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Responses of *Acacia tortilis* and *Acacia xanthophloea* to seasonal changes in soil water availability in the savanna region of Kenya

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Abstract

Comparative field studies were conducted on *Acacia tortilis* (Forsk.) Hyne and *Acacia xanthophloea* Benth. trees growing in a semi-arid environment in Kibwezi, Kenya, to assess root access to soil water at varying soil depths and how this may affect the expression of morphological and physiological traits developed during drought. Measurements of soil water content, leaf growth, shoot elongation, sap flow in the xylem of stems and branches, leaf water potential, leaf transpiration and stomatal conductance were carried out. Further, water use efficiency (WUE) over long-term periods was examined via carbon isotope discrimination ($\delta^{13}C$) on leaves. Whole tree and leaf specific hydraulic conductance were determined from sap flux or leaf transpiration and the water potential gradient between soil (as predawn potential) and canopy, respectively.

Leaf growth and shoot elongation depended on soil water availability (SWC) and plant tissue water status. *A. xanthophloea* showed greater ($40\,kg\,d^{-1}$) water use compared to *A. tortilis* trees of comparable sizes ($20\,kg\,d^{-1}$) during favorable conditions of SWC. Decline in SWC reduced water use and the onset and rate of decline in sap flux was determined by the rooting depth. *A. xanthophloea* showed earlier response (onset at $SWC = 0.24\,m^3\,m^{-3}$) to water stress than *A. tortilis* (onset at $SWC = 0.14\,m^3\,m^{-3}$). Midday depression in stomatal conductance and subsequent decline in transpiration during favorable SWC as observed in *A.*

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xanthophloea was attributed to increased hydraulic resistance and stomatal closure. Rooting patterns and root characteristics could account for the observed morphological and physiological differences between *A. tortilis* and *A. xanthophloea* as well as between small and large *A. tortilis* trees. However, seasonal responses were modified by species-inherent characteristics, which are expressed during drought. Access to deeper soil water resources and the abilities of trees to extract and efficiently transport water may explain differences in drought resistance among species and tree distribution in the arid savanna.

Keywords: Acacia; $\delta^{13}C$; Hydraulic conductance; Savanna; Soil water content; Stomatal conductance; Transpiration

1. Introduction

Savanna ecosystems are subject to alternating wet and dry seasons and occupy 65% of Africa, 60% of Australia and 45% of South America. Most of these areas receive rainfall amounts between 150 and 500 mm yr^{-1}, falling within relatively short time period and the ratio of precipitation to potential evaporation (PET) ranges from 0.05 to 0.65 (Tinley, 1982). Such areas are classified as arid and semi-arid lands (ASAL) (Walker and Noy-Meir, 1982) and are considered to experience varying degrees of heat and water stress (Mauat and McGinty, 1998), limiting the establishment, growth and distribution of trees (Kramer, 1980). Analysis of arid and semi-arid areas of Africa show potentially large losses of plant species diversity, with low landscape heterogeneity as a result of climate and land-use changes, over-exploitation and lack of tree regeneration (Rutherford et al., 1999; Climate change, 2001), leading to serious land degradation (Burley, 1982). In Kenya, ASAL occupy about 38 million ha or 60% of the total land area, most of which is under great pressure from extended drought, sedentarization of pastoralists and migration of people into these fragile ecosystems (Government of Kenya (GOK), 1986). The annual loss of woody vegetation in the Kenyan drylands currently stands at ca. 19,000 ha. This loss of forest cover and other types of woody vegetation will lead to increasing scarcity of a wide range of forest products, environmental degradation and loss of biodiversity, unless urgent measures are taken to address the situation. This calls for new hypotheses that clearly define ecosystem interactions and can predict the extent and nature of ecosystem changes and plant species geographical shifts in the event of increased drought and changes in land-use systems. Such studies must be broad-based and aimed at designing adaptive and mitigating strategies with respect to ecosystem management, biodiversity conservation and vulnerability to stress.

Soil water availability (SWC) is recognized as a key factor determining tree growth and activity, species composition and distribution as well as ecosystem functioning and long-term water, carbon and nutrient balances in the ASAL (Noy-Meir, 1973; Walker and Noy-Meir, 1982; Ehleringer, 1994; Reynolds et al., 2004). Soil moisture recharge in the ASAL is mainly through rainfall, yet precipitation in these regions