

Influence of Soil-Water Potential on the Water Relationships of Honey Mesquite

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Highlight: *Thermocouple psychrometry was used to measure soil and plant water potentials of honey mesquite growing under irrigated and nonirrigated field conditions. The trees growing on the irrigated area experienced more internal stress (average minimum water potential, -30.9 bars) than trees growing under nonirrigated conditions (average minimum water potential, -19.4 bars). The water potential in the trees and transpiration rates adhered to a very distinct daily pattern. Minimum water potential occurred about noon in the trees growing on both sites. During the growing season, the average transpiration rate of the trees on the irrigated area was $9.59 \times 10^{-5} \text{ g cm}^{-2} \text{ min}^{-1}$, while the average transpiration rate for those trees growing on the nonirrigated area was $7.15 \times 10^{-5} \text{ g cm}^{-2} \text{ min}^{-1}$. The trees growing under irrigation produced 2 times more foliage than the trees growing without irrigation. Consequently, the greatest amount of soil water depletion occurred under irrigation. The results of this study indicated that water loss via transpiration in honey mesquite growing in shallow soils or on upland sites (relatively dry situations) is not as great as the amount lost from trees growing on bottomland and on riparian sites.*

Mesquite (*Prosopis*) is an "undesirable" woody plant that occurs in many of the warm deserts of the world and reportedly (McGinnies and Arnold, 1939; Dwyer and DeGarmo, 1970) uses water inefficiently. Mesquite has been reported to be only half as efficient as olive (*Olea europea*), a true xerophyte, with reference to water loss (Bakke, 1915). Wendt et al. (1968) found that soil water level (0.1 to 15.0 bars) had no significant influence on the transpiration rate of mesquite seedlings. Yet mesquite is able to survive during long periods of drought and in areas characterized by less than 15 cm annual rainfall. Thus mesquite must be adapted to a broad range of soil water conditions.

It is generally accepted that the physiological processes of a plant are markedly influenced by water stress (Beckett and Dunshee, 1932; Kozlowski, 1949; Stocker, 1960; Gates, 1964; and Hsiao, 1973). Seasonal growth responses of forest trees and most other woody vegetation are more sensitive to fluctuations in soil water than to any other environmental factor (Kramer and Kozlowski, 1960). Shimshi (1963) stated that stomatal aperture, transpiration, and photosynthesis were

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reduced as soil water content decreased. Slatyer (1957a) reported that transpiration could be slowed because of the effect of turgescence on stomatal closure.

Because transpiration is primarily a passive phenomenon, it does not necessarily cease at any particular stress level. It could be expected, however, that transpiration would be reduced at low water potentials because of stomatal closure and decreased movement of water in the soil (Slatyer, 1957b).

This study was designed to determine the influence of soil water potential on the water relationships of mature honey mesquite (*P. glandulosa* Torr. var. *glandulosa*) and its influence on the soil-plant-atmosphere continuum.

Materials and Methods

The water relationships of honey mesquite were studied using 10 trees growing on an Amarillo fine sandy loam site on the Texas Tech University campus in Lubbock. A border dike was placed around the area (approximately 0.2 ha) containing half the trees. These trees were irrigated weekly to maintain a soil water potential of -1.0 bar or more (less negative). Soil water potential more positive than -1.0 bar could not be read accurately. Soil water conditions of the nonirrigated area were determined by the natural environmental conditions.

Double-junction temperature compensated Spanner thermocouple psychrometers¹ (Spanner, 1951; Rawlins, 1966; Peck, 1969; Brown, 1970; Wiebe et al., 1971; and Easter and Sosebee, 1974) utilizing the Peltier effect, were used to measure the soil water potential at three locations in each area. The psychrometers were installed at depths of 15, 30, 45, 60, 120, and 180 cm at each location.

The Spanner thermocouple psychrometers were also used to determine the water potential at three different heights within each tree. A hole was drilled into the wood just inside the bark and the psychrometers were installed in contact with the current annual rings. Branch installations were placed in the axil of two branches as described by Wiebe et al. (1970). Silicone vacuum grease was used to prevent desiccation of the wood around the psychrometers. Polyurethane foam was used to insulate the psychrometers against fluctuations in ambient temperature and to secure them in position. The psychrometers were located within the trees to avoid exposure to direct sunlight. Measurement of the water potentials was obtained by using a semiautomatic thermocouple psychrometer readout meter (Schimmelpennig, 1972). Prior to installation, each thermocouple psychrometer was calibrated against standard solutions of 0.1, 0.5, 1.0, and 1.5 mol/kg KCl at temperatures ranging from 10 to 40°C.

Water potential measurements were made three to four times throughout the day from June 1 through August 24, 1972. Simultaneously, leaf diffusive resistance was measured

¹ EMCO, Angola, Indiana 46703.

