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Water-holding Capacity and Evaporation Control Characteristics of Five Cellulose-fiber Mulches

Paul J. Birzins[1]

Kalamalka Research Station & Seed Orchard, B.C. Ministry of Forests, 3401 Reservoir Road, Vernon, B.C., Canada V1B 2C7

John J. Balatinecz[2]

Faculty of Forestry, University of Toronto, Toronto, Ont. Canada M5S 1A1

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Abstract. **Water-holding capacity, evaporation rate from mulch slurries, and the effect of mulches on soil water loss was determined for peat, coarse paper-fiber, fine paper-fiber, and 2 commercial mulches. Evaporation rate decreased when a mulch exhibited a low water-holding capacity, long fibers, and was applied dry rather than in a slurry. A commercial mulch consisting of straw and hay fibers, cotton, and wastepaper had the lowest water-holding capacity, longest fibers, and the greatest evaporation control.**

Reduction of soil-water evaporation is the primary function of a mulch in areas where soil moisture is limiting (4). Efficiency of the water transport mechanism affects soil water evaporation (3). A mulch cover will inhibit the transport mechanism by lengthening the water diffusion pathway between the soil capillaries and the air interface. Depending upon the chemical and physical nature of the mulch and the environmental conditions, the prolonged retention of soil water created by a mulch-induced lengthened diffusion pathway can increase plant survival (1). The economical and biological impact of increasing soil water retention can be related to the physical nature of the mulch. The identification of desirable mulch properties and methods of application can aid in water conservation.

The purpose of this study was to compare the evaporation control ability of 5 cellulose fiber mulches by examining 3 mulch properties: water-holding capacity, evaporation rate from mulch slurries, and the effect of mulches on soil-water loss when mulches are applied wet or dry. The 5 mulches tested were: 1) peat; 2) coarse paper-fiber (hammermilled wastepaper passed through a 0.95 cm screen); 3) fine paper-fiber (hammermilled wastepaper passed through both a 0.95 and 0.45 cm screen); 4) commercial mulch #1 (hardwood fibers dyed green); and 5) commercial mulch #2 (sun-dried straw and hay fibers, cotton, and wastepaper).

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[1]Former Graduate Student.

[2]Professor.

Water-holding capacity was determined by a modification of an established procedure (2). A mixture of 20 g of air-dried mulch fiber in one liter of water was poured onto a #35 endecotts screen with an aperture of 500 microns (similar to a soil sieve). Dry weights and wet weights of the mulches were measured and the water-holding capacity was determined by the formula: water-holding capacity = (wet weight − air dry weight of mulch)/oven dry weight of mulch. The mulch was oven dried at 110°C to a constant weight. This test was replicated with 3 samples per mulch.

There is no established procedure for determining the evaporation rate from mulch slurries, so 1.24 g of mulch and 18 ml of water in a petri dish comprised the basic experimental unit. This proportion of mulch: water is used in operational hydromulching by the Ontario Ministry of Transportation and Communications. The slurries were agitated for 40 min in a sieve shaker, placed in a growth chamber which had a temperature of 29.4°C and 30% relative humidity, typical for a hot, dry summer day in Toronto, and allowed to evaporate until all the water had evaporated in one of the treatments (9 hr). Weights were determined every hour. Treatments were replicated 3 times in a randomized complete block design.

To test the effect of mulches on soil-water loss, a factorial combination consisting of 6 treatments (5 mulches and a bare soil control), 2 application methods (wet and dry), and 3 watering time phases was replicated 3 times with a randomized block design. Each of the 30 mulch experimental units consisted of a 52 g plastic container without holes (with a surface area of 154 cm^2, and a depth of 13 cm), containing 1387 g of sandy loam soil, and 2.4 g of mulch. This quantity of mulch is equivalent to 1,560 kg/ha. The bare soil control lacked the mulch surface cover.

The sandy loam soil (consisting of 75%, 9% and 16% sand, silt, and clay, respectively) contained 2.45% water by wt. originally. To decrease soil variability, the soil was passed through a sieve with a 0.64 cm^2 mesh and shaken down to a 12 cm depth in each pot.

The wet application method involved shaking a beaker containing 2.4 g of mulch and 35 ml of water for 40 min in an automatic shaker. The wet and dry mulches were applied manually to the soil surface to ensure uniform and comparable covering of the surface to a depth of about 1 cm.

A total of 368 ml of water was added to the soil in each container to bring the soil to its water holding capacity. This value was determined before the experiment commenced by saturating soil in plastic containers which had holes in the bottom, and waiting until drainage ceased and then determining the amount of water remaining in the soil at the high moisture level. The pots were placed in a growth chamber with temperature settings of 29.5°C during the day, 16.5° at night, and 30% relative humidity. The 13-hr lighting schedule consisted of 3085 W from 19 gro-lux fluorescent lamps. Air movement in the chamber was nominal. The pots were weighed daily. A low soil moisture level of about 8% by weight was reached in 72 hr. Based on weight loss per pot, rewatering occurred every 70 ± 2 hr to bring the soil to its water holding capacity. Each pot of each treatment was re-watered at about the same time. The pots were watered through the surface layer (mulch or bare soil depending upon the treatment) 3 times during a 12-day period. Total evaporative losses were calculated for the three 24-hr time phases within each of the 3 watering periods.

Commercial mulch #2 had the lowest water-holding capacity and peat and commercial mulch #2 the highest rates of evaporation from mulch slurries (Table 1, Fig. 1). When applied dry to soil-filled pots, commercial mulch #2 exhibited the lowest rate of soil water evaporation. The wet application method resulted in higher evaporation rates than the dry application method, particularly during the 1st time phase (Tables 1, 2).

