COPPICE THINNING EFFECTS ON TRANSPIRATION IN EMORY OAK WOODLANDS

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Management-related research of the Emory oak (*Quercus emoryi*) woodlands in southeastern Arizona has focused primarily on the growth and yield of coppice to shorten rotation periods for fuelwood harvesting (Bennett 1990; Farah et al. forthcoming; Touchan 1986; Touchan and Ffolliott 1999). Nyland (2002) has defined coppice as the natural regeneration of stump sprouts or root suckers. To obtain a better understanding of the hydrological functioning of the Emory oak woodlands for management purposes, Folkerts (1999) and Ffolliott and Gottfried (2000) have reported differences in water use between mature and coppice tree forms. The change in transpiration (estimated by water use) due to tree harvesting can change the water budget, thereby affecting understory plant growth, wildlife habitats, or groundwater aquifer recharge in these woodlands (Ffolliott and Gottfried 2000). The objective of the current study was to improve our knowledge about the hydrologic functioning of the dryland oak woodlands by analyzing the response of transpiration rates to coppice thinning treatments.

Reducing transpiration losses by coppice thinning may be one way to increase the water for other uses (e.g., forage production). Folkerts (1999) and Ffolliott and Gottfried (2000) reported an average transpiration rate of 17.5 liters per day for mature trees compared to only 4 liters per day for coppice sprouts. Extrapolating these data to an annual basis on a per-hectare unit area, the mature trees in the uncut stand transpired approximately 1900 liters of water annually compared to the harvested stand which transpired 3168 liters annually (Ffolliott and Gottfried 2000; Folkerts 1999). The greater rate of transpiration in the harvested stand was attributed to its larger number of vigorous post-harvest stump sprouts. It was estimated that the unharvested Emory oak stand would transpire 47.5 percent of the annual precipitation compared to the harvested site which would transpire up to 79.2 percent.

STUDY AREA

The study area is in the San Rafael Valley at the base of the Huachuca Mountains. The site is situated on a south-facing slope approximately 1750 m in elevation. The distribution of precipitation is bi-modal, averaging 552 mm annually, with short-duration, intensive summer monsoons and moderate winter (mostly) rainfall. The dominant soil group on the site is the Casto-Martinez-Canelo type formed from old alluvium, made up of sedimentary and igneous rock (Hendricks 1985). Hendricks (1985) described the soil association as having a clayey texture with slow permeability and containing excessive amounts of rock fragments.

The oak woodlands in southeastern Arizona are composed mainly of Emory oak, Arizona white oak (*Quercus arizonica*), and Mexican blue oak (*Q. oblongofolia*). Emory oak is characterized as a broadleaf, evergreen, medium-sized tree (9–12 m in height). Most Emory oak regeneration results from stump or root sprouts (coppice) rather than seedling establishment (Bennett 1990).

METHODS

The sampling site was last harvested for fuelwood in 1981. Four types of thinning treatments were initiated in 1984: thinned to one sprout, thinned to two sprouts, thinned to three sprouts, and an unthinned control. Representative sets of four rootstocks for each treatment (total of 16 rootstocks) were selected for the study. The dominant sprout of each rootstock, determined by size and appearance, was selected for measurement.

Heat-pulse velocity was measured on the dominant sprout every 2 weeks using the sap-flow instrument developed by Swanson (1962). The sap-flow method allows for nondestructive and time-

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efficient sampling of the measured stems. First, a drill jig was strapped to the selected stem for the purpose of precisely drilling the holes to a depth just inside of the bark and within the outlying sapwood layers. Two thermistor probes attached to a meter were inserted into the drilled holes and allowed to reach a balance. When a balance was obtained, a heat pulse was applied for one second through the heat probe located between the two thermistors. The heat pulse acted as a tracer within the column of flowing sap. A stopwatch was started when movement away from the balance point was visually detected, and the elapsed time or the time required for the meter to return to a balance was determined. The placement of the thermistor probes at 0.5 cm below and 1.0 cm above the heat probe allowed the heat-pulse velocity to be calculated according to the following equation:

$$\text{HPV (cm/hr)} = 900/t_0.$$

HPV represents the heat-pulse velocity in centimeters per hour and t_0 is the elapsed time in seconds from the initial heat-pulse application until the two thermistors regained equilibrium (Swanson 1962).

The water use of an individual sprout was determined from the cross-sectional area of sapwood and the heat-pulse velocity measurements. The resulting sap-flow (in cubic centimeters per hour) was then transformed to liters per day for analyses of treatment differences. The cross-sectional area of sapwood was measured on representative oak sprouts; diameter at breast height (dbh), average bark thickness, and diameter of heartwood were used to develop a linear regression of sapwood area to dbh. This regression was then used to estimate the cross-sectional sapwood area of the sprouts being measured for transpiration.

