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ECOLOGICAL SIGNIFICANCE OF SMALL LEAVES IN THE CEDAR GLADE ENDEMIC *TALINUM CALCARICUM*

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ABSTRACT

Leaf temperatures of the succulent terete–leaved, summer–active, C_3 species *Talinum calcaricum*, air temperatures in the immediate vicinity of the leaf, and incoming solar radiation were monitored in the field during parts of two days in late June. Leaf temperatures averaged 3.25 C above air temperatures when solar irradiance was high (0.80–1.48 cal cm^{-2} min^{-1}) and 0.68 C when solar irradiance was low (0.15–0.37 cal cm^{-2} min^{-1}). The highest leaf temperature recorded was 37.2 C. We suggest that the small (ca., 165 mm^2) leaves of *T. calcaricum* are adaptive because they can achieve a positive energy balance in the high radiation cedar glade environment in summer at temperatures within the range of normal functioning of the enzymatic reactions of photosynthesis.

INTRODUCTION

Talinum calcaricum Ware (Portulacaceae) is a small, succulent–leaved hemicryptophyte endemic to cedar glades of northern Alabama, middle Tennessee and southwestern Kentucky (Baskin and Baskin, 1986, 1989, pers. observ.). In the cedar glades, the species is restricted to the very shallow soil zones where there is little or no competition from other plant taxa (Ware, 1969a), although soil water may remain below the permanent wilting point for long periods in summer (Freeman, 1933). The active phases of the life cycle of *T. calcaricum* occur between April and September, and plants continue to flower and set seeds during the hottest, driest part of the summer.

Two morphological adaptations of *T. calcaricum* to its cedar glade habitat are succulent leaves and a thick cuticle (Ware, 1969a). A third morphological feature of this species that may be an adaptation to the hot, dry cedar glade environment is small leaves (ca. 165 mm^2). When resistance to water vapor loss by a leaf is high and it is absorbing a high radiation load (e.g., the succulent leaves of *T. calcaricum* on sunny days in summer), temperatures of a small leaf will remain lower than those of a large leaf (Gates, 1968; Gates et al., 1968). In which case, small leaves may be advantageous to the plant in that their temperatures would not rise above those required for normal functioning of enzyme–mediated reactions (e.g., photosynthesis).

Recently, there has been considerable interest in various aspects of the autecology of *Talinum* species in the eastern United States (Ware, 1969a,b; Ware and Quarterman, 1969; Murdy et al., 1970; Ware, 1972; Bouchard and Franz, 1977; Martin et al., 1982; Martin and Zee, 1983; Carter and Murdy, 1986; Murdy and Carter, 1987; Martin et al., 1988). However, we know of no previous reports on leaf temperatures of any of the species in their natural habitat. Thus, the purpose of this study was to measure leaf temperatures of *T. calcaricum* in its cedar glade habitat in summer and to relate these to air temperatures and incoming solar radiation.

METHODS

Leaf and air temperatures and solar irradiance were monitored in a cedar glade north of LaVergne in Rutherford County, Tennessee, on 29 and 30 June 1971 (Baskin and Baskin, 1973, 1977). Temperature measurements were made on a nonshaded, fully–grown leaf of *T. calcaricum* that had an area of ca. 165 mm^2. Readings of leaf and air temperatures and incoming solar radiation were taken at 15–min intervals. Leaf and air temperatures were measured using 40–gauge wire, copper–constantan thermocouples and a multichannel null potentiometer. The thermocouple was inserted into the leaf so that the copper–constantan wire junction (ca. 1 mm long) was completely embedded in the tissue. Air temperatures were measured in the immediate vicinity of the leaf, and the air temperature thermocouple was shaded during readings.

Solar irradiance was measured with a Yellow Springs Instrument model 68 direct reading pyranometer using a YSI model 6701 probe equipped with a silicon solar cell. The solar cell is responsive to wavelengths of 0.4–1.1μ and has been calibrated against an Eppley 180 pyranometer in natural sunlight. The sensing element was mounted on a ring stand one meter above the ground surface and was held in an exactly horizontal position.

