Improving the Soil Water Conservation, Growth and Yield of Eggplant by Applying Pozzolan Mulch

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Abstract: This study was conducted at the Agricultural Research Station of King Abdulaziz University at Hada Al-Sham 120 km northeast of Jeddah during two growing seasons 2012-2013. In this study the effect of the volcanic rock (pozzolan) as a soil mulch on soil water conservation, water consumption, yield and fruit quality of Eggplant (Solanum melongena L.) var. Black Beauty was investigated. Two pozzolan mulch layers (5 and 10 cm) were used together with an uncovered soil (control). Nine lysimeter water discharge plots were used to determine the plant water consumption through measurement of the water discharged from the lysimeter plots through the soil profile. Results showed that the 5 cm pozzolan mulch significantly increased the soil water conservation, plant water consumption and yield and fruit quality of eggplant compared with control. However, no significant differences were observed with the 10 cm pozzolan mulch in improvement of soil water conservation and productivity of eggplant. The results of this experiment showed the potential of using the pozzolan as mulching material for improving the soil water conservation and crop productivity on sustainable basis.

Key words: Eggplant • Pozzolan mulch • Water consumption • Water conservation

INTRODUCTION

Eggplant is one of the main vegetables of the family Solanaceae, cultivated Worlwide. It is used in stuffing, cooking and pickles [1]. The effects of low soil moisture contents on growth and yield of many vegetables and field crops are well documented [2, 3, 4]. Kirmak et al. [5] and Chaves et al. [6] reported reductions in eggplant fresh yield under drought stress. Lovelli et al. [7] found that the sensitivity to water stress of eggplant was expressed in high marketable yield decrements and a drop in water productivity. However, eggplants cultivated under normal irrigation have improved water use capacity and nutrient uptake probably due to the maintenance of the internal water balance of the crop [8].

Mulching of cultivated soils (e.g., crop residue, plastic film, sand or gravel) helps to improve the soil quality and productivity through its favourable effect on soil properties [9]. Conservation of soil moisture is one of the major benefits of mulch farming system [9, 10, 11]. Agele et al. [12] reported that mulching with plastic film improved soil moisture, increased soil temperature, root and shoot biomass and leaf area development of sunflower. Similarly, Li et al. [11] showed that plastic mulching could serve as a water vapour barrier against evaporation losses, enhance the soil moisture storage capacity and improve the biological activity. In addition to soil water conservation through the reduction of evaporation from the soil surface, mulching increase the crop growth by increasing water availability for plant use.
Furthermore, control of pest and weeds and increased availability of nutrients to plants after soil mulching also contribute to higher crop yield [13, 14, 15]. Recently, Zhao et al. [16] reported that plastic mulch in combination with a layer of straw mulch produced the highest seed and biomass yield of sunflower in a three-year field experiment.

Although the beneficial effects of mulching with plastic sheet and crop residues on soil properties and plant growth have been widely reported. Use of pozzolan as mulching material for improving soil properties and crop productivity is also an emerging era in research. Pozzolan (volcanic rock) is a siliceous material possessing cementitious properties. Pozzolan application to soil can improve the aggregate stability and strength and thus improve the soil moisture storage capacity [17]. Al-Sulaimani and Byari [18] reported that pozzolan mulching significantly increased the growth and yield of three eggplant cultivars compared with uncovered soil in the two-year experiments. Therefore, the present study aimed to investigate the effect of pozzolan mulch on growth and yield of eggplant and on soil water conservation.

**MATERIALS AND METHODS**

The experiment was conducted during two growing seasons 2012-2013 at the Agricultural Research Station of KAU at Hada Al-Sham, 120 km north east of Jeddah City to study the effect of pozzolan mulch layers (5 and 10 cm) on the yield and water consumption of eggplant and on soil water conservation. Pozzolan powder produced from volcanic rocks was obtained from Sheikh Abdulhamid Al-Malki Company, Madena Monawarah. Nine Lysimeter plots were used for determining water discharged through the soil profile. The experimental area was prepared by thoroughly ploughing the soil and dividing it into equal plots (2 x 1.6 m²). Each plot was divided into rows 50 cm apart. Treatments consisted of pozzolan covering of 5 cm (C1), 10 cm (C2) and the uncovered soil (C3) with three replicates following RCBD design. Seedlings were developed in the nursery and were transplanted, 60 cm apart, in the experimental plots at the age of 5 weeks.

