Pak. J. Bot., 45(5): 1715-1720, 2013.

INTERACTIONS OF *ACACIA TORTILIS* (FORSK.) SUBPSP. *RADDIANA* (SAVI) WITH HERBACEOUS VEGETATION IN RELATION WITH TREE SIZE UNDER NORTH AFRICAN PRESAHARAN REGION

FATHIA ABDALLAH* AND MOHAMED CHAIEB

UR Diversité végétale & Ecosystèmes en milieu Aride,
Faculty of sciences, University of Sfax, BP 1171, 3000 Sfax, Tunisia
** Corresponding author's e-mail address: f.abdallah1@yahoo.fr*

Abstract

Twelve individuals were selected to determine the effects of tree size (crown area) on herbaceous species composition, total cover, perennial and annual species density, species number and floristic diversity in an *Acacia tortilis* subsp. *raddiana* (Savi) pseudo-savanna in southeastern Tunisia. Except for annual species density, all vegetation parameters were increased under tree canopy compared to the open area. Tree size appeared to affect tree herbaceous interaction. The positive effect of *Acacia* tree in herbaceous vegetation increases with tree size.

Introduction

Savannas are generally defined as a grassland ecosystem with trees sufficiently small or widely spaced so that the canopy does not close with an unbroken herbaceous layer (Werner *et al.,* 1991). *Acacia tortilis* tree is one of the most xerophytic Acacias of the African savannas, well represented in the north and south of the Sahara Desert. Although the attention that the African Acacias have received from researchers, regarding the ecological (development and fight against desertification) and economic (agroforestry resources, production of natural substances) role they can play, the ecological role of *Acacia tortilis* subsp. *raddiana* in its ecosystem remains poorly studied. In fact, the influence of woody plants on herbaceous understory cover and biomass can be positive or negative depending on sampling location, savanna species, and climate. Woody species may alter the density and the vigor of understory plants (Foster *et al.,* 1984), which may generate patterns of herbaceous species composition that are more different beneath the tree canopy than beyond the tree canopy (Skarpe 1991).

Recent studies in Tunisian arid ecosystems concluded that many factors can influence tree herbaceous interaction. Indeed, herbaceous composition and distribution patterns beneath the canopy change with pasture intensity and abiotic stress (Abdallah & Chaieb, 2010). The question that prompted this study was: does tree size increase elicit significant changes in understory vegetation?

Material and method

Study site: The study area lies in Tunisian Bou Hedma National Park in northern Africa (BHNP), pseudo-savanna of *Acacia tortilis* subsp. *raddiana* (34° 39' N and 9° 48' E) (Fig. 1). Following Emberger's classification (Emberger, 1954), the climate is Mediterranean arid with temperate winters. The average annual rainfall varies from 150 mm in the plain (a. s. l. 100 m) to 300 mm on the highest peak of the mountain range (a. s. l. 800 m) with a high inter-annual variability. Average temperature varies from 32 to 36°C in summer and from 4 to 7°C in winter (Derbel *et al*., 2007). The soil of the experimental areas is composed of quaternary sandy deposits and covered by *Acacia tortilis* subsp. *raddiana*. In this area *Acacia* tree is considered as a pseudo-savanna, with scattered tree or shrub *A. tortilis* spp. *raddiana* a native tree species in the study area. According to Le Houérou (1969), the *A. tortilis* population is considered as a pseudo-savanna, with scattered tree associated with several species of grasses, shrubs and ligneous chamaephytes such as *Cenchrus ciliaris*, *Cynodon dactylon*, *Digitaria commutata*, *Hammada schmittiana*, *Hammada scoparia*.