RESULTS AND DISCUSSION

Data showing the relationship between incoming solar radiation and leaf and air temperatures are shown in Figure 1. Leaf temperatures tracked solar radiation more closely than they did air temperatures. When solar irradiance was high (0.80–1.48 cal cm^{-2} min^{-1}), leaf temperatures (N=29) of *T. calcaricum* averaged 3.25 0.19 C (mean SE) above air temperatures. On the other hand, when solar irradiance was low (0.15–0.37 cal cm^{-2} min^{-1}) leaf temperatures (N=13) were 0.68 0.21 C above air temperatures.

Since several other species of *Talinum* fix carbon via the C_3 photosynthetic pathway (Welkie and Caldwell, 1970; Syvertsen et al., 1976; Martin et al., 1982; Martin and Zee, 1983), *T. calcaricum* probably also utilizes this pathway. If *T. calcaricum* is a C_3 plant, then unlike many succulents, which have CAM photosynthesis (Szarek and Ting, 1977; Szarek, 1979), the stomates of *T. calcaricum* would be open during the day. Thus, the radiant energy (solar+thermal) absorbed by the leaves ($-Q_{abs}$) would be dissipated via latent heat of evaporation (LE), as well as by reradiation (R) and convection (C). That is, when the temperature of the leaf is not changing, $-Q_{abs}$ (energy in) = R+C+LE (energy out). However, since the leaves of *T. calcaricum* do not wilt readily, even when the plant is growing in dry soil in full sun, the transpiration rate must be very low and essentially all of the energy absorbed by the leaves would be dissipated by reradiation and convection. The amount of heat reradiated by plant leaves (or any other body) increases as their temperature increases (Stefan's Law). Thus, since small leaves are better heat convectors than large ones (Gates, 1968), small leaves will achieve energe balance with their surroundings at lower temperatures than large leaves.

In *Talinum calycinum* Engelm., the rate of photosynthesis declined sharply between 35 and 40 C (Martin et al., 1988). If this also is the case in *T. calcaricum*, it then becomes obvious why small leaves are an adaptive feature of this summer–active cedar glade endemic. They can achieve energy balance in a high radiation environment at a leaf temperature of around 35–36 C (Figure 1) and thus maintain a relatively high rate of photosynthesis. The highest leaf temperature of *T. calcaricum* recorded in this study was 37.2 C, on 29 June. On the same day, pad temperatures of a nearby plant of *Opuntia compressa* (Salisb.) Macbr. (= *O. humifusa* Raf.), a species with CAM photosynthesis (Koch and Kennedy 1980), reached 48 C. The surface area of the *O. compressa* pad was 18,010 mm^2 (Baskin and Baskin, 1973).

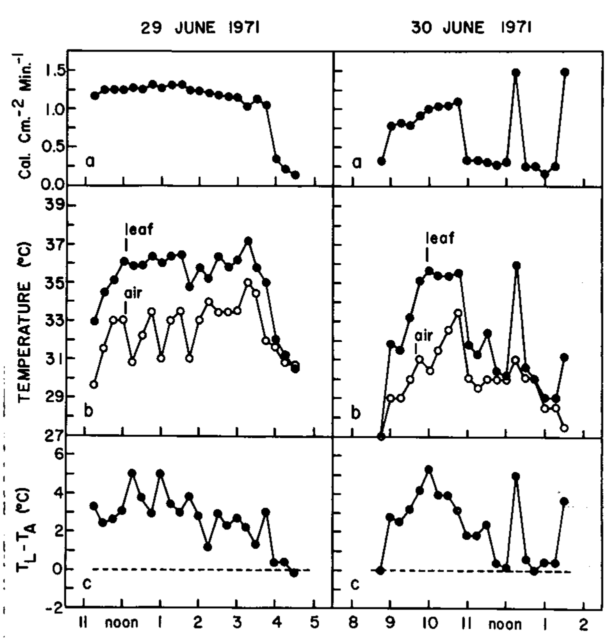

Figure 1. Leaf temperatures of *Talinum calcaricum*, air temperatures, and incoming solar radiation in a middle Tennessee cedar glade on 29 and 30 June 1971.

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