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Inventory and geographical distribution of *Acacia* Mill. (Fabaceae Mimosaceae) species in Algeria

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ABSTRACT The geographical distribution of the genus *Acacia* Mill. (Fabales Mimosaceae) in Algeria was determined after the prospect, localization and description of the various species populations overall Algerian territory. Twenty-four regions were prospected, based on relative species abundance. Among the ten-species found in Algeria, only *A. karroo* and *A. saligna* can be found in the whole country. However, there are some concentrations in certain northern regions. *Acacia decurrens* was only found in the Northeast, with high concentrations at the National Park of El Kala. Five of them are recorded in the southwest (*A. albida*, *A. ehrenbergiana*, *A. nilotica*, *A. seyal* and *A. tortilis*). *Acacia farnesiana* is indicated in the Northeast and the Northwest. *Acacia laeta* individuals were very rare. According to the climatic data during the years 2000-2016, the following species adapted to the annual pluviometry, that is lower than 100 mm: *A. albida*, *A. ehrenbergiana*, *A. laeta*, *A. nilotica*, *A. seyal* and *A. tortilis*. Three species (*A. karroo*, *A. farnesiana* and *A. saligna*) are in zones with an annual pluviometry between 250 and 500 mm). *Acacia decurrens* is located in a zone in which the annual precipitation exceeds 1000 mm. This study shows the distribution of the *Acacia* species in Algeria.

KEY WORDS *Acacia*; Desert trees; distribution maps; aridity; Forestry.

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INTRODUCTION

The diversity of the biological resources constitutes, since a few decades, a central theme for several disciplines that conjugate their efforts, not only for its preservation, but also for its long-sustainable use. Indeed, the ligneous vegetation plays a fundamental role in the structure and the functioning of arid and semi-arid ecosystems (Mahamane & Mahamane, 2005). One of the most problems, urgent to solve today, is the restoration and reconstruction of degraded ecosystems. Reforestation of degraded landscapes can have positive effects on the ground, and allows regeneration of long-lasting ligneous communities (Cao et al., 2011).

For a successful reforestation campaign, the use of native species like some *Acacia* Mill. (Fabales Mimosaceae) trees is sometimes recommended (Foroughbakhch et al., 2001). Autochthonous species of *Acacia* are often adapted to drought, thermal and salt constraints (Fuentes-Ramírez et al., 2011; Kheloufi et al., 2016a). As such, they participate in grounds restoration and allow natural fertilization by fixing variable quantities of atmospheric nitrogen due to the association of their roots with soil microorganisms (*Rhizobium*) (Boukhatem et al., 2012). Several *Acacia* species live frequently the vegetation in arid and semi-arid lands of sub-Saharan Africa (Richardson & Kluge, 2008). They are widely known and used by the local populations as forage legumes (Abdulrazak et al., 2000). The productivity and the stability of these forest ecosystems with *Acacia* trees are strongly dependent on water availability. Indeed, species of the genus *Acacia* are not very resistant to drought constraint in spite of their presence in arid and semi-arid circles (Gimeno et al., 2010). Most of them are drought-avoiding species. Their survival in these circles is especially due to the water uptake efficiency of their root systems. Salinity constraint can also be added to water deficit and can affect *Acacia* species from germination to the first stages of growth (Kheloufi et al., 2016a).

Recently, several works were undertaken for a better understanding of the *Acacia* species, which could allow a good plan for a fast and permanent reforestation in the regions where the grounds degradation expanded in Algeria (Mansouri, 2011; Kheloufi, 2017; Kheloufi et al., 2017). However, in spite of these species that are often used to explain certain ecological and physiological characteristics of the environment, very few works were interested in their real or potential distribution area in Algeria.

The cartography of areas occupied by various species can be made either on the basis collected data, or by compiling bibliographical data or collections of herbarium. The realization of maps in this work represents a contribution to *Acacia* species distribution in Algeria to fill potential knowledge gaps in this domain. Furthermore, a synthesis of various taxonomic names with a historical reference table was established to eliminate any confusion in the study of a defined species belonging to this genus.