Transpiration data on each sample date were averaged for each of the three coppice treatments and the control. An analysis of variance test at the 0.1 alpha level was used to evaluate significant differences in the average daily water use among the treatments for the sampling period between May 2000 and January 2002, excluding a gap in measurements from the middle of May 2001 to the middle of July 2001. T-tests were performed at the 0.1 alpha level to evaluate differences between treatments. The estimated transpiration rate per rootstock was calculated by multiplying the daily water use of the measured stem by the number of dominant stems per rootstock for that treatment.

The effect of precipitation on estimated daily transpiration rates was interpreted from precipitation-transpiration graphs. Precipitation measurements were obtained from the Coronado National Memorial weather station located approximately 8 km from the study site.

RESULTS

The linear regression model relating sapwood area to dbh was

$$\text{sapwood area } (m^2) = \left[(0.0251 \text{ x } (\text{dbh}) - 0.0355) \text{ x } 0.0929\right]$$

with an $r^2 = 0.85$ and a standard error of 0.00074 m^2. Sapwood area ranged from 23.0 to 62.6 sq cm. The treatment of thinning to two sprouts transpired the greatest volume of water (mean ± SE), at 9.72 ± 0.36 liters per day during the 19-month study. The treatment of thinning to one sprout transpired the least, with an average of 8.27 ± 0.35 liters per day. An analysis of variation test with an alpha level of 0.1 identified significant differences among the four treatment means. Paired t-tests between treatment means indicated that only the coppice thinned to one sprout and the control were not significantly different at the $\alpha = 0.1$ level.

Estimated transpiration rates during the sampling period are presented in Figure 1. The mean daily transpiration rate of the measured stems for the treatments and the mean daily water use for the rootstocks per treatment are given in Table 1. Paired t-tests between the estimated transpiration rates per rootstock for each treatment show that all are significantly different at the 0.1 alpha level. The unthinned control with an average of 4.5 dominant stems per rootstock was estimated to have the greatest daily transpiration rate.

The most recent 20-year mean annual precipitation at the Coronado National Memorial was 552 mm. The annual precipitation in 2000 and 2001 was 778 mm and 544 mm, respectively; several large storms in October of 2000 provided the main differences between the two years. The mean daily transpiration rates for each treatment were averaged to clearly present the transpiration trends with daily precipitation records (Figure 2).

DISCUSSION

Changes in solar radiation, air temperature, relative humidity, wind speeds, and/or cloud cover over the course of a day may have caused variation among the daily transpiration rates. The

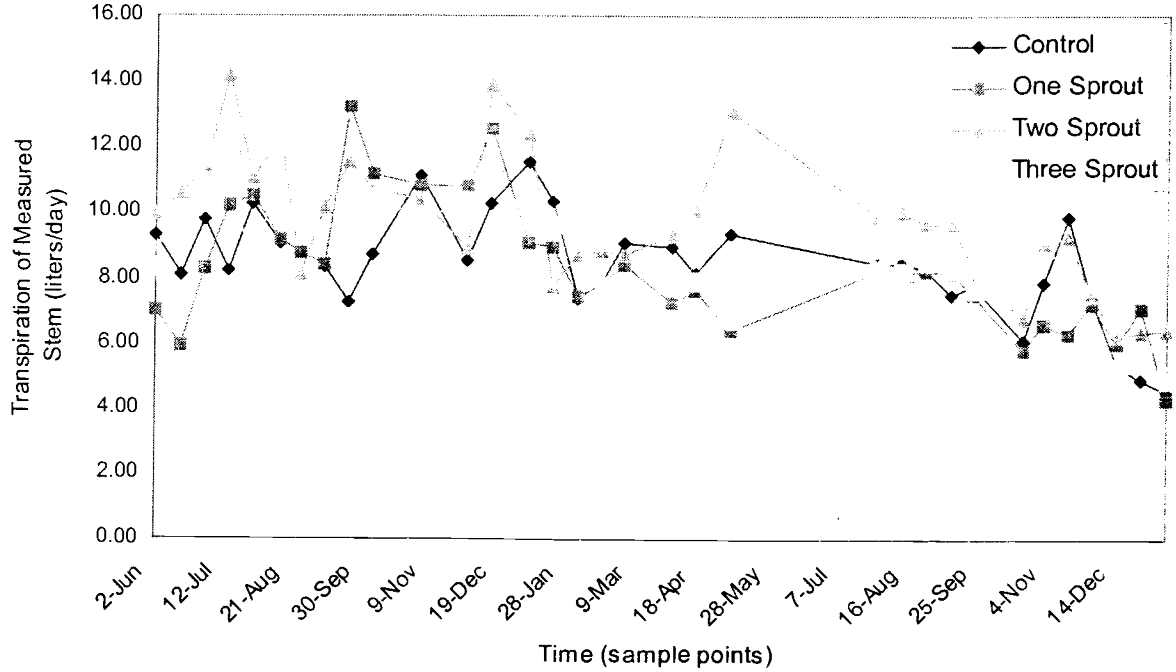

Figure 1. Average individual daily transpiration rates for three coppice treatments and a control from May 2000 to January 2002.