A mulch that has a low water-holding capacity is desirable since it allows water to percolate into the soil, and the mulch then

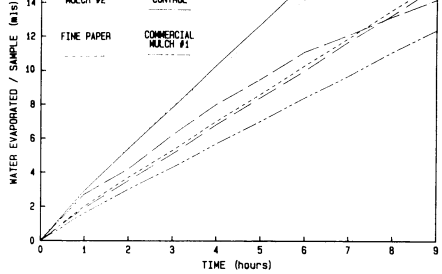

Fig. 1. Cumulative water evaporation for various mulch slurries.

Table 1. Mulch water-holding capacity and water loss from mulch slurries and mulched soil plots.

Mulch	Mean water-holding capacity[z] (retained water/dry mulch wt)	Moisture evaporation from mulch slurries[y] (Y − mls, X − hr)	R^2	Mean water loss from mulched soil plots (g/24 hr)[x]		
				Wet application		Dry application
Fine paper-fiber	17.0 a	Y = 1.65X + 0.381 b	0.98	57.6 a		43.0 c
Commercial mulch #1	16.9 a	Y = 1.35X + 0.255 d	0.99	56.6 a		48.7 b
Coarse paper-fiber	15.7 b	Y = 1.64X + 0.210 b	0.99	59.3 a		41.5 c
Peat	12.6 c	Y = 2.46X + 0.439 a	0.99	60.5 a		41.8 c
Commercial mulch #2	9.6 d	Y = 1.91X + 1.53 a	0.96	49.0 b		35.3 d
Water control	---	Y = 1.54X + 1.15 c	0.95	---		---
Bare soil control	---	---	---	---	55.4	---

[z]Mean separation in column by Duncan's multiple range test, 5% level.
[y]Mean separation in column by slope homogeneity test, 5% level (5). Range of X represents the linear portion of the data.
[x]Mean separation in rows and columns by Duncan's multiple range test, 5% level.

Table 2. Total evaporative water loss (g/24 hr) from mulched soil plots (5 mulch types combined) for the time phase × application method interaction.

Time phase (24 hr)	Application method[z]	
	Wet	Dry
1	65.0 a	48.2 b
2	52.6 b	39.6 c
3	52.3 b	38.4 c

[z]Mean separation in rows and columns by Duncan's multiple range test, 5% level.

might provide an effective evaporation barrier. This property was exhibited by commercial mulch #2. Since water has a high volumetric heat capacity (1 cal/cm^{3}C), mulches with high water-holding capacities would have relatively low temperature changes with unit changes in the heat budget. A large portion of the heat energy would be used to evaporate the water.

The evaporation rate from commercial mulch #2 slurry was relatively high, since the mulch-water interaction was minimal, no solid impervious mulch layer was created and drainage was prevented. The other mulches, with the exception of peat, exhibited reduced rates of water evaporation. Increased absorption of water into the fibers could have decreased the immediate availability of water for evaporation. Capillarity and absorption forces associated with the mulch matrix of these high water-holding capacity mulches would help increase the energy required for evaporation. Since water held by the mulch is at a lower energy level than that of a free water surface at the same position, and water flows from a position of higher to one of lower energy, the reduced evaporation rate also might be attributed to an indirect water transport/evaporation mechanism. Some water might move into the mulch as water is being evaporated from the mulch surface.

The majority of the mulch slurries evaporated water faster than the water control. The dark color of peat would help create a low albedo level and hence an increased amount of energy would be absorbed, elevating the evaporation rate. In addition, the surface area created by the mulches could have increased heat absorption, or simply a pathway for increased water evaporation. Based on a visual assessment, it is hypothesized that commercial mulch #1 evaporated water more slowly than the water control because an immediate drying of the surface layer decreased the thermal conductivity and trapped water in the lower portion of the mulch, reducing efficiency of the transport mechanism.

In comparing mulches by examining their effect on soil moisture loss, all 3 main effects (mulch, time phases, and application method) and the mulch × application interaction were significant (Tables 1, 2). Table 1 includes the bare soil control, which had a mean evaporation rate of 55.4 g/24 hr; however, the data were not used in the statistical analysis. The water loss from the bare soil treatment was lower than that from the majority of mulches when applied wet. Since the soil initially was at its water holding capacity, the increased evaporation rate in time-phase one can be explained by the greater proportion of water near the surface, available for evaporation.

Commercial mulch #1 had the lowest evaporation rate, and commercial mulch #2 and peat the highest (Table 1). Visually, it was apparent that commercial mulch #2 also had the longest fiber lengths. The fine particle size distribution of commercial mulch #1 and peat may have resulted in capillary flow to the mulch surface. In addition, as stated earlier, the dark color of peat might have resulted in greater heat absorption and hence, an increased rate of evaporation.

If mulches are applied wet, and capillary flow through the mulch is possible, resistance to water movement to the surface is reduced, and little resistance to mulch-water evaporation exists since matric forces are decreased by the increased supply of water. The application of a dry mulch to a moist soil is a better means of water conservation than hydromulching the soil.

Literature Cited

1. Ayling, R.D. and P.J. Birzins. 1981. Comparison of some mulches for used in Brazilian eucalypt nurseries. Turrialba. 31:209–215.
2. Hoover, T.P. 1976. Water-holding capacity for hydromulch. California Dept. Transp. Final Rpt. CA-DOT-TL-2167-1-76-36.
3. Lee, R. 1978. Forest microclimatology. Columbia Univ., New York.
4. Oke, T.R. 1978. Boundary layer climates. Methuen and Co., London.
5. Steel, R.G.D. and J.H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, New York.