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Wood chip mulch thickness effects on soil water, soil temperature, weed growth and landscape plant growth

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Abstract

Wood chip mulches are used in landscapes to reduce soil water evaporation and competition from weeds. A study was conducted over a three-year period to determine soil water content at various depths under four wood chip mulch treatments and to evaluate the effects of wood chip thickness on growth of 'Husker Red' *Penstemon digitalis* Nutt. plants. The effects of four wood chip thicknesses (depth of application: 0, 2.5, 5, and 10 cm) on soil water content, weed numbers, soil temperature, and height, width, stalk number, and first flower date of 'Husker Red' *Penstemon* were investigated. The addition of mulch, at all mulch thicknesses, conserved soil water compared to when no mulch was used. The differences in soil water content likely influenced some of the plant growth factors measured. Weed numbers were significantly higher at 0 and 2.5 cm mulch thickness compared to 5 and 10 cm thickness. In general, mid-day soil temperatures were highest at the shallower soil depths in the unmulched plots. Flowering plants in 2008 in the unmulched treatment were slightly shorter than in the mulched treatments. There were no significant differences in the number of flower stalks per plant although there was a trend for a lower number of stalks with the mulched treatment. The time of first flower was, on an average, about 2 days earlier for the unmulched treatment compared to the 10 cm mulch thickness. Wood chip mulch helped conserve soil water, which in turn had some effects on plant growth.

Key words: Wood chips, mulch thickness, 'Husker Red', *Penstemon*, soil water, soil temperature, weeds, neutron probe

Introduction

Efficient use of water in outdoor landscapes will become an increasingly important issue as the competition for water intensifies. Reports show that 40 to 70% of residential water use in the United States is applied to landscapes which indicate that landscape water use will be part of long-term strategies for conserving water (St. Hilaire *et al.*, 2008).

Mulching is a commonly recommended practice to conserve soil water, moderate soil temperatures, reduce weed growth, reduce maintenance, reduce soil borne diseases, reduce soil erosion and enhance survival (Awan, 1964; Broschat, 2007; Calkins *et al.*, 1996; Faucette *et al.*, 2007; Mata *et al.*, 2002; Nier and Upham, 2006). Mulches can also provide a visual design element in landscape plantings (Ashworth and Harrison, 1983; Holloway, 1990; Nier and Upham, 2006). Mulches of various types can affect plant growth (Bailey, 1991; Choi *et al.*, 2005; Geyer, 2003; Gruda, 2008; Ramakrishna *et al.*, 2006).

Mulches of all types, both organic and inorganic, have the potential to significantly conserve soil water (Ashworth and Harrison, 1983; Goswami and Saha, 2006; Iles and Dosmann, 1998; Kratsch, 2007). However, mulches need to be used correctly (Nier and Upham, 2006). Additional documentation on soil water content under mulches would be useful for making mulching recommendations for conserving soil water of landscape beds in semiarid climates. The objectives of this study were to determine the effects of wood chip mulch thickness on soil water content, weed population, soil temperature, and growth of 'Husker Red' *Penstemon digitalis* Nutt, which is a herbaceous perennial plant with wide adaptation and requires only moderate amounts of water (Lindgren, 1984).

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Materials and methods

In May 2006, an area (55 x 4.5 m) located at the University of Nebraska–Lincoln (UNL) West Central Research and Extension Center (WCREC) in North Platte, Nebraska, was clean tilled and then watered to bring the soil water content up to field capacity. Soil at this site is a Cozad silt loam (fine-silty, mixed, mesic *Fluventic Haplustoll*) with a pH ranging from 7.6 to 7.8. Sixteen neutron tubes were inserted into the soil, 6.4 m apart. Four plants of 'Husker Red' *Penstemon* were equally placed 0.3 m from each of the 16 tubes. Four treatments of varying thickness of wood chips were applied to a 4.5 square m area around each tube, with four replications. The four treatments were: 10, 5, 2.5, and 0 cm of wood chips.

