The Effects of Three Types of Lithic Mulches on Salinity And Moisture Conservation In A Heavy Textured Soil

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ABSTRACT

An open air, pot experiment was conducted to investigate the effectiveness of three types of lithic mulches (tephra, white and dark gravels) and three mulch thicknesses (5, 7.5 and 10 cm) on soil moisture conservation and salinity control of the surface layer of a heavy textured soil. The experimental design was complete randomized block with three replications. The results showed that all lithic mulch types studied significantly reduced cumulative evaporation in short term (10 days). In long term, white and black gravel mulches were more effective than tephra mulch. In general, increasing thickness of the lithic mulch layers resulted in less evaporation, but there was not much differences between 7.5 and 10 cm thicknesses. All combinations of mulch types and mulch thicknesses significantly reduce salt accumulation in soil surface layer (0-10 cm), and there was no significant differences between them. Therefore, use of any of the lithic mulches studied with a minimum thickness of 5 cm can be recommended for soil salinity management of green floors in arid region.

INTRODUCTION

Soil salinity and drought are the major abiotic stresses that limit crop production in agricultural lands of arid areas. Global warming and climate change would also affect the quality and quantity of water resources in arid regions. Potential temperature rise will result in increasing potentials for water evaporation from soil, which in turn increases the risk for soil salinization [1]. Considering the population growth in the world and industrial development, water demand increasing for urban uses and limitations of the world’s fresh water resources, it is obvious that in the near future less water might be allocated to agricultural lands, particularly for landscaping. In addition to water, salinity is also another limiting factor for development of green areas and landscapes in arid and semi-arid regions of the world.

One of the most effective ways to reduce evaporation and thus increasing water conversation in soil, is using mulch. Favorable effects of different mulch types on reduction of soil moisture evaporation and improvement of saline soils, has attracted the attention of soil scientists and researchers for several decades. Mulching has positive effects on the control of weeds in ornamental plants [2]. Utilization of mulches in ornamental plant production and landscapes leads to better conservation of soil moisture, prevention of crusting, modifying soil temperature, reduction of erosion, and germination and production of high quality ornamental plants [2, 3]. The open spaces of green areas and landscapes can be covered with different types of mulches for beautification of the area and to prevent the spread of weeds [4]. Significant reduction in the growth of weeds in a field experiment under white plastic and sawdust mulches as compared to control has been reported [5]. Significant reduction in soil temperature and soil moisture evaporation under grass and transparent and black plastic mulches in a field experiment has been reported [6].

Lithic mulch, such as sand, gravels and tephra (volcanic rocks), have been used in landscapes and parks. They are usually more resistance against a people traffic and sunlight, and are suitable for beautifying the landscape and parks. White lithic mulch due to the intense reflection of sunlight can cause damage to sensitive plants. Dark colored lithic mulches by retaining heat can cause stress in some plants [7]. Results of a study showed that dark gravels as compare to white gravels had less evaporation rate and 5 cm layer of mulch can

Keywords:
Evaporation, Gravel mulch, Rock mulch, Soil moisture, Soil salinity, Tephra mulch
store between 80 to 85 percent of the rain in the soil [8]. In a three year field experiment in Uzbekistan, the effect of straw mulch irrigation water salinity on cotton production in a saline field was studied [9]. The results showed that during this period the average soil salinity under the mulch treatment was reduced by 20% as compared to the control. Cotton yield and water use efficiency in mulch treatments were also significantly higher than the treatments without mulch [9]. Results of a 2 year field experiment with rice husk mulch also showed significant reduction in soil salinity in a rain fed potato field [10]. Utilization of palm leaf mulches had better performance than control and plastic mulch in increasing soil moisture storage, reduction of soil temperature, reduced accumulation of salt in the soil and increasing sorghum yield [11].

The use of tephra rocks as mulch is a common practice in arid Canary Islands, where the farmers keep them in field for 20 years. The advantages of tephra mulch are high hydraulic conductivity, low weight compared to other lithic mulches, no water absorption, increased infiltration of rainwater in the soil, reduced excessive evaporation, reduction of erosion and reduction of soil salinity and sodium content [12]. Khorasani [1] reported that the use of tephra mulch with 1-1.5 cm diameter, significantly reduced the cumulative evaporation of soil moisture. Thickness of 5, 10 and 15 cm of tephra mulch reduced evaporation by 25, 65 and 66%, respectively. The results of a 4 year field experiment showed that tephra mulch application (height of 12 cm) resulted in 76 and 86% reduction in soil salinity at the depth of 0-40 cm of a clayey and a loamy soil, respectively.

