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Cuphea Growth and Development: Responses to Temperature

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INTRODUCTION

Species from the genus *Cuphea*, Lythraceae, are known to produce seed rich in medium chain fatty acids (MCFA), which are important feed-stocks in the manufacturing of soaps and detergents and numerous other related products (Thompson 1984). In the US there are no crops grown that serve as an economical replacement of MCFA. Consequently, the US chemical industry imports most MCFA as coconut (*Cocos nucifera* L.) and palm kernel (*Elaeis guineensis* Jacq.) oils from southeast Asia.

Several species of *Cuphea* have been shown to have potential for agronomic domestication (Hirsinger 1985). Breakthroughs over the past decade in domesticating *Cuphea* have resulted from the development of select germplasm lines from a fertile interspecific hybrid arising from a cross between *C. viscosissima* and *C. lanceolata* (Knapp 1993). *Cuphea viscosissima* is native to the eastern US, while *C. lanceolata* is a native of central Mexico. PSR23 is one such selected line from this hybridization that shows potential for field cultivation (Knapp and Crane 2000).

Small-scale field production of PSR23 in the northern Corn Belt of the US has shown that it can be successfully propagated in a cool temperate short-season climate (Forcella et al. 2000). However, to determine the optimum environment and management techniques for production of semi-domesticated *Cuphea* germplasm, a better understanding is needed of the effects of temperature on growth and development processes. In the present study we investigated photosynthesis, growth and development of *Cuphea* (PSR23) under four temperature treatments.

METHODOLOGY

Cuphea (PSR23, *C. viscosissima* Jacq. × *C. lanceolata* f. silenoides W.T. Aiton) seeds were sown in 19 L pots filled with a mix of 1 soil:1 sand:1 peatmoss and started in a greenhouse at a day/night temperature of 28°/20°C with a 16 hr photoperiod. Seven days after emergence, plants were transferred to growth chambers at one of four temperature treatments. The treatments consisted of four different sinusoidal diurnal temperature cycles resulting in daytime maximum and nighttime minimum temperatures of 18°/12°, 24°/18°, 30°/24°, and 35°/27°C giving daily mean temperatures of 15°, 21°, 27°, and 31°C, respectively. Plants were grown under a 16 hr photoperiod with a photosynthetic photon flux of 550 μmol m^{-2} s^{-1} at canopy height. Relative humidity was controlled between 55% to 65% during daylight and 65% to 75% during nighttime hours. Plants were kept well watered throughout the study and fertilized once a week with a commercial fertilizer (*Peat-Lite Special®, 20–19–18, N–P–K, Peters, Milpitas, California).

Photosynthesis was measured with a LI-6400 Portable Photosynthesis System (LI-COR, Lincoln, Nebraska) on attached, fully expanded, light exposed leaves. At 40 days after planting (DAP), for each treatment, six individual leaves from different plants were measured at midday under maximum growth temperature and a PPFD of 1200 μmol m^{-2} s^{-1}, supplied by artificial light.

Plants were sampled for biomass analysis at 40 and 69 DAP and plant material was separated into stems, leaves, and reproductive organs. Plants at 40 DAP were in vegetative growth (VG), while between 40 and 69 DAP they had all entered reproductive growth phase (RG). The rate of total dry matter (TDM) accumulation at VG was calculated as the TDM at 40 DAP divided by DAP, while the TDM accumulation rate at RG was calculated as the difference in TDM between 40 and 69 DAP divided by the difference in DAP. Biomass data is reported on a per plant basis. Seed was collected at final harvest, which for the 18°/12°, 24°/18°, and 30°/24°C treatments was 118, 96, and 98 DAP, respectively. The seed was dried in an forced-air oven at 30°C for two weeks before counting and weighing. During the study, no viable seed was produced by plants grown under the 35°/27°C temperature regime.

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*Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

RESULTS AND DISCUSSION

Leaf photosynthetic rates, measured at daily maximum growth temperatures 40 DAP, were relatively stable over the wide temperature range used in this study (Fig. 1). Plants grown at 24°/18°C showed the highest mean photosynthetic rate, while that of those cultured at 35°/27°C was 25% less. Regression analysis of photosynthesis data using a quadratic fit, revealed that the predicted temperature optimum for photosynthesis was about 23°C. By comparison, the temperature optimum for *Cuphea* (PSR23) derived in this study is much lower than that of C_3 subtropical species such as rice (*Oryza sativa* L.) and soybean (*Glycine max* L.) (Vu et al. 1997) and is slightly higher, but similar to that of spring wheat (*Triticum aestivum*) (Bird et al. 1977).