In the mulched plots 1.83 m long neutron tubes were installed; in the unmulched plots the tubes were 3.05 m long. The treatments were arranged in a randomized complete block design. In 2008, additional chips were applied to bring the mulched treatments back to the original thickness. The wood chips were a mix of soft and hard wood and were not dyed. Wood chips larger than 10 cm were discarded.

During the three-year study (2006-2008), no irrigation water was applied to the study area. The only moisture received was from precipitation (Fig. 1). Volumetric soil water content was measured in all plots at six depths (0-0.30, 0.30-0.61, 0.61-0.91, 0.91-1.22, 1.22-1.52, and 1.52-1.83 m) on selected dates in 2006 (6/6, 6/13, 6/27, 7/5, 7/20, 8/15, and 9/13), 2007 (3/13, 5/11, 5/24, 7/3, 7/13, 8/1, 8/13, 8/27, and 10/3) and 2008 (5/20, 6/12, 6/26, 7/3, 7/16, 7/31, 8/12, 8/28, and 9/19) (Fig. 2) using the neutron probe method (Evett and Steiner, 1995). Additional volumetric soil water measurements were recorded in the unmulched plots at depths of 1.83-2.13, 2.13-2.44, 2.44-2.74 and 2.74-3.05 m on the same dates in 2006, 2007 and 2008 to determine the depth of water extraction by plant roots. Selection of dates was based on obtaining a sufficiently dense data set to trace soil water changes over time.

Periodically, during each growing season, weed numbers were recorded. Grassy and broadleaf (dicot) weeds were counted separately. Once the weeds were counted, they were removed. No herbicides or fertilizers were applied. Weed counts were made on July 5, August 4, and September 12 in 2006; April 16, July 26, and September 13 in 2007; and July 9, August 9, and September 20 in 2008.

Soil temperatures were measured approximately at mid-day at 7 and 12 cm soil depths on May 10, 2007 and at 2, 7 and 12 cm soil depths on July 26 and November 9, 2007. A Soiltest Inc. (Chicago, Illinois) Model G-200 soil thermometer was used to make the measurements.

Plant height at flowering was measured on June 27 in 2007 and July 9 in 2008. In 2006, because plants did not flower, only foliage height and width were measured. The average number of flower stalks per plant was recorded in July of 2007 and 2008. The average first date of flower was recorded in 2007.

A split plot in time model analysis of variance was used to test the effects of mulch thickness and sampling date on soil water content (Statistix 8, Analytical Software, 2003). The analysis of variance was conducted separately for the 0-0.61, 0.61-1.83, and 0-1.83 m soil depths. For significant main effects and interactions, means separations were conducted using the Least Significant Difference (LSD) method. Significance was determined at the 0.05 probability level. Analysis of variance was conducted with SAS (SAS for Windows, v. 9.1, SAS Inst., Cary, NC) using Proc GLM with LSD at the P=0.05 for means separations for weed count, soil temperature, plant height and width, stalk number and first flower date.

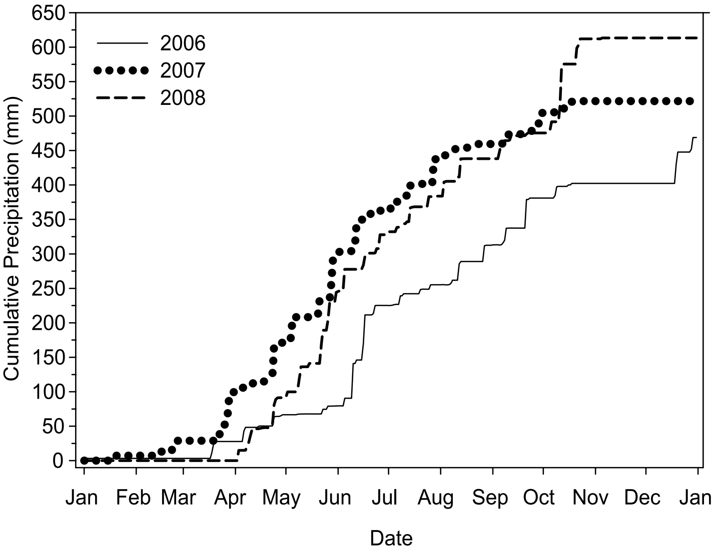

Fig. 1. Cumulative precipitation as a function of time in 2006, 2007 and 2008

Results and discussion

Total annual precipitation amounts were 469, 522, and 623 mm in 2006, 2007, and 2008, respectively (Fig. 1). The average annual precipitation in North Platte, Nebraska, is approximately 499 mm.

