Evapotranspiration of Cool-season Grasses Grown with Minimal Maintenance

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Abstract. Evapotranspiration (ET) of three perennial ryegrass (*Lolium perenne* L.) cultivars and one cultivar each of colonial bentgrass (*Agrostis tenuis* L.) and tall fescue (*Festuca arundinacea* L.) was measured in the field. Soil water depletion was measured with a neutron probe. Under minimal maintenance (i.e., no irrigation and infrequent mowing), ET was not significantly different for five perennial grasses. All grasses used more water than the bare-ground treatment. Soil water uptake was greatest in the upper soil layer (0 to 25 cm) and decreased with depth. Few differences in water uptake were noted among grasses within each soil layer.

In western Oregon, some fruit and vines are not irrigated. Crops rely on stored soil moisture during the hot, dry periods. The Willamette Valley receives an average of 760 to 1020 mm of precipitation per year, most occurring in the fall through early summer. Orchard or vineyard alleys are typically maintained with sod cover or as bare ground using herbicides or a flail. Grass strips are recommended to reduce soil erosion, improve traffic conditions, and reduce soil compaction. In addition, sod extracts soil moisture and can reduce late-season vegetative growth on certain grape production sites (Vomocil, 1986). Disadvantages of using grass-cover crops include possible increased frost hazard and competition for soil nutrients and water (Vomocil, 1986). Perennial grass-cover crops might increase water stress during dry summer months by competing for stored soil moisture. Yield, vegetative growth, and fruit quality are correlated with soil moisture (Hardie and Considine, 1976; Van Reuyen et al., 1980).

Estimates of potential water use by cool-season grasses maintained as turf range between 2.4 to 7.5 mm·day⁻¹ (Beard, 1973; Shearman, 1986). Vomocil (1986) noted that few studies determined water use by cool-season grasses under minimal maintenance, i.e., nonirrigated with three to four mowings per season. This information would be useful in selecting grasses for interplanting in vineyards or orchards. This study measured evapotranspiration (ET) of nonirrigated grasses,

evaporation from a bare soil, and computed reference ET of a well-watered grass sod.

Five perennial grasses, including 'Elks', 'Manhattan II', and 'Derby' perennial ryegrass (*Lolium perenne*), 'Olympic' tall fescue (*Festuca arundinacea*), and 'Highland' colonial bentgrass (*Agrostis tenuis*), were randomized with a bare-ground treatment in a complete-block design, replicated four times. Plots were prepared 6 July 1985 on a mixed, mesic Cumulic Ultic Haploxeroll soil (Chehalis silty clay loam) at the Lewis Brown Horticulture Farm located 5 km east of Corvallis. The facility is at 44.6° N latitude, 123.2° W longitude, and 69 m elevation.

Seed of each species was sown 16 July 1985 at 22.4 kg·ha⁻¹ in 4.6 × 4.6-m plots. Bare-ground plots were established using napropamide plus simazine followed with bromoxynil and glyphosate. Plots were irrigated four times daily for 2 weeks after planting to encourage uniform germination and they were fertilized with urea and 15N-15P-15K at 20 kg N/ha. Selective broadleaf herbicides (2,4-D, mecoprop, and dicamba) were applied to grass plots to develop a pure stand of the desired species. During the 3-year monitoring period, turf was mowed every 4 weeks at 3-cm height April through June. Additional irrigation or fertilization was omitted following establishment in 1986.

Access tubes made of 5-cm diameter aluminum pipe were installed to a depth of 137 cm to measure soil water content with a neutron meter hydroprobe moisture depth gauge (model 503DR, Campbell Pacific Nuclear, Pacheco, Calif.). Moisture readings at five depths (0 to 15, 15 to 25, 25 to 35, 35 to 75, and 75 to 105 cm) were recorded every 7 to 14 days from 14 Apr. to 28 July in 1986, 15 Apr. to 27 Aug. in 1987, and from 10 May to 23 Aug. in 1988. Grass ET and evaporation were determined by three computer programs written in Fortran to analyze neutron probe data (Cuenca, 1988). One program establishes the data files, the second

relates soil moisture content with depth and time, and the third produces a hydrologic balance and estimated ET. Two calibration constants of soil moisture content with probe readings were developed at 0 to 15 cm and 15 to 105 cm soil horizons (Braunworth and Mack, 1987).

