Water Retention and Evaporative Properties of Landscape Mulches

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INTRODUCTION

The use of mulches in landscape plantings is increasing. Mulches have been promoted by water conservation, green waste reduction, and other programs primarily to reduce evaporation from soil. In addition, many of the materials used for mulching provide an improved aesthetic appearance for the landscape and provide weed control. Many different materials are available from composted products such as manures, sludge, and greenwaste to non-composted products such as wood chips and yardwaste from landscape maintenance operations, bark products from lumber mills, and rock (CIWMB).

Mulches can benefit landscapes by reducing soil evaporation, cooling the soil, suppressing weed growth, and possibly providing nutrients for plant growth. Several studies have evaluated the moisture retention and cooling of soils under mulch (Bennett, Borland, and Groenevelt, et al.) An energy balance study evaluated (by measuring radiation, temperatures, and reflectivity) the changes in environment and growth of landscape plants resulting from mulch applications, (Montague and Kjeldren.). A number of trials have evaluated mulch for weed control (Lanini, et al.) and relationships between weed emergence and physical properties of mulches have been developed (Teasdale and Mohler). Additional studies have evaluated the effect of mulch on plant material performance (Litzow and Pellett). However, little information or standards have been developed on the water holding capacity or evaporation rate of mulch materials themselves. This information would be important in determining accurate and effective landscape irrigation management.

In the landscape, we observed that the use of mulch can affect the movement of water applied by sprinklers or rainfall. For example, investigation of a failing landscape that was heavily mulched revealed that sprinkler applied water was not penetrating through the mulch layer and the plant materials were suffering from lack of water. Although the irrigation manager was applying an adequate amount of water, frequent applications appeared to be absorbed and evaporated from the mulch, resulting in under-irrigation and plant death.

This study was designed to determine the water retention characteristics of mulches and evaporation of sprinkler irrigation water from them under field conditions independent of plant materials.

MATERIALS AND METHODS

Treatment Selection

The study was undertaken at two locations in San Diego County, CA: Cuyamaca College in El Cajon, CA and Quail Botanical Gardens in Encinitas, CA. The locations represented inland valley (El Cajon) and coastal (Encinitas) climatic conditions and were in full sun. Twelve mulch treatments were selected to represent an array of materials and application depths (Table 1). Reported recommendations on mulch depth are variable in the industry, but 2-4 inches of mulch is a common suggestion for landscaped areas (Bennett, Borland, CIWMB). Therefore, 8 of the mulch treatments in this study were applied 3 in. thick.

Landscape managers are encouraged to make use of ground yardwaste products available at little or no cost at municipal landfill sites. The yardwaste material used in the study came from the Miramar landfill in San Diego. It is produced by tub-grinding landscape greenwaste and was minimally composted. The yardwaste treatments were applied in 1-, 3-, and 5-in. depths. Composted yardwaste was also available at the landfill. Xerimulch and Gro-Mulch were obtained from Kellogg Supply, Inc. (Carson, CA). Xerimulch is a fine-screened bark product and Gro-Mulch contains very fine composted organic material and sewage sludge. A-1 Soils Co. (Hanson Aggregates, San Diego, CA) provided the medium-sized bark chunks, 1-in. rock, and their "Organic Ground Cover" (OGC), which is a blend of screened wood chips and bark. The landscape fabric was a 5-mil Tyvec® (Dupont) cloth commonly available at landscape supply dealers. Frequently, landscape personnel place fabric under one of the organic mulches, so fabric with OGC was also included in the study. The control treatment was un-mulched bare soil.

TABLE 1. Mulch materials and application depth of the 12 treatments studied at Quail Botanical Gardens and Cuyamaca College.

