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Effect of Mulch Type and Width on Soil Water Potential and Plant Survivorship in a Semi-Arid Riparian Ecosystem

Abstract

Restoration of riparian ecosystems after long-term agricultural practice generally requires the re-establishment of shrubs and trees. Synthetic mulches are often used to enhance establishment where natural rainfall is not always sufficient. We examined the effect of plastic mulch type (permeable and non-permeable) and distance from the center of the mulch to the edge (half the width) on soil water potential and plant survivorship. Permeable squares (1.8 m wide), plus narrow (1.6 m wide) and wider (4 m wide) strips of both types were used. In the soil moisture experiment, Water Mark© sensors were placed at 10, 30, and 60 cm depths in each of 12 experimental units in late March 2002. Mulch type had no effect on soil moisture retention. Wide strips held water longer than narrow strips. Seedlings of ponderosa pine and snowberry were used for the survivorship experiment and were planted into other mulch strips in late March. Plants were placed near the center of narrow strips and in three locations (center and about 1 m in from the two edges) in wide strips. Survivors were counted on 31 August. Survival of ponderosa pine and snowberry was significantly greater on wide strips than on narrow strips. Wider strips likely reduce the number of roots of surrounding plants that can reach the stored water. Under the conditions of the test, the best strategy for successful restoration of ponderosa pine and snowberry is to plant them into wide mulch strips. The type of mulch was not important in this study, thus the least expensive mulch type should be used.

Introduction

Restoration in riparian ecosystems after long-term agriculture often requires planting native trees and shrubs (Sweeney et al. 2002). Restoration of native trees and shrubs in semi-arid ecosystems is more successful when competition for water is reduced (Ross and Walstad 1986). Hand removal of competitive plants within a 0.6 m radius around planted ponderosa pine (*Pinus ponderosa*) was necessary for establishment in a grassy area in Idaho (Cleary et al. 1978). Hand removal of competitive plants is not likely to control rhizomatous competitors and does not provide long-term control. Chemical control of competitive plants improves the vigor of planted trees in forest ecosystems (Cleary et al. 1978). While chemical control is successful, there is the risk that residues can enter stream water (Abu-Hamdeh and Abu-Qudais 2001). Thus, herbicide use is restricted in riparian zones (Oester 2000) and depends on the distance to water. Plastic mulches provide long-term (5 to 7 years) control of competitive vegetation (Atchison and Ricke 1996; Bond and Grundy 2001) and can be used near water.

Plastic mulches suppress weeds (Abu-Hamdeh and Abu-Qudais 2001) and reduce the evaporation of water (Li et al. 1999, Jin et al. 1999) from semi-arid soils (Fisher 1995). Various plastic mulch types (Geyer 2001) and widths are used to improve the success of shrub and tree plantings (Adams 1997; Bendfeldt et al. 2001). Plastic mulches vary in their permeability to water and air depending on pore size and density. Permeable mulches are more commonly used because they promote infiltration of precipitation and allow for significant air exchange. Non-permeable plastic mulches do not allow water to infiltrate directly through the mulch, but precipitation can be directed to planting holes. Non-permeable plastic mulch is commonly used in agriculture applications in dry climates to direct precipitation to plantings (Fisher 1995). Plastic vapor traps are used to direct water to plantings in dry climates (Munshower 1993). Non-permeable plastic mulch may also increase the risk of pathogenic infection because of high humidity and the lack of adequate air exchange. The risk of pathogenic infection is higher in nurseries when plants are subjected to high humidity and lack of adequate air exchange (Dole and Wilkins 1999). We tested the hypothesis that there is a difference between non-permeable and permeable plastic mulch in their ability to

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restrict evaporative loss of water and their effect on survivorship of planted trees and shrubs.

Mulch sizes and configurations range from narrow strips to squares to wide strips. Narrow widths may not offer adequate protection from competitors, while wide strips are difficult to handle (Atchison and Ricke 1996). We investigated the relationship between mulch dimension (distance from the center of the mulch to the edge) and soil water potential and survivorship.

The amount of riparian habitat restored depends on the survivorship of planted trees and shrubs, the difficulty of applying mulch, and the cost of mulch. The cost of plastic mulch depends on type and size. The purpose of this study was to determine the effect of mulch type and width on soil water potential and survivorship of ponderosa pine and snowberry (*Symphoricarpos alba*).