In the top 0.61 m of soil, treatment (mulch thickness) by sampling date effect on soil water content were significant (Table 1). In all three years, the unmulched treatment had a lower soil water content in the top 0.61 m, although this effect was not statistically significant on every sampling date (Fig. 2). Deeper in the soil (0.61-1.83 m), there was no significant effect of mulch thickness on soil water content, nor was the treatment by date effect significant (Table 1). The only significant effect at these deeper depths was the effect of sampling date, explained by wetting and drying of soil over time (discussed later in this paper). At these deeper depths, there were some trends for higher soil water content for the unmulched treatment in all three years (data not shown).

Table 1. Analysis of variance for the effects of treatment (mulch thickness) and sampling date (2006-2008) and their interaction on depth of soil water in the 0 to 0.61, 0.61 to 1.83, and 0 to 1.83 m soil depths. Data for the significant treatment by date interaction of the 0 to 0.61m soil depth is shown in Fig. 2.

Effects	0-0.61 m	0.61-1.83 m	0-1.83 m
	------------------------------ $P > F$ --------------------------		
Treatment (T)	0.036	0.715	0.521
Date (D)	<0.001	<0.001	<0.001
T×D	<0.001	0.419	0.212

These data indicate that the addition of mulch, at all thicknesses, conserved soil water compared to the unmulched treatment. Other researchers have found similar results. For example, in a study by Granatstein and Mullinix (2008), mulching reduced cumulative irrigation application by 20% to 30%, and water depletion was greatest under unmulched treatments and was significantly higher at a soil depth of 10 cm compared to 20, 30, and 50 cm depths.

For all four mulch treatments, soil water content increased after rains (Fig. 2). Soil water content closer to the soil surface (Fig. 2) was more responsive to rains compared to soil water content at deeper soil depths (data not shown). The significant date effects (Table 1) are due to wetting of the soil by rains and drying of the soil because of plant water uptake and evaporation from the soil (Fig. 2). In 2006, there was 28 mm rain on June 11, increasing soil water content, measured on June 13, for all four mulch treatments at the 0 - 0.61 m depth (Fig. 2). Soil water content in the unmulched treatment increased the least, possibly because of greater evaporation since the rainfall of June 11, and/or more runoff associated with this rainfall event. Less infiltration and thus more runoff of rain water is expected on an unmulched, bare soil compared to a mulched soil.

On July 20, 2006, the soil dried down considerably (Fig. 2) due to high plant water use associated with high evaporative demand in the middle of summer and little rainfall since June. On August 15, soil water content increased at all depths because of 15 mm rainfall on August 8 and 32 mm rainfall on August 13. In 2007 and 2008, similar responses of soil water content to rainfall and dry periods were observed (Fig. 2).