**Irrigation:** Drip irrigation was used to irrigate plants for 3 days/week at 200 L/plot for the first day, 150 L/plot for the second day and third day. The water discharged from each lysimeter plot was measured after irrigation.

**Fertilization:** NPK fertilizer (20:20:20) were applied to each plot at the rate of 600 kg/ha in four equal doses. The first dose was applied at planting, the second dose was applied after one month of planting, the third dose at flowering and the last one was at the beginning of fruit collection.

**Data Collection:** Data on yield and yield components like fruit length, diameter and the total fruit yield (t/ha) was recorded from ten randomly selected plants from each plot. Data on fruit quality traits like fruit pH, carotene (mg g⁻¹), vitamin C (mg g⁻¹) and total soluble solids (TSS) (mg g⁻¹) were determined by following the standard methods. Chlorophyll a and b contents were determined by following the protocol as described by Arnon [19].

**Plant Water Consumption Measurements:** Plant water use efficiency (WUE) and total plant water consumption (WC) (mm m⁻²) were determined using the following water balance equation:

\[ ET = Wi + P - Wd + \Delta W \]

where,
- \( ET \) = Evaporation of plant during fixed period of time (mm).
- \( Wi \) = Depth of added water during fixed period of time (cm).
- \( P \) = Amount of rain water during fixed period of time (mm).
- \( Wd \) = Amount of water discharged from lysimeter during fixed period of time (mm).
- \( \Delta W \) = Variation occurring in soil moisture content during the fixed period of time and this value is negligible value usually neglected.

**Statistical Analysis:** The data was analysed by using analysis of variance and means were compared using LSD test at \( p \leq 0.05 \) according to El-Nakhlawy [20] on SAS 2000 statistical software.

**RESULTS AND DISCUSSION**

**Plant Water Consumption:** The results in Table 1 illustrated the values of the eggplant water use as determined by the lysimeter under both pozzolan soil cover and the uncovered soil. Covering the soil with 10 cm pozzolan resulted in significant reduction in the
Table 1: Effect of pozzolan soil cover on eggplant water consumption with the use of Lysimeter

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>AVERAGE WATER USE (mm/week)</th>
<th>Weekly water use (mm/week)</th>
<th>AVERAGE WATER USE (mm/week)</th>
<th>Weekly water use (mm/week)</th>
<th>AVERAGE WATER USE (mm/week)</th>
<th>Weekly water use (mm/week)</th>
<th>Growth period (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 cm pozollan</td>
<td>4</td>
<td>7</td>
<td>11.67</td>
<td>18.17</td>
<td>27.25</td>
<td>40.95</td>
<td>65.12</td>
</tr>
<tr>
<td>5 cm pozollan</td>
<td>23.17</td>
<td>31.92</td>
<td>53.67</td>
<td>50.17</td>
<td>48.25</td>
<td>48.25</td>
<td>65.12</td>
</tr>
<tr>
<td>Uncovered</td>
<td>29.08</td>
<td>39.17</td>
<td>60.17</td>
<td>57.67</td>
<td>56.83</td>
<td>56.83</td>
<td>65.12</td>
</tr>
</tbody>
</table>

Fig. 1: Effect of pozzolan cover on the daily water use by egg plant during growth period

Water consumed by the eggplants compared to the 5 cm pozzolan covering and the uncovered soil. The 10 cm pozzolan layer reduced water consumption at a rate of 554.7 kg/season compared to 734.8 kg/season for the 5 cm layer and 799 kg/season for the uncovered soil. Similar effects of mulching on plant water consumption and water use efficiency were observed in maize [11] and sunflower [12, 16].
Fig. 2: The eggplant net water use curve during the growth period

Fig. 1 illustrated the effect of pozzolan soil cover on the plant daily average water use (WU), where it can be seen that water use was increased till week 15 then started reduced. The curve also showed the clear effect of pozzolan cover on the (PWU) with the 10 cm layer giving the least (PWU) followed by the 5 cm layer and then the highest (PWU) was attained by the uncovered soil (control). Pozzolan cover reduced the evaporation rate of soil water thus increasing the soil water content at the rhizosphere. On the other hand, Fig. 2 illustrated the eggplant net water use curve during the growth period where it showed reduction in the rate of total water use (TWU) with increasing pozzolan thickness. The least TWU was observed under the 10 cm layer followed by the 5 cm layer compared with uncovered soil where highest TWU was observed.