Climatic parameters: The study on the interaction between *A. tortilis* subsp. *raddiana* and herbaceous vegetation was conducted during the growing season 2004/2005. The rainfall was the main contributing recharging source of soil water, since the surface of the groundwater was not directly available to the plants. Throughout this year (a dry year) was characterized by a total rainfall 69.4 mm, which fell for 15 days. The received precipitations during autumn (September-November) did not exceed 29.5 mm (Fig. 2). The precipitation during the autumn is necessary for the germination of annual species and for the beginning of development of perennial species. Climatic data were supplied by the meteorological station of Bou Hedma National Park (Annual Reports).

Data sampling: The present study was conducted during the spring 2005, period of peak vegetation cover. A total of 60 transects (7.5 m long) were sampled in order to measure floristic composition and total plant cover using the quadrat point method (Daget & Poissonet, 1971). Transect data were collected in two blocks of tree size (large crown and small crown). In each block, we randomly selected six individuals. The average crown diameter was deducted from the longest length of the vertically projected canopy surface. The average crown diameter of the large and the small crown is about 9.167±3.54m and 3.524±1.076m, respectively. A total of 24 transects were placed under the large crown tree canopies, 24 transects were placed under the small crown tree canopies and 12 transects in the open area. Observations were made every 5 cm, for a total of 150 points along each transect to determine total plant cover (in %) and cover (in %) of each herbaceous species sampled.

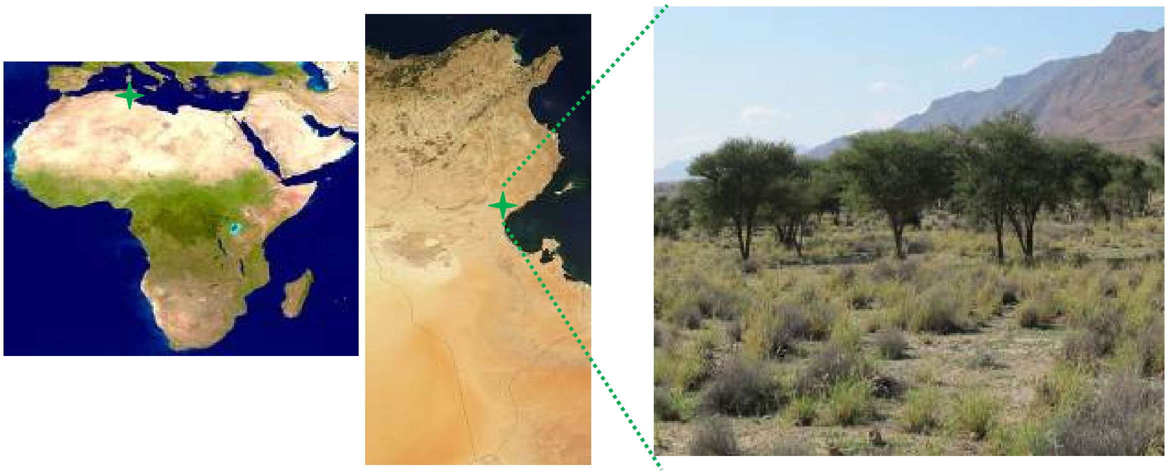

Fig. 1. Localization of the study site: National Parc of Bou Hedma.

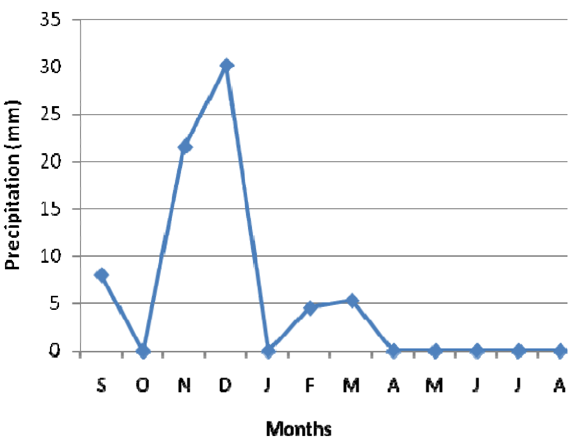

Fig. 2. Changes of the monthly mean precipitation in the study site during the experimental period (2004/2005).

