Relative Drought Resistance of Desert Willow, Fruitless Mulberry, and Yellow Bells

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ABSTRACT

Desert willow and yellow bells had a higher capacity to avoid drought than fruitless mulberry under moist conditions, but the reverse was true under dry conditions. Desert willow and yellow bells had a higher tolerance to dehydration than fruitless mulberry, resulting in a higher relative resistance to drought under either moist or dry conditions. Detached leaves from desert willow and yellow bells plants grown under stress restricted water loss better than those grown under no stress. Fruitless mulberry leaves lost water at essentially the same rate regardless of irrigation.

INTRODUCTION

A plant's drought resistance is a measure of the water stress sufficient to kill 50 percent of the plants under consideration (Levitt, 1980). Water stress is expressed as the environment water potential so

\[ R_d = -P_{e50} \]

where \( R_d \) is the drought resistance and \( P_{e50} \) is the environment water potential at which 50 percent of the plants die.

Plants have mechanisms to avoid drought by increasing water uptake or restricting water loss (drought avoidance), and to a lesser extent, mechanisms that allow them to survive dehydration (drought tolerance). The effectiveness of avoidance mechanisms is estimated by the ratio of environment water potential to the plant water potential environment at steady state under conditions of drought:

\[ A_d = P_e / P_p \]

where \( A_d \) is drought avoidance, \( P_e \) is the environment water potential, and \( P_p \) is the plant water potential (Levitt, 1980). A value of 1 indicates the plant is unable to avoid reaching equilibrium with its environment whereas values greater than 1 indicate increasing avoidance. A true measure of avoidance is possible only at steady state (when the rate of water uptake equals the rate of water loss), a condition that is difficult to achieve. Relative avoidance is estimated by measuring the plant and environment water potential just before dawn, when the plant is close to steady-state conditions.

Tolerance mechanisms for surviving dehydration are evaluated by allowing detached leaves to come to equilibrium with atmospheres of known water potential in a dry environment and determining cell survival. The water potential resulting in 50 percent cell survival is a measure of drought tolerance:

\[ T_d = -P_{p50} \]

where \( T_d \) is drought (desiccation) tolerance, \( P_{p50} \) is plant water potential at which 50 percent of the cells die.

Drought resistance can be estimated from the product of avoidance and tolerance if avoidance is measured at \( P_{e50} \):

\[ T_d x A_d = -P_{p50} x P_{e50} / P_{p50} = -P_{e50} = R_d \]

The product of tolerance and relative avoidance (measured at levels other than \( P_{e50} \)) can be termed relative resistance and indicates resistance under dynamic conditions. Examining relative resistance for several species...
under varying degrees of stress will reveal aspects of their response to drought. The component of avoidance due to increased water uptake is difficult to measure, but the component due to restricting water loss can be examined by measuring water loss of detached leaves as they dry. If leaves from stressed plants restrict water loss greater than those from unstressed plants then this reflects an adaptation to drought (production of a thicker cuticle, stomatal closure, etc.).

The objective of this study was to examine these relationships for three common landscape plants, fruitless mulberry (Morus alba), desert willow (Chilopsis linearis) and yellow bells (Tecoma stans).

MATERIALS & METHODS

Field plots 120 x 120 x 180 cm deep were constructed of fiberglass panels sealed with silicone and filled with Bluepoint loamy fine sand. One-year-old plants were planted into the plots and irrigated uniformly during establishment for 1 year. Subsequently, four plants of each species were irrigated via calibrated drip irrigation emitters with 2.5, 3.8, or 5.0 cm water (36.6, 54.9, and 73.2 liters or enough to wet the soil to 30, 45, and 60 cm depths, respectively) when the soil water content at 30 cm, measured by neutron probe, reached 0.025 g cm$^{-1}$.

Plants were not irrigated during measurement periods that began in August and continued through October during 1987 and 1988. Predawn plant water potential, atmospheric water potential, and soil water content were measured weekly during this time. Plant water potential was measured on four leaves from each plant with a pressure bomb. Atmospheric water potential was measured with a psychrometer and soil water content with a neutron probe. Avoidance, the ratio of environment to plant water potential, was related to atmospheric water potential, soil water content, irrigation level and, via indicator variables, to species by multiple linear regression.

To determine tolerance, detached leaves from each plant were placed on floating screens in sealed plastic chambers containing saturated salt solutions resulting in atmospheric water potentials from 4 to 22 MPa (Winston and Bates, 1960). After allowing 2 weeks for equilibration at 21°C, percent cell survival was determined by microscopic examination following vital staining with Evan's Blue. Cell survival was related to atmospheric water potential, irrigation level, and species by multiple linear regression.

Rate of water loss from detached leaves was also determined biweekly throughout the test period. Four leaves from each plant were weighed periodically for 18 hours, then dried to a constant weight in an infrared heater. Water loss over 18 hours was divided by dry weight and related to irrigation level and species by multiple linear regression.

RESULTS

Avoidance was related to atmospheric water potential and species (Fig. 1). Neither soil water content nor irrigation level had a significant effect on this relationship. Regression lines for desert willow and yellow bells were not significantly different, but fruitless mulberry had a significantly different intercept and slope. Under moist conditions all three species had low avoidance with desert willow and yellow bells superior to fruitless mulberry. Under dry conditions fruitless mulberry had significantly higher avoidance than desert willow or yellow bells. Under periods of drought the fruitless mulberry is more adept at either restricting water loss or increasing water uptake than desert willow and yellow bells.