MATERIAL AND METHODS

Study site

Algeria is riddled with a multitude of reliefs. The North is crossed from West to East by a double mountainous barrier (Tell Atlas and Saharan Atlas). The ground is covered with numerous forests in the center, with vast plains in the East and the Sahara, which represents 84% of the national territory. Algeria is located in North Africa, between the latitudes 37°4’ N and 18°58’ N and the longitudes 8°40’ W and 11°59’ E. Algeria is the largest country in Africa by area, which extends over 2,381.741 km^2. It is administratively divided into 48 regions.

Distribution maps

The realization of the real and potential distribution maps was based only on ground observations made over all the national territory. We did not consider herbarium collections because a valuable information was missing (Population characteristics where plant samples were collected). The method used for mapping species distributions corresponds to the real distribution area. Georeferenced distribution maps were realized by GIS software (ArcGIS 10.3). Moreover, we consider the data collected from the Forests Department and the National Parks, National Forest Research Institute (2013–2016). Geographical positions were recorded using a Magellan eXplorist 200 GPS Receiver.

Field data collection and inspection collect

Twenty-four regions were the object of diverse observations on the *Acacia* species distribution. The most important criterion in the choice of sites is the presence of one of the ten studied species. Every site is located at first with the GPS Receiver (Elevation, Latitudes and Longitudes). On every site, the global average mean surface was 10 000 m^2 (100 m×100 m), according to the recommendations of Küchler & Zonneveld (1988) for dry lands. The scale held to indicate the presence of every species was (> 50 individuals by 10 000 m^2).

The reserved environmental factors vary according to a climatic gradient from North to South of the country. The climate is the most important environmental factor influencing forest growth and species distribution (Guisan & Thuiller, 2005).

Aridity characterization and climatological classification

In this study, we have retained the annual mean precipitation of of 17 year-period (2000–2016), annual average temperature and elevation. Climatic data was provided by the World Climate Data: Tutiempo available on the website: www.tutiempo.net.

Aridity index of De Martonne of each habitat was calculated by the equation established by De Martonne (1926), and this index allowed the species to be classified according to the aridity of their respective habitats. This classification was used in the presentation of the results.

$$\mathrm{IM} = \frac{\mathrm{P}}{\mathrm{T} + 10}$$

IM = De Martonne Aridity Index

P = Annual average rainfall in mm.

T = Annual average temperature in degrees centigrade.

RESULTS AND DISCUSSION

Distribution by Climate

Algeria's geographical diversity produces a range of climatic conditions. The northern part of the country has a Mediterranean climate with mild, wet winters and hot, dry summers. The plateau region has a semi-arid climate, with greater contrasts between summer and winter. Temperatures vary the most in the Sahara desert region, which has an arid climate with almost no annual rainfall. Summer temperatures average about 25°C in the northern coastal region, 27°C in the plateau, and 34°C in the desert, where readings as high as 49°C have been recorded. Average winter temperatures range from about 5°C on the plateau to about 11°C in the north; winter lows in the desert can plummet to as low as -10°C. The hot, dusty wind known as the Sirocco often blows in the summer.

The Algerian ground seems accommodating an interesting species diversity of *Acacia* genus with rustic character, which survive in extreme pedoclimatic conditions and which would be good to rehabilitate and to introduce into reforestation programs. The species listed during the site prospecting were: *A. albida*, *A. laeta*, *A. ehrenbergiana*, *A. nilotica*, *A. seyal* and *A. tortilis*, considered as native species (Ozenda, 1977), while those introduced were: *A. farnesiana*, native of America (Berhaut, 1975), *A. karroo*, native of South Africa (Palmer & Pitman, 1972) and finally *A. saligna* and *A. decurrens* both native of Australia (Auld, 1983). Average annual precipitation, minimal and maximal temperatures (2000–2016), and site elevation are shown in Table 1.

According to the Aridity index of De Martonne (Figure 11) and the bioclimatic classification of Algeria, which spread out over a 17-year period (2000–2016) (Table 1), *A. albida*, *A. ehrenbergiana*, *A. laeta*, *A. nilotica*, *A. seyal* and *A. tortilis* are listed in Saharan regions (precipitation < 100 mm), *A. farnesiana* is listed in dry regions (precipitation between 100–300 mm), *A. karroo* and *A. saligna* were found in high numbers in semi-arid regions (precipitation ranges between 300-600 mm), and finally *A. decurrens* is listed only in a region with humid Mediterranean climate (precipitation > 1000 mm). The drought undergone by plants can thus differ significantly from the aridity index.