Diversity indices Shannon & Weaver 1949 (H') were used to measure species diversity.
H' = - ∑ pi $\log_2$ pi The Shannon index (H'; Shannon & Weaver 1949),

Pi: the relative frequency of the species: Pi = ni/n where ni: the average cover of the species i, and n the total cover of all species.

The density of perennial and annual species per square meter was determined within 48 quadrats of 7.5 m^2 under tree canopies and 12 in the open area.

To assess the DM of aboveground parts of vegetation, we used the formula proposed by Le Houérou (1987): DM (kg $ha^{-}1$) = r*43.1±3.6 (r: perennial species cover in %).

To evaluate the change of the effect of *A. raddiana* on herbceous strata under different tree size, we calculated the Relative Neighbour Effect (RNE) index as follow:

$$RNE = (So-Sc)/X,$$

where Sc and So are H', plant cover, plant biomass, or density under tree canopy and in the open area, respectively, and X is either Sc (when SC >So) or So (where So>Sc) (Markham & Chanway, 1996). To facilitate the interpretation of the results, we have multiplied RNE values by-1 (Callaway *et al*., 2002). RNE ranges from-1 to 1with positive values indicating facilitation and negative values indicating competition.

Data analysis: All data were analysed using SPSS software package. Multiple-comparison and one-way analysis of variance (ANOVA) procedures were used to compare the differences among the treatments. Difference at $p<0.05$ level was considered as statistically significant. Figures were drawn using Microsoft Excel software.

Results

Floristic composition: A total of 32 species representing 29 genera and 15 families were recorded in the study site. Species number increase with the increase of tree size (Table 1). There were 12 species in the open area, 19 and 25 species under small and large tree crown respectively. In the same way, the increase of *Acacia* tree size favors perennial species installation. Under the drought condition of this year the tree canopy facilitate the development of many annual species such as *Neurada procumbens*, *Paronychia arabica*, *Asphodelus tenuifolius*, *Chenopodium album*, *Sisymbrium irio*.

Total plant cover and plant biomass: Statistical analyses of total plant cover and DM yield produced a significant difference between large crown tree and the open area (F = 8.28; p<0.05, F=5.87; p=0.05). The highest mean of these parameters was recorded under *A. raddiana* canopies (Fig. 3a; 3b). However, a non significant difference was found between small crown tree and the open area (F=1.26; p>0.05, F=2.15.65; p=0.17) and between the two crown blocks (f=1.28; p>0.05, F=1.55; p=0.23).

Plant density: The density of perennial species was significantly increased by tree presence. In fact, a higher perennial density was recorded both under large (F = 5.28, p<0.05) and small (F=4.95; p<0.05) tree crown versus the open area (Fig. 3d). However, no significant difference was found between the two crown blocks. Conversely, the density of annual species was significantly higher in the open area than under tree canopy (F=16.5; p<0.01 under small tree crown and F=8.65; p<0.05 under large tree crown) (Fig. 3c). The effect of *Acacia* on this parameter decrease with the increase of crown size.

Table 1. List of plant species present under different tree age. The Botanical family, as well as its presence (1) or absence (0). Under each tree age is shown. P: Perennial and A: Annual.