Seasonal ET was partitioned into water uptake from four soil layers (0 to 25, 25 to 35, 35 to 75, 75 to 105 cm). Soil water uptake was calculated for standard 10-cm layers, since field data represented a range of layers from 10 to 40 cm.

Weather data for 12-hr periods were obtained about 1 km north of the experimental site. Cuenca and Martinez (unpublished data) selected data and computed reference crop ET for a well-watered grass according to the Food and Agriculture Organization Modified Penman equation (Doorenbos and Pruitt, 1977).

Seasonal ET averaged 2.5, 1.5, and 1.8 mm·day⁻¹ in 1986, 1987, and 1988, respectively, with no significant differences in the seasonal ET rates among the five grass species (Table 1). In all years, seasonal water use by bare ground was less than that by the grass areas.

Our seasonal computed ET (Table 1) was lower than those reported by Beard (1973) or Shearman (1986). In those studies, ET was monitored under well-watered conditions, whereas our lower ET rates were likely due to drier soil condition and minimum fertilizer. Although Feldhake et al. (1984) evaluated grass quality with deficit irrigation, they failed to mention the effect on ET.

The similarity in grass soil water uptake is in contrast to the different growth characteristics among the species that were expected to affect ET (Troughton, 1957; Beard, 1973). Deep-rooted grass species, such as *F. arundinacea*, were expected to use more water than shallow-rooted grasses, such as *A. tenuis*, because deep roots could allow plants to transpire by extracting soil water stored deeper in the profile (Sheffer et al., 1987). In 1987, *L. perenne* and *A. tenuis* were brown and dry by 17 June, while *F. arundinacea* remained green until mid-August. The apparent variation in growth habits, however, did not result in significant differences in seasonal ET rates.

Monthly ET values for the five grass covers were similar but greater than the evaporation values for bare ground in most months. In June 1987 and July 1988, monthly ET rates were similar among all six treatments, likely due to low rainfall and low soil water content in all treatments, which would tend to restrict ET (Tables 1 and 2). However, in August 1987 and 1988, bare-ground plots exhibited significantly greater evaporation than the grasses. Periodic rainfall, coupled with warm temperatures, increased evaporation on bare ground, whereas grasses appeared to hold the moisture.

In general, grass ET values as a percentage of a reference crop ET were higher in May than later, due to greater precipitation and greater soil moisture levels. ET rates of grasses during July 1987 increased over those

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Table 1. Mean monthly and seasonal evapotranspiration (ET) of bare ground and five grass covers, Corvallis, Ore.

Ground cover	April	May		June		July		August		Seasonal	
	ET (mm·day ⁻¹)	ET (mm·day ⁻¹)	Ref. ET (%)	ET (mm·day ⁻¹)	Ref. ET (%)	ET (mm·day ⁻¹)	Ref. ET (%)	ET (mm·day ⁻¹)	Ref. ET (%)	ET (mm·day ⁻¹)	Ref. ET (%)
1986^z											
Bare ground	2.0	2.7	59	1.0	19	1.1	21	---	---	1.7	34
Five grasses ^y	2.9	3.7	80	2.4	44	1.0	20	---	---	2.5	50
Reference ET ^x	---	4.6	100	5.4	100	5.1	100	---	---	5.0	100
Significance											
Bare vs. grass	**	**		**		NS				**	
Among grasses	NS	*		NS		NS				NS	
1987^z											
Bare ground	0.8	1.2	24	0.8	12	1.3	23	1.4	26	1.1	20
Five grasses	2.2	2.6	55	0.7	11	1.7	31	0.3	6	1.5	27
Reference ET	---	4.7	100	6.5	100	5.5	100	5.4	100	5.5	100
Significance											
Bare vs. grass	**	**		NS		**		**		**	
Among grasses	NS	NS		NS		NS		NS		NS	
1988^z											
Bare ground	---	2.6	73	1.8	33	0.8	13	0.5	9	1.3	25
Five grasses	---	3.0	83	3.3	62	1.1	18	0.2	3	1.8	35
Reference ET	---	3.6	100	5.3	100	6.0	100	5.4	100	5.1	100
Significance											
Bare vs. grass		NS		**		NS		**		**	
Among grasses		NS		*		NS		NS		NS	

^zSeason included 105 days between 14 Apr. and 28 July 1986; 133 days between 15 Apr. and 27 Aug. 1987; and 105 days between 10 May and 23 Aug. 1988.

