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Thermal plasticity and limitations in tropical trees

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Abstract

Tropical forests are the most carbon dense and biodiverse terrestrial biome on earth. In a time of global warming and biodiversity crisis, their preservation must be of high priority. At the same time, they likely operate close to their thermal limits because of a historically and seasonally stable environment. With climate change, thermal limits may be crossed more regularly, leading to increased physiological heat stress and tree mortality, which may decrease forest carbon storage. This thesis explores how physiological strategies dealing with climate change differ between tropical tree species, giving them a chance at survival, and how flexible different species are in their strategies.

A variety of tree species were studied at differing temperatures along an experimental elevation gradient in Rwanda as well as in controlled climate chambers. Drought effects were included in some studies.

Thermal acclimation was found for both leaf physiological and water-use traits. With an increase in growth temperature, the photosynthetic optimum temperature (T_{opt}) increased, while a strong downregulation of leaf respiration capacity acted to maintain constant or even decreased respiration rates (R). Traits relevant for tree water use responded to warmer climate by decreasing hydraulic conductance (K_{plant}) and leaf minimum conductance (g_{min}), while leaf osmolality and stomatal conductance did not change. In comparison with studies from other biomes, the acclimation in T_{opt} of photosynthesis was lower and not even statistically significant in the field study. The downregulation in respiratory capacity was stronger than in trees from other biomes. Leaf osmolality, a trait related to water acquisition and status, showed no increase, contrary to results from drought studies from other biomes. Acclimation in traits related to water transport (K_{plant} and g_s) and minimum leaf water loss (g_{min}) was similar to studies from other biomes.

Successional groups were found to make use of highly differing physiological strategies. Early successional (ES) species had high water use and reached high rates of photosynthesis to facilitate fast growth. Late successional (LS) species were more conservative in water use and lower in defoliation, reflecting a low growth, resource saving strategy. Tree mortality due to warming was higher in the LS species. With their low transpiration rates, excessive overheating occurs more frequently than in ES species, leading to photosynthetic heat stress and potential carbon starvation. The ES species showed higher sensitivity to drought, likely due to wasteful water-use strategies, increasing the risk for hydraulic failure.

The work in this thesis improves our understanding on thermal acclimation capacities of tropical trees and species differences in the susceptibility to heat and drought. It shows a generally lower acclimation capacity of tropical trees compared to trees from other biomes and contrasting heat and drought sensitivity in ES and LS species. This is valuable information for models predicting the future of tropical forests under climate change. If the interspecific differences in climate sensitivity observed here lead to corresponding shifts in tree community composition, this would greatly impact the carbon storage and biodiversity of this biome.

Keywords

acclimation, African tropical forest, chlorophyll fluorescence, climate change, drought, hydraulic, montane, photosynthesis, respiration, successional strategies, temperature, tropical trees, warming