Journal of Asia-Pacific Biodiversity 9 (2016) 56–62

HOSTED BY

Contents lists available at ScienceDirect

Journal of Asia-Pacific Biodiversity

journal homepage: http://www.elsevier.com/locate/japb

Original article

Plant diversity in different bioclimatic zones in Tunisia

Hana You [a], Hyeyoung Jin [b], Abdelhamid Khaldi [c], Myeongja Kwak [a], Taeyoon Lee [a], Inkyin Khaine [a], Jihwi Jang [a], Hyunkyung Lee [a], Iereh Kim [a], Taihyeon Ahn [b], Jeonghwa Song [b], Yujin Song [b], Ali Khorchani [c], Boutheina Stiti [c], Suyoung Woo [a,*]

[a] Department of Environmental Horticulture, University of Seoul, Seoul, South Korea
[b] Division of Horticulture and Education, Korea National Arboretum, Pocheon, Gyeonggi, South Korea
[c] Institute for Research in Rural Engineering Water and Forestry, Tunis, Tunisia

ARTICLE INFO

Article history:
Received 29 December 2015
Received in revised form
4 January 2016
Accepted 5 January 2016
Available online 13 January 2016

Keywords:
bioclimatic zone
medicinal plants
Mediterranean climate
plant biodiversity
Tunisia

ABSTRACT

The Republic of Tunisia, located in northern Africa, faces various environmental challenges caused by anthropogenic practices such as overgrazing, deforestation, and desertification. The conversion of natural ecosystems is the major cause of plant biodiversity loss. Tunisia can be divided into three main climatic zones as follows: a northern Mediterranean climate zone, a central steppe climate zone, and a southern desert climate zone. Because of this great environmental diversity, there are distinctive vegetation and various genetic resources in Tunisia. This research was conducted to investigate plant biodiversity within the various bioclimatic zones and to characterize useful plant resources in Tunisia. We investigated native, medicinal and aromatic, desert, and soil erosion control plant species.

Copyright © 2016, National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA). Production and hosting by Elsevier. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Tunisia, located on the shores of the Mediterranean, is a rich repository of various plant resources. There are 22,500 species of vascular plants in the Mediterranean (Myers et al 2000), with approximately 11,700 found in the 'hotspot region' including Tunisia (Thompson et al 2005). This region has a very high inhabitant's density (Myers et al 2000) and has therefore been in the spotlight for the research of plant biodiversity. Overall, about 70% of wild plants have potential worth as ornamental plants, medicinal plants, or for biotechnological uses (United Nations Environment Programme 2002).

There are dynamic climate zones in Tunisia (Figure 1). The humid region is located in the northwest forest of Tunisia that accounts for 3.6% of the nation's total land area. The annual average rainfall in the northern area is 1,500 mm and this region shows a typical Mediterranean climate. The semiarid area, located in the central part of Tunisia, has a steppe climate that accounts for 20% of the nation's total land area. The southern area is divided into two climate regions (Tarhouni et al 2007), namely, arid and desert areas. The total annual average rainfall in the arid and desert areas are 200 mm and 50 mm, respectively (Table 1). There are around 1 million ha of forest in Tunisia, and the forest only accounts for 6% of the nation's total land area. Moreover, due to deforestation and desertification, land degradation has accelerated in the arid and semiarid regions (Korea Rural Economic Institute 2014).

Environmental problems caused by industrialization and urbanization are important social issues in Tunisia. Water pollution, desertification caused by overgrazing and soil erosion, and plant biodiversity loss are the most serious problems (Baban et al 1999; Darkoh 2003; National Report 1997). The worst environmental situation is found in the central region of Tunisia (Nefzaoui 2004), and this is mainly attributed to economic and technological management problems.

According to the National Environmental Report of Tunisia (1997), 74% of the country is at risk of soil erosion. To cope with this problem, the Tunisian government has produced a guidebook for combating desertification for the 12 local governments (Zaghouan, El Kef, Siliana, Kasserine, Kairouan, Sidi Bouzid, Gafsa, Tozeur, Kebili, Tataouine, Medenine, and Gabes) in the south. In

* Corresponding author.
E-mail address: wsy@uos.ac.kr (S. Woo).
Peer review under responsibility of National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA).

http://dx.doi.org/10.1016/j.japb.2016.01.002
pISSN2287-884X eISSN2287-9544/Copyright © 2016, National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA). Production and hosting by Elsevier. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