Treatment	Mulch	Depth
1.	Yardwaste	1"
2.	Yardwaste	3"
3.	Yardwaste	5"
4.	Composted Yardwaste	3"
5.	Xerimulch (Kellogg Supply, Inc)	3"
6.	Organic Ground Cover (OGC; A-1 Soils)	3"
7.	Gro-Mulch (Kellogg Supply, Inc)	3"
8.	Medium Bark (A-1 Soils)	3"
9.	Landscape Fabric (5-mil Tyvec®)	-
10.	Landscape Fabric + OGC	3"
11.	1" Rock (A-1 Soils)	3"
12.	Control (no mulch, bare soil)	-

Site Preparation and Experimental Design

At each site the soil was rototilled to a depth of approximately 8 inches and raked smooth. Temporary sprinkler irrigation systems were installed and the mulch treatments applied in 5 ft. by 5 ft. experimental plots. The 12 treatments were replicated three times for a total of 36 plots at each site in a Randomized Complete Block Design. To measure the evaporation from the treatments, a nursery flat was placed in the center of each experimental plot to allow for removal, weighing, and replacement of a sample from each plot. For the 3- and 5-in. deep treatments, the sides of the flats were extended by attaching the sides of one or two additional flats (bottom removed) to the initial flat.

Irrigation Systems

The temporary irrigation systems consisted of PVC pipe and fittings with sprinklers set above grade. Catch can tests were performed and analyzed to determine the system precipitation rates and uniformity. The irrigation system utilized four Hunter Industries PGP Series sprinklers located 5 ft. outside of the plot corners (40 ft. by 40 ft. spacing) at the Quail Gardens site. The precipitation rate was 0.86 in. per hour with a distribution uniformity of 79%. At the Cuyamaca College site, the irrigation system consisted of eight Hunter Industries PGM series sprinklers located approximately 18 inches outside of the plot perimeter. At this site the precipitation rate was 0.62 in. per hour with a distribution uniformity of 80%.

After the irrigation systems were installed and the mulch treatments were in place, the systems were operated twice at weekly intervals at each site to settle the mulch materials in the plots.

Testing Procedure

The irrigation systems were run long enough to apply approximately one inch of water to the plot area, thoroughly wetting the mulch treatments and underlying soil without ponding or runoff. The systems were run in the late afternoon of October 2 and 3, 1995 at the Cuyamaca College and Quail Gardens sites, respectively. On the following morning and on subsequent days, flats containing the mulch treatments were weighed to collect data on water retention and loss. The experiment was repeated again at the Quail Gardens site on October 12, 1995. This experiment was conducted similarly to the initial two experiments with the exception that flats of soil and soil covered with fabric were placed and weighed in the control and fabric treatments.

Water holding capacity for each mulch treatment was determined by collecting the mulch materials in each flat at the conclusion of the evaporation studies, placing the samples in paper bags, and drying in a forced air oven at 45 C. for 26 days. The dry weight was subtracted from wet weight data from the field experiment and converted to inches of water.

Reference evapotranspiration (ETo) data was obtained from California Irrigation Management Information System (CIMIS) automated weather stations at representative locations. These included data from in Escondido (CIMIS station 74) and Oceanside (CIMIS station 49), representative of El Cajon and Encinitas, respectively.

Data Analysis

Actual mulch weights were calculated by subtracting the tare weight of the sampling flat from the total sample weight. The weight of water lost since the previous sample was calculated by subtraction and converted to inches of water loss. Water loss data was then analyzed using analysis of variance and range programs in the MSTATC statistical computer program to determine statistical significance, means, and mean ranking and separation (LSD).

RESULTS

The experiments undertaken in this study show that many mulch materials can absorb, hold, and release significant amounts of water after overhead irrigation. The water holding capacities of the mulch treatments ranged from 0.0 in. for the control and fabric treatments to 1.1 in. for the 5-in. depth yardwaste treatment. (Table 2). Corresponding values in inches per foot depth of material ranged from 0.0 in./ft. for the control and fabric treatments to 0.09 in./ft. for 1-in. rock to 3.64 in./ft. for the Gro-Mulch treatments.

The different materials showed significantly different rates of water loss. Water losses from mulch treatments ranged from 0.0 to 0.18 inches per day (Tables 3, 4, and 5). Mulches with the highest water holding capacity lost the most water. Ranking of water lost from the mulch treatments was similar in the experiments at both sites.