Lack of rainfall and fresh water resources in arid regions are major obstacles for expansion of green areas and landscapes. Application of lithic mulches seems to be a viable option for reduction of soil moisture evaporation and soil salinity management. Scientific information on the use of lithic mulches for soil moisture conservation and salinity management in green areas and parks in arid regions of Iran is lacking. Therefore, the main objective of this study is to compare the effectiveness of three types of lithic mulches (tephra, white and dark gravels) and three thickness of the mulches on soil moisture conservation and salinity control of the surface layer of a heavy textured soil.

MATERIALS AND METHODS

An open air, pot experiment was conducted in the city of Shiraz during spring and summer of 2013. The experimental design was complete randomized block with three replications. The treatments consisted of three types of lithic mulches (tephra, white gravel and dark gravel) and three mulch thicknesses (5, 7.5 and 10 cm). Tephra is a rock with volcanic origin. The soil used for this experiment was collected from 0-30 cm depth of a saline farm around Shiraz. It was a calcareous, Clay loam soil with pH of 7.63 and salinity of 27 dS/m.

Plastic, light gray pots with 30 cm in height and diameter of 28 cm were used in the experiment. In order to make proper condition for ventilation and drainage, 4 holes were made under the pots with diameter of around 1 cm, were filled with fine gravel to a depth of 2 cm (about 1250 g). Each pot was carefully filled with 8.7 kg of air dried soil to ensure consistent bulk density for all the pots (about 1.4 g/cm³) and then, was irrigated 2.5 liter of tap water. After free drainage from bottom of the pots was stopped, appropriate mulch treatments were placed on the soil surface (except control treatment), and immediately the pots were weighted. The first weighing was the reference weight of each pot. The experiment was continued till 60 days after placing the mulches, during which the pots were weighting at 10 am regularly. The weighting was continued during 10 days daily and after that, the pots were weighted every 3 days. Weight difference between two days of pot weightings was equal to daily evaporation. The sum of daily evaporations during experimental period, was equal to cumulative evaporation. After the last weighting, 500 g soil samples from 0-10 and 10-20 cm layers were collect and air dried. The salinity of these soil samples were measured by measuring electrical conductivity of the saturated paste extract (ECe) [13]. Soil samples from the middle of the first layer were collected to determine their moisture contents gravimetrically [14].

The experimental data were statistically analyzed by SAS statistical software. The comparison between treatments were performed by Duncan's multiple range test (DMRT) at 5% probability level.

RESULTS AND DISCUSSION

Cumulative Evaporation from the Soil:

The effects of the type and thickness of the lithic mulch on the amount of cumulative evaporation from soil was evident from the first day after start of the experiment. All types of the mulches at any thickness significantly reduced cumulative evaporation from soil as compared to control (no mulch, thus zero thickness) on days 1 (Table 1). Although, cumulative evaporation decreased with increasing mulch thickness in all mulch types, but there was no significant differences between any mulch thicknesses at any mulch type treatment. In general, at any thickness, there was not difference between different types of mulches, except that at 5 cm thickness treatment, tephra mulch had significantly higher cumulative evaporation than white gravel (Table 1).

At day 10, cumulative evaporation of all treatment combinations were still significantly lower than the control. The lowest cumulative evaporation was in dark gravel-10 cm treatment, which was not significantly
different than dark gravel-7.5 cm and white gravel-10 cm treatments (Table 1). On this day, all thicknesses of tephra mulch had higher cumulative evaporation than the other two lithic mulches, but was significantly lower than control. Khorsandi [1] in their study showed that the use of tephra of mulch significantly reduces evaporation of soil moisture. These results are consistent with the results of the present study.

At day 21, the cumulative evaporation under all combinations of mulch thickness treatments of white and dark gravel mulches were significantly lower than control, but there was no difference between any tephra mulch and thickness treatment with control (Table 1). These results indicate that tephra mulch is less efficient than white and dark grays in terms of longevity for reducing cumulative evaporation. The lowest cumulative evaporation was in dark gravel-10 cm treatment, which was not significantly different than dark gravel-7.5 cm and white gravel-10 cm treatments.

