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Elevated night-time temperatures increase growth in seedlings of two tropical pioneer tree species

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Summary

- Increased night-time temperatures, through their influence on dark respiration, have been implicated as a reason behind decreasing growth rates in tropical trees in the face of contemporary climate change.
- Seedlings of two neo-tropical tree species (*Ficus insipida* and *Ochroma pyramidale*) were grown in controlled-environment chambers at a constant daytime temperature (33°C) and a range of increasing night-time temperatures (22, 25, 28, 31°C) for between 39 d and 54 d. Temperature regimes were selected to represent a realistic baseline condition for lowland Panama, and a rise in night-time temperatures far in excess of those predicted for Central America in the coming decades. Experiments were complemented by an outdoor open-top chamber study in which night-time temperatures were elevated by 2.4°C above ambient.
- Increasing night-time temperatures resulted in > 2-fold increase in biomass accumulation in growth-chamber studies despite an increase in leaf-level dark respiration. Similar trends were seen in open-top chambers, in which elevated night-time temperatures resulted in stimulation of growth.
- These findings challenge simplistic considerations of photosynthesis-directed growth, highlighting the role of temperature-dependent night-time processes, including respiration and leaf development as drivers of plant performance in the tropics.

Introduction

Contemporary global warming has been accompanied by the narrowing of the diel (24 h) temperature range by the asymmetric rise in night-time and daytime temperatures (Kukla & Karl, 1993; Easterling *et al.*, 1997). The complex interaction of changing atmospheric chemistry, water-vapor feedback, and cloud behavior is difficult to predict (Dai *et al.*, 1997; Lobell *et al.*, 2007), yet it is likely that the emergence of novel temperature regimes in the tropics (Diffenbaugh & Scherer, 2011) will include the continued asymmetric rise of night-time temperatures (IPCC, 2007), with potentially profound implications upon plant growth in an already compromised ecosystem (Wright, 2010).

Several recent meta-analysis of plant responses to increasing temperature (Lin *et al.*, 2010; Way & Oren, 2010) have highlighted how tropical species may be particularly vulnerable to increases in both daytime and night-time temperatures. In temperate and boreal systems productivity is often limited by seasonal minima, and an increase in temperature may be associated with the extension of the growing season or a shift towards a temperature optimum for growth. By contrast, humid tropical (lowland) systems with their relatively stable climatic envelope (Wright *et al.*, 2009) are presumed to operate at, or close to their thermal optimum (Janzen, 1967; Ghalambor *et al.*, 2006) and may possess only limited tolerance to increasing temperatures (Colwell *et al.*, 2008; Laurance *et al.*, 2011; Corlett, 2012).

Dark respiration (R_d) (i.e. non-photorespiratory mitochondrial respiration) provides cells with metabolic precursors, usable energy (i.e. ATP), and reducing equivalents (e.g. NADH) (Ryan, 1991; Amthor, 2000). As in all organisms, R_d of tropical trees is known to rise in response to short-term increases in temperature (Cavaleri *et al.*, 2008) and, as such, the elevated respiratory-carbon loss at higher growth temperatures has been invoked in the explanation of empirical (Clark *et al.*, 2003, 2010; Loescher *et al.*, 2003; Larjavaara & Muller-Landau, 2012) and predicted (Cox *et al.*, 2000; Cowling & Shin, 2006) decreases in productivity of tropical forests with changing climate. However, this interpretation precludes long-term acclimatization of R_d (Atkin & Tjoelker, 2003; Atkin *et al.*, 2005) and is predicated upon carbon-source dynamics, the net balance between photosynthesis (A) and R_d determining plant growth. This framework does not address potential changes in carbon use efficiency (Hansen *et al.*, 2009) or phenological development (Wolfe-Bellin *et al.*, 2006), the highly dynamic nature of thermal responses seen in R_d (Atkin *et al.*, 2005), or how plant metabolic rates may be sink rather than source mediated (Körner, 2003; Sala *et al.*, 2012). Indeed, if we assume growth to be regulated within a simplistic source-centric framework increased R_d in response to temperature would need to reflect a substantive increase in maintenance costs (e.g.