The knowledge of temperature averages can influence the distribution areas as well as the reforestation programs because it determines the choice of forest species used according to their resistance or not in the extreme temperatures. However, these data do not reflect exactly the weather conditions of the sites, knowing that the climatic data are recorded in meteorological stations located in very precise places. We can suppose that there are differences in temperature with various places because the regions have important surfaces. However, these

Acacia Species	Average annual precipitation (mm)	Average annual temperature		Elevation (m)
		T min (°C)	T max (°C)	
A. albida	106.3	16.4	30.2	539
A. decurrens	1015.5	12.8	22.9	70
A. ehrenbergiana	49.2	16.7	31.8	709.5
A. farnesiana	257.8	13.3	26.6	274.5
A. karroo	386.3	11.6	23.7	713.5
A. laeta	94.2	15.7	29.7	1170
A. nilotica	80.7	16.7	31.2	466.5
A. saligna	499.3	12.3	24.1	446.7
A. seyal	125.4	16.4	29.4	609
A. tortilis	73.9	16.3	31.0	645.5
Mean (24 regions)	268.9	14.9	28.1	564.4
SEM	218.9	1.8	2.9	205.1

Table 1. Mean values and standard error of climatic factors and site elevation where the species is present.

observations remain a good indication of weather conditions on the various sites.

Distribution by region and biological characteristics

The distribution areas of *Acacia* species are represented according to a North-South climatic gradient and always in the territorial limits of Algeria (Figs. 1–10 and Figs. 12–16). Except of *A. karroo*, species distribution of *A. albida*, *A. ehrenbergiana*, *A. laeta*, *A. nilotica*, *A. seyal* and *A. tortilis* do not seem to cross the North of Algeria. However, the lack of data on this observation does not allow to confirm with certainty this hypothesis.

According to the morphology of *Acacia* species listed in Algeria, there are three groups of species. In the first group, they are the thorny with compound leaves (*A. albida*, *A. ehrenbergiana*, *A. farnesiana*, *A. karroo*, *A. laeta*, *A. nilotica*, *A. seyal* and *A. tortilis*). The second regroups with *A. decurrens*, which is not a thorny tree, but has compound leaves. The last group is represented by *A. saligna*, which is not a thorny species, but has phyllodes (petiole or rachis modified into a leaf). These morphological characters confer an adaptation for every species to its environment.

Table 2 represents a synthesis of various taxonomic names with a historical reference of every species listed in our study. It is a bibliographical synthesis of certain works which handle the ligneous species and their systematics through time.

Biological characteristics of the various species were based on observations, bibliographical research and comparisons between the listed species.

Acacia albida Delile, 1813

Acacia albida is a multipurpose tree widely distributed in semi-arid regions (Fig. 1). The most remarkable distinctive character of this species is its reverse phenology. Leafed in dry season, defoliated in rainy season (Wood, 1992). The simple observation of leafing trees, flowering or fruiting, reveals a great variability within the same population. *Acaciua albida* is a species with high ecologic plasticity, as it thrives on almost any type of soil but is most frequently found growing on rocky, muddy, or sandy substrate. The popular medicine or the family pharmacy also revealed a very interesting advantage of this species in the treatment of bronchopulmonary infections, head troubles, high blood pressure, and malaria (Sheded et al., 2006).

Acacia decurrens Willd., 1806

This species is one of the most represented in the northeast of Algeria, with much more populations concentrated in El-Kala's National Park (Fig. 3). *Acacia decurrens* is a Mediterranean Basin species. It is a fast-growing tree with well-developed vegetation (Kheloufi et al., 2016a).

