THE EFFECT OF MULCH TYPE AND THICKNESS ON THE SOIL SURFACE EVAPORATION RATE

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ABSTRACT

There is a continual drive to conserve water and improve irrigation efficiency in agriculture, especially in regions where water resources are limited and regulated. Mulching is one cultural practice which can be used to reduce water needs. Using certain agricultural byproducts as mulch is a sustainable practice which can provide other benefits as well such as improving soil. Wheat straw, grass clippings, and leaf debris are fairly abundant byproducts which can be used as mulch. An experiment was conducted to determine which of these readily available mulching materials would be best at conserving soil moisture, and at which thicknesses, 5, 10, and 15 cm. Soil water content was monitored every three days for a duration of three weeks, when no discernable differences were measured. Within the first 3 days, a mulch layer of at least 5 cm reduced surface evaporation to 40% compared to the water losses from bare soil, and all mulch types were equally effective. While there were no differences between the mulch types, the mulching rate did have a significant effect on water loss. Doubling the mulching rate from 5cm to 10 cm maintained soil moisture 10% higher throughout most of the experiment. However, increasing the rate further to 15 cm had no discernible effect. This experiment clearly demonstrates that what might otherwise be agricultural waste can be used to significantly conserve soil moisture, providing more resources for crops and reducing overall costs of production.

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INTRODUCTION

Improving water efficiency is an ongoing goal in agricultural production, especially in California, where water resources are limited and regulated. One reason that there is a push to use less water in agriculture is because of increasing demand generated by the growing population. The water demands of urban populations are essentially fixed and growing, so water availability for agricultural producers is constantly reduced, and the associated costs rise. To address both of these issues, producers are searching for new ways to reduce their water demands.

Mulching is one cultural practice which can be used to addresses this problem. Covering the ground with mulch saves water by preventing surface evaporation. The layer can also greatly reduce or eliminate weed propagation, which will also result in higher water use efficiency.

Using certain agricultural byproducts as mulch is a sustainable practice which can reduce water use and provide other benefits as well. Wheat straw, grass clippings, and leaf debris are fairly abundant byproducts. Many producers already generate these mulching materials, and currently spend resources to dispose of them. Mulching using this waste is a cost effective practice which would conserve water, moderate soil temperature, reduce waste, and improve the soil.

Considering the fact that each of these mulches is widely available, which mulch is the most functional? This experiment was conducted to determine which of these low-cost organic mulches functions best at conserving soil moisture. The information generated by this experiment can help producers choose the material and thickness that will best suit their mulching needs.

LITERATURE REVIEW

Water availability is a major obstacle to sustainable agricultural production in California and other arid areas. It may not always be possible to procure more water, so farmers must adopt management practices which maximize water use efficiency. Applying organic mulches is one cultural practice which can help this goal.

Evaporation from the soil surface significantly affects crop water use efficiency. Surface evaporation accounts for 25-50% of total evapotranspiration (Liu et al., 2002; Hu et al., 1995). Mulching with production byproducts such as wheat straw increases water retention and prevents soil evaporation (Steiner, 1989; Li and Xiao, 1992; Baumhardt and Jones, 2002; Kar and Singh, 2004). This also ensures a more even moisture distribution throughout the soil profile, which further improves water use.

Organic mulches also improve water use efficiency indirectly. As the mulch decomposes, humus is added to the soil, which increases its water holding capacity (Unger, 1974). A mulch layer prevents weed seedling growth by inhibiting light penetration to the soil surface (Ossom et al., 2001). Lower weed prevalence significantly improves water use efficiency.

Mulches have other benefits as well. A mulch layer can reduce soil erosion by minimizing the impact of raindrops and water runoff (Bhat et al., 2006; Sauvage, 1995; Khera, 1995; Verma, 1979). The severity of certain diseases can also be reduced by mulching. For instance, applying mulch to the understory of wine grapes resulted in a 97 percent reduction in infestation by *Botrytis cinerea* compared to a bare ground treatment (Jacometti et al, 2007). This reduction in disease was significantly correlated with increased soil biological activity and elevated rates of vine debris decomposition.

