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Environmental effects on morphology of *Acacia tortilis* group in the Red Sea Hills, North-Eastern Sudan and South-Eastern Egypt

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Abstract

Acacia tortilis is a drought-resistant species. Its survival and existence in the arid and semi-arid area of Northern Africa and Arabian Peninsula is due to its ability to endure the harsh condition and therefore, it is generally forms open pure stands or mixed stands in these drylands. Wherever it grows, it plays an important role in human, animal and other plant species lives. Yet the relation between its adaptive features and their relation to the environmental conditions is not studied in a large scale of environmental variation. The main objective of this study is therefore to examine if the immediate environmental factors, other than human utilization, are associated to the expressed morphological variables among the *A. tortilis* sub-taxa. Three subspecies are collectively reported in the study area, Red Sea Hills of Sudan and Egypt. According to different literatures, they are distinguished by features of high plasticity under the variable pressure of human activity and climate. Such features are hair density in some parts of the plant, crown shape and number of stems. In the current study, the result of analysing 520 samples of *A. tortilis* – collected from 25 different localities representing various altitudinal gradients – showed a correlation between the expressed morphological studied and the immediate environment. When data from both regions studied as one data set, elevation, above sea level, was the only significant response variable and higher hair density was associated to plants growing in Sudan. However, when only data from Sudan was studied separately, elevation, hillside and lower part of the catchment were the statistically significant response variables. In the Egyptian data set, the statistically significant response variables were elevation, khor bank and the upper, mid, and lower part of the catchment. An intra-morphological correlation was also shown. These results may suggest that the current *A. tortilis* sub-taxa are ecotype. Genetic and anthropogenic studies are needed to verify this assumption.

Keywords: *Acacia tortilis*; Red Sea Hills; Arid land; Intra-species morphological correlation; Species morphological–environmental correlation

1. Introduction

Trees of African dry lands are not only adapted to high temperature variation and long droughts (Baumer, 1983), extremely low rainfall, high moisture variability and high potential evapotranspiration (Thornthwaite, 1948) but also to intense use by desert dwellers in form of animal browsing, coppice and logging (Krzywinski and Pierce, 2001). *Acacia tortilis* Forssk (Hayne) is one of the most common arboreal species in arid and semi-arid regions across Northern Africa and the Arabian Peninsula (Wickens, 1998; Kassas, 1957; Badi et al., 1989; Manger and Abd ElAti, 1996; Andersen, 1999; Shaltout, 2002). *A. tortilis* is drought resistant, can tolerate strong salinity and seasonal waterlogging and generally forms open forests in pure stands or mixed stands in these drylands. It is also adapted to an environment with little and unreliable rainfall (Ayyad and Ghabbour, 1985) and under these constraints, it is as well adapted to anthropogenic pressures as it is the sole source of animal fodder, firewood and shelter for nomads. Combined pressures and their variation are reflected in its growth forms.

An increasing and pronounced reduction in *A. tortilis* density is reported (Ward and Rohner, 1997; Kennenni, 1990; Andersen, 1999). In the Red Sea Hills of Egypt and Sudan, the combination of climatic and anthropogenic factors, especially charcoal production, is reported to play a key role in this decline in numbers (Alstad, 1991; Christensen, 1998; Krzywinski and Pierce, 2001).

The taxonomy of the subspecies of *A. tortilis* has been considered a puzzle (Brenan, 1957, 1983; Shrestha et al., 2002); http://www.worldagroforestry.org/Sites/TreeDBS/TSSD/synonyms.cfm?sname=Acacia%20tortilis20.05.2005). The morphological features used to separate sub-taxa in the *A. tortilis* complex are largely overlapping and the taxa display

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high phenotypic plasticity (Brenan, 1957, 1983; El Amin, 1973, 1976, 1990; Täckholm, 1974; Ross, 1979; El Houri, 1982; Kordofani, 1989; Kordofani and Ingrouille, 1992). However, the morphological characters may very well be phenotypic expressions of ecological factors (both biotic and abiotic). For example in arid land, the degree of hair density on certain parts of the plant, regulating evapotranspiration (Stebbins, 1952) and radiation budget (Rozema et al., 1997), and the crown shape, may have been altered by browsing, coppicing and age (Kennenni and Vandermaarel, 1990) and the number of trunks, which can be a result of animal browsing at saplings stage or chopping of trunks for wood.

The rate of speciation is dependent on geographical and ecological variables; therefore, ecological opportunity is the key to speciation and invasion (Levin, 2003). However, since morphological features are highly affected by ecological factors such as climate as well as by human and animal utilization, this may lead to a poor taxonomy when evaluation for speciation is dependent only on characters highly subjected to change. It is characteristic of vegetation patterns in arid landscapes to exhibit a high temporal and spatial variation in growth dependent upon ecological variation in particular soil moisture. The expressed variability in morphology can therefore either be due to environmental or genetic factors. The main objective of the current study is therefore to examine the influence of environmental variables, and spatial variation, on the expressed morphology of *A. tortilis* in the Red Sea Hills in North-Eastern Sudan and South-Eastern Egypt.