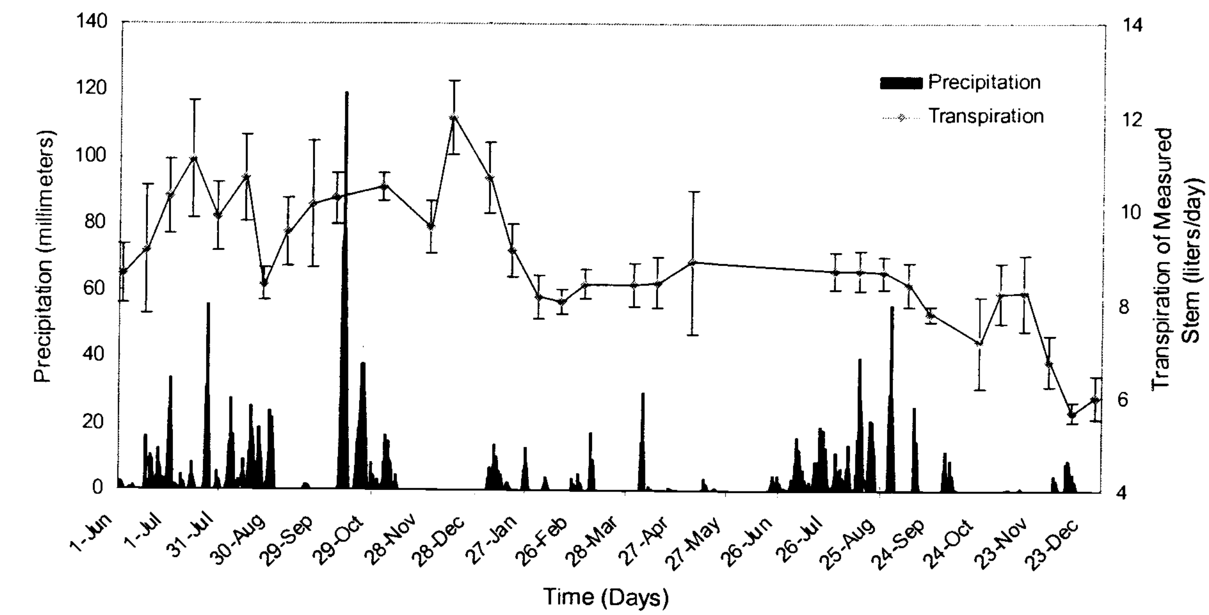

Figure 2. Average daily transpiration rates of all sprouts in relation to daily precipitation from May 2000 to January 2002 (bars on the water use line represent standard errors).

Table 1. Averages and standard errors for individual and total rootstock daily transpiration rates and diameter at breast height (dbh) measurements for coppice thinning treatments of Emory oak over the study period.

	Thinning Treatment			
	Control	One Sprout	Two Sprouts	Three Sprouts
Individual daily average water use (liters/day)	8.37 ± 0.29	8.27 ± 0.35	9.72 ± 0.36	8.82 ± 0.35
Total rootstock daily average water use (liters/day)	37.65 ± 1.29	8.27 ± 0.35	19.43 ± 0.71	26.47 ± 1.06
Average dbh of measured stem (cm)	7.9	7.9	8.4	8.1

number of sprouts from a rootstock affects the total transpiration for a particular rootstock. Factors that may impact transpiration rates include the sprout's ability to sequester water from an extensive interconnected root system or the leaf area of individual sprouts.

Precipitation influences the average daily transpiration rates (Figure 2); higher annual precipitation in 2000 produced a higher average daily transpiration rate than in 2001. An apparent lag between a precipitation event and transpiration rate was also noted. This delay could reflect the time required for water to infiltrate and percolate to soil depths where it can be absorbed by tree roots. Additional information on available moisture in the soil profile at periodic time intervals following precipitation is needed to clarify the relationship.

Coppice thinning following tree harvesting is also an important management tool. Touchan and Ffolliott (1999) and Farah et al. (forthcoming) have reported that average growth and yield of oak coppice is greatest when a thinning treatment leaves one residual sprout. However, the impact of tree harvesting on the water budget and the structural diversity of woodlands requires planning and management to attain a desired objective. The increased proportion of annual precipitation used for transpiration noted by Ffolliott and Gottfried (2000) could decrease available water for streamflow or on-site uses. Alternatively, a thinning treatment that leaves three residual sprouts improves wildlife habitat diversity, but decreases available water due to increased transpiration losses. Therefore, it is critical that land managers first determine realistic management objectives and then prescribe the appropriate silvicultural treatments.

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