Leaf water use efficiency (WUE), derived from the ratio of photosynthesis to transpiration, represents µmoles of CO_2 fixed per mmole of water transpired (Fig. 1). As the maximum daily growth temperature increased from 18° to 24°C there was nearly a 2-fold decline in leaf WUE. Though WUE remained stable at 30°C it again declined dramatically at 35°C and was approximately 3.5-fold lower than leaves that developed at 18°C (Fig. 1). These results indicate that under high temperatures *Cuphea* leaves are not efficient water users while fixing carbon.

Both growth stage and temperature greatly affected the rate of total dry matter (TDM) accumulation (Fig. 2). The response of TDM accumulation to temperature was similar at both growth stages, with plants grown at 30°/24°C showing the highest rates (Fig. 2). In contrast, *Cuphea* grown at the lowest and highest temperature regimes showed considerably lower rates. Compared to plants grown at 30°/24°C, TDM rates for the 18°/12°C treatment were 89% and 51% lower at the VG and RG stages, respectively. The TDM rates for *Cuphea* grown at 35°/27°C were 63 and 27 % less than 30°/24°C-grown plants at the VG and RG stages, respectively. Regression of the data showed that the predicted temperature optimum for TDM accumulation was 24°C, corresponding in this study to day/night temperatures of 27°/21°C. The temperature optimum for TDM accumulation is about 4°C greater than that for photosynthesis.

Regardless of temperature treatment, it is clear that when plants entered reproductive phase the rate of TDM accumulation increased dramatically (Fig. 2). We have also observed this same trend in field-grown *Cuphea* (data not shown). It appears that *Cuphea*, at least genotype PSR23, may not possess very high "seedling vigor." Slow vegetative growth could potentially restrict *Cuphea*'s ability to effectively compete with weeds under field conditions during early season growth.

The dry weight of reproductive tissues (i.e., flowers and pods) at 69 DAP is compared among the four

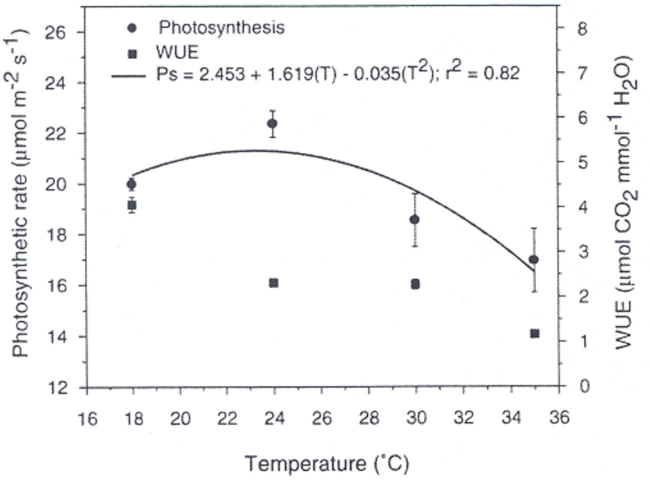

Fig. 1. Leaf photosynthetic rate and water use efficiency (WUE) as a function of daytime maximum growth temperature at 40 DAP. Values represent means ± SE, n = 6. For the regression equation, Ps = photosynthesis and T = max. growth temperature.