At day 29, the cumulative evaporation of all combinations of mulch type and mulch thickness treatments were not significantly different than the control, except dark gravel-10 cm treatment, which was significantly lower than control and all tephra mulch thicknesses (Table 1). At day 42, there was not significant differences between control and any of the combinations mulch type and mulch thickness treatments. Thus, from this day till the end of the experiment (60 days), the mulch treatments did not have any effect on reducing cumulative evaporation of water from the soil.

**Soil Salinity (EC$_e$):**

The effects of mulch type and mulch thickness treatments on soil salinity (EC$_e$) at the end of the experiment (day 60) were significant (Table 2). At control treatment (no mulch, 0 thickness), EC$_e$ of the first soil layer (0-10 cm) was a little lower than the second soil layer (10-20 cm), however, there was no significant differences between them. At the beginning of the experiment, all pots received 2.5 liter of tap water, which has caused salt leaching from first to second soil layer. But these results indicate that, after 60 days, due to high evaporation from bare soil (control), the salts have moved back to the first layer. Therefore, no significant differences between the EC$_e$ of the two soil layers were observed in control treatment (Table 2).

EC$_e$ of the first soil layer under all combinations of mulch type (tephra, white and dark grays) and mulch thickness (5, 7.5 and 10 cm) treatments were significantly lower than EC$_e$ of the second soil layer (Table 2). These results indicate that any combinations of the mulch treatments were effective in controlling the lower EC$_e$ of the first soil layer which was achieved after initial leaching. There was no significant differences between all mulch treatments in both soil layers (Table 2). These results indicates that any type of mulch with minimum thickness of 5 cm is effective in controlling the salinity of the soil surface layer. Terasaki et al. [15] reported that in their study, significant reduction of soil moisture evaporation by grays mulches has delayed salt accumulation in the layer near the soil surface. Similar results has been reported for tephra mulch in a field experiment [12]. These results are consistent with the results of the present study.

**Table 1:** Effects of the type and thickness of the lithic mulches on cumulative evaporation (ml) in different days.

<table>
<thead>
<tr>
<th>Mulch thickness (cm)</th>
<th>Mulch type</th>
<th>1 day after start of the experiment</th>
<th>10 day after start of the experiment</th>
<th>21 day after start of the experiment</th>
<th>29 day after start of the experiment</th>
<th>42 day after start of the experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Tephra</td>
<td>442 a</td>
<td>1388 a</td>
<td>1845 a</td>
<td>2013 a</td>
<td>2143 a</td>
</tr>
<tr>
<td>5</td>
<td>Tephra</td>
<td>103 bc</td>
<td>78 cd</td>
<td>1455 c</td>
<td>1530 c</td>
<td>1607 a</td>
</tr>
<tr>
<td>7.5</td>
<td>Tephra</td>
<td>88 cd</td>
<td>75 cd</td>
<td>1490 c</td>
<td>1725 d</td>
<td>1900 a</td>
</tr>
<tr>
<td>10</td>
<td>Tephra</td>
<td>92 cd</td>
<td>57 d</td>
<td>1515 ab</td>
<td>1572 ab</td>
<td>1855 a</td>
</tr>
<tr>
<td>0</td>
<td>White gravel</td>
<td>442 a</td>
<td>1388 a</td>
<td>1845 a</td>
<td>2013 a</td>
<td>2143 a</td>
</tr>
<tr>
<td>5</td>
<td>White gravel</td>
<td>70 d</td>
<td>682 c</td>
<td>707 c</td>
<td>758 c</td>
<td>783 c</td>
</tr>
<tr>
<td>7.5</td>
<td>White gravel</td>
<td>75 cd</td>
<td>658 cd</td>
<td>528 de</td>
<td>572 de</td>
<td>682 c</td>
</tr>
<tr>
<td>10</td>
<td>White gravel</td>
<td>53 d</td>
<td>57 d</td>
<td>445 e</td>
<td>445 e</td>
<td>445 e</td>
</tr>
<tr>
<td>0</td>
<td>Dark gravel</td>
<td>442 a</td>
<td>1388 a</td>
<td>1845 a</td>
<td>2013 a</td>
<td>2143 a</td>
</tr>
<tr>
<td>5</td>
<td>Dark gravel</td>
<td>76 cd</td>
<td>783 c</td>
<td>528 de</td>
<td>572 de</td>
<td>528 de</td>
</tr>
<tr>
<td>7.5</td>
<td>Dark gravel</td>
<td>65 cd</td>
<td>572 de</td>
<td>445 e</td>
<td>445 e</td>
<td>445 e</td>
</tr>
<tr>
<td>10</td>
<td>Dark gravel</td>
<td>57 d</td>
<td>445 e</td>
<td>445 e</td>
<td>445 e</td>
<td>445 e</td>
</tr>
</tbody>
</table>