Yield and Yield Components

Fruit Length and Diameter: The results in Table 2 indicated significant effect (P<0.01) of pozzolan soil cover on the yield of eggplant and its yield components compared to the uncovered soil. However, there was no significant difference between 5 and 10 cm pozzolan layers (Table 3). The results presented in Table 3 showed that the highest means are given by the 5 cm layer with an increase of 41.61 % in fruit length and 39 % in fruit diameter, followed by the 10 cm layer with 39.78 and 30.7 % increase in fruit length and diameter, respectively, without significant difference among them, compared to the uncovered layer which gave the least mean values. These results are in agreement with the findings of Pirbonah et al. [22], who found that covering the soil with three layers of straw has given the highest values of eggplant fruit length and diameter.

Eggplant Fruit Yield: The statistical analysis in Table 2 showed significant differences (P<0.01) between the soil covering treatments with regard to eggplant fruit yield. Covering the soil with pozzolan significantly dominated the uncovered soil treatment giving a percentage increase in yield estimated as 67.42 % under the 5 cm and 56.90 % under the 10 cm pozzolan layer. The 5cm pozzolan layer also dominated the 10 cm layer in yield, but with no significant difference between them (Table 3). This increase in eggplant fruit yield under the pozzolan soil cover compared to the uncovered soil may be due to the increase in soil water in the rhizosphere thus ameliorating the soil temperature and retaining fertilizers which in turn led to this increase in yield compared to control. These results are in agreement with the findings of Pirbonah et al. [22], who covered the soil with three layers of straw (1, 2, 3 cm) and found significant increase in fruit length and diameter and in the total yield compared to the control (uncovered soil). Also, Byari and El-Toukhy [23] and Nkansa [24] found significant increases in the number of fruits per single eggplant and in fruit size and fruit yield when the soil was covered with transparent polyethylene compared to the uncovered soil.
Table 2: Analysis of variance of the fruit length and diameter (cm) and eggplant yield(tha) and water use efficiency(mm/m3) Under effect of season and pozzolan

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Length (cm)</th>
<th>Diameter (cm)</th>
<th>Yield</th>
<th>Water consumption (season)</th>
<th>Water use efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td>1</td>
<td>7.07 ns</td>
<td>1.32 ns</td>
<td>8.78 ns</td>
<td>3.25 ns</td>
<td>205 ns</td>
</tr>
<tr>
<td>Season/rep.</td>
<td>4</td>
<td>0.11</td>
<td>0.35</td>
<td>4.64</td>
<td>0.003</td>
<td>0.38</td>
</tr>
<tr>
<td>Pozzolan cover</td>
<td>2</td>
<td>16.6**</td>
<td>8.62**</td>
<td>21.96**</td>
<td>91850**</td>
<td>1190ns</td>
</tr>
<tr>
<td>Season x pozzolan</td>
<td>2</td>
<td>0.89 ns</td>
<td>0.32 ns</td>
<td>0.25 ns</td>
<td>66.6**</td>
<td>8.76 **</td>
</tr>
<tr>
<td>Experimental error</td>
<td>8</td>
<td>1.34</td>
<td>0.54</td>
<td>504.04</td>
<td>183984</td>
<td>0.294</td>
</tr>
</tbody>
</table>

* significant at 0.05 level
**significant at 0.01 level

Table 3: Means of fruit length diameter, yield and WUE of eggplant under the effect of soil cover by pozzolan