Acacia ehrenbergiana Hayne, 1827

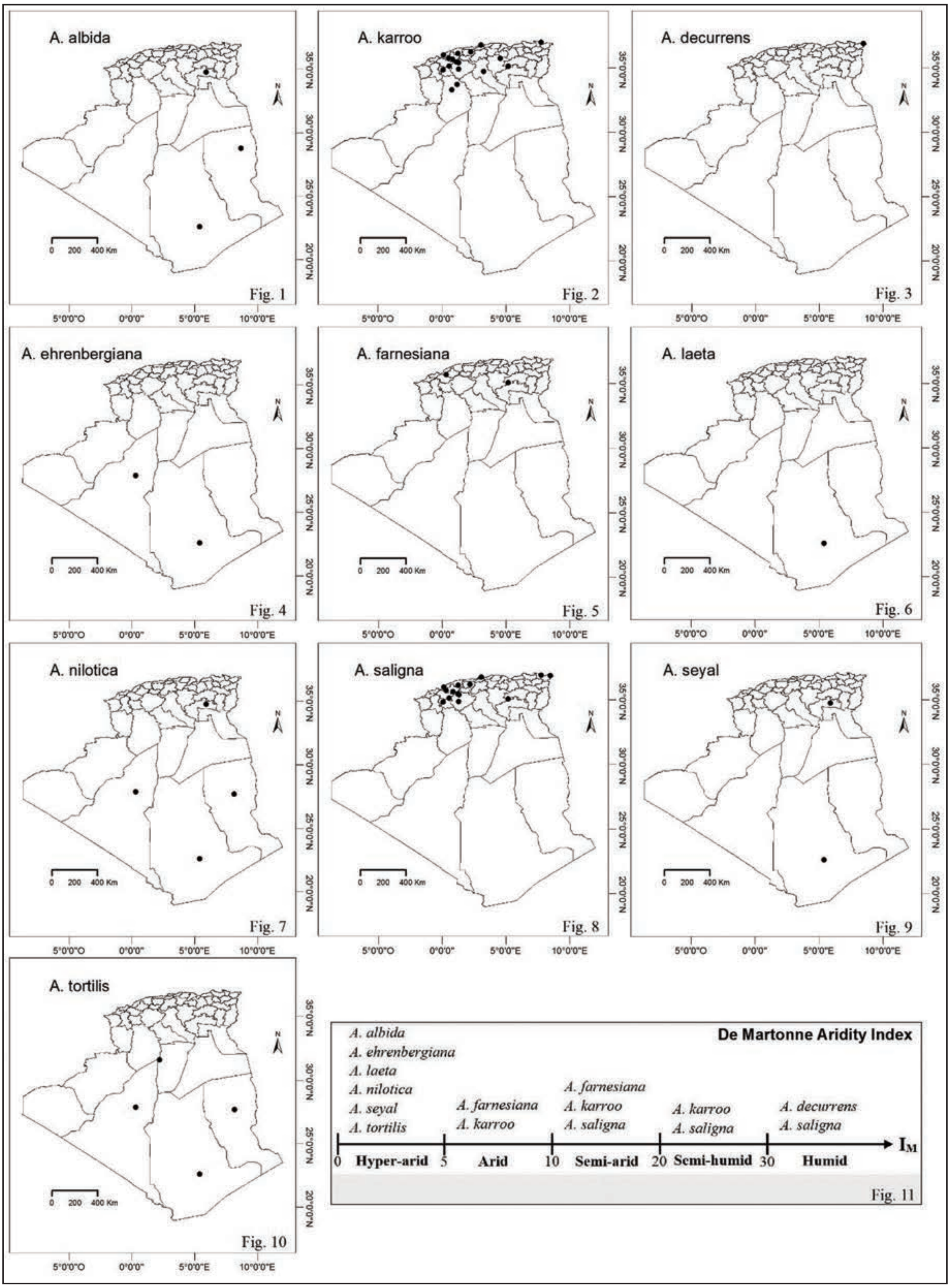
This species was found on clayey, rocky, and sandy soil in the dry zones. By exploiting the data sources, it has been showed that *A. ehrenbergiana* was located only in two places (Adrar and Tamanrasset) along water courses (Fig. 4).

