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Field studies on the ecological strategies of *Prosopis juliflora* in a dryland ecosystem 1. A leaf gas exchange approach

M.A. Elfadl*, O. Luukkanen

Viikki Tropical Resources Institute, P.O. Box 27, 00014 University of Helsinki, Finland

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Abstract

The diurnal patterns of gas exchange were measured for *Prosopis juliflora* trees grown under dryland conditions in the Sudan. Our objective was to characterize some of the physiological traits of this species to gain more insight into its ecophysiological characteristics, which may in turn contribute to the improvement of management practices. Maximum photosynthetic rates, obtained early in the morning, peaked at 17.6 $\mu mol\, m^{-2}\, s^{-1}$. Maximum transpiration was 102.4 $mg\, m^{-2}\, s^{-1}$, which corresponded to a maximum stomatal conductance of 0.555 $mmol\, m^{-2}\, s^{-1}$. A marked decrease in photosynthesis was observed before midday together with a reduction in stomatal conductance and transpiration rate. However, water loss was initially high in early morning, continuing throughout the day at a decreasing rate. The decline in photosynthesis was mainly the result of non-stomatal limitations since the percentage decrease in photosynthesis is larger than that of stomatal conductance. These limitations on photosynthetic activity are likely to have been induced by intensive solar radiation and high temperature and enhanced by the increasing vapour pressure deficit. Stomata were open during the morning to maximize productivity in the favourable period, gradually starting to close towards midday. Stomata did, however, remain slightly open throughout the brief adverse conditions of midday to allow transpiration to protect the photosynthetic apparatus. Results suggest that *Prosopis juliflora* is aggressively invasive only in areas with an abundant supply of water.

Keywords: *Prosopis juliflora*; Ecophysiology; Adaptation; Dryland; Sudan

*Corresponding author. Tel.: +358 9 191 58619; fax: +358 9 191 58646.
E-mail address: mohamed.elfadl@helsinki.fi (M.A. Elfadl).

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1. Introduction

In the natural dryland environment, trees are frequently subjected to seasonal water stress, which limits their growth and development. Trees differ markedly in their ability to withstand desiccation and have evolved complex mechanisms to cope with various environmental stresses including drought. Plants respond to drought through changes in morphological, physiological, biochemical and metabolic processes that are collectively termed drought resistance mechanisms.

Many gas exchange features of trees in temperate and Mediterranean climates have been reported in association with natural prevailing stress conditions such as inadequate irradiance and low temperature (Tenhunen et al., 1987; Somersalo and Krause, 1989; Breda et al., 1993; Leitsch et al., 1994). In drylands it has been established that water scarcity is the main factor limiting productivity, and many studies have focussed only on morphological and physiological adaptations to drought (Kozlowski, 1981; Abrams, 1990; Henskens et al., 2001). Previous reviews have speculated that the combined effect of these stresses may inhibit photosynthesis, possibly leading to destruction of the photosynthetic apparatus (Long et al., 1994; Horton et al., 1996).

Several *Prosopis* species have been widely introduced and naturalized in many arid and semi-arid areas of the world. They are drought-resistant, fast-growing and nitrogen-fixing species that are able to grow in harsh conditions where native species fail to grow (Pasiecznik et al., 2001). *Prosopis juliflora* was introduced to the Sudan in 1917, mainly for afforestation to combat desertification and to provide fuel wood. Eighty years after the species introduction, the Sudan government and local people alike viewed *Prosopis* as a noxious and problematic tree because of its aggressive invasive ability, especially on irrigated agricultural fields. *Prosopis* was subsequently deemed unsuitable, and on 26 February 1995, a ministerial decree for its eradication was issued, followed by a national eradication campaign.

In growing recognition of the concern of local communities and the divergent opinions about *Prosopis*, the last 10 years have witnessed several meetings and workshops aimed at analysing the situation objectively (VITRI, 2000; FNC, 2003). However, these debates have largely involved researchers, managers, politicians, non-governmental organizations (NGOs) and grass-root populations. No consensus has been reached, and the *Prosopis* problem is increasingly becoming a priority on the political agenda.

Despite the potential expansion of *Prosopis juliflora* as a crop for the drylands of the Sudan (Elfadl, 1997), limited data are available on the physiological characteristics underlying its drought resistance mechanism(s). To our knowledge, no studies have specifically addressed the gas exchange characteristics of *Prosopis juliflora* under field conditions of excessive light, high temperature and water stress. Here, we investigated the gas exchange characteristics of this tree species to provide insights into the ecophysiological traits enabling it to increase in abundance and become invasive in pastoral and irrigated fields in many regions of the Sudan. The implications of these traits are indicated in the concluding remarks of the paper.

2. Materials and methods

2.1. Research site and species

Investigations were conducted during August 1994 at a prosopis plantation (625 trees ha^{-1}) near the Umdamir village, Tendelti, Sudan (13°15′N, 32°15′E). Individual trees