Gro-Mulch 3 in. deep and yardwaste 3 and 5 in. deep had the highest amounts of water held and the highest rates of water lost (Tables 3 and 4). All mulch treatments lost the most amount of water on the first day after irrigation. The rock mulch held the least amount of water and lost the least amount in each experiment. Xerimulch, bark, Organic Ground Cover (OGC), and fabric covered with OGC had intermediate amounts of water lost (Tables 3, 4, and 5). Differences between the Gro-Mulch treatment, the un-mulched control and fabric covered soil were not significant in the second experiment at Quail Botanical Gardens (Table 5).

Table 2. Mean water holding capacity of mulch treatments in inches for treatment depth (with standard deviation) and in inches per foot depth of material.

TRT #	Treatment and Depth	Inches water	Std Dev	Inches/Foot
7	Gro-Mulch - 3"	0.91	0.11	3.64
3	Yardwaste - 5"	1.13	0.17	2.72
2	Yardwaste - 3"	0.63	0.11	2.51
1	Yardwaste - 1"	0.20	0.04	2.34
4	Composted Yardwaste - 3"	0.40	0.15	1.59
10	Fabric + OGC - 3"	0.35	0.04	1.42
6	OGC - 3"	0.31	0.01	1.25
8	Bark - 3"	0.28	0.03	1.11
5	Xerimulch - 3"	0.20	0.01	0.81
11	1” Rock - 3"	0.02	0.01	0.09
9	Fabric	-	-	-
12	Control	-	-	-

Table 3. Mean water lost between measurement days for each mulch treatment in inches, LSD @ 0.05 level of confidence, interval of days for the loss, and ETo in inches for the measurement period at the experiment performed at Cuyamaca College, El Cajon, CA.

TRT #	Treatment	10/4	10/5	10/6	10/7	10/8	10/9	10/17	Total
7	Gro-Mulch – 3"	0.177	0.080	0.042	0.045	0.030	0.030	0.156	0.560
3	Yardwaste – 5"	0.101	0.063	0.039	0.046	0.032	0.033	0.153	0.467
2	Yardwaste – 3"	0.094	0.054	0.032	0.038	0.023	0.027	0.110	0.378
4	Comp Ydwste - 3"	0.113	0.051	0.028	0.048	0.005	0.022	0.076	0.343
10	Fabric + OGC - 3"	0.086	0.044	0.025	0.028	0.024	0.023	0.100	0.330
6	Org Gr Cover - 3"	0.085	0.043	0.025	0.033	0.022	0.026	0.101	0.335
8	Bark - 3"	0.080	0.034	0.021	0.026	0.017	0.018	0.052	0.248
1	Yardwaste – 1"	0.074	0.040	0.015	0.019	0.004	0.004	-0.002	0.154
5	Xerimulch – 3"	0.061	0.027	0.013	0.018	0.015	0.011	0.029	0.174
11	Rock - 3"	0.043	0.011	0.004	0.011	0.004	0.008	-0.006	0.075
9	Fabric	-	-	-	-	-	-	-	-
12	Control	-	-	-	-	-	-	-	
	LSD @ 0.05	0.0128	0.009	0.004	0.013	0.014	0.003	0.023	-
	Interval (Days)	1	1	1	1	1	1	8	14
	ETo for Period	0.19	0.17	0.17	0.16	0.16	0.15	1.15	2.15

Table 4. Mean water lost between measurement days for each mulch treatment in inches, LSD @ 0.05 level of confidence, interval of days for the loss, and ETo in inches for the measurement period at the first experiment conducted at Quail Botanical Gardens, Encinitas, CA.