* For each day, the means with a letter in common are not significantly different than each other according to DMRT at 5% probability level.
The results of this research showed the application of lithic mulches (tephra, white and dark gravels) with the thicknesses of 5, 7.5 and 10 cm is an effective way for reduction of cumulative evaporation from soil. All lithic mulch types studied significantly reduced cumulative evaporation in short term (10 days). In long term, white and black gravel mulches were more effective than tephra mulch. This has implication on the irrigation scheduling of ornamental plants and trees in parks and green floors. Based on the results of this experiment, gravel mulches can reduce soil moisture evaporation for a longer time, thus, plants perhaps can be irrigated with longer intervals. This has economic implication in maintenance of parks and green floors. In general, increasing thickness of the lithic mulch layers resulted in less evaporation, but there was not much differences between 7.5 and 10 cm thicknesses. Considering the economics of mulch application, 5 and 7.5 cm thickness of these lithic mulches can be recommended.

All mulch types and mulch thicknesses were effective in controlling salinity of the soil surface layer (0-10 cm). There was no differences in soil surface salinity of any combinations of mulch types and thicknesses. Therefore, use of any of the lithic mulches studied with a minimum thickness of 5 cm can be recommended for soil salinity management of parks and green floors in arid region of Iran. However, availability of budget, design of the green floors and color preferences for beautification of the parks and green floors should be considered in choosing any of these lithic mulches.

**REFERENCES**


**Table 2:** Effects of the type and thickness of the lithic mulches on soil salinity (EC, dS/m) at the end of the experiment (day 60).

<table>
<thead>
<tr>
<th>Soil depth (cm)</th>
<th>Mulch type</th>
<th>Mulch thickness (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0-10</td>
<td>Tephra</td>
<td>28.9 bc</td>
</tr>
<tr>
<td></td>
<td>White gravel</td>
<td>28.9 bc</td>
</tr>
<tr>
<td></td>
<td>Dark gravel</td>
<td>28.9 bc</td>
</tr>
<tr>
<td>10-20</td>
<td>Tephra</td>
<td>30.1 ab</td>
</tr>
<tr>
<td></td>
<td>White gravel</td>
<td>30.1 ab</td>
</tr>
<tr>
<td></td>
<td>Dark gravel</td>
<td>30.1 ab</td>
</tr>
</tbody>
</table>

* Means with a letter in common are not significantly different than each other according to DMRT at 5% probability level.

**Conclusion:**

The results of this research showed the application of lithic mulches (tephra, white and dark gravels) with the thicknesses of 5, 7.5 and 10 cm is an effective way for reduction of cumulative evaporation from soil. All lithic mulch types studied significantly reduced cumulative evaporation in short term (10 days). In long term, white and black gravel mulches were more effective than tephra mulch. This has implication on the irrigation scheduling of ornamental plants and trees in parks and green floors. Based on the results of this experiment, gravel mulches can reduce soil moisture evaporation for a longer time, thus, plants perhaps can be irrigated with longer intervals. This has economic implication in maintenance of parks and green floors. In general, increasing thickness of the lithic mulch layers resulted in less evaporation, but there was not much differences between 7.5 and 10 cm thicknesses. Considering the economics of mulch application, 5 and 7.5 cm thickness of these lithic mulches can be recommended.

All mulch types and mulch thicknesses were effective in controlling salinity of the soil surface layer (0-10 cm). There was no differences in soil surface salinity of any combinations of mulch types and thicknesses. Therefore, use of any of the lithic mulches studied with a minimum thickness of 5 cm can be recommended for soil salinity management of parks and green floors in arid region of Iran. However, availability of budget, design of the green floors and color preferences for beautification of the parks and green floors should be considered in choosing any of these lithic mulches.

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