Eco-physiological studies of tamarind (*Tamarindus indica* L.) in tropical arid environment

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The present work was conducted with the aim to improve wild underutilized fruit-bearing tree species. In tropical ecosystems, wild fruit trees play multiple roles in biodiversity conservation and guaranteeing food security besides income generation through marketing of fruits and other byproducts.

The present study involved characterization of some eco-physiological characteristics of tamarind (*Tamarindus indica* L.) in tropical arid environments. Its purpose was to (1) understand the strategies behind the water management mechanisms of T. *indica*; and (2) characterize the mycorrhizal diversity of the rhizosphere associated with tamarind *in situ*, in three agro-ecological zones of Senegal, besides understanding its ecology. Four specific objectives were associated with this study: (1) identification of the climatic factors determining the distribution of tamarind trees; (2) assessment of in situ mycorrhizal diversity associated with wild tamarinds stands in Senegal; (3) evaluation of the effects of mycorrhizal inoculation on a number of morphological and physiological parameters of different tamarind ecotypes from Senegal; and (4) characterization of mechanisms of water management of tamarind trees *in situ*.

To achieve these objectives, field work was conducted from May 2009 to September 2010 during which the water and tamarind plant relationships were characterized (Chapter 6). This was done *in situ* in two sites: one in Sahel zone (Niokhoul) and the second in the Sudano-Sahelian zone (Mbassis). At each site, three T. *indica* specimens were chosen (based on their DBH) for investigation. An experimental design was implemented to characterize the response of tamarind trees to water and climate over time. Experimental trials were also conducted in the greenhouse and laboratory from February 2007 to April 2010 using a factorial design with two factors (two mycorhizae species and three tamarind ecotypes from the three agro-ecological zones of Senegal) in two water regime status (stressed and irrigated plants) with the aim to characterize their effects on physiological parameters and growth. Another experiment was carried out in the greenhouse on the soil taken from the tamarind tree areas, within each agro-ecological zone to identify the mycorhizae associated with tamarind and to characterize the level of mycorhizal dependence of tamarind trees *in situ* (Chapter 4 and 5). Finally, the current stand of tamarind population was evaluated using the transect method to predict its projected distribution based on climatic parameters using MAXENT model (Chapter 3).

The following were basic findings of this study:

- Avoidance is the main physiological mechanism of tamarind in its adaptation to water stress. When tamarind faces drought stress, it shows a decrease in water potential in a range of -3 to -3.5 MPa. In case of severe and prolonged drought, there was reduction of leaf transpiration marked by leaf drop that can be moderate (less than 50%) or complete (more than 80% drop of the total leaf volume from a single tree). Daily water consumption of tamarind was estimated to vary between 0.3 to 0.6 $mm.d^{-1}$ (during the hot dry season) and from 3.2 to 6.9 $mm.d^{-1}$ during the rainy season. Moreover, we found that tamarind has a good (70-80%) physiological plasticity (capacity to regain an equilibrium water status). Physiological plasticity decreases with the onset of drought (cold dry season).

- Three types of arbuscular mycorrhizal fungi (*Acaulospora* spp., *Glomus* spp. and *Scutellospora* spp.) were found associated with tamarind (*T. indica*). These results indicate that T. *indica* has a wide spectrum of mycorrhizal association. Gradient of mycorhisation frequency of trees was observed following the north (Sahel)/south (Sudan) axis. Frequency of trees mycorhisation was around 11.17% in the Sahel region which was significantly higher than that of the Sudano-Sahel zone (5.72%) and the Sudan (3.85%). In controlled environments and in the seedling stage, results did not show significant differences in responses to mycorrhizal inoculation (*Glomus mosseae, G. aggregatum*) between ecotypes/provenances of tamarind within different agro-ecological zones of Senegal. Moreover, we noted significant differences ($P < 0.05$) for morphological variables (root collar diameter and plant height) and eco-physiological parameters (net photosynthesis, stomatal conductance and water use efficiency) between inoculated plants and controls. The latter results clearly indicate that (i) tamarind growth is enhanced by the presence of mycorrhizal fungi of the genus *Glomus* and (ii) mycorrhizal associations contributed significantly to improve tolerance of tamarind to drought stress.

- Results of the MAXENT model have shown that seasonal variations in air temperature, maximum temperature of the warmest month, precipitation during the wettest month and precipitation during the wettest quarter, were the most important climatic variables in explaining the actual distribution of tamarind in Senegal. The maximum temperature for the development of tamarind was found to be around 40°C, beyond which development of T. *indica* is highly affected. Future projections (2020, 2050 and 2080) show a significant reduction in the optimum area of development of tamarind in Senegal. An almost total disappearance of the potential area for the development of tamarind was predicted for Senegal by 2080. Causes for the latter are debatable and variable: anthropogenic (uses of wood inducing high pressure on the species) and climatic (by 2100, temperature is predicted to rise by 2° to 6°C in West Africa).

Adult tamarind tree