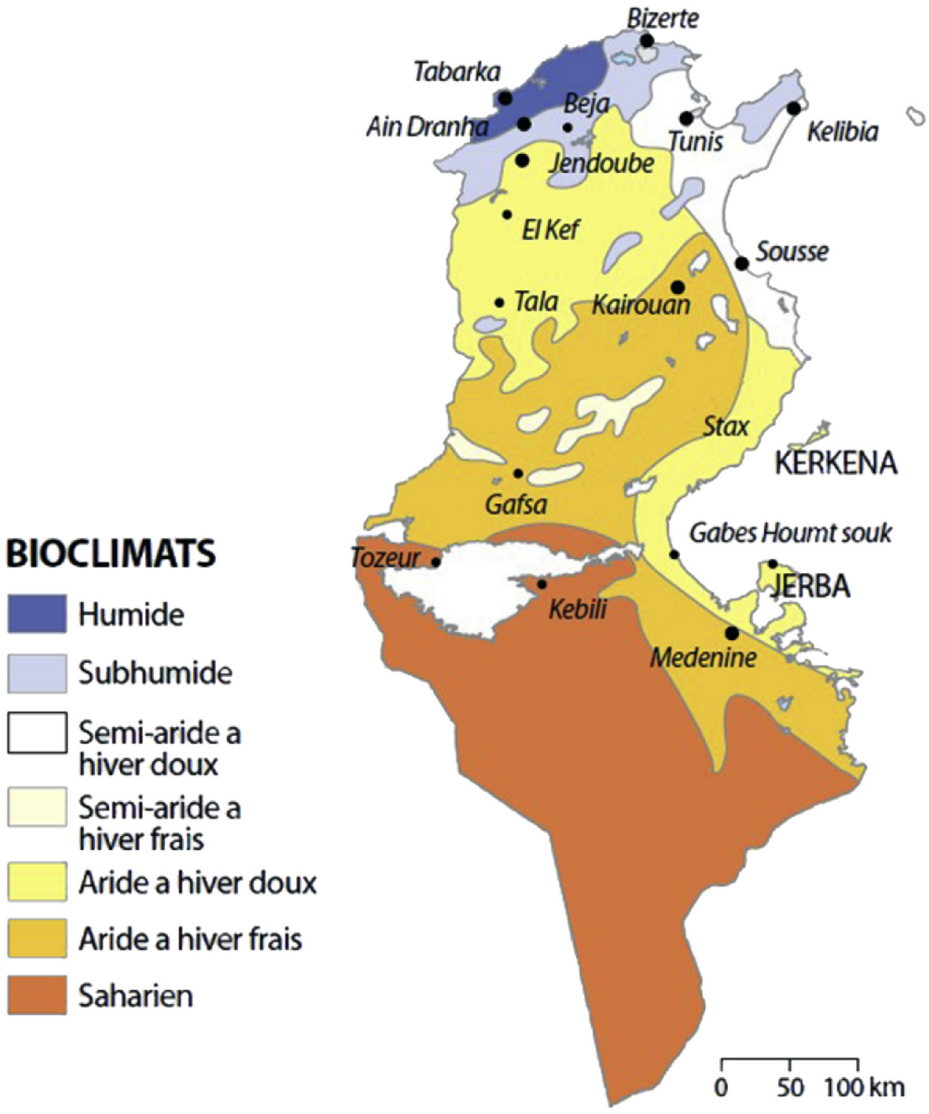

Figure 1. Bioclimatic zones of Tunisia, North Africa, bordering the Mediterranean Sea.

Table 1. The bioclimatic zones and agroecological zones in Tunisia.

Annual rainfall (mm)	Bioclimatic zones	Annual rainfall (mm)	Agroecological zones
800–1200	Humid	500–1000	North
600–800	Subhumid	400–500	Dorsal
400–600	Semiarid		
100–400	Arid	200–400	Center
20–100	Desert (Saharan)	<200	South

the Menzel Habib southern steppe region, monitoring studies on the process of desertification were carried out from 1975 to 2000. As a result, the forests, climate change, and changes in land use appeared to cause significant changes in ecosystem structure and biodiversity (Hanafi and Jauffret 2008). In particular, the vegetation ecology of Tunisia has undergone a severe decline over the course of a century under the long-term impact of humans and livestock (Le Houérou 2000).

To minimize the reduction in plant diversity that threatens humanity's survival and prosperity, an ecological understanding of plant communities is essential (Gondard et al 2003). Tunisian coastal areas and desert areas are important habitats for salt-resistant plants, drought-resistant plants, and medicinal plants. Therefore, this study was conducted to investigate the useful plant resource distribution pattern of plant diversity in Tunisia.