Methods

Study Site

The site chosen for the experiment is in the Touchet River floodplain about 5 km west of Prescott, Washington. Yearly precipitation is about 375 mm (Walla Walla County Conservation District 2002). The studies were conducted in a cultivated area that had recently grown alfalfa (*Medicago sativa*). The cultivated area contained alfalfa plus several invasive species including tumbleweed (*Salsola kali*), yellow starthistle (*Centaurea solstitialis*), common mullein (*Verbascum thapsus*), Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), mayweed (*Anthemis cotula*), common tansy (*Tanacetum vulgare*), and burr chervil (*Anthriscus caucalis*). The soil is a silt-loam with few rocks. The experiment was conducted in a field surrounded by trees, of which black cottonwood (*Populus trichocarpa*) was common. The study area is approximately 30-100 m from the river.

Experimental Treatments

The plastic mulch used for treatments came in two widths, narrow (1.8 m) and wide (4.6 m). The narrow non-permeable mulch is a reinforced polyethylene Layfield© plastic 0.30 mm thick. The wider non-permeable mulch is a reinforced polyethylene Brent© plastic also 0.30 mm thick. The permeable mulch is a black woven polypropylene Lumite© plastic 0.46 mm thick (Atchison and Ricke 1996). In this experiment permeable squares, plus narrow and wider strips of permeable and non-permeable types were used. The mulches were rolled onto the soil surface, uncultivated for at least one year, with soil placed along the edges for stability. After placement in the field, the dimensions above ground were about 1.8 m for the squares, 1.2 m x 18.8-20 m for the narrow, and 4 x 9-12 m for the wider strips. For analysis, mulch dimension is defined as the distance to soil water potential sensors from the nearest edge of the mulch. For example, narrow strips that are 1.2 m wide have a mulch dimension of 0.6 m. In the soil water experiment, two replicates of each narrow mulch type, two each of the square and wide permeable mulch type, and one of the wide non-permeable mulch were used along with three no mulch controls totaling 12 experimental units. In the survivorship experiment four permeable narrow, four permeable wide, three non-permeable narrow, and three non-permeable wide strips were used. The experiment began in the third week of March 2002 with the random placement of mulch.

In the soil moisture experiment Water Mark© soil moisture sensors (Shock et al. 1993) were placed at 10, 30, and 60 cm depths in each of experimental units between the 23rd and 26th of March. Each sensor was placed in its own hole about 25 cm from the adjacent sensor. Sensors were placed in a line near the middle of each strip. The hole was created using a 2.54-cm diameter rod pushed down to a few centimeters above the desired depth. The sensor was then placed in the hole and pushed through the remaining soil with a pipe that fit the end of the sensor. This forms a tight seal between the sensor and the soil. Breaks in the mulch around the soil sensor holes were sealed with Silicon Seal©. Soil temperature used to calculate soil water potential was measured on top of each sensor with thermocouple wire.

Ponderosa pine and snowberry were used for the survivorship experiment. Plants were raised in a nursery in tubes (tublings). In late March, plants were placed near the center of the narrow strips and in three locations (center and about 1 m in from the two edges) in the wide strips. Plants were planted about 1.2 m apart in all mulch treatments. Ponderosa pine plants were less than 50 cm tall and snowberry plants were less than 20 cm tall on 23 April.

Sampling and Statistical Analyses

Soil water potential observations were taken in the late afternoon on 30 March, 23 April, 19 May, 29 June, 21 July, and 29 August. Soil water potential data within each experimental unit were averaged across depths. The initial count of plants for the survivorship experiment was done on 23 April. The count of survivors was done on 31 August.

Analyses were done using JMP version 5, software (SAS Institute, 2002). Analysis of variance (ANOVA), regression with the lack-of-fit test, the Tukey-Kramer HSD test, and Student's t-test were used to compare treatments and means. Error terms are one standard error of the mean. Statistical significance is set at the $P = 0.05$ level.

Results

Soil Moisture

The relation between average soil water potential and time, the square of time, mulch dimension, and the interaction between time and mulch dimension was significant ($P < 0.001$) by ANOVA. The square of time accounts for curvature in the relation between soil water potential and time (Figure 1). Mulch type had no significant effect on soil water potential (Table 1).