Plastic mulches offer many of the same benefits as organic mulches. In high value vegetable crop production, plastic mulches have shown to improve yields for many decades (Emmert, 1957; Schales and Sheldrake, 1965; Waggoner et al., 1960). Using plastic mulch increases soil moisture retention and temperature, and prevents weed growth. However it doesn't provide the same benefits of organic mulches, such as increasing soil organic matter and increasing microbial activity (Jacometti et al, 2007). The majority of plastic films are not biodegradable, so disposing of them without causing a negative environmental impact is also a continual problem (Johnson, 1989). Biodegradable plastics are more expensive, and have yet to be widely adopted. Plus, plastic mulches might not be as effective as organic mulch at improving yields in arid and subtropical regions, because of the increase in soil temperature relative to organic mulches (Hanada, 1991). Plastic mulches also have a higher initial cost, while organic mulches can be more cost effective, especially if the mulch is a byproduct of other on-site operations.

Higher water-use efficiency will help to reduce costs. The amount of water available to agricultural producers will continue to decrease due to the growth of demand from the municipal and industrial sectors of California's economy, which will also result in higher costs.

MATERIALS AND METHODS

An experiment was designed and conducted with the following objectives: (1) Determine which of three low cost, widely available organic mulches functions best at conserving soil moisture. (2) Determine the effect of mulch thickness on soil moisture retention.

The experiment was established in an open field in Prunedale, CA. Nine mulch treatments and one bare soil treatment, replicated four times, were installed in 40, 30cm tall by 60 cm wide by 90 cm long trays in a completely randomized design. The treatments were three different mulch types: grass clippings, leaf debris, and straw, each applied at three depths: 5, 10, and 15 cm.

Mulches

The grass clipping mulch was made by mowing a perennial rye grass. The clippings were allowed to dry out, and then were collected to be used as the grass mulch. Leaf debris from an apple orchard was collected and used for the leaf debris mulch. Baled straw was purchased from a farm supply store, and the straw was evenly shredded to be used as a straw mulch.

Soil

Soil was collected from the field at a depth of 4-12 inches. The soil type was an Arnold loamy sand. The soil was filtered of stones and other foreign material, and was then thoroughly mixed to ensure uniformity.

Setup:

Each tray was filled to a depth of 10cm with soil. After adding the soil layer, each tray was fully saturated with water, and allowed to drain. For the first replication of each treatment, the mulch was added to the appropriate depth. The mulch layer was then removed and weighed, and afterward, replaced. The other replications were then filled with a mulch layer of equal weight and depth. The trays were then randomly arranged on the ground in a grid-like fashion, four trays wide by 10 trays long.

Collecting Data:

Soil moisture loss was monitored every three days, beginning one day after saturation, and ending when no significant difference in weight was measured. This was accomplished by weighing the total container weight. The weight was recorded, and subtracted from the previous weight to determine total soil moisture loss for that period of time.

Data Analysis:

After all of the data were collected, the water loss for each experimental unit at each sampling was divided by the weight of the saturated soil to obtain percentage water loss. A repeated measures analysis of variance was then conducted, using mulch type and depth as between subject effects. Afterward, the mean separation was accomplished by single degree of freedom orthogonal contrasts, comparing the 5cm depth to the combination of 10 and 15 cm depths, and the 10 cm depth to the 15 cm depth. The data analysis was conducted using the SAS Institute 2010 software package.

RESULTS

The effect of three different mulch types, grass clippings, leaf debris, and straw, at three different depths, 5cm, 10cm, and 15 cm on soil surface evaporation was determined from soil trays filled with 10 cm of soil with the respective mulch layer applied. The control trays contained no much. The trays were weighed every three days to determine the percentage water loss.

The study clearly demonstrated that mulching with at least a 5 cm layer reduces soil surface evaporation, even using the 0.01 significance level, (p = 0.0089). This was especially the case at the beginning of the study, when the soil was fully saturated. In the first 3 days, a mulch layer of at least 5 cm reduced surface evaporation to 40% compared to the water losses from bare soil.

