

## Effects of Heat and Drought on Photosynthesis in Redbuds

Jason J. Griffin and Thomas G. Ranney  
N.C. State University, Dept. of Horticultural Science  
Raleigh, NC 27695-7609

**Index Words:** carbon assimilation, *Cercis canadensis*, *Cercis mexicana*, environmental stress, heat stress, photosynthetic capacity, stomatal conductance, water deficit stress

**Nature of Work:** Stress tolerant landscape plants are becoming increasingly important throughout the United States. Recent droughts, unseasonably warm weather, and greater demands on water supplies, have led to mandatory water restrictions in many parts of the country. Irrigation of lawns and gardens is often restricted or prohibited altogether resulting in an increased demand for plants with greater heat and drought tolerance.

Drought and high temperature are two stresses that typically occur together, and when combined, can be particularly detrimental to landscape plants. These stresses can have additive and interactive effects. Low soil water availability causes a reduction in stomatal conductance ( $G_s$ ) and transpirational cooling that contribute to elevated leaf temperature and membrane destabilization (2). Water stress can also lower both the maximum rate of photosynthesis as well as reduce the optimum temperature for assimilation (1,5). Supraoptimal temperatures can compound the effects of drought stress by further limiting key metabolic processes including photosynthesis.

Maintaining  $G_s$  and photosynthesis under drought and high temperature stress can be an important adaptation. Species from warmer climates typically maintain higher rates of photosynthesis than species from cooler climates when exposed to elevated temperatures (3,4). Such elevated rates of photosynthesis compensate for the temperature-induced increase in respiration and reduce the potential for photoinhibition by maintaining electron transport and reducing free radical formation. Maintenance of photosynthesis during moderate drought events can also provide for greater carbon fixation, growth, and survival.

*Cercis canadensis* L. (eastern redbud) and the closely related *C. mexicana* Rose (Mexican redbud) were selected to further investigate the effects of both heat and drought on photosynthesis. These two species were selected due to their opposing native habitats. *Cercis canadensis*

is native to cooler, mesic, woodland habitats in the Eastern United States, while *C. mexicana* is native to warmer, xeric sites from West Texas to Mexico City.

Two-year-old seedlings were obtained for this study and one of each species was planted into each 10 gallon (40 L) container filled with an amended pine bark substrate. Plants were placed in a greenhouse and allowed to establish under natural photoperiod. Greenhouse temperatures were then raised to 95/77 °F (35/25 °C) day/night to acclimate the plants to high temperature. Two weeks later, irrigation was withheld from half of the containers to simulate the onset of a drought. Throughout the drying cycle, net photosynthetic carbon assimilation ( $P_n$ ) and  $G_s$  were measured (CIRAS-1, PP-Systems Inc.) at saturating light (2000  $\mu\text{mol}/\text{m}^2/\text{sec}$ ) and 350 ppm  $\text{CO}_2$ . Substrate moisture content was determined using a soil moisture analyzer (Dynamax Theta Probe) that was calibrated to the specific container substrate. Once container water content of water stressed plants reached 2-5% (by vol.) plants were brought into a laboratory to measure leaf gas exchange under controlled temperatures. Maximum photosynthetic capacity was measured as a function of increasing temperature. A recently matured leaf was placed in the cuvette at 68 °F (20 °C) under saturating light and  $\text{CO}_2$  (2000 ppm) and allowed to acclimate for 20 min before a measurement was taken. Leaf temperature was then increased in 9 °F (5 °C) increments to 113 °F (45 °C) with a reading taken at each increment following a 20 min acclimation period at that temperature. The experiment was a randomized complete block design with seven replications and treatments were arranged as a split-split plot. Data were then subjected to ANOVA and regression analyses.

**Results and Discussion:**  $P_n$  for both species declined at similar rates with increasing water stress (Fig. 1A). However,  $P_n$  for *C. mexicana* remained higher at all soil water contents. The higher  $P_n$  of *C. mexicana* at decreasing soil water contents appeared to result, in part, from the maintenance of greater  $G_s$  (Fig. 1B), allowing for continued uptake of  $\text{CO}_2$ . Greater  $P_n$  is significant because carbon assimilation is the primary method to dissipate absorbed light energy. When the stomata are closed, as is typical under conditions of drought and high temperature,  $P_n$  is reduced, and conditions favoring photoinhibition arise. *Cercis mexicana* was able to maintain greater  $P_n$  under water deficit stress than *C. canadensis*.

Measurement of the temperature response of  $P_n$  under saturating  $\text{CO}_2$  (maximum photosynthetic capacity) is an effective means for evaluating the response of the photosynthetic apparatus to increasing temperatures,

independent of stomatal limitations. Results from these measurements indicated that there was little difference in the temperature optimum for maximum photosynthetic capacity among taxa or as influenced by water status (Fig. 2). However, *C. mexicana*, whether well-watered or drought-stressed, had a substantially greater maximum photosynthetic capacity than did similarly treated *C. canadensis* (Fig. 2). In fact, photosynthetic capacity for water-stressed *C. mexicana*, was similar to the irrigated *C. canadensis*. These results indicate that while both species are well adapted to hot, dry conditions, the greater photosynthetic capacity of *C. mexicana* would further allow for improved carbon balance and potentially reduced photoinhibition during both heat and drought stress.