2. Materials and method

2.1. Description of the study area

The landscape of the Red Sea Hills can be divided into units defined by climate, geology, and geomorphology (Babiker, 2004). Among these units are the seasonal watercourses (locally are known as khors or wadis), and it is mainly along the flood plains where perennial vegetation occurs. The study area covers two major regions, North-Eastern Sudan (between 18° 40 and 19° 11N latitude and 35° 54 and 37° 5E longitude) and South-Eastern Egypt (between 24° 9N and 25° 5N latitude and 33° 58E and 35° 3E) (Fig. 1). Due to the prevalent climatic conditions, mainly low precipitation and high evapotranspiration, the region can be classified according to the aridity index as arid land (Thornthwaite, 1948). The Egyptian localities fall within the range of hyper arid deserts while the Sudanese localities are in this context less arid (Goldman et al., 1968) (Fig. 2). These climatic conditions in the Red Sea Hills are a product of (1) location within the tropical zone; (2) the presence of the Red Sea as an adjacent body of water, and (3) the Red Sea Hills as an effective physical barrier (El Tom, 1991). The distribution of the available surface and subsurface water resources is governed by the drainage system of the khors/wadis.

The northern (Egyptian) localities therefore experience less frequent summer rain and less influence of orographic rain from the sea than the southern (Sudanese) localities. The high

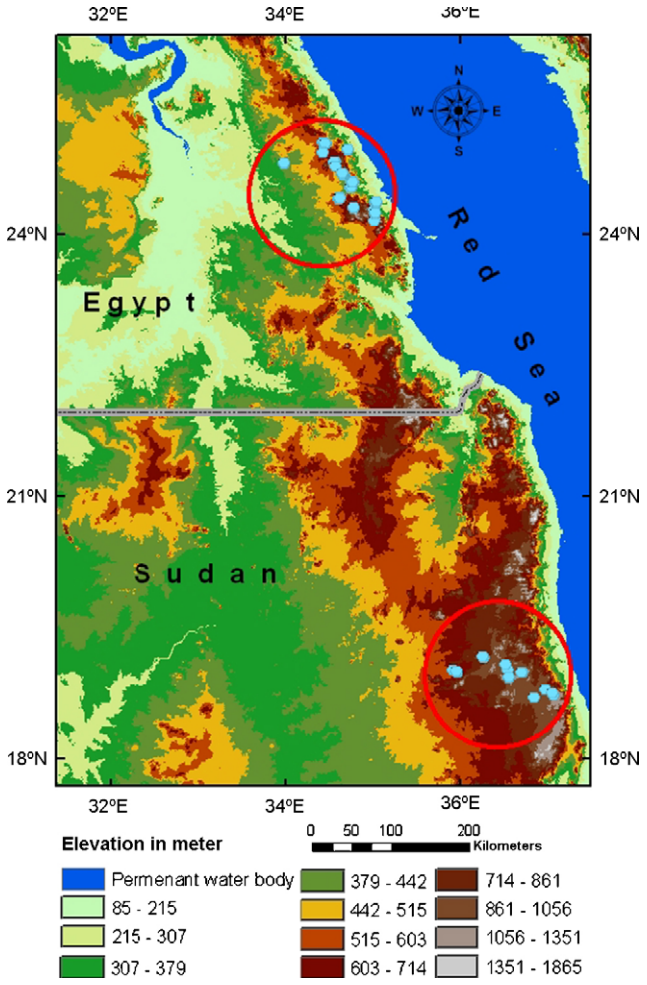

Fig. 1. Map showing the location of the study area, the two main regions are indicated by red circles, based on digital elevation model. Blue dots indicate the various localities studied. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

mountains and plateaus in the south act as an effective barrier to climatic influence of air masses from either side of the watershed. This effect is however in places modified by lower altitude mountain passes that created corridors.

2.2. Localities studied and samples collection

In each of the two major regions a number of localities were selected from either upper, middle or lower in the part of the *khor/wadi* (Fig. 3A). A total of 33 localities in the Red Sea Hills in Sudan and Egypt were examined in the period from February to April 2003 (February and March in Egypt and April in Sudan). Of these, 25 were selected for closer study within the frame of reference of this paper to cover the growth of *A. tortilis* along khors/wadis. The elevations in meters above sea level (m.a.s.l.) range from 1079 (Upper Amat in Sudan) to 216 (Wadi Abu Ghusun in Egypt). Sudanese localities were located at higher altitude than those in Egypt. The stated elevations are averages of the elevations of the plant samples in each locality extracted from the free downloaded Digital Elevation Model, source http://seamless.usgs.gov/, using ArcGis version 9.0.1