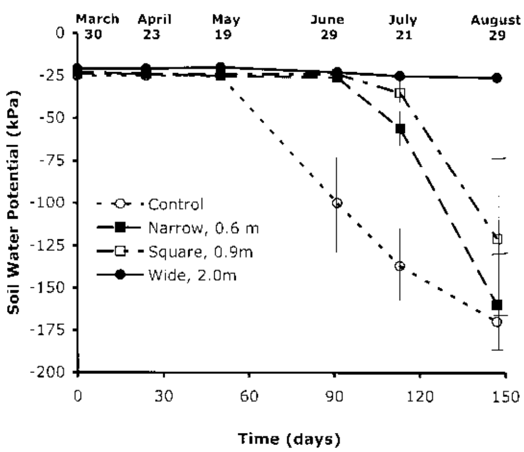

Figure 1. The relation between time since the first reading on March 30, 2002 and mean (across depth and mulch type) soil water potential for control (no mulch) and three mulch dimensions defined by the distance from the soil moisture sensor to the nearest edge of the mulch. Bars are one standard error of the mean.

TABLE 1. The effect of time, mulch type (permeable, non-permeable), mulch dimension, and the interaction between time and mulch dimension on soil water potential.

Source	df	F	P
Time	1	41.16	<0.0001
$Time^2$	1	29.93	<0.0001
Dimension	1	16.87	0.0002
Dimension x Time	1	21.77	<0.0001
Type	1	0.13	0.7159

Because there was no difference between permeable and non-permeable mulch types on soil water potential, these data were pooled to examine the relation between mulch dimension and soil water potential over time. Control plots (dimension zero) began to dry earlier than mulch plots. By day 91 (29 June), control plots had dried to -100.4 ± 24.9 kPa (n = 3), significantly drier than all mulch plots (-23.2 ± 1.6 kPa, n = 9) by the Tukey-Kramer HSD test (Figure 1). By day 144 (29 August), square (0.9 m) and narrow (0.6 m) mulch plots were as dry as the control plots with a pooled soil water potential of -155.4 ± 15.5 kPa (n = 9) by the Tukey-Kramer HSD test (Figure 1). The wide mulch plots (2 m) remained wet at -24.6 ± 1.9 kPa (n = 3) on day 144 (Figure 1).

The effect of mulch dimension on soil water potential became stronger as the season progressed (Figure 2). There was no linear relationship before June 29. On 29 June, the relation [soil water potential = $(-29.8 \pm 2.17) + (5.8 \pm 1.68)$ dimension] was significant ($r^2 = 0.63$, $P = 0.0103$). On 21 July,

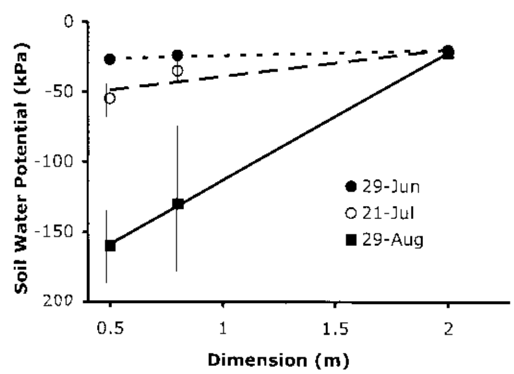

Figure 2. The relation between mulch dimension (the distance from the soil moisture sensor to the nearest edge of the mulch) and soil water potential when soils were drying. Bars are one standard error of the mean.

the relation [soil water potential = (-65.1 ± 11.82) + (22.3 ± 9.14) dimension] was also significant (r^2 = 0.46, P = 0.0449). The difference between these two slopes was not significantly different from zero. By 29 August, the relation [soil water potential = (-213.1 ± 30.16) + (94.6 ± 23.32) dimension] remained significant (r^2 = 0.70, P = 0.0048) with the difference between the slope and that of 21 July, significantly different from zero. On all three dates, the lack-of-fit test for the linear model was insignificant indicating that the linear model is adequate. Thus, as the summer progresses and evaporative demand increases, the effect of mulch dimension on soil water potential becomes stronger.

Survivorship

The initial count of ponderosa pine ranged from 4 to 32 individuals in each plastic mulch strip. Survivorship of ponderosa pine ranged from zero to 94 % depending on mulch dimension. The initial count of snowberry ranged from 6 to 12 with survival ranging from 11 to 100% depending on mulch dimension.