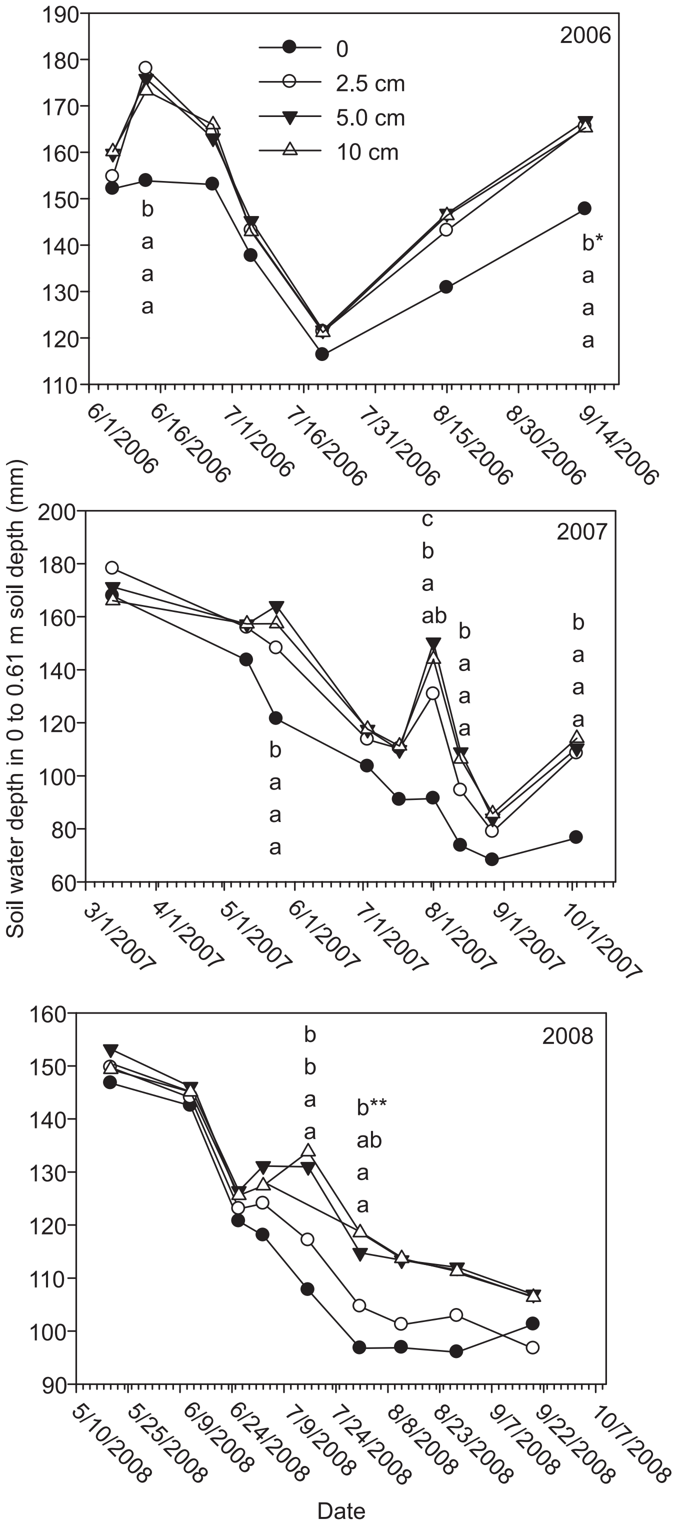

Fig. 2. Soil water depth under four mulch treatments in the top 0.61 m of soil in 2006, 2007, and 2008. Each data point is the average of four replications. For each date, treatments with the same letter are not significantly different at the 0.05 probability level based on LSD. Treatment differences represented by letters from top to bottom correspond to the treatments in the legend from top to bottom: 0, 2.5, 5, and 10 cm mulch thickness, respectively. *P>F = 0.0509; **P>F = 0.0533.

In the unmulched treatment, soil water content decreased with time all the way down to the deepest depth measured: 2.74-3.05 m (Fig. 3). Every year in the spring, the soil at this depth was filled with water above field capacity. During the summer the soil dried out well below field capacity, suggesting that the *Penstemon* roots could be extracting water to a depth of at least 3 m. At this depth, all this soil drying was probably not caused by direct water uptake by plant roots. Soil water redistribution, driven by evaporation of water at the soil surface, may also have contributed to the change in soil moisture down to a depth of 3 m.

There were significant differences in total weed counts between the treatments. In general, weed numbers were significantly higher at the 0 and 2.5 cm mulch thicknesses compared to the 5 and 10 cm thicknesses (Table 2). Weed counts in 2008 were somewhat higher than in 2006 and 2007, probably because of more rainfall in 2008. Results of a study by Granatstein and Mullinix (2008) are a good comparison for this study in which percent weed cover was 3% for plots mulched with wood chips and 40% for unmulched plots. Similar results with wood chips and shredded bark have been reported by Ashworth and Harrison (1983) and Broschat (2007).