Materials and methods

The University of Seoul and Institut National de Recherche en Genie Rural, Eaux et Forêts (INRGREF) conducted this study in Tunisia from 2010 to 2015. The exploration and acquisition of valuable plant resources in Tunisia covered several regions including forests and coastal areas in the northeastern part, central steppe, and desert areas of the south (Figure 2). *Quercus suber* and *Olea europaea* (Figure 3) were surveyed in Zaghouan and Beja, respectively. *Rosmarinus officinalis*, *Ceratonia silique*,

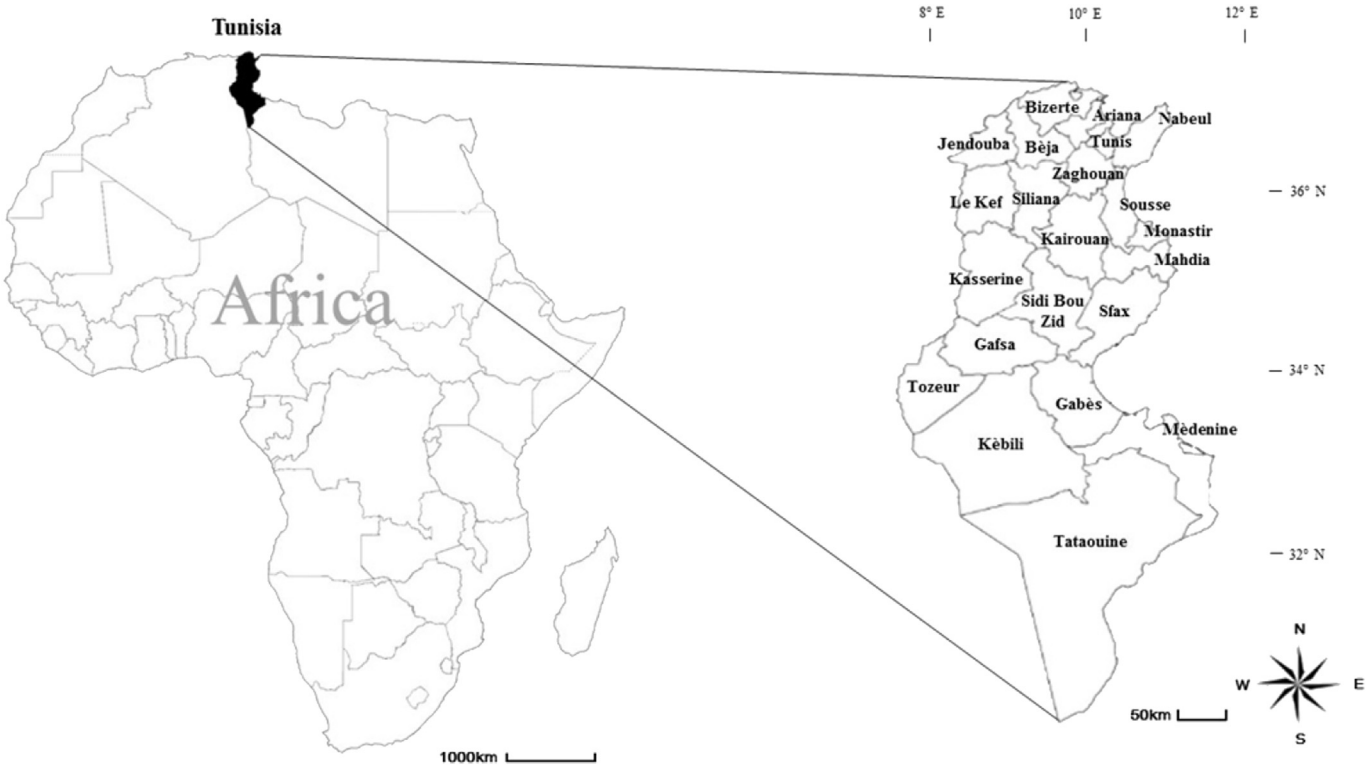

Figure 2. Location of Tunisia, North Africa, bordering the Mediterranean Sea.

Pistacia lentiscus, and *Thymus capitatus* (Figure 4) were investigated in Zaghuan, Tunis, Beja, and Kairouan, respectively. *Eryngium maritimum*, *Artemisia campestris*, *Astragalus armatus*, and *Juniperus phoenicea* (Figure 5) were investigated in Beja, Gabes, Madenine, and Bizerte, respectively. *Acacia tortilis*, *Stipagrostis pungens*, *Argania spinosa*, and *Peganum harmala* (Figure 6) were investigated in Sidi Bouzid, Madenine, Gabes, and Kebili, respectively.

Figure 3. Native tree species in Tunisia. A and B, *Quercus suber*; C and D *Olea europaea*.