Botanical family	Species	P/A	Open area	Small crown	Large crown
Poaceae	*Stipagrostis ciliata*	P	0	1	1
	Cenchrus ciliaris	P	0	1	1
	Cynodon dactylon	P	1	1	1
	Eragrostis papposa	P	1	1	1
	Schismus barbatus	A	0	0	1
	Stipa capensis	A	1	1	1
Geraniaceae	*Erodium laciniatum*	A	0	1	0
Fabaceae	*Astragalus cruciatus*	A	0	0	1
Zygophyllaceae	*Fagonia cretica*	P	0	1	1
	Peganum harmala	P	1	0	1
Chenopodiaceae	*Bassia indica*	A	0	0	1
	Hammada schmittiana	P	1	1	1
	Hammada scoparia	P	1	1	1
	Chenopodium album	A	0	0	1
	Atriplex halimus	P	0	0	1
Asteraceae	*Artemisia compestris*	P	0	0	1
	Artemisia herba alba	P	0	0	0
	Rhanterium suaveolens	P	0	1	1
	Anacyclis clavatus	A	0	0	1
Apiaceae	*Deverra tortuosa*	P	0	1	1
Brassicaceae	*Diplotaxis simplex*	A	1	0	1
	Moricandia suffruticosa	P	1	0	0
	Matthiola longipetala	A	0	1	1
	Sisymbrium irio	A	0	1	1
Malvaceae	*Malva aegyptiaca*	A	1	1	1
Plantaginaceae	*Plantago albicans*	P	0	0	1
	Plantago ovata	A	1	1	1
Neuradaceae	*Neurada procumbens*	A	0	1	1
Solanaceae	*Lycium chawii*	P	1	1	0
Labiaceae	*Salvia aegyptiaca*	A	1	0	1
Caryophyllaceae	*Paronychia arabica*	A	0	1	0
Liliaceae	*Asphodelus tenuifolius*	A	0	1	0
Number of annual species		16	5	10	12
Number of perennial species		16	7	9	13
Total number of species		32	12	19	25