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Fruit length (cm)</th>
<th>Fruit diameter (cm)</th>
<th>Yield (t ha⁻¹)</th>
<th>Seasonal water consumption (kg m⁻²)</th>
<th>Water use efficiency (kg m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncovered (control)</td>
<td>7.09 a*</td>
<td>5.84 b</td>
<td>16.65 b</td>
<td>797.5 a</td>
<td>21.9 c</td>
</tr>
<tr>
<td>Pozzolan layer 5cm</td>
<td>10.04 a</td>
<td>8.12 a</td>
<td>27.89 a</td>
<td>731.7 b</td>
<td>41.7 b</td>
</tr>
<tr>
<td>Pozzolan layer 10cm</td>
<td>9.91 a</td>
<td>7.64 a</td>
<td>26.14 a</td>
<td>558.0 c</td>
<td>49.2 a</td>
</tr>
<tr>
<td>LSD</td>
<td>1.54</td>
<td>0.98</td>
<td>2.85</td>
<td>0.79</td>
<td>0.72</td>
</tr>
</tbody>
</table>

*Means with the same letters do not differ significantly at the level (0.05) according to the LSD.

Our results also endorsed the finding of Radicetti et al. [25] where mulching with winter cover crop residues under different tillage systems made significant improvement in marketable fruit yield of eggplants. Likewise, sunflower biomass and seed yield increased under plastic mulch and straw layer compared with uncovered soil [16].

**Eggplant Water Use Efficiency (WUE):** The analysis of variance (Table 2) revealed a significant effect (P<0.01) of soil covering by pozzolan on the eggplant water use efficiency (WUE) and water consumption (WC). The data also showed a significant effect (P<0.01) in the interaction between the season and the pozzolan cover. The highest (WUE) and the least (WC) was recorded in eggplant grown under the 10 cm pozzolan cover giving WUE of 49.2 kg/m² and water consumption of 558 mm/season, with a significant difference from the 5 cm pozzolan covering which gave 41.7 kg/m² WUE and 731.7 kg/season WC. The uncovered soil gave the least WUE about 21.9 kg/m² and the highest water consumption of 797.5 kg/season. This rise in the WUE of the 10 cm pozzolan cover may be related to the least water consumption rate by 10 cm covering layer as compared to the 5 cm pozzolan layer and uncovered soil which experienced high water consumption rates 731.7 and 799.5 kg/season, respectively (Table 3). Covering the soil with pozzolan enabled the soil to conserve water and ameliorate the soil temperature, reduced the fertilizer loss and ultimately increased the eggplant WUE. This is in agreement with the findings of Byari and Eltoukhy [23], Pessarakli and Dris [26] and Nkansah [24].

**Characteristics of Fruit Quality:** The combined analysis of variance preented in Table 4 illustrated significant effect of the pozzolan soil cover on eggplant fruit quality characteristics (P<0.01) for the acidity, carotene, vitamin C and total soluble solids (TSS). The values of the means (Table 5) showed significant differences between the pozzolan covered soil and the uncovered soil treatment. Covering the soil with 5 cm pozzolan gave the highest values of fruit carotene (2.09 mg/g), acidity (0.2 %), vitamin C (3.63 mg/g) and TSS (5.2 mg/g) compared to the uncovered soil as shown in Table 5, with no significant difference between 5 and 10 cm pozzolan covering. These results demonstrated that this increase in the soil capacity of conserving water and making it available to plants which resulted from pozzolan soil covering enabled the plants to easily absorb sufficient water. Also, it is known that water is the medium which harbors all photosynthetic and physiological activities in plants, this in turn will enhance and initiate the formation of total and dissolved pigments, vitamins and sugars inside the plant cells. These results are in agreement with those obtained by Roe et al. [27], who recorded significant increase in fruit quality characteristics of chili and cucumber under compost soil covering and with the findings of Ekinici and Dursun [28], who detected significant increase in the fruit total sugar content with soil mulching.

