Leaf age effects on intrinsic water-use efficiency of Jatropha curcas

Rajaona A., Asch F., Brueck H.
University of Hohenheim, Department of Crop Production and Agroecology in the Tropics and Subtropics.
hbrueck@uni-hohenheim.de
Section: Crop Water Stress Management, Garbenstr. 13, 70593 Stuttgart, Germany]

Jatropha curcas L. (Physic nut) is a drought-resistant shrub belonging to the family Euphorbiaceae. It is increasingly cultivated in Central and South America, South-East Asia, India and Africa for biofuel production and claimed to grow profitably on marginal or degraded land in arid and semi arid zones with annual rainfall of 300-1000 mm. While yield and physical properties of the oil have been assessed in several studies, nutrient and water demand of Physic nut are not well characterized, adaptation of Jatropha to grow on marginal land implying efficient use of scarce resources such as water and nutrients (Jongschaap et al., 2007). Taking marginal sites as one of the dominant target environments in which Jatropha will be cultivated, an improved understanding of leaf activity and resource use is required. Water scarcity is one of the major growth constraints on these sites and water availability has been proved to have positive effects on plant growth (Wu et al., 2009). The assessment of carbon gain versus water loss on the field scale can be complemented by measurements of instantaneous water-use efficiency at the leaf level. Leaf activity varies according to leaf age and the microclimate and the response of both factors in terms of gas exchange needs to be parameterized. This information can be combined with detailed information about canopy size and dynamics on a Jatropha plantation in Fenoarivo, South-West Madagascar.

Materials and Methods

Plants were cultivated in pots and leaf area development and gas exchange of leaves were regularly monitored. Leaf area development was described by sigmodial growth curves and these information was used to define 4 age classes (1: young, 2 and 3: expanding, 4: fully expanded). Leaf gas exchange was measured on irrigated and droughted plants. Additionally to this greenhouse study a field experiment aims at quantifying leaf area dynamics of a 3-year old Jatropha plantation on lateritic soil with a planting density of 1.250 plants / ha in Fenoarivo, SW Madagascar. Leaf area dynamics are monitored with hemi-view canopy system and 3-D arrangement of twigs with image analysis software. Irrigation scheduling according to ETo was imposed on half of the plants in order to investigate water supply effects on leaf area as compared to rainfed conditions.

Results and discussions

Results from the greenhouse study indicate that instantaneous WUE (A/E and A/gs) of young leaves was lower in droughted than irrigated plants. Inversely, droughted fully-expanded leaves had a higher WUE than well-watered plants (Fig. 1). CO2 assimilation rate (A), transpiration rate (E) and stomatal conductance (gs) of expanding irrigated and droughted leaves were significantly higher than those of the young and fully expanded leaves. Instantaneous water-use efficiency was interactively affected by leaf age and water supply level: A/E of expanding leaves was higher than that of fully-expanded irrigated leaves. Conversely, A/E of young droughted leaves was lower than that of other age classes and A/gs of mature leaves was significantly higher than that of expanding leaves.

A constant instantaneous WUE over the life span of leaves indicates that regulation of gs is effective in terms of assimilatory capacity. Constancy of WUE over leaf developmental stages has been shown (Field and Mooney, 1983), however effective regulation of gs may not occur in all plant species and under all environmental (stress) conditions. E.g., a decline of intrinsic WUE (A/gs) with leaf age has been shown by

Escudero and Mediavilla (2003) in two out of nine tree species. A higher A/E of expanding leaves compared to young and old leaves has been illustrated by Wullschleger and Oosterhuis (1989) in cotton. Our results point in the same direction indicating that stomatal control matching the assimilatory capacity is not realized throughout the life span of leaves. Notably, regulation of WUE of different leaf age classes is different under drought and irrigated conditions. These data from greenhouse studies will be complemented with field data which are collected in the ongoing field experiment (data in preparation).

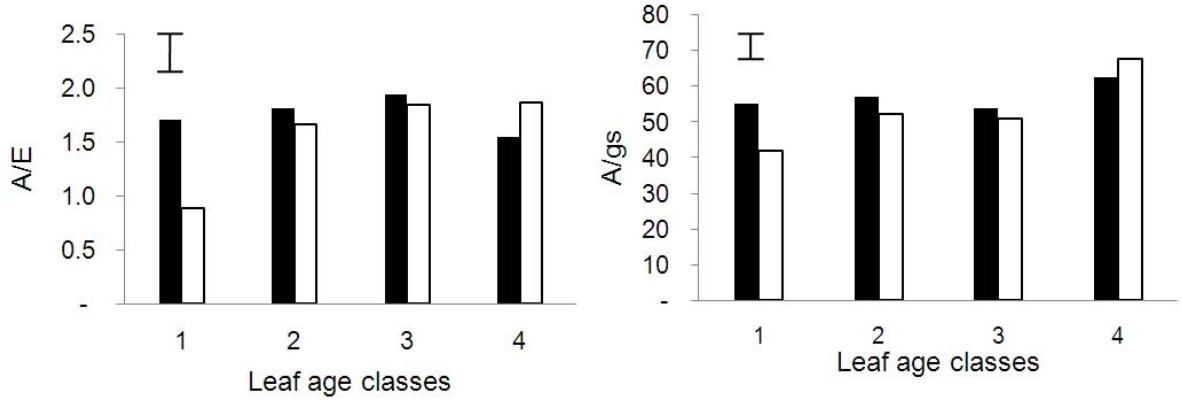

Figure 1: Intrinsic WUE (A/gs), WUE expressed as ratio of net photosynthesis to transpiration (A/E) of leaf age classes as affected by water treatment (irrigated: black; droughted: unfilled).

Effects of leaf age and water supply indicate that stomatal conductance is not regulated in a way to fully adjust to assimilatory capacity of Jatropha leaves. This information should be considered in approaches which aim at quantifying leaf activity of field-grown bushes which are characterized by spatially highly divers conditions in terms of microclimatic parameters.

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