Mid-day soil temperatures varied with the mulch treatment as well as with the soil depth at which the temperatures were recorded (Table 3). In general, soil temperatures were highest at the shallower soil depths in the unmulched plots. The dates of measurement were typical (26 July) to sunny and warm (10 May and 9 November) for the time of the year. Soil temperatures could affect both plant size and the rate of growth of these plants. The increased soil temperature in the unmulched treatment may have increased evaporation from the 2 cm soil depth, decreasing the soil water content compared to the mulch treatments. Ashworth and Harrison (1983) found that 5 cm of bark mulch reduced the range of diurnal soil temperature changes but they did not comment on seasonal and soil depth changes in soil temperatures.

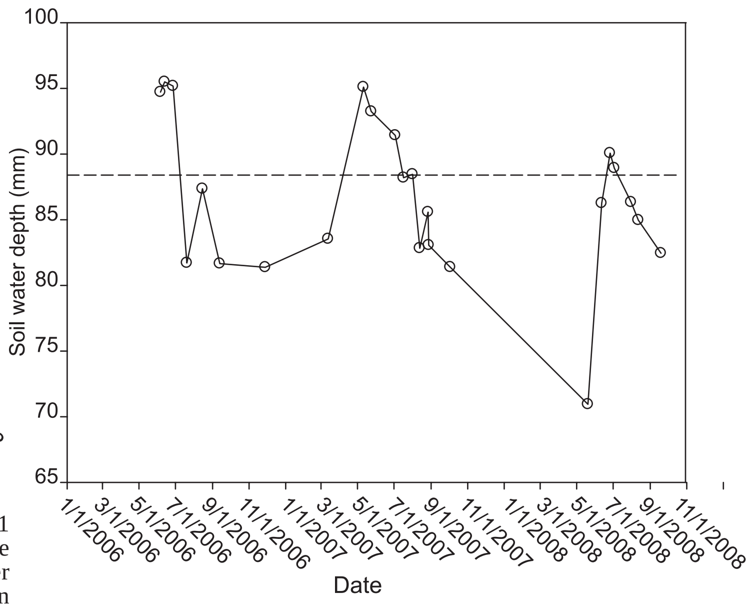

Fig. 3. Soil water depth in the unmulched treatment between 2.74 and 3.05 m soil depth. Dashed line represents the estimated soil water depth at field capacity for this soil (volumetric soil water content at field capacity = 0.29 $m^3 m^{-3}$, Klocke *et al.*, 1999).

Table 2. Number of weeds in mulch treatments from 2006-2008 for broadleaf weeds, grassy weeds and total weeds. Each number is an average of four replicates over three dates

Mulch thickness	2006 B[z]	2006 G[y]	2006 T[x]	2007 B[z]	2007 G[y]	2007 T[x]	2008 B[z]	2008 G[y]	2008 T[x]
0 cm	47.0a[w]	12.3a	59.3a	38.0a	2.8ab	40.8a	82.8a	14.8a	97.5a
2.5 cm	51.5a	12.3a	63.8a	23.5ab	5.3a	28.8a	50.2ab	5.0ab	55.3ab
5 cm	18.5b	3.3a	21.8b	7.8bc	1.0ab	8.8b	14.8b	2.3b	17.0b
10 cm	5.5b	0.8a	6.3b	1.8c	0.3b	2.0b	2.3b	2.3b	4.5b

[z] Number of broadleaf weeds. The major broadleaf weeds were prostrate spurge (*Euphorbia supian* Ref.), spotted spurge (*Euphorbia maculata* L.), purslane (*Portulaca oleracea* L.), and henbit (*Lamium amplexicaule* L.).

[y] Number of grassy weeds. The major grassy weeds were smooth crabgrass [*Digitaria ischaemum* (Schreb.) Schreb. ex Muhl.], yellow foxtail (*Setaria glauca* L. Beauv.), and stinkgrass [*Eragrostis cilianesis*(All.) *E. Mosher*].