Percent cell survival was related to atmospheric water potential and species. Again, irrigation level had no significant effect. Regression lines for desert willow and yellow bells were not significantly different, but fruitless mulberry had a significantly different intercept (Fig. 2). Desert willow and yellow bells were both more tolerant of dehydration and more variable than fruitless mulberry. Thus more cells of the former species would survive dehydration than would the latter, which is consistent with the native habitat of desert willow and yellow bells. The atmospheric water potential that resulted in 50 percent cell survival (tolerance) was predicted to be 7.9, 7.1, and 4.9 MPa for desert willow, yellow bells, and fruitless mulberry, respectively (Table 1). Under moist conditions (10.22 MPa atmospheric water potential), yellow bells and desert willow are predicted to have a higher relative avoidance and resistance than fruitless mulberry. Under dry conditions (99.89 MPa atmospheric water
potential), fruitless mulberry is predicted to have a higher relative avoidance than desert willow or yellow bells but, due to the higher tolerances, the latter species have a higher relative resistance.

The rate of water loss by detached leaves was related to irrigation level (Fig. 3). The rate of water loss by desert willow and yellow bells leaves varies with irrigation level. Leaves from plants irrigated with 2.5 cm water lose less than do those irrigated with 5 cm water. This means leaves from plants under drought stress have adapted to restrict water loss. Fruitless mulberry leaves lose less water over time than do yellow bells leaves at any irrigation level. However, these leaves lose water at the same rate regardless of irrigation level so fruitless mulberry leaves from plants under drought stress have not adapted to restrict water loss. This suggests that increasing water uptake may be more important than restricting water loss in fruitless mulberry drought avoidance. This is consistent with the extensive fibrous root system of the mulberry and implies that in a mixed planting, such as a landscape, the fruitless mulberry could extract water from the soil at the expense of other plants in the landscape.

The ability of a plant to survive drought is a combination of its ability to avoid drought and survive dehydration. Relative drought resistance shown in Table 1 is the product of dehydration tolerance (Fig. 2) and drought avoidance (Fig. 1). Desert willow and yellow bells have a higher relative resistance than fruitless mulberry under both moist and dry conditions, despite the latter’s higher avoidance under dry conditions (Fig. 1). Thus, while fruitless mulberry is more efficient at removing water from soil, desert willow and yellow bells will survive better than fruitless mulberry once the soil becomes dry. Neither soil water content nor irrigation level had an effect on drought avoidance or dehydration tolerance. The results demonstrate that, under the conditions of this test, irrigating these plants to a depth of 30 cm approximately every month is sufficient to maintain life and suggest irrigating to a depth of 45 cm would maintain an acceptable appearance. The greater relative resistance of desert willow and yellow bells indicates they would survive on less water.

NOTE

This research was conducted at the Texas A&M University Research and Extension Center at El Paso.

REFERENCES


Table 1. Predicted relative avoidance, tolerance, and relative resistance for desert willow, fruitless mulberry and yellow bells under moist ($P_e = 10.2$ MPa) and dry ($P_e = 99.9$ MPa) conditions.

<table>
<thead>
<tr>
<th>Species</th>
<th>Relative Avoidance</th>
<th>Tolerance</th>
<th>Relative Resistance</th>
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<tbody>
<tr>
<td></td>
<td>$P_e / P_p^2$</td>
<td>$-P_{e50}$</td>
<td>$P_e / P_p * -P_{e50}$</td>
</tr>
<tr>
<td></td>
<td>MEAN LCL UCL</td>
<td>MEAN LCL UCL</td>
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<tr>
<td>$P_e = 10.2$ MPa</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Desert willow</td>
<td>19.8 5.6 33.9</td>
<td>7.9 5.9 10.7</td>
<td>156.4</td>
</tr>
<tr>
<td>Fruitless mulberry</td>
<td>14.6 0.1 29.1</td>
<td>4.9 3.7 5.8</td>
<td>71.5</td>
</tr>
<tr>
<td>Yellow bells</td>
<td>21.9 6.7 37.1</td>
<td>7.1 5.3 9.6</td>
<td>155.5</td>
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<td>$P_e = 99.9$ MPa</td>
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<tr>
<td>Desert Willow</td>
<td>93.0 80.6 105.4</td>
<td>7.9 5.9 10.7</td>
<td>734.7</td>
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<tr>
<td>Fruitless mulberry</td>
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<td>4.9 3.7 5.8</td>
<td>562.5</td>
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<tr>
<td>Yellow bells</td>
<td>88.1 77.2 99.1</td>
<td>7.1 5.3 9.6</td>
<td>625.5</td>
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</table>

$P_e$ - environment water potential, $P_p$ - plant water potential, $P_{e50}$ - plant water potential at 50% cell survival.

$LCL, UCL$ - lower and upper 95% confidence limits.
Fig. 1. Regression of desert willow, fruitless mulberry, and yellow bells relative drought avoidance on atmospheric water potential.
Fig. 2. Regression of desert willow, fruitless mulberry, and yellow bells cell survival on atmospheric water potential.
Fig. 3. Rate of water loss from detached leaves of desert willow, fruitless mulberry, and yellow bells as influenced by irrigation level (1 = 2.5 cm, 2 = 3.8 cm, 3 = 5 cm).