^yGrass covers: 'Highland' *A. tenuis*, 'Olympic' *F. arundinacea*, 'Manhattan II' *L. perenne*, 'Elka' *L. perenne*, 'Derby' *L. perenne*.

^xReference ET was computed with the FAO-modified Penman equation by R. Cuenca and A. Martinez-Cobb (unpublished data).

^zData unavailable.

NS, *, **Nonsignificant or significant at $P = 0.05$ or 0.01 , respectively, by F test. Data are means of four observations for bare ground and each grass cover.

of June due to rainfall (Tables 1 and 2). Although grasses lack apparent growth due to water stress in late summer, rainfall events can increase ET rates due to increased evaporation from the soil. The reference crop ET ranged from $\approx 90\%$ in May 1988 to $\leq 5\%$ later in the season. Although the grasses used more water than the bare-ground treatment, they used less water than a well-watered grass, thereby supporting the concept of less water use when grass strips are alternated with crop rows and drip-irrigated.

Table 2. Monthly precipitation for 3 years during study periods at Corvallis, Ore.

Month	Rainfall (mm)		
	1986	1987	1988
April	34	6	86
May	67	22	49
June	7	5	1
July	19	58	1
August	0	0	0
Total	127	91	137

Soil water uptake decreased with depth (Table 3). This result was expected, since most grass roots are near the soil surface and rainfall fills the uppermost soil layers first and then may be lost by ET. The water loss rates for bare ground were equal to or lower than those for grass cover treatments. Few differences in water uptake were noted among grasses within each soil layer. Although *A. tenuis* and *F. arundinacea* had the greatest root mass below 50 cm (Doty, 1988), water uptake rates were similar for the grasses in the 35 to 75 and 75 to 105 cm soil horizons. Grass soil water uptake rates from the 35- to 75-cm soil horizon exceeded evaporation from bare ground.

Our study suggests that ET of these three cool-season grass species grown under minimal maintenance was not an important characteristic to consider when selecting a grass as a cover crop. However, management practices, such as mowing and fertilization, have been shown to influence ET. (Sullivan and Sprague, 1943; Biran et al., 1981; Feld-

hake et al., 1983).

Under minimal maintenance, including lack of irrigation, ET of these cool-season grasses was similar. Grass water use in western Oregon peaks in late spring or early summer and declines as soil water is depleted through the season. Other characteristics, such as establishment rate and wear tolerance may be more important considerations than water use when choosing a grass species as a cover crop in a low-maintenance system.

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Table 3. Contribution of five soil layers to total seasonal soil water uptake of bare ground and five grass covers from 1986-1988 at Corvallis, Ore.

Ground cover	Soil water uptake (mm·day ⁻¹) ^z											
	Soil layer (cm)											
	1986				1987				1988			
	0-25	25-35	35-75	75-105	0-25	25-35	35-75	75-105	0-25	25-35	35-75	75-105
Bare ground	0.57	0.05	0.04	0.01	0.36	0.05	0.03	0.01	0.37	0.11	0.05	0.03
Five grasses ^y	0.67	0.14	0.12	0.06	0.38	0.09	0.07	0.04	0.39	0.15	0.11	0.07
Significance												
Bare vs. grass	**	**	**	**	**	**	**	NS	NS	**	**	NS
Among grasses	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

^zSoil water uptake rates based on a 10-cm soil depth at the five layers for comparison; data are means of 4 observations of bare ground and each grass.

^yGrass covers: 'Highland' *A. tenuis*, 'Olympic' *F. arundinacea*, 'Manhattan II' *L. perenne*, 'Elks' *L. perenne*, 'Derby' *L. perenne*.

NS, *, **Nonsignificant or significant at $P = 0.05$ or 0.01 , respectively, by F test.