The effect of mulch dimension and type on survivorship was tested with ANOVA for both species. There was no effect of mulch type on ponderosa pine or snowberry survivorship, thus mulch type data were pooled. Survivorship of both ponderosa pine and snowberry were significantly greater on wide than on narrow mulch (Table 2). Survivorship of snowberry is about twice that of ponderosa pine.

TABLE 2. The effect of mulch dimension on mean % survivorship (± se, n) of ponderosa pine and snowberry.

	Mulch Dimension (m)		
Species	Narrow (0.6 m)	Wide (2.0 m)	*P*
Ponderosa pine	16.7 ± 3.77, 7	50.3 ± 8.44, 7	0.0034
Snowberry	35.3 ± 9.78, 4	98.3 ± 1.67, 5	<0.0001

Discussion

The main findings of this study were that plastic mulch type had no effect on soil water potential or survival and that there is a linear relationship between mulch dimension and soil water potential. Plant survivorship was significantly greater on wide compared to narrow mulch.

Soils dried through the period with control plots drying faster than those covered by mulch. This is expected because plastic mulch reduces moisture loss by reducing evaporation (Atchison and Ricke 1996) and by reducing water lost through surrounding plants. The increased rate of water loss from the no-mulch controls is due, in part, to the presence of numerous early successional plant species (Larcher 1995). There was no effect of mulch type on soil water potential. The permeable and non-permeable plastic mulches used in this study have the same net effect on soil water balance even though the materials differ in their permeability to water. The width of mulch had a strong effect on soil water potential. Wide mulch strips can keep roots of surrounding plants away from stored moisture. All mulch strips were surrounded by green vegetation that was taller than vegetation further away from the mulch edge without access to the water stored under the mulch. The linear relation between dimension and soil water potential suggests that a plastic mulch dimension of 2 m is needed to eliminate water loss in this environment. A better estimate of the minimal mulch dimension needed to prevent water loss would require investigations between 0.9 and 2 m. The true form of the relation may be curvilinear with a minimum dimension less than 2 m.

There was no effect of mulch type on survivorship of ponderosa pine or snowberry. Given that there was no effect of mulch type on soil water potential there may be no difference between the mulch types for the risk of pathogenic loss of plants. Non-permeable mulch had holes where the plants were placed that may allow for sufficient exchange of air to reduce the risk of pathogens. More experimentation is required to determine if there is any risk of pathogenic loss of plants placed in non-permeable mulch in dry climates. We did not attempt to positively identify the cause of death.

Survival of both species in wide mulch strips was much greater than in narrow strips. Survivorship of ponderosa pine in narrow strips was only 16.7%. Plastic mulch needs to be wide enough to keep roots of plants growing along the edge from accessing water near the transplant. The recommended dimensions (1.2 x 1.2 m) of planting squares in Manhattan, KS (Atchison and Ricke 1996) is equal to a distance of 0.6 m from the middle to an edge. This is the same dimension as the narrow strips in our experiment. In the semi-arid climate of Prescott, WA, the optimal dimension of plastic mulch is between 0.9 and 2 m. The smaller dimension for Manhattan may be adequate because of greater yearly (760 mm) precipitation (Geyer 2001) while a larger dimension is needed in the lower (375 mm) precipitation of Prescott. It is likely that the optimal dimension of plastic mulch depends on yearly precipitation.

Non-permeable plastic mulches could have the advantage if plants are placed in formed depressions so that water can be directed to the transplant. Using non-permeable mulches formed to direct water to the transplant may also reduce the minimum mulch size needed to optimize survivorship in dry climates.

Under the conditions of the test, the best strategy for restoration success of ponderosa pine and snowberry is to plant them into 4 m wide plastic mulch strips. Wide strips retained soil water longer than narrow strips. The optimal width of plastic mulch likely depends on yearly precipitation. The type of mulch was not important, thus the least expensive mulch type should be used. The least costly method of restoration will be a function of material and the survival of transplants.

Acknowledgments

The Walla Walla County Conservation District provided financial support. We thank Michael Pelissier for help with experimental design. Douglas Higbee, Miljan Ignjatic, and John Royce are thanked for technical support. Susan Nelson and Dr's. Edith B. Allen, Scott Wilson, and Edward Rykiel are thanked for suggestions that improved the manuscript.

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Received 21 December 2003
Accepted for publication 13 August 2004