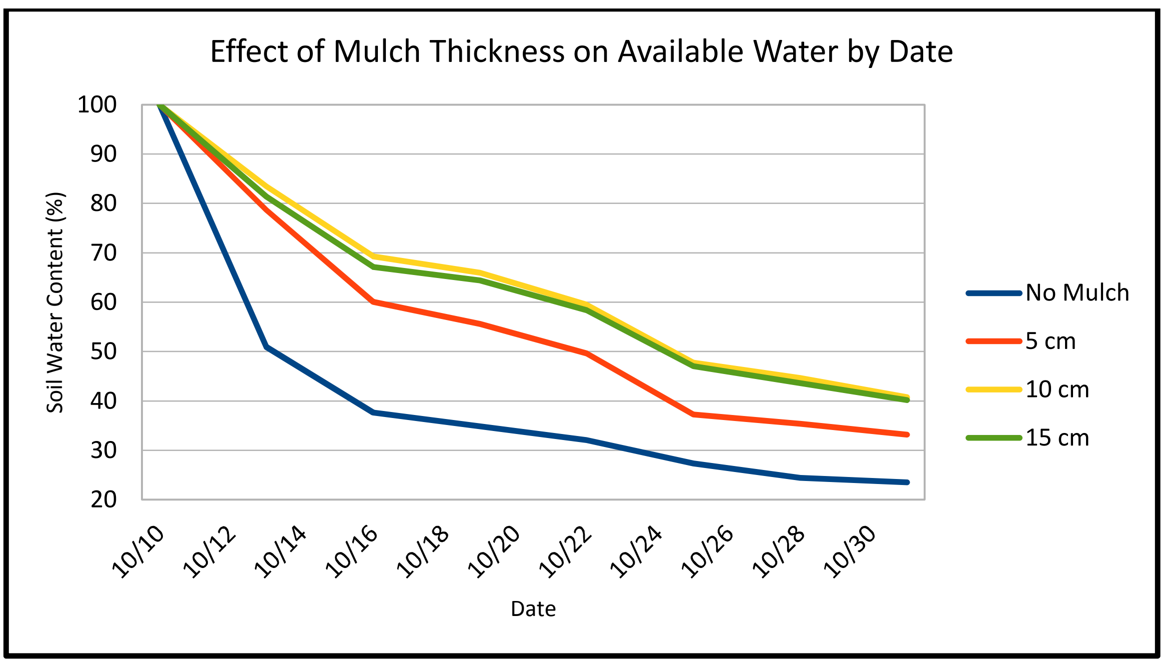

Figure 1. The effect of the three different mulch thicknesses on the soil water content throughout the experiment.

Mulch thickness also had an effect on the rate of water loss. The mean separation, which was accomplished using single degree of freedom orthogonal contrasts, indicated a clear separation between the 5 cm depth and combination of 10 and 15 cm depths, (p = 0.0023). In effect, doubling the mulching rate from 5cm to 10 cm maintained soil moisture 10% higher throughout most the experiment. However, increasing the depth to 15 cm, the highest mulching rate treatment, didn't significantly reduce evaporation further, (p = 0.9551).