Acacaia farnesiana (L.) Willd., 1806

Acacia farnesiana is native to tropical America (Traveset, 1990). It was introduced in all the tropical regions where it has often naturalized. It is considered as pantropical today. This shrub is very ramified with grey-brown bark, its abundant branches are armed with strong thorns (Prickles). The straight and white thorns are 1.5 to 5 cm in length. *A. farnesiana* is a drought-tolerant mimosa, but not cold-tolerant (Maldonado-Magaña et al., 2011). It is listed only in two specific zones, in Relizane to prevent soil erosion of the national road, and Batna (M'doukel) to combat desertification by dune fixing (Fig. 5).

Acacia karroo Hayne, 1827

It is one of the fastest of the fast-growing trees which takes place at the second position after *A. saligna*. Leaves are composed by many leaflets. Branches are armed with very long sharp thorns. This tree is a reliable source of forage due to foliage, flowers and pods. The tree attracts insects by its flowers and its gum, and attracts insectivorous birds. It is a considerable source of shade in the dry regions and a site of nesting for several species of birds. The wood is hard, tough, durable and its gum is edible (Anderson & Pinto, 1980). This spe-



Figures 1–10. Geographical distributions of *Acacia* species in Algeria.
Figure 11. Classification of *Acacia* species following De Martonne Aridity Index (IM) in Algeria.

cies is listed in most of the Algerian territory and its behavior varies from an ecotype to another (Fig. 2).

Acacia laeta R. Br., 1814

It is found only in the south of the country (Fig. 6). This species colonizes almost all types of soil. *Acacia laeta* is a shrub of 4–10 m tall with fissured, grey-green bark. Prickles in pairs, claw-shaped, just below each node, recurved and sometimes with a third intermediate prickle which is curved towards the top (Anderson et al., 1968). Leaves are composed and are very characteristic with their tough aspect and their pubescence especially on the lower face.

Species	Synonymes	References
A. albida	*Acacia albida* Delile, 1813 *Faidherbia albida* (Delile) Chev., 1934	(Arbonnier, 2009)
A. decurrens	*Mimosa decurrens* Donn, 1796 *Acacia decurrens* Willd., 1806 *Acacia angulata* Desv., 1814	(Moffett & Nixon, 1974)
A. ehrenbergiana	*Acacia ehrenbergiana* Hayne, 1827 *Acacia flava* Schweinf (Forssk.) Schweinf., 1896	(Arbonnier, 2009)
A. farnesiana	*Acacaia farnesiana* (L.) Willd., 1806 *Acacia pedunculata* Willd., 1806	(Clarke et al., 1989)
A. karroo	*Acacia eburnea* sensu auct. non (L.f.)Willd.,1806 *Acacia horrida* sensu auct. non (L.) Willd., 1806 *Acacia karroo* Hayne, 1827 *Acacia natalitia* E. Mey., 1836 *Acacia inconflagrabilis* Gerstner, 1948	(Jami et al., 2012)
A. laeta	*Acacia laeta* R. Br., 1814 *Acacia trentiniani* A. Chev., 1901	(Arbonnier, 2009)
A. nilotica	*Acacia arabica* var. *tomentosa* Benth., 1842 *Acacia nilotica* subsp. *tomentosa* (Benth.)Brenan, 1957	(Arbonnier, 2009)
A. saligna	*Mimosa saligna* Labill., 1806 *Acacia saligna* (Labill.) H.L. Wendl., 1820 *Acacia cyanophylla* Lindl., 1839 *Acacia lindleyi* Meisn., 1844 *Racosperma salignum* (Labill.) Pedley, 1987	(Dhileepan et al., 2006)
A. seyal	*Acacia seyal* Delile, 1813	(Arbonnier, 2009)
A. tortilis	*Acacia raddiana* Savi, 1830 *Acacia tortilis* var. *pubescens* A. Chev., 1927 *Acacia tortilis* fo. *raddiana* (Savi) Roberty, 1948 *Acacia tortilis* var. *raddiana* (Savi) Brenan, 1957	(Arbonnier, 2009)

Table 2. Bibliographical synthesis of various taxonomic names of ten *Acacia* species listed in Algeria.