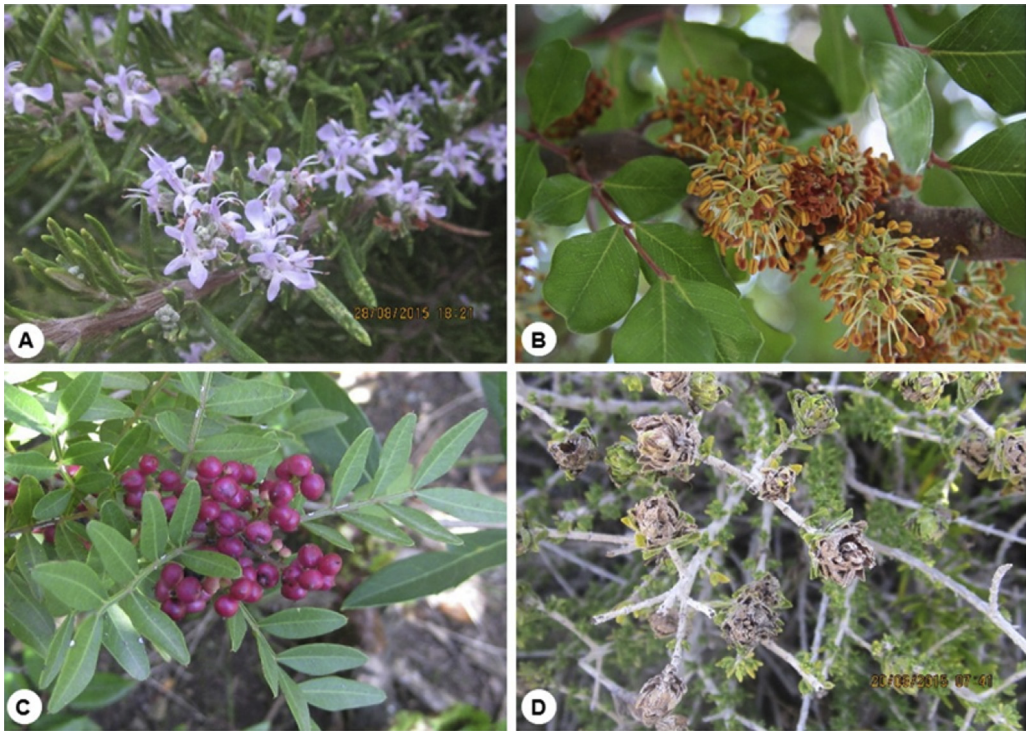

Figure 4. Native shrub species in Tunisia: A, *Rosmarinus officinalis*; B, *Ceratonia silique*; C, *Pistacia lentiscus*; and D, *Thymus capitatus*.

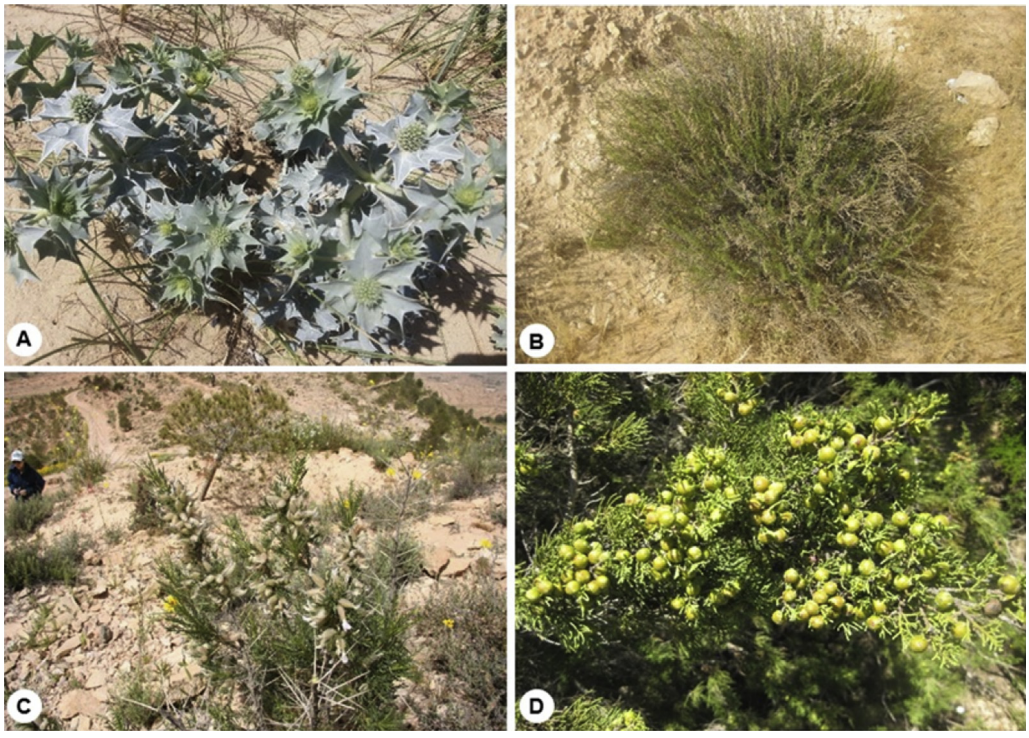

Figure 5. Medicinal and aromatic species in Tunisia. A, *Eryngium maritimum*; B, *Artemisia campestris*; C, *Astragalus armatus*; D, *Juniperus phoenicea*.

Results and discussion

Native plants

Representative species of the Mediterranean area are *Quercus ilex* (the evergreen oak/holm oak) and *Pinus halepensis* (Aleppo pine). The northern Mediterranean coast of Tunisia is formed of cork oak (*Q. suber*) forest (Figures 3A and 3B). Trees such as *Cupressus sempervirens* (italian cypress) and *O. europaea* (olive tree; Figures 3C and 3D) also grow in the Mediterranean region.