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Effects of Morphactin and DCPTA on Stem Growth and Bioinduction of Rubber in Guayule

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Abstract. Morphactin applied to stems of guayule (*Parthenium argentatum* Gray) at rates of 1000 and 5000 ppm caused significant increases in stem diameter over nontreated controls after 120 days. However, rubber content remained unchanged. Additional treatment with DCPTA did not stimulate rubber accumulation in the morphactin-treated plants. Morphactin treatments also caused a decrease in plant dry weight. Morphactin and DCPTA in combination appeared to have a negative, synergistic effect on plant growth. Lack of rubber accumulation in morphactin-treated plants was attributed to disorganized, convoluted, vascular cells within the cortical tissue, which is the primary site of rubber accumulation. Chemical names used: methyl-2-chloro-9-hydroxy-fluorene-9-carboxylate (morphactin); 2-(3,4-dichlorophenoxy)-triethylamine (DCPTA).

Guayule is a potential source of natural rubber in arid regions of the world. Unlike the rubber tree (*Hevea brasiliensis* Mull. Arg.), where rubber forms in laticifers, rubber formation in guayule takes place in parenchyma cells of stem cortical tissue (Artschwager, 1943). Maximum rubber yield is the result of a large bark : wood ratio (Artschwager, 1945; Estilai, 1985; Healey et al., 1986). Thus, if the bark, or potential rubber-bearing cells, could be increased in proportion to the wood, or nonrubber-bearing cells, rubber accumulation could possibly be increased.

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Morphactin has been shown to cause localized swelling of cortex tissue in Monterey pine (*Pinus radiata* D. Don) when applied topically to the bark (Doss et al., 1977). This bark-banding treatment was originally used as a systemic means of introducing morphactin for growth inhibition in pine and other species (Backhaus et al., 1976). However, the compound caused undesirable swelling due to increased cambial and peridermal activity (Doss et al., 1977).

Rubber synthesis in guayule was reported to be enhanced by treating plants with DCPTA (Yokoyama, 1977; Hayman et al., 1987). Therefore, the purpose of our study was to use morphactin to induce swelling in stems of guayule to increase the bark : wood ratio in an attempt to increase the rubber-forming capacity of the stems. The effect of DCPTA was then tested, alone or following various morphactin treatments, to measure the effectiveness of increasing rubber accumulation in guayule.

The study was conducted in 1982 at the Arizona State Univ. Farm Laboratory, Tempe. Plants were propagated from a bulk seed collection from the guayule breeding program

of G. Hansen at the Los Angeles State and county Arboretum, Los Angeles. Plants were transplanted into the field at 1 × 0.36-m spacing and flood irrigated about six times per year. After 2 years of growth, height and stem diameter measurements were taken at 20-day intervals, beginning 1 July, and continued for 120 days. Morphactin was applied 9 July and DCPTA on 30 Sept. Increases in growth over this interval were calculated as a percentage of the initial measurement. Stem diameters were obtained with a micrometer by averaging the widest and narrowest values of the stem at ground level. Plants were harvested after 14 weeks to determine dry weight and rubber content.

To test for enhancement of rubber-bearing cells, six treatments (all per plant) were used: a) nontreated control, b) 1000 ppm morphactin, c) 5000 ppm morphactin, d) 400 ppm DCPTA, e) 1000 ppm morphactin followed by 400 ppm DCPTA, and f) 5000 ppm morphactin followed by 400 ppm DCPTA. Morphactin treatments preceded the DCPTA treatments by 83 days to allow sufficient time for increasing stem diameters. Morphactin solutions were applied according to the procedures of Backhaus et al. (1976). The compound was supplied from a commercial formulation (Maintain CF 125-U.S. Borax) containing 12.5% morphactin that was then formulated in a phytobland oil and applied to the bark. Dosage was varied by adjusting the concentration of Maintain CF-125 in culinary Wesson corn oil to make either a 1000- or 5000-ppm solution. The morphactin bark-banding solution was prepared by mixing 4 ml (5000 ppm) or 0.8 ml (1000 ppm) of CF-125 with 4 ml of SPAN 80, an emulsifier, and adjusting each to 100 ml with Wesson oil. A plant received 10 ml of this solution applied with a paint brush along the length of the main stem. Shallow cuts through the suberin layer were made before the morphactin application to ensure solution penetration.

DCPTA was obtained from H. Yokoyama, USDA/ARS, Pasadena, Calif., and was applied as a foliar spray. Each plant received 25 ml of a 400-ppm solution (Hayman et al., 1987) on 30 Sept., 83 days after morphactin application. Plants were harvested 36 days after DCPTA applications, dried at 50°C in a forced-air oven for 48 hr, and weighed. Leaves and peduncles were removed before