[x] Total number of broadleaf and grassy weeds.

[w] Numbers with different letters in each column indicate a significant difference at *P*=0.05 using the Least Significant Difference method in SAS.

Weed counts were made on July 5, August 4, and September 12 in 2006; April 16, July 26, and September 13 in 2007; and July 9, August 9, and September 20 in 2008.

Table 3. Soil temperatures (°C) at mid-day on three dates in 2007 averaged over four replicates

Mulch thickness	10 May, T_{max} = 27.8[z]		26 July, T_{max} = 33.3			9 November, T_{max} = 17.7		
	7 cm[y]	12 cm[y]	2 cm[y]	7 cm[y]	12 cm[y]	2 cm[y]	7 cm[y]	12 cm[y]
0 cm	16.7a[x]	15.1a	34.2a	28.1a	26.2a	18.0a	12.1a	8.1a
2.5 cm	15.4b	14.3b	30.1b	26.4b	25.3b	14.6b	9.7b	7.1b
5 cm	14.1c	13.6c	31.7ab	26.2b	24.9c	15.6b	10.1b	7.3b
10 cm	13.7c	13.3c	31.5ab	26.4b	24.6c	16.1b	10.3b	7.7a

[z] T_{max} is maximum air temperature (degrees centigrade). [y] Depth at which temperatures were measured. [x] Numbers with different letters in each column indicate a significant difference at *P*=0.05 using LSD

The only difference in plant height of flowering plants occurred in 2008. Plants in the unmulched treatment were slightly shorter than in the mulched treatments (Table 4). There was no statistically significant difference in the number of flower stalks among the mulch thicknesses (Table 5). However, there was a trend towards fewer flower stalks in the unmulched treatment. The time to the first flower was, on the average, about 2 days longer at the 10 cm mulch thickness compared to the 0 cm mulch thickness. This may have been due to soil temperature differences rather than soil water differences.

This study documented the value of wood chips as mulch for conserving soil water and reducing weed populations. The most apparent effect of mulch thickness on soil water content occurred in soil zones closest to the surface. Soil closer to the surface is more rapidly affected by rain whereas the deeper soil is more buffered by the soil layers closer to the surface. Using neutron probes to monitor soil water appears to be very effective in determining soil water levels in experimental landscape situations. Personal observations would also suggest the need to stir the mulch periodically to encourage infiltration and reduce runoff. The presence of mulch and its thickness affects both water infiltration into the soil and evaporation of water from the soil, resulting in modifications of soil moisture under the mulch.

Table 4. Plant height and width (numbers are average of four replicates)

Mulch thickness	12 September 2006 Height (cm)	12 September 2006 Width (cm)	27 June 2007 Height (cm)	9 July 2008 Height (cm)
0 cm	12.4a[z]	24.7b	76.3a	68.4b
2.5 cm	12.7a	28.0ab	78.3a	78.5a
5 cm	12.1a	28.9ab	79.9a	76.4a
10 cm	12.7a	31.6a	80.6a	76.5a

[z]Numbers with different letters in each column indicate a significant difference at *P*=0.05 using LSD

Table 5. Stalk number and first flower date (numbers are average of four replicates)

Mulch thickness	Number of flower stalks 2007	Number of flower stalks 2008	Date of first flower 2007 (days after 1 June)
0 cm	11.0a[z]	14.1a	24.7b
2.5 cm	10.8a	20.1a	26.4a
5 cm	13.3a	20.8a	26.1ab
10 cm	13.0a	18.4a	27.0a

[z]Numbers with different letters in each column indicate a significant difference at *P*=0.05 using LSD

There were no differences in plant top growth among mulch treatments in this study. 'Husker Red' *Penstemon* is a versatile plant adapting to different climates and soils which may account for the small differences in growth. There was a tendency for earlier flowering with no mulch. The difference in flowering time may be related to soil water and/or temperature differences. The results from this study will likely be applicable to other plant species as well as for certain other organic mulch materials.

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