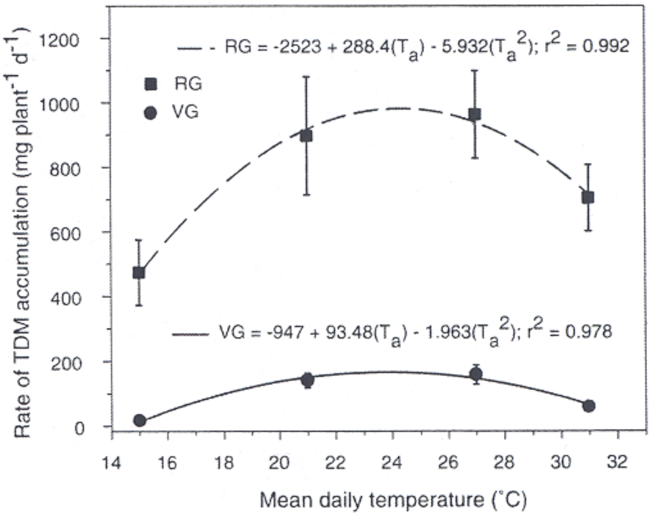

Fig. 2. Total dry matter (TDM) accumulation rate per plant as a function of mean daily growth temperature at 40 DAP (VG=vegetative growth) and between 40 and 69 DAP (RG=reproductive growth). Values represent means ± SE, n = 6. For the regression equations, T_a = average daily temperature.

temperature treatments in Fig. 3A. Below a mean temperature of 21°C and above 27°C there was about a 5-fold decline in the weight of reproductive tissues (Fig. 3A). The temperature optimum for reproductive tissue growth at 69 DAP, predicted from regression analysis, was 23°C. As expected, the low temperature regime (18°/12°C) slowed down the development of plants. Although development of reproductive tissues was relatively low at 69 DAP, by 120 DAP (when plants were harvested for seed) there was considerable reproductive growth (data not shown). Seed size was also greatly impacted by temperature. The weight per 1000-seed linearly declined with temperature (Fig. 3B). In comparison to seed formed at 18°/12°C, those developed at 30°/24°C weighed 50% less. As temperature increases, higher plants generally experience stimulated growth, increased respiration, and decreased length of life cycle. However, above the optimum for growth, dry matter accumulation often declines due to both increased respiration and decreased length of time for vegetative growth and effective seed filling (Morison and Lawlor 1999).

CONCLUSIONS

Cuphea, semi-domesticated germplasm PSR23, favors cool to moderate climates and may have a high water use requirement for growth. Vegetative biomass production tends to have a higher temperature optimum and is much more tolerant to high temperatures than reproductive development. Independent of temperature, growth rate of plants during vegetative phase is considerably slower than that during reproductive phase. Seed production of *Cuphea* (PSR23) may be best suited for regions with cool to moderate growing season temperatures and high annual precipitation.

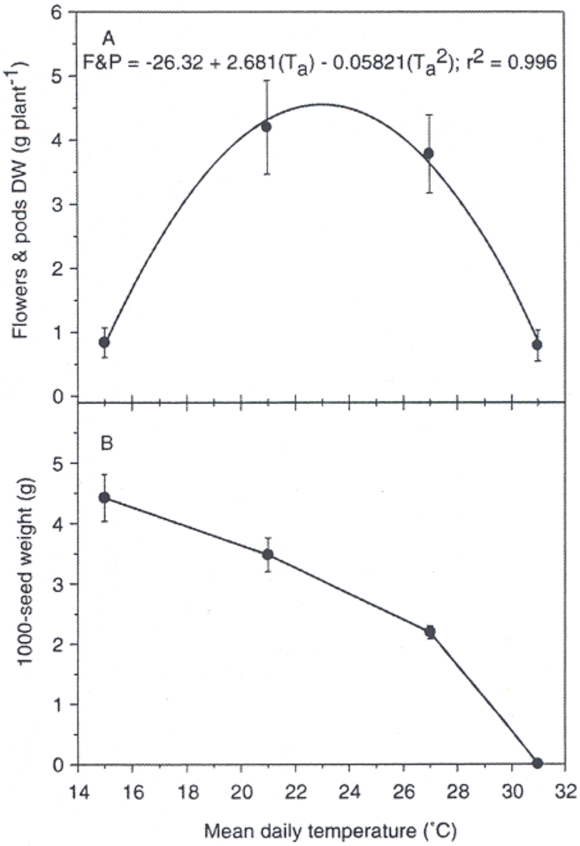

Fig. 3. Reproductive tissue (flowers & pods) dry weight accumulated at 69 DAP (A), and 1000-seed weight after final harvest (B), as a function of mean daily temperature. Values in A are means ±SE, n = 6, and B are means ±SD, n=3. For the regression equation (3A) F&P = flower and pod DW and T_a = average daily temperature.

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