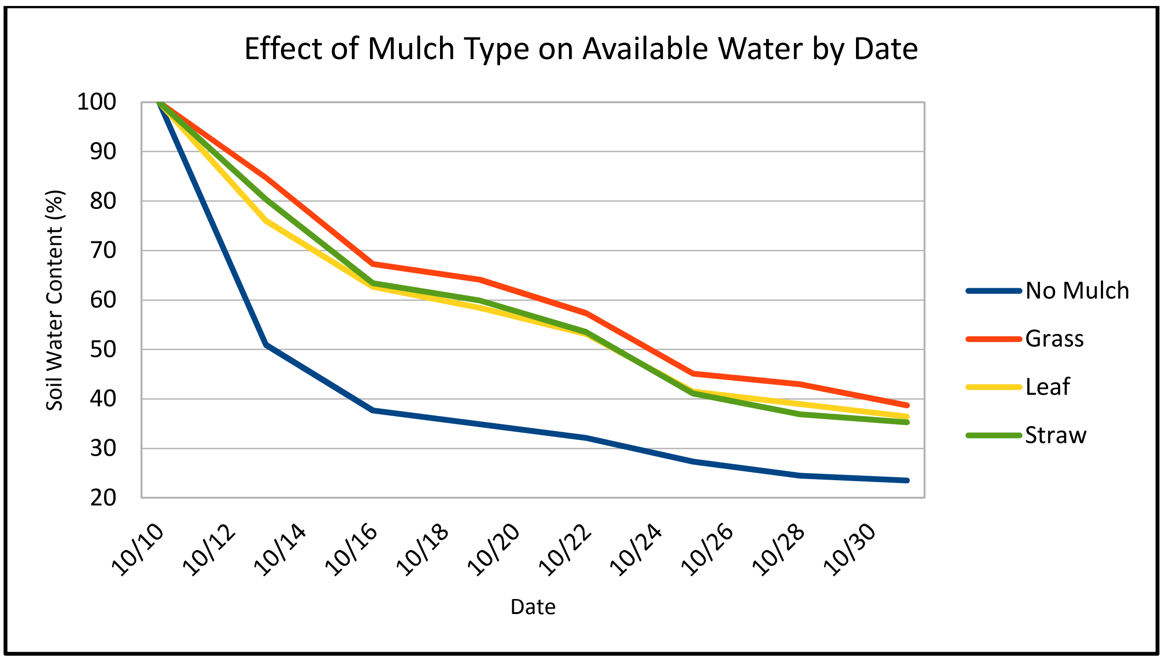

Figure 2. The effect of the three different mulch types on the soil water content throughout the experiment.

All mulch types were equally effective at reducing soil evaporation. Samples covered with grass clippings lost slightly less water, however the reduction in evaporation was not significant, even at the 0.05 level, (p = 0.2854).

DISCUSSION

This experiment demonstrated that even a relatively thin layer of plant debris can conserve a considerable amount of water, especially right after an irrigation. Within the first 3 days, bare soil lost half of the moisture content, whereas soil covered with mulch layer of 5 cm lost only 20%. That extra 30% would considerably improve the irrigation efficiency in a cropping situation, especially with shallow rooting plants such as vegetables and berries. Furthermore, the moisture is the soil is at a much lower tension, so it is much more easily absorbed by the crop.

Although these materials are permeable, a thick layer isn't necessary in order for the mulch to function. A thick enough layer still reduces the amount of sunlight hitting the soil. The mulch also maintains the humidity right at the soil surface, and prevents airflow which keeps the moisture in the soil. In fact, the results show that mulching rates above 10cm for these three materials are no more ineffective. While doubling the mulching rate from 5 to 10 cm resulted in a reduction in water loss, the higher rate didn't lead to a significant decrease in surface evaporation.

All three mulching materials performed equally well. The similarity in structure between the grass clippings and straw mulch could explain the similar effect on soil moisture retention. Since the leaf debris has a much larger surface area compared to the other two materials, I was expecting it to be slightly more effective at preserving surface moisture. However, there was no significant difference.

The results of the experiment would justify a change in practices in many situations. For instance, many vineyards use grass as an inter-row cover crop. Instead of simply mowing the cover crop and leaving the cuttings in the center rows, the clippings could be thrown beneath the vines, maintaining a mulch layer. This small change in practices, with no major change in costs, could easily lead to considerable savings in water and improved plant growth.

Improving soil tilth, structure and water holding capacity is necessary to ensure continued cropping success, and this practice also works towards these goals. When incorporated into the soil after the cropping season, the mulch will increase percentage of organic matter, further improving the water holding capacity of the soil. The higher percentage of organic matter will also lead to better structure, reducing aggregation especially in heaver clay soils. Even in situations where a manager has to purchase the mulching material such as straw, the savings in water and improvement in crop performance coupled with the soil building properties would likely justify the cost.

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