The Maquis or Matorral contains a wide range of vegetation type in the Mediterranean region, with sclerophyllous (hard-leaved)

Figure 6. Arid and semiarid species in Tunisia. A, *Acacia tortilis*; B, *Stipagrostis pungens*; C, *Argania spinose*; D, *Peganum harmala*.

shrubs being the most common. Maquis has typical plants including *R. officinalis* (rosemary; Figure 4A), *C. silique* (carob tree; Figure 4B), *P. lentiscus* (mastic tree; Figure 4C), *T. capitatus* (thyme; Figure 4D), *Lavandula* stoechas (lavender), and *Helianthemum nummularium* (rockrose) among others. Maquis is found on siliceous soil in humid and subhumid zones. Garrigue is characterized by a low and sparse woody system on bare soil or soil with a grassy cover (Food and Agricultural Organization 2015). The native species in the northern Tunisia forest area include *Myrtus communis* (myrtle), *Arbutus unedo* (strawberry tree), *Erica arborea* (tree heath), and *Crataegus monogyna* (hawthorn), which have been commonly used as folk remedies (Korea National Arboretum 2013a,b).

Medicinal and aromatic plants

Some medicinal plants that originated in North Africa are widely used in traditional folk medicine. These are used in various health systems and are of economic importance. Up to 80% of the population in Africa use traditional medicine to meet their health care needs (United Nations Environment Programme 2002). Asia and Latin America continue to use traditional medicine as a result of historical circumstances and cultural beliefs. Traditional medicine accounts for around 40% of all health care delivered in China (World Health Organization 2002). Tunisia has more than 500 species of medicinal and aromatic plants, and a total of 2,163 varieties; the majority of these plants are found in harsh environments such as arid and semiarid conditions.

E. maritimum (sea holly; Figure 5A) is a perennial plant that belongs to the Apiaceae family, and is one of the major medicinal plants found in the area. Because the plant contains high levels of polyphenol and flavonoid (Lisciani et al 1984), it is effective in preventing diseases including atherosclerosis, diabetes, and cancer. In addition, some researchers investigated the ability of *E. maritimum* essential oil extracts to scavenge free radicals. They determined that the essential oil acts as an antioxidant (Darriet et al 2014).

A. campestris (field wormwood; Figure 5B) is a perennial shrub belonging to the Asteraceae family that grows in the arid and semiarid areas and is widely used as a traditional medicinal plant for diabetes, bronchitis, diarrhea, high blood pressure, and nerve pain treatment. Essential oil extracted from this plant has been used as an antidiabetic agent, antifungal disinfectant, insect repellent, and antispasmodic (Akrout et al 2011). According to a recent study, the essential oil is also effective in treating diabetes by protecting the kidneys (Sefi et al 2012).

A. armatus (milkvetch; Figure 5C) is a perennial shrub belonging to the Fabaceae family that grows in the arid and semiarid areas. *A. armatus* is widely distributed in Maghreb, which includes the three countries of northern-western Africa, namely, Morocco, Algeria, and Tunisia, and is the endemic species of northern Africa distributed in the pre-Saharan zones. In North Africa, this plant is used to treat cough, asthma, arthritis, anemia, and paralysis. In addition, this plant contains polyphenols that are effective for the relief of fatigue and antiaging (Bouaziz et al 2009). Khalfallah et al (2014) recently reported eight flavonol glycosides in *A. armatus*, which are known to be effective in preventing atherosclerotic vascular disease by assisting in mineralization. In Tunisia, *A. armatus* is generally used as a tonic, a stimulant, and an anemia treatment for medicinal purposes; in addition, it is an indicator of desertification of arid areas caused by overgrazing (Khalfallah et al 2014).

The ability of halophytes to resist oxidative stress generated by salinity is a distinguishing feature that is controlled by physiological and biochemical resistance mechanisms such as the maintenance of ion homeostasis, the accumulation of osmolytes, antioxidant defense and reactive oxygen species regulation, and the compartmentalization of toxic ions in the vacuole (Flowers and Colmer 2015; Flowers et al 2015). In Tunisia, halophytes such as *Cakile maritima*, *Limoniastrum monopetalum*, *Mesembryanthemum*

crystallinum, *Mesembryanthemum edule*, *Salsola kali*, and *Tamarix gallica* are widely used as traditional medicinal plants (Ksouri et al 2008).

J. phoenicea (phoenician juniper; Figure 5D) is a perennial shrub belonging to the Cupressaceae family that grows across the northern and central regions of Tunisia. The leaves of *J. phoenicea* have a strong scent; as such they are usually used for the production of essential oil. Keskes et al (2014) determined that the essential oil extracted from this plant has the potential to treat obesity and diabetes due to the presence of α-amylase and pancreatic lipase, which promote the decomposition of carbohydrates and fat, respectively. This species is also known for efficient treatment against dysmenorrhea and prostatitis (Wahida et al 2011). In addition, it was revealed that *J. phoenicea* extracts contain phenolic compounds that function as an antioxidant.