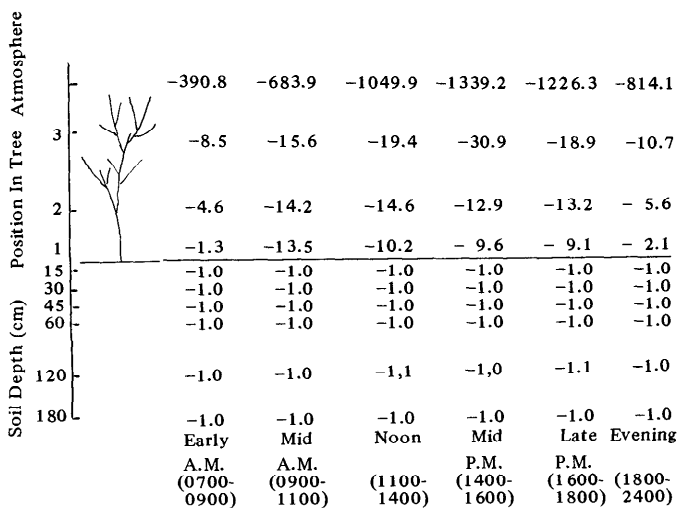


Fig. 1. Average soil-plant-atmospheric water potentials (bars) at various times of day (June through August, 1972) for irrigated honey mesquite.

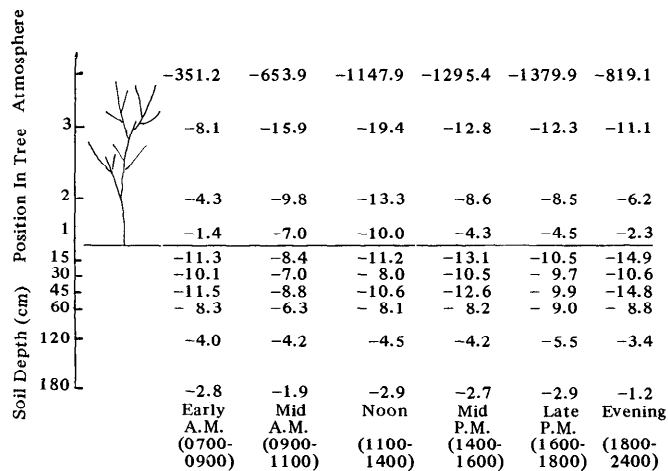


Fig. 2. Average soil-plant-atmospheric water potentials (bars) at various times of day (June through August, 1972) for nonirrigated honey mesquite.

using a diffusive resistance porometer (Kanemasu et al., 1969) from which transpiration rates were calculated according to van Bavel et al. (1965). Soil temperature, air temperature, leaf temperature, relative humidity, wind speed, and time of day were recorded at the time of each water potential and diffusive resistance measurement.

These data were analyzed using a stepwise regression analysis in an attempt to determine the importance of the various environmental factors to the water relationships of honey mesquite.

Result and Discussion

A soil-plant-atmosphere water potential gradient was established within the trees growing under irrigation (Fig. 1). The water potential of the trees growing without irrigation did not conform to the expected continuum of decreasing free energy from the soil, through the plant, into the atmosphere. Rawlins et al. (1968) reported that plant water potential was always lower than water potential of the soil at 25 cm. However, on the nonirrigated area of this study, water potential of the trees was greater (less negative) than the soil (Fig. 2). Although the anticipated water potential gradient was not obtained within the trees growing without irrigation, this gradient was approached as the transpiration rate reached its daily peak. Similar water potential gradients from the soil through the plant have been reported by Rawlins (1964), Barrs (1966), and Taerum (1973). Most often the inverted water potential gradients have been attributed to psychrometric error. However, inverted water potential gradients of plants in relatively dry soil may exist (Taerum, 1973).

Trees growing on both areas exhibited decreasing water potential with increasing height. The plant water potential gradients were similar to those found in Douglas fir (*Pseudotsuga menziesii*) and redwood (*Sequoia sempervirens*) by Scholander et al. (1965) and in juniper (*Juniperus scopulorum* Sarg.), elm (*Ulmus pumila* L.), Russian olive (*Elaeagnus angustifolia* L.), and maple (*Acer glabrum* Torr.) by Wiebe et al. (1970).

Soil without irrigation attained a low water potential of approximately -18.0 bars with no obvious physiological stress in the trees growing there. However, the trees on the irrigated site were often under greater internal stress than the trees on

the nonirrigated site. The average minimum water potential in the trees growing on the irrigated site was -30.9 bars whereas the average minimum water potential obtained in the trees on the nonirrigated sites was -19.4 bars. These results support those reported by Haas and Dodd (1972). Permanent wilting in honey mesquite apparently occurs at a water potential lower than the classical -15.0 bars.