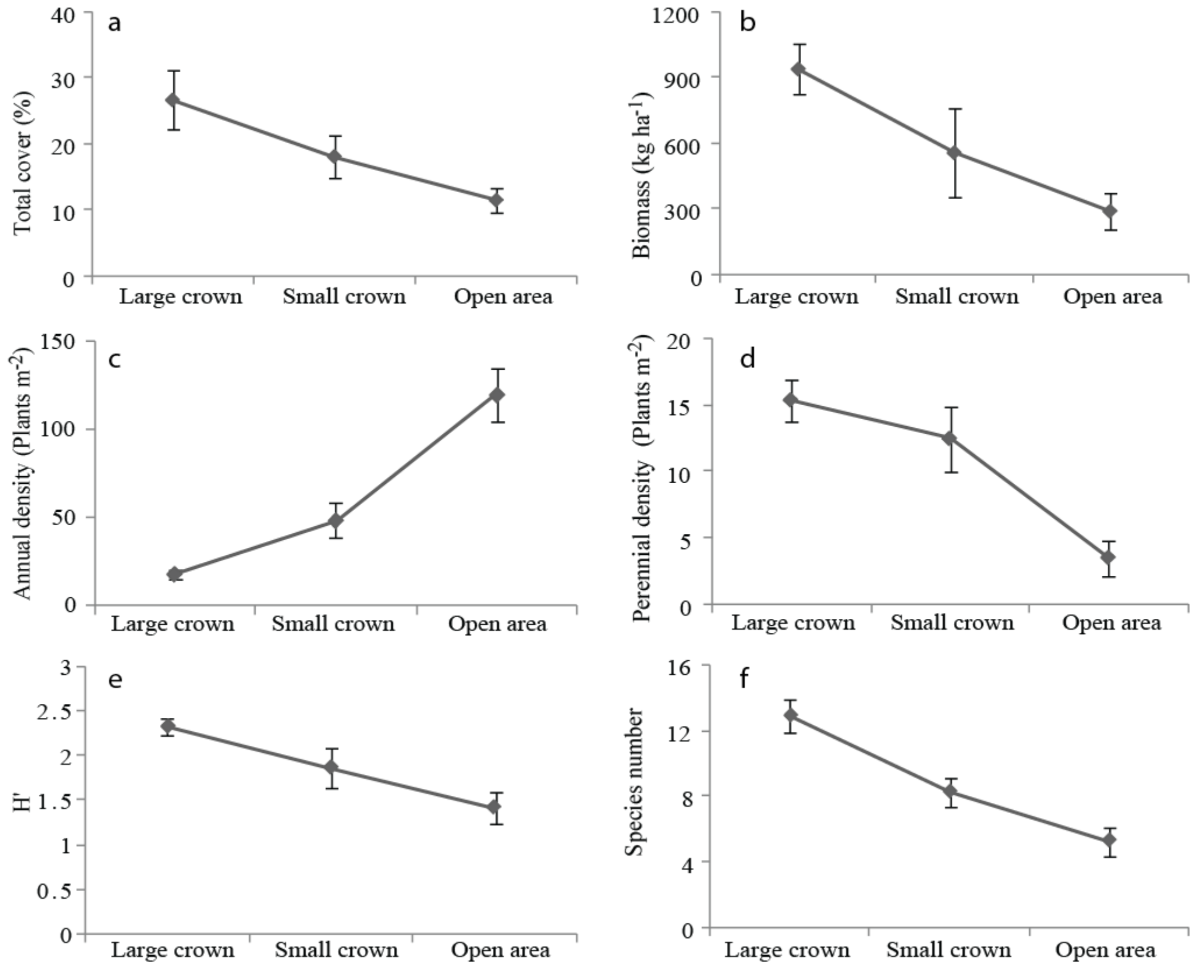

Fig. 3. Variation of vegetation parameters under tree crown diameter: (a) Total plant cover, (b) Dry matter, (c) Annual species density, (d) Perennial species density, (e) Flora diversity and (f) Species number.

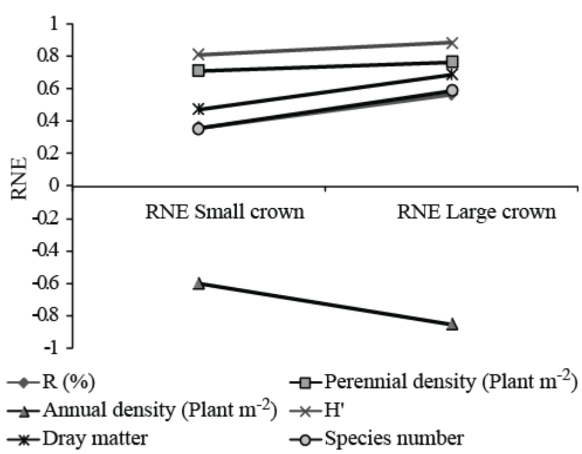

Fig. 4. Relationship between tree size and the relative neighbour index (RNE).

Flora diversity: ANOVA showed significant differences in flora diversity between the large tree crown and the open area (F=19.56; p<0.01). The highest values were recorded under tree canopy (Fig. 3e). In spite of the positive effect of *Acacia* tree in this parameter, it remains non significant between small tree crown and the open area (F=0.96.65; p=0.38). In the same way no significant difference was found between small and large tree crown (F=0.08; p=0.79). The effect of *Acacia* on this variable change with size.

Relative neighbor effect (RNE): RNE based on the different vegetation parameters could be related to the tree size, with RNE value increase from the open area to large tree crown (Fig. 4). This means that facilitation is more pronounced under large tree crown. However, negative RNE value for annual species density was recorded.

Discussions

Our results indicate that the establishment and development of *A. tortilis subsp. raddiana* in the tunisian arid ecosystem resulted in improvements of all vegetation parameters. Its individual influence increases with the increase of the tree crown size. Trees with a small crown diameter expressed minimal influence on understory vegetation compared to larger trees (Samuel *et al*., 1997). The present study consistently shows higher herbaceous cover and biomass under the tree canopies compared to open area. On the other hand, we found some differences in species composition between the understory large, small crown tree and open areas. Perennial species density was higher than under the canopy of large trees that had less annual species density. These results agree with those of Holmgren *et al*., 1997, who argued that in the dry sites, larger tree crown would increase woody seedling success by reducing water stress. In the same way, Vaitkus & Eddleman (1991) showed increased herbaceous species and biomass beneath larger canopies. Higher herbaceous cover and biomass at the canopy edge is the result of increased humidity, decreased wind and temperature, and increased nutrient availability. In fact, the presence of an overstory canopy can increase herbaceous production during a drought (Frost & Mc Dougald 1989). These results agree with those of Su & Zhao (2003) (in the semi-arid northern China) who noted that this effect was mostly due to the soil conditions improvements. In fact, increased nutrient availability (specially the N and P), can ultimately increase biological yield (Saeed *et al*., 2013; Khan *et al*., 2013).