Desert plants

Steppe and desert climate regions are important habitats for plants that have adapted to dry conditions. *Acacia tortilis* subsp. raddiana (umbrella thorn acacia; Figure 6A) belongs to the Fabaceae family and grows up to 20 m in height. *A. tortilis* is resistant to high temperatures and dry environmental conditions; in addition, plants over 2 years of age are resistant to frost. They play an important role in the growth and physiology of ground cover plants. This plant is a key species in the desert area and mainly inhabits the pre-Saharan region in Tunisia (Mills et al 1993). This species is widely used for vegetation restoration in arid areas due to the development of root system that helps with nitrogen fixation, thereby generating favorable conditions for the growth of plants (Fterich et al 2014). Other *Vachellia* species such as *V. albida*, *V. senegal*, *V. seal*, *V. mellifera*, and *V. etbaica* also play a crucial role in the maintenance of soil fertility.

The perennial herb *Stipagrostis pungens* subsp. (Desf.) De Winter (three-awn grass; Figure 6B), commonly known by its Arabic name "Sbat", is a grass that grows between 50 cm and 100 cm in height. It belongs to the Poaceae family and is a tall perennial with deep roots, long leaves, and erect stems. Because of its adventitious root system, *S. pungens* can survive in areas with as little as 70 mm of rainfall/y (Bendali et al 1990). This plant is also good for dune fixation in desert; therefore, *S. pungens* plays an important role to prevent the progression of desertification and to introduce vegetation in arid areas.

The perennial evergreen shrub *Argania spinosa* (argan; Figure 6C), commonly known as *argan*, *Moroccan iron wood*, or *iron wood*, is a medium-sized, thorny tree, growing from 8 m to 10 m in height and 1 m in diameter. It belongs to the Sapotaceae family and is widely used for the treatment of many skin problems, such as neurodermatitis, eczema, acne, and severe burns. It is rich in vitamin A, unsaturated fats, tocopherols, and phenolic compounds. It is also drought resistant, remaining in a state of dormancy for several years during prolonged droughts (Diaz Barradas et al 2010). These plants have evolved to form features that can improve the absorption and transport of moisture to cope with dry conditions (Larcher 1995; Levitt 1980). Niinemets et al (2006) also reported that coping with water stress is related to changes in both morphological structure and chemical composition of the leaves.

P. harmala (syrian rue; Figure 6D) is a perennial shrub belonging to the Zygophyllaceae family whose roots can reach a depth of 6.1 m under the ground and can survive in extremely dry regions in southern Tunisia. These plants are used as indicators for desertification due to overgrazing in sandy rangelands (Ping et al 2006). This plant has a very bitter taste due to the production of a toxic alkaloid.

Erosion control plants species

Some scholars have reported that there were very few terrestrial ecosystems that have not changed around the Mediterranean region (Aronson et al 1993a,b; Belgacem et al 2013). Floret and

