than pozzolan in the surface. It caused the N content in surface to be higher than the deeper layers. These result is in agreement with [14] and [15], they found that
that excess salts can reduce the accumulation of nitrogen in the soil and consequently in the plants.

The highest phosphorus content in the upper layer of the soil occurred at PP in the soil surface, and then followed by pozzolans in 10 cm and 20 cm soil depth respectively (Figure 1.b). In the deeper layer, the highest P content found at PP in 20 cm soil depth, and then followed by PP in 10 cm soil depth, PP in soil surface and no pozzolan treatment respectively.

Phosphorus in upper layer under PP in the soil surface gave the highest content. On the reverse order, P content in deeper layer was the least contents. It might be caused by the ability of pozzolan to retain the phosphorus inside. PP in the soil surface under upper layer retained more phosphorus than pozzolans in 20 cm soil depth, but the opposite result was occurred on the P content in deeper layer. It was caused by the PP in 20 cm depth hold the P content more than PP in soil surface in deeper layer. These results are similar with [14], they found that in the moisture condition the amount of phosphorus increased by decreasing salinity levels in the soil.

Fig. 1: Effect of Pozzolan Placements (0: Initial Soil, 1: Control, 2: Soil Surface, 3: 10 cm in Soil Depth, and 4: 20 cm in Soil Depth) on Soil N (a), P (b), K (c), EC (d), pH (e) and OM (f)
Soil K content after experiment increased in both layers and all PP treatment (Figure 1.c). In the control (no pozzolan treatment), K content in both layers increased after experiment. It might be caused by adding NPK fertilizer during the experiment in each season. In this treatment, the amount of soil K content in deeper layer was higher than upper layer. It might be caused by irrigation water which washed and accumulated the K content in deeper layer.

Under the upper layer, the highest soil K content obtained from PP on soil surface and the least soil K content found in the PP in 20 cm soil depth. Under the deeper layer, the highest soil K content occurred on the pozzolan in 20 cm soil depth and the least soil K content happened in pozzolan in the soil surface. It might be indicated that pozzolan would be very effective and efficient to retain K in the soil.

Moist condition of the soil treated by pozzolan retain potassium element. Some researchers reported the same result with this experiment [16, 9]. They explained that the availability of soil moist condition increased the availability of macronutrient. On this case, the wetting condition on the soil increased soil potassium content.

The ability of pozzolan to retain the water normally decreased the soil EC. Pozzolan placed in soil surface decreased soil EC in the top layer, and pozzolan placed in 20 cm soil depth decreased soil EC in the deeper area (Figure 1.d). It indicated that the availability of pozzolan reduced the soil EC.

Besborodov and his friends [17] found the same result, they evaluated the effects of wheat straw mulching and different levels of irrigation water salinity on soil salinity in a 3-years field study. The salinity in the upper 15 cm layer after 3 years under mulching treatments was significantly less than the non-mulching treatments. On average, there was a 20% increase in surface soil salinity of the non-mulching treatments compared to the mulching treatments.

The least soil pH under the upper layer recorded with the PP in soil surface, and the highest soil pH found with the PP in 20 cm depth (Figure 1.e). The opposite result was occurred on the deeper layer, which the highest soil pH occurred on the PP in surface, and the least soil pH was happened in the PP in 20 cm soil depth. If pozzolan placed in the soil surface, so the soil pH in the upper layer lower than soil pH in deeper layer. Pozzolan played a role in retaining the water from infiltration and evaporation, so the availability of more water in pozzolan might be reduce the soil pH. Moreover, pozzolan contained Ca as weakness salt to reduce pH. These results were also published by [11] and [18]. They explained that pozzolan containing of Ca that bond the Na element, and ultimately decreased pH in calcareous soil.

The ability of pozzolan to reduce the salt content on the soil increased the soil organic matter. It showed by Figure (1.f), that the least soil organic matter occurred on the no pozzolan treatment and the highest soil organic matter found on the PP in soil surface under the upper layer. No different results expressed by [19], [20], [21], and [22].

Squash Yield

The ability of pozzolan to reclaim the calcareous saline sodic soil evidenced by increasing squash yield. Pozzolan significantly affected to the squash yield with p < 0.01 in both seasons (Table 3). The highest squash yield resulted by PP on the soil surface (Table 4). This treatment increased squash yield significantly 9.91 ton/ha in winter and 9.27 ton/ha in spring. This result might be caused by the ability of pozzolan to decrease soil EC and pH and increase soil N, P, K and organic matter. Previous research has shown the same result that gravel rock mulching was an effective method to improve crop yield [10, 23]. They found that gravel rock mulching increased the soil fertility and consequently increased the yield of some vegetable crops.
Pozzolan as a soil amendment significantly enhanced the soil chemical properties in calcareous saline sodic soil with the pozzolan placement in the soil surface as the recommended treatment. It characterized by decreasing soil EC and pH and increasing soil N, P, K and organic matter. Squash yield significantly increased by 9.91 ton/ha in winter and 9.27 ton/ha in spring.

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References


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