Water potential in the trees was quite variable throughout the day. This variation was correlated with the time of day for

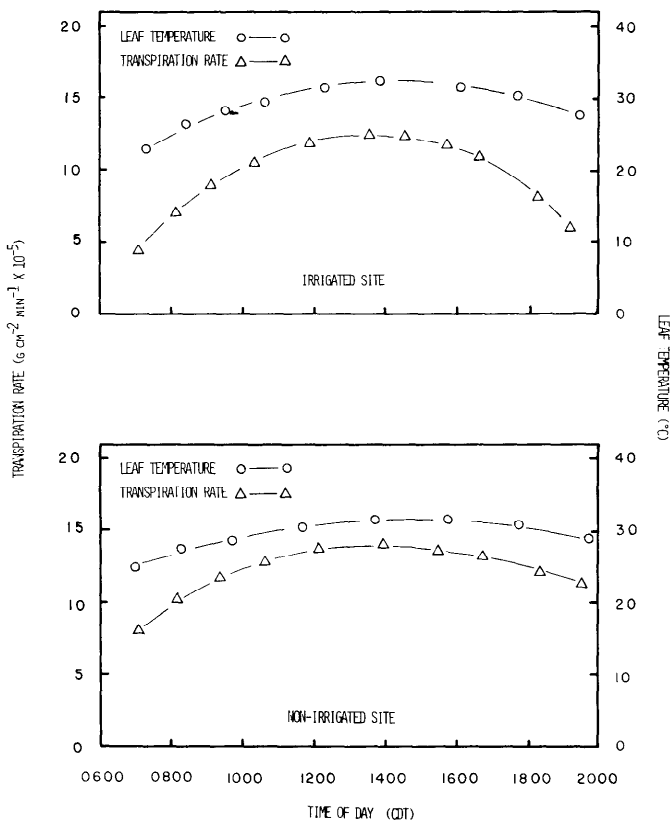


Fig. 3. Average leaf temperatures ($^{\circ}\text{C}$) and transpiration rates ($\text{g cm}^{-2} \text{min}^{-1}$) at various times of day (June through August, 1972) for irrigated and nonirrigated honey mesquite.

all positions in the tree. Maximum stress occurred about noon in the trees growing with and without irrigation. Water potential of the soil was not correlated ($r = .004$) with the water potential in the trees. Similarly, Cary (1971), Haas and Dodd (1972), and Slatyer (1955) found that evaporative demands directly influenced plant water potential until a critical water potential in the soil was reached. Leaf resistance exhibited more influence on the water potential of trees growing on both the irrigated and the nonirrigated area than any other parameter measured.

Environmental factors most influential ($R = 0.61$) on the leaf diffusive resistance of the trees growing under irrigation were atmospheric water potential, leaf temperature, and wind speed. Whereas, the leaf diffusive resistance of the trees growing without irrigation was influenced most ($R = 0.64$) by soil and leaf temperature and by soil water potential. The influence of atmospheric conditions on leaf diffusive resistance decreased as the soil water potential decreased. Transpiration rates (calculated from leaf diffusive resistance measurements) adhered to a very distinct daily pattern (Fig. 3). The average transpiration rate (June 1 through August 24, 1972) of the trees growing under irrigation ($9.59 \times 10^{-5} \text{ g cm}^{-2} \text{ min}^{-1}$) was significantly greater than the average transpiration rate of the trees growing without irrigation ($7.15 \times 10^{-5} \text{ g cm}^{-2} \text{ min}^{-1}$). The soil on the irrigated site was never flooded to the exclusion of soil air except for a very brief period following irrigation. Childers and White (1942) found that flooding decreased transpiration rates of apple (*Malus pumila*) trees within two days after flooding. In our study, transpiration rates following irrigation were as high as those the day before irrigation. Therefore, flooding had no detectable adverse effect. The trees growing under irrigation produced at least twice as much foliage as the trees growing without irrigation. Therefore, the amount of water lost via the honey mesquite trees growing on the irrigated site was substantially greater than the amount of water lost from the trees growing on the nonirrigated site.

The results of this study indicated that the zone of the soil where the roots are most actively absorbing water is within the upper 60 cm since the transpiration rates of trees growing on the two areas were significantly different. The soil water potentials of the two areas were significantly different in the upper 60 cm. But, the water potential at 120 and 180 cm depths approached field capacity; therefore, adequate soil water was available to the deeper roots on both areas. If the primary absorption zone of the roots was below 120 cm (e.g., tapping an underground water supply), the transpiration rates of trees growing on the two areas should have been similar.

The results of this study also indicated that honey mesquite growing in shallow soils or on upland sites does not deplete the soil water supply as greatly as purported. However, when soil water is available, such as on bottomland and riparian sites, honey mesquite becomes an extravagant user as Wendt et al. (1968) suggested.

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