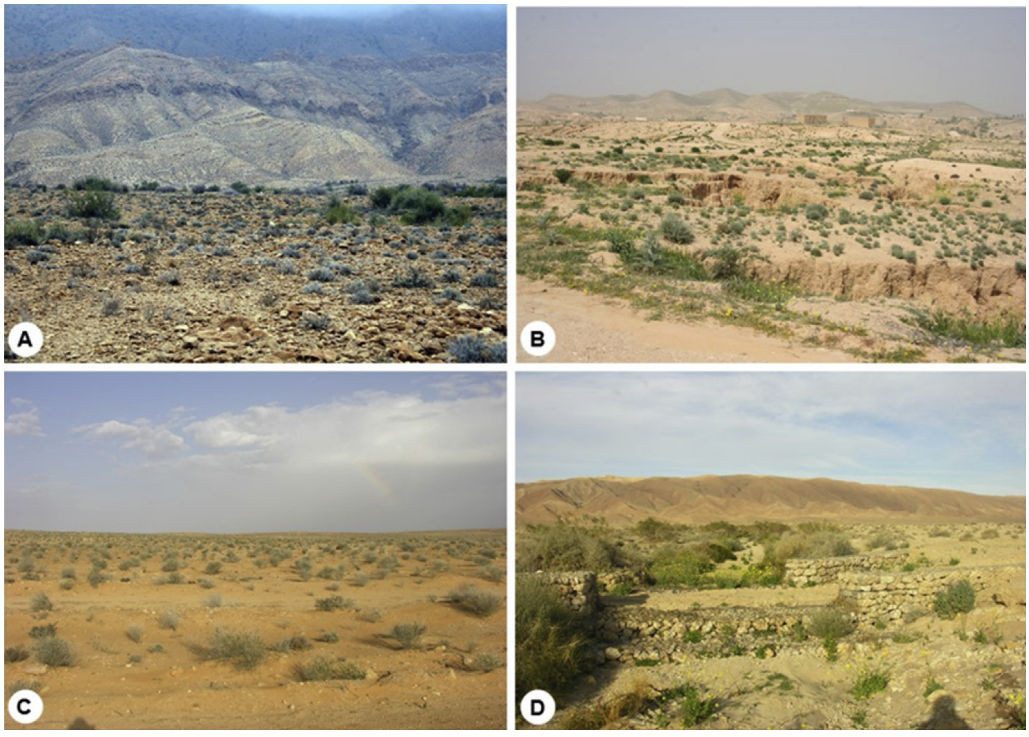

Figure 7. Landscape of arid and semi-arid regions in South Tunisia. A, Gafsa; B, C and D, Gabes.

Pontanier (1982) reported that one third of Tunisia territory was in danger of desertification. In particular, the loss of biodiversity caused by overgrazing is a serious issue in southern Tunisia (Figure 7). Because of the extremely dry soil, only 1–10% of vegetation covers the ground and the dry biomass of perennial plants is 100 kg/y/ha (Gamoun et al 2012).

An effective means for ensuring plant diversity should be based on improved skills related to conservation management of potential plants to combat desertification. Aronson et al (1993a) pointed out that the sustainable management of degraded ecosystems in arid and semiarid lands could be likened to the relationships and potential pathways between ecological restoration (a complete or near-complete return of a site to a pre-existing state) and rehabilitation (a repair of damaged or blocked ecosystem). The main protected species in Tunisia include *Cenchrus ciliaris*, *Salvia aegyptiaca*, *Echiochilon fruticosum*, *Helianthemum sessiliflorum*, *Helianthemum kahiricum*, *Helianthemum scoparium*, *Haloxylon schmittianum*, *Marrubium deserti*, and *Deverra tortuosa*. These species are important parts of arid and semiarid landscapes that prevent soil erosion and desertification. However, they are negatively influenced by various human activities (Belgacem et al 2013; Floret and Pontanier 1982; Gamoun et al 2012).

Acknowledgments

This paper was supported by a research project (Grant No. KNA1-2-23, 15-4; Project Title: “Development of Display Plant Materials and Management Techniques” of Tropical Plant Resources Research Center) of the Korea National Arboretum.

References

Akrout A, Gonzalez LA, Jani HE, et al. 2011. Antioxidant and antitumor activities of *Artemisia campestris* and *Thymelaea hirsute* from southern Tunisia. *Food and Chemical Toxicology* 49:342–347.

Aronson J, Floret C, Floc'h E, et al. 1993a. Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands. I. A view from the South. *Restoration Ecology* 1:8–17.

Aronson J, Floret C, Floc'h E, et al. 1993b. Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands. II. Case studies in Southern Tunisia, Central Chile and Northern Cameroon. *Restoration Ecology* 1:168–187.

Baban SMJ, Foster IDL, Tarmiz B. 1999. Environmental protection and sustainable development in Tunisia: an overview. *Sustainable Development* 7:191–203.

Belgacem AO, Tarhouni M, Louhaichi M. 2013. Effect of protection on plant community dynamics in the Mediterranean arid zone of southern Tunisia: a case study from Bou Hedma national park. *Land Degradation and Development* 24:57–62.

Bendali F, Floret C, Le Floc'h E, et al. 1990. The dynamics of vegetation and sand mobility in arid regions of Tunisia. *Journal of Arid Environments* 18:21–32.

Bouaziz M, Dhouib A, Loukil S, et al. 2009. Polyphenols content antioxidant and antimicrobial activities of extracts of some wild plants collected from the south of Tunisia. *African Journals of Biotechnology* 8:7017–7027.

Darkoh MBK. 2003. Regional perspectives on agriculture and biodiversity in the drylands of Africa. *Journal of Arid Environments* 57:261–279.

Darriet F, Andreani S, De Cian M, et al. 2014. Chemical variability and antioxidant activity *Eryngium maritimum* L. essential oils from Corsica and Sardinia. *Flavour and Fragrance Journal* 29:3–13.

Diaz Barradas MC, Zunzunegui M, Ain Lhout F, et al. 2010. Seasonal physiological responses of *Argania spinose* tree from Mediterranean to semi-arid climate. *Plant Soil* 337:217–231.

Floret C, Pontanier R. 1982. L'aridité en Tunisie présaharienne. Climat, sol, végétation et aménagement. *Travaux et Documents de l'ORSTOM* 150:544 (in French).

Flowers TJ, Colmer TD. 2015. Plant salt tolerance: adaptations in halophytes. *Annals of Botany* 115:327–331.

Flowers TJ, Munns R, Colmer TD. 2015. Sodium chloride toxicity and the cellular basis of salt tolerance in halophytes. *Annals of Botany* 115:419–431.