Acacia nilotica subsp. ***tomentosa*** (Benth.) Brenan, 1957

Two subspecies of *A. nilotica* (*nilotica* and *tomentosa*) are known in Algeria. They require several types of soil and occupy various distribution areas. As this study does not consider this differentiation in subspecies, the distribution is relatively uniform (Fig. 7). *Acacia nilotica* is native to dry areas of tropical Africa and western Asia (Giri et al., 2007). Leaves have a considerable nutritional value and are especially used as forage supply for ruminants (cows, sheep and goats) (Kheloufi & Mansouri, 2017). *Acacia nilotica* trees contribute to improve the soil characteristics and can be used as firewood (Lal & Khanna, 1994).

Acacia saligna (Labill.) H.L. Wendl., 1820

It is the only *Acacia* tree with phyllodes present in Algeria. Adult phyllodes change from juvenile bipinnately compound leaves to phyllodes. This species colonizes all the northern Algeria (Fig. 8). This tree tolerates a wide variety of soil (even alkaline soils) and behaves normally close to very saline soils (Sebkha, chott) and coasts. Indeed, *A. saligna* can tolerate salt spray, hot coastal sun, extreme winds and sandy soil (Mansouri, 2011). It is used for the creation of good windbreak, and it is one of the fast-growing species. The best example is the project of sand quarry reforestation in association with the selected rhizobia by Mansouri (2011) in the region of Aïn Temouchent (Northwest of Algeria). The zone is located at 2 meters of altitude and 400 meters from the coast. The 1840 planted trees of *A. saligna* develop really well this day by protecting a broad biodiversity and preventing soil erosion. This species, due to high rusticity and good adaptation, is going to be used as a pioneer species, promoting the improvement of soil fertility in short periods of time, and promoting a better development of other, more productive species.

Acacia seyal Delile, 1813

Acacia seyal is a shrub species, which grows on gravel, rocky, and sandy grounds. Branches exude generally a translucent gum. Leaves are composed by a series of opposing leaflets and have an extremely short petiole. This study re-

Figure 12. *Acacia farnesiana*, Relizane, Algeria. Figure 13. *Acacia karroo*, Oran, Algeria. Figures 14, 15. *Acacia saligna*, Aïn Temouchent, Algeria.

Figure 16. *Acacia tortilis*, Tamanrasset, Algeria.

vealed its presence in the South with another presence in the region of Biskra (Fig. 9). The height that this tree can reach is 17 meters and 60 cm in diameter at breast height. It is common in several parts of Africa, especially to the North of the equator (Menzies et al., 1996).

Acacia tortilis subsp. ***raddiana*** (Savi) Brenan, 1957

Acacia raddiana is the most common tree found in the Sahara (Coughenour & Detling, 1986). It is a symbol of the desert in northern Africa. Among all the Acacia species located in Algeria, *A. tortilis* subsp. *raddiana* is apparently the most bound to the desert (Fig. 10). It is a pioneer species of the dry ecotypes. It is a slow-growing species when compared to other *Acacia* species, and constitute a major element that allow the preservation of ecological balance and the fight against desertification (Kheloufi et al., 2016b). The various parts of the species: roots, leaves, pods, gum and bark are very useful for medical, pastoral and commercial purposes (Al-Fatimi et al., 2007). *Acacia tortilis* grows generally in rocky, muddy, and sandy grounds.

CONCLUSIONS

The aridity of a region is not only determined by the climatic factors (rainfall and temperatures), but also by other factors which are topographical relief, wind speed which affect directly the evaporation, and ecolopedological conditions. Each abiotic condition, be it mining, geographical, or pedological (rainfall, wind, nature of the soil, geographical location, altitude, etc.) is added to the influence of human activity (reforestation, deforestation) to establish a specific distribution of each plant species, in space and time. By considering this species distribution and the specific wealth, acacias establish good indicators of the ecological zones in Algeria. This good concordance is related to the quantity and to the quality of the data on one hand, and to the ecological characteristics as well as to the importance of the species population on the other hand.

The distribution maps give essential tools in the understanding of the species ecology and serve the actions of natural resources preservation. The interacting effects of environmental temperature and spatial scale on species diversity using our extensive databases on tree distributions divided Algeria in two large separate regions. Therefore, *Acacia* trees are, with regard to the obtained results, good indicators of climatic zones in Algeria. Some species present the elements of appreciation of the land conditions as the presence of the water or a specific ground.

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