TRT #	Treatment & Depth	10/5	10/6	10/7	10/8	10/9	10/10	Total
7	Gro-Mulch - 3"	0.140	0.055	0.063	0.019	0.034	0.023	0.334
3	Yardwaste - 5"	0.075	0.045	0.067	0.017	0.035	0.025	0.264
2	Yardwaste - 3"	0.064	0.037	0.050	0.016	0.027	0.018	0.212
4	Comp Ydwste - 3"	0.059	0.026	0.043	0.001	0.017	0.010	0.156
10	Fabric + OGC - 3"	0.047	0.026	0.042	0.008	0.021	0.013	0.157
6	Org Gr Cover - 3"	0.049	0.027	0.033	0.019	0.020	0.012	0.160
8	Bark – 3"	0.042	0.021	0.033	0.012	0.017	0.008	0.133
1	Yardwaste - 1"	0.051	0.026	0.040	-0.001	0.011	0.005	0.132
5	Xerimulch - 3"	0.036	0.018	0.021	0.012	0.013	0.006	0.106
11	1" Rock - 3"	0.013	-0.003	0.020	-0.014	-0.002	0.001	0.015
9	Fabric	-	-	-	-	-	-	
12	Control	-	-	-	-	-	-	
	LSD @ 0.05	0.016	0.009	0.019	0.013	0.006	0.004	
	Interval (Days)	1	1	1	1	1	1	
	ETo for Period	0.13	0.14	0.13	0.13	0.13	0.12	0.78

Table 5. Mean water lost between measurement days for each mulch treatment in inches, LSD @ 0.05 level of confidence, interval of days for the loss, and ETo in inches for the measurement period at the second experiment conducted at Quail Botanical Gardens, Encinitas, CA.

TRT #	TREATMENT & DEPTH	10/12	10/16	10/18	TOTAL
12	Control	0.207	0.290	0.029	0.526
9	Fabric	0.173	0.302	0.045	0.520
7	Gro-Mulch - 3"	0.170	0.265	0.041	0.476
3	Yardwaste - 5"	0.108	0.181	0.048	0.337
2	Yardwaste - 3"	0.099	0.148	0.037	0.284
4	Comp Ydwste - 3"	0.103	0.097	0.022	0.222
1	Yardwaste - 1"	0.085	0.094	0.007	0.186
10	Fabric + OGC - 3"	0.072	0.093	0.018	0.183
6	Org Gr Cover - 3"	0.115	0.054	0.013	0.182
8	1" Bark - 3"	0.069	0.080	0.011	0.160
5	Xerimulch - 3"	0.058	0.054	0.005	0.125
11	1" Rock - 3"	0.023	0.004	-0.003	0.024
	LSD @ 0.05	0.044	0.051	0.008	
	Interval (Days)	1	4	2	7
	ETo for Period	0.07	0.46	0.22	0.75

DISCUSSION

These results are relevant to water conservation goals of landscape irrigation managers and water agency personnel. Many landscape plant materials can survive on water levels at or below 50 percent of ETo. Irrigation scheduling research suggests levels of 30 percent of ETo or less for drought tolerant plant materials used in the landscape (Shaw and Pittenger). Mulches are recommended to reduce evaporation losses from soil surfaces and thus further reduce irrigation needs of landscapes. However, until now there was no information on the water retention and evaporation rates of mulches used in the landscape.

In this study, the water lost from mulch treatments was as much as 100 percent of ETo on the first day following irrigation (Table 4). In the second experiment at Quail Gardens, water loss was not significantly different between soil, soil covered with fabric, and soil covered with Gro-Mulch for five days following irrigation (Table 5). This indicates that although the Gro-Mulch may be insulating soil from moisture loss, the water lost to the atmosphere is not different from bare soil or fabric covered soil. For these three treatments, the average evaporative loss exceeded 100 percent of ETo for the five days immediately following overhead irrigation. Hence, if irrigation managers are irrigating drought tolerant plant materials with overhead irrigation systems more frequently than every five days, the evaporation component exceeds the estimated plant water needs by 300 percent.

The water holding capacity and evaporation data from the bark, OGC, Xerimulch, and rock show that these materials had minimal water loss after two days. Rock and Xerimulch had the least evaporative loss of all treatments. However, the evaporation loss from bark, OGC, and yardwaste (1-inch deep) during the first two days after irrigation exceeded 40 percent of ETo (Table 3). In the first experiment at Quail Botanical Gardens, water loss from the mulch materials averaged less than 30 percent of ETo after six days. This information indicates that overhead irrigation should not be applied more frequently than every six or seven days in similar environmental conditions. Under this regime, the irrigation manager is taking advantage of the insulative properties of mulches while minimizing the evaporative loss from the mulch itself.