Food and Agricultural Organization. 2015. Available at: http://www.fao.org/forestry/country/61335/en/tun/ [Date accessed: 20 January 2016].

Fterich A, Mahdhi M, Mars M. 2014. The effect of *Acacia tortilis* subsp. *raddiana*, soil texture and soil depth on soil microbial and biochemical characteristics in arid zones of Tunisia. 2014. *Land Degradation and Development* 25:143–152.

Gamoun M, Hanchi B, Neffati M. 2012. Dynamic of plant communities in Saharan rangelands of Tunisia. *Arid Ecosystems* 2:105–110.

Gondard H, Jauffret S, Aronson J, et al. 2003. Plant functional types: a promising tool for management and restoration of degraded lands. *Applied Vegetation Science* 6:223–234.

Hanafi A, Jauffret S. 2008. Are long-term vegetation dynamics useful in monitoring and assessing desertification processes in the arid steppe, southern Tunisia? *Journal of Arid Environments* 72:557–572.

Keskes H, Mnafgui K, Hamden K, et al. 2014. *In vitro* anti-diabetic, anti-obesity and antioxidant proprieties of *Juniperus phoenicea* L. leaves from Tunisia. *Asian Pacific Journal of Tropical Biomedicine* 4:S649–S655.

Khalfallah A, Karioti A, Berrehal D, et al. 2014. A new flavonol triglycoside and other flavonol glycosides from *Astragalus armatus* Willd. (Fabaceae). *Records of Natural Products* 8:12–18.

Korea National Arboretum. 2013a. *Plants of grassland and Sahara Desert (Central and Southern Tunisia)*. Gyeonggi-do, South Korea: Korea National Arboretum.

Korea National Arboretum. 2013b. *Plants of Mediterranean (northern and east coastal areas of Tunisia)*. Gyeonggi-do, South Korea: Korea National Arboretum.

Korea Rural Economic Institute. 2014. Available at: http://www.krei.re.kr [Date accessed: 20 January 2016].

Ksouri R, Megdiche W, Falleh H, et al. 2008. Influence of biological, environmental and technical factors on phenolic content and antioxidant activities of Tunisian halophytes. *Comptes Rendus Biologies* 331:865–873.

Larcher W. 1995. *Physiological plant ecology*. New York: Springer.

Le Houérou HN. 2000. Restoration and rehabilitation of arid and semiarid Mediterranean ecosystems in North Africa and West Asia: a review. *Arid Soil Research and Rehabilitation* 14:3–14.

Levitt J. 1980. *Responses of plants to environmental stresses*. New York: Academic Press.

Lisciani R, Fattorusso E, Surano V, et al. 1984. Anti-inflammatory activity of *Eryngium maritimum* L. rhizome extracts in intact rats. *Journal of Ethnopharmacology* 12:263–270.

Mills LS, Soulé ME, Doak DF. 1993. The keystone species concept in ecology and conservation. *BioScience* 43:219–224.

Myers N, Mittlemeier RA, Mittlemeier CG, et al. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403:853–858.

National Report. 1997. *The state of the environment in Tunisia*. Tunis, Tunisia: Tunisian Republic Ministry of Environment and Land Use Planning.

Nefzaoui A. 2004. Rangeland improvement and management options in arid environment of Central and South Tunisia. *Cahiers Options Méditerranéennes* 62:1–26.

Niinemets U, Cescatti A, Rodeguiero M, et al. 2006. Complex adjustments of photosynthetic potentials and internal diffusion conductance to current and previous light availabilities and leaf age in Mediterranean evergreen species *Quercus ilex*. *Plant Cell Environment* 29:1159–1178.

Ping A, Shinobu I, Nawen Z, et al. 2006. Plant species as indicators of the extent of desertification in four sandy rangelands. *African Journal Ecology* 45:94–102.

Sefi M, Fetoui H, Soudani N, et al. 2012. *Artemisia campestris* leaf extract alleviates early diabetic nephropathy in rats by inhibiting protein oxidation and nitric oxide end products. *Pathology Research and Practice* 208:157–162.

Tarhouni M, Belgacem AO, Neffati M, et al. 2007. Dynamique des groupements végétaux dans une aire protégée de Tunisie méridionale. *Cahiers Agricultures* 16:23–29 (in French).

Thompson JD, Lavergne S, Affre L, et al. 2005. Ecological differentiation of Mediterranean endemic plants. *Taxon* 54:967–976.

United Nations Environment Programme. 2002. *Global Environmental Outlook 3*. London, UK: Earthscan Publications Ltd.

Wahida B, Amor M, Nabil C. 2011. *An Inventory of Ethnomedicinal Plants used in Tunisia*. Ethnomedicinal Plants: Revitalizing of Traditional Knowledge of Herbs. p. 333.

World Health Organization. 2002. *WHO traditional medicine strategy 2002–2005*. Geneva, Switzerland: World Health Organization.