**Leaf Chlorophyll Contents:** The analysis of variance (Table 4) of the effect of pozzolan soil covering on eggplant chlorophyll a and b content demonstrated significant effect (P<0.01) of pozzolan soil covering on the leaf chlorophyll a and b content. Results of means
Table 4: Analysis of variance of fruit quality characteristics and leaf chlorophyll a and b under the effect of season and pozzolan soil cover

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>Carotene</th>
<th>Acidity</th>
<th>Vitamin C</th>
<th>TSS</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td>1</td>
<td>0.06 ns</td>
<td>0.002 ns</td>
<td>0.013 ns</td>
<td>0.03 ns</td>
<td>0.002 ns</td>
<td>0.004 ns</td>
</tr>
<tr>
<td>Season/rep.</td>
<td>4</td>
<td>0.04</td>
<td>0.001</td>
<td>0.02</td>
<td>1.18</td>
<td>0.004</td>
<td>0.01</td>
</tr>
<tr>
<td>Pozzolan cover</td>
<td>2</td>
<td>0.37*</td>
<td>0.02**</td>
<td>3.21**</td>
<td>12.98**</td>
<td>0.08*</td>
<td>0.03*</td>
</tr>
<tr>
<td>Season X pozzolan</td>
<td>2</td>
<td>0.0004 ns</td>
<td>0.005 ns</td>
<td>0.05 ns</td>
<td>0.14 ns</td>
<td>0.01 ns</td>
<td>0.002 ns</td>
</tr>
<tr>
<td>Experimental error</td>
<td>8</td>
<td>0.08</td>
<td>0.001</td>
<td>0.03</td>
<td>0.38</td>
<td>0.02</td>
<td>0.005</td>
</tr>
</tbody>
</table>

* significant at 0.05 level  
**significant at 0.01 level

Table 5: Means of fruit quality characteristics and chlorophyll A and B content under the effect of pozzolan soil covering

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Carotene mg g⁻¹</th>
<th>Acidity %</th>
<th>Vitamin C mg g⁻¹</th>
<th>TSS mg g⁻¹</th>
<th>Chlorophyll content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control(uncovered)</td>
<td>1.63b</td>
<td>0.09b</td>
<td>2.21c</td>
<td>2.43b</td>
<td>0.37b</td>
</tr>
<tr>
<td>5cm pozzolan</td>
<td>2.09a</td>
<td>0.20a</td>
<td>3.63a</td>
<td>5.20a</td>
<td>0.58a</td>
</tr>
<tr>
<td>10cm pozzolan</td>
<td>2.02a</td>
<td>0.19a</td>
<td>3.22b</td>
<td>4.68a</td>
<td>0.57a</td>
</tr>
<tr>
<td>LSD(0.05)</td>
<td>0.38</td>
<td>0.04</td>
<td>0.22</td>
<td>0.83</td>
<td>0.18</td>
</tr>
</tbody>
</table>

*Means with the same letters do not differ significantly at the level (0.05) according to the LSD (Table 5) detected significant differences between pozzolan cover (5 and 10 cm) and the uncovered soil treatment, with no significant difference between the pozzolan layers 5 and 10 cm. The soil pozzolan cover layer 5 cm made significant improvement in the leaf chlorophyll a and b contents up to 0.58 and 0.38 mg/g, respectively, compared with uncovered soil. It seems that there was an increase in the capability and the efficiency of the plants for the optimum use of water which has become more available due to the pozzolan cover. Pozzolan cover also enabled the soil to conserve more water and to reduce fertilizer leaching thus initiating more plant growth. These results are in agreement with the findings of Ibrahim [29], who covered two soil types (sandy and clayey) with pozzolan 20 % and obtained 40 % increase in the water conserved by the sandy soil and 37% increase in the water conserved by clayey soil. Also, Roe et al. [27] covered the soil with compost and found healthy dark green leaves with increase in leaf area index in both chilli and cucumber plants. Bhardwaj and Kumar [30] found significant increase in leaf weight and in fruit quality of chili and cucumber plants by soil mulching. Similarly, Radicetti et al. [25] reported increase in chlorophyll contents of eggplant under crop residues mulch with different tillage systems.

CONCLUSION

It can be concluded that mulching of soil with pozzolan improved the water use efficiency, yield and fruit quality of eggplant. Furthermore, pozzolan mulch seems to be an effective tool for soil moisture conservation thus, may contribute to sustainable crop production from water scarce regions.  

REFERENCES