This study provides information on the water retention and evaporative loss rates for mulches commonly used in the landscape. Irrigation managers can utilize this information in deciding the mulch material to use, the type irrigation system, and frequency of irrigation. Under drip irrigation, evaporative loss would be minimized and any mulch material could be selected. With overhead irrigation, coarser mulches with lower water holding capacity or a thinner layer of mulch could be utilized. The irrigation manager should know the amount of water held by the mulch and apply additional water to compensate for this amount. Water savings can then be achieved by extending the interval between irrigations. Additional landscape variables affecting irrigation amounts include the type of plant material and its water needs, the uniformity of the irrigation system, and the percent of the irrigated landscape covered by mulch.

This study shows that mulch selection and irrigation frequency decisions can significantly impact the water needs of the landscape. Gross water and energy savings associated with informed selection of mulch materials and sound irrigation scheduling can be estimated using ETo estimates and a range of irrigation management situations. For example, ETo for San Diego is approximately 44.0 inches per year. If a drought tolerant landscape is irrigated with overhead sprinklers, the choice of mulch and irrigation frequency significantly affect water use. Table 6 provides a range of water and energy savings for several landscape scenarios using drought tolerant plant material and overhead irrigation in San Diego together with data from this study (Table 5). This example could be further refined by incorporating rainfall data, seasonal variation in ETo, percent cover of plant material, and estimates of irrigation uniformity and efficiency. However, the information provided gives an indication of the impact that mulch selection and irrigation frequency have on water use.

Table 6. Water use estimates per acre per year for drought tolerant landscape in San Diego utilizing overhead irrigation with different mulches and variable irrigation frequency.

ETo (Inches)	Mulch Treatment and Thickness	Irrigation Frequency (Days)	Estimated Percent of ETo	Water Use (Ac Ft/Ac/Yr)
44.0	None	7	70	2.6
44.0	None	<5	100	3.7
44.0	Yardwaste 3"	7	38	1.4
44.0	Yardwaste 3"	5	54	2.0
44.0	Bark 3"	5	32	1.2
44.0	Bark 3"	7	30	1.1

CONCLUSION

This study described the water holding capacities and evaporative losses occurring in 12 mulch treatments common to landscapes in California. Presentation of these data is not intended to discourage overall use of mulches, but to aid in providing best management practices for the wise use of mulch materials. Landscape management personnel can use this information in selecting mulch materials and determining irrigation schedules to maximize the performance of plant materials while conserving water and energy.

Further studies are necessary to determine the effects of mulch treatments in planted conditions under sprinkler and drip irrigation. This would provide information on overall effects of mulches in water conservation and growth of plant materials.

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REFERENCES

Bennett, J. 1982. Mulches to retain moisture and cool the soil. Horticulture. 60(7):55–56.

Borland, J. 1990. Mulch; examining the facts and fallacies behind the uses and benefits of mulch. Am. Nurseryman.172(4):132–143.

California Integrated Waste Management Board (CIWMB). 2002. A landscaper's guide to mulch. CIWMB Publication # 443-02-010.

Groenevelt, P.H., P. van Straaten, V. Rasiah, and J. Simpson. 1989. Modifications in evaporation parameters by rock mulches: Soil Tech. 2:279–285.

Lanini, W.T., J.M. Shribbs and C.E. Elmore. 1988. Orchard floor mulching trials in the USA. Le Fruit Belg. 56(3): 228-249.

Litzow, M and H. Pellett. 1983.Influence of mulch materials on growth of green ash. Journal of Arboriculture. 9(1):7-11.

Montague, T. and R. Kjeldren. 2004. Energy balance of six common landscape surfaces and the influence of surface properties on gas exchange of four containerized tree species. Scientia Horticulturae. 100(1):229-249.

Shaw, D.A., and D.R. Pittenger. 2004. Performance of landscape ornamentals given irrigation treatments based on reference evapotranspiration. International Irrigation Association 25th Annual Show Proceedings.

Smith, A.M., and D.A. Rakow. 1992. Strategies for reducing water input in woody landscape plantings: J. Arboric. 18:165–170.

Teasdale, J.R. and C.L. Mohler. 2000. The qualtitative relationship between weed emergence and the physical properties of mulches. Weed Sci. 48(3):385-392.