**Significance to Industry:** The demand for low-maintenance landscape plants with greater tolerance to environmental stresses is steadily increasing. In many cases, selection of plants that are well adapted to combined stresses might be particularly desirable. The above results indicate that *C. mexicana*, which is native to regions with high temperatures and minimal rainfall, was able to maintain basic physiological processes under combinations of extreme environmental stresses. These adaptations can contribute to reduced injury, faster recovery once stresses are alleviated, and ultimately improve growth and survival.

#### Literature Cited:

1. Briggs, G.M., T.W. Jurik, and D.M. Gates. 1986. Non-stomatal limitation of CO<sub>2</sub> assimilation in three tree species during natural drought conditions. *Physiol. Plant.* 66:521-526.
2. Hale, M. and D. Orcutt. 1987. *The Physiology of Plants Under Stress*. John Wiley & Sons. New York.
3. Ranney, T.G. and M.M. Peet. 1994. Heat tolerance of five taxa of birch (*Betula*): Physiological response to supraoptimal leaf temperatures. *J. Amer. Soc. Hort. Sci.* 119:243-248.
4. Ranney, T.G. and J.M. Ruter. 1997. Foliar heat tolerance of three holly species (*Ilex* spp.): Responses of chlorophyll fluorescence and leaf gas exchange to supraoptimal leaf temperatures. *J. Amer. Soc. Hort. Sci.* 122:499-503.
5. Smolander, H. and J. Lappi. 1984. The interactive effect of water stress and temperature on the CO<sub>2</sub> response of photosynthesis in *Salix*. *Silva Fennica.* 18:133-139.

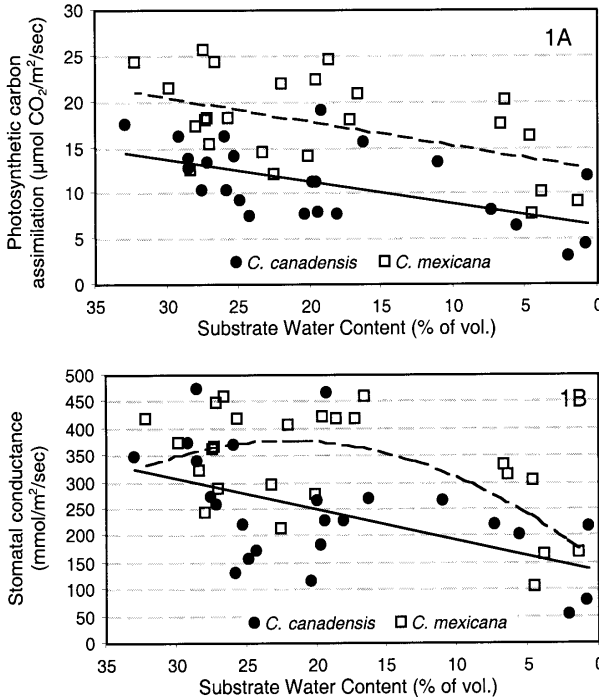


Fig. 1. A. Net photosynthesis and regression of *C. canadensis* (solid line;  $y=0.24x+6.5$ ) and *C. mexicana* (broken line;  $y=0.26x+12.7$ ) as a function of substrate water content. B. Stomatal conductance and regression of *C. canadensis* (solid line;  $y=5.8x+135$ ) and *C. mexicana* (broken line;  $y=-0.47x^2+20.8x+148$ ) as a function of substrate water content.

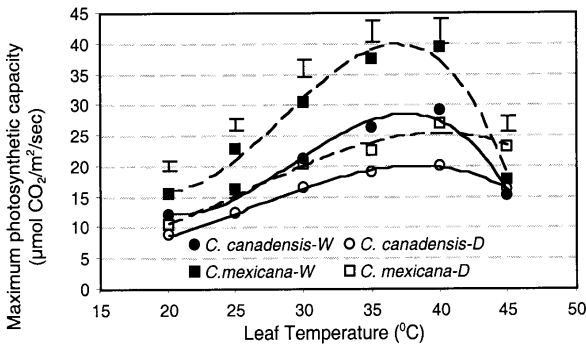


Fig. 2. Maximum photosynthetic capacity measured under saturating light and CO<sub>2</sub>, and regression models of *C. canadensis* (solid lines) and *C. mexicana* (broken lines) as a function of leaf temperature: *C. canadensis*-Watered,  $y=-0.0069x^3+0.606x^2-16.2x+149$ ; *C. canadensis*-Drought,  $y=-0.002x^3+0.155x^2-3.3x+27.6$ ; *C. mexicana*-Watered,  $y=-0.0097x^3+0.83x^2-21.5x+191$ ; *C. mexicana*-Drought,  $y=-0.0017x^3+0.13x^2-2.3x+18.7$ . Vertical bars represent one standard error of the mean at each temperature.