The redistribution of resources has been shown for *A. tortilis subsp. raddiana*, with higher levels under the canopy edge than in the open area (Abdallah *et al*., 2012, Abdallah & Chaieb, 2012). However, since the positive effects of tree development on soil properties increased with time (Jeddi *et al*., 2010), the effect of tree canopy on herbaceous vegetation increase with shrub age (Pugnaire & Lazaro 2000). The plant cover (especially of perennial species) can catch windblown sand under the plant tussocks, which enhances microclimatic conditions and water retention and minimizes evaporation (Abdallah *et al.*, 2008). This increased habitat availability, together with the amelioration of the harsh climatic conditions typically found in semi-arid environments, favor the presence of facilitative interactions between plants (Callaway, 1995; Maestre & Cortina, 2005). On the other hand, under these drought conditions, the reduction of annual species density under tree canopies can be attributed to a competitive way between annual and perennial species especially for water.

Our findings do not match with the results of (Haworth & Mc Pherson 1994) who reported reporting a decrease in the magnitude of the facilitative effect with tree size). Similarly, Stuart-Hill & Tainton (1989) reported that tall trees generally suppressed grass growth more than shorter trees. In same case, Aguiar & Sala (1994) and Archer (1995) considered that when trees are young and small, facilitation may be more important than competition, and grass production is enhanced as trees and shrubs become larger. The competition may overshadow facilitation and adversely affect herbaceous production. These discrepancies could be due to differences in climate, topography, soils, geomorphology, herbivory, and fire (Backéus 1992, Walker, 1987).

References

Abdallah, F., Z. Noumi, A. Ouled-Belgacem, R. Michalet, B. Touzard and M. Chaieb. 2012. The influence of *Acacia tortilis* (Forssk.) ssp. *raddiana* (Savi) Brenan presence, grazing, and water availability along the growing season, on the understory herbaceous vegetation in southern Tunisia. *J. Arid Envi.*, 76: 105-114.

Abdallah, F., Z. Noumi, B. Touzard, A. Ouled Belgacem, M. Neffati and M. Chaieb. 2008. The influence of *Acacia tortilis* (Forssk.) Subsp. *raddiana* (Savi) and livestock grazing on grass species composition, yield and soil nutrients in arid environments of South Tunisia. *Flora,* 203: 116-125.

Abdallaha, F. and M. Chaieb. 2010. Interactions of *Acacia raddiana* with herbaceous vegetation change with intensity of abiotic stress. *Flora*, 205: 738-744.

Abdallaha, F. and M. Chaieb. 2012. The influence of trees on nutrient, water, light availability and understory vegetation in an arid environment. *Applied Vegetation Science* (in press).

Aguiar, M.R. and O.E. Sala. 1994. Competition, facilitation, seed distribution and the origin on patches in a Patagonian steppe. *Oikos*, 70: 26-34.

Archer, S. 1995. Tree-grass dynamics in a *Prosopis*-thornscrub savanna parkland: reconstructing the past and predicting the future. *Ecoscience*, 2: 83-99.

Backéus, I. 1992. Distribution and vegetation dynamics of humid savannas in Africa and Asia. *J. Veg. Sci.*, (3): 345-57.

Beena, S., A.Z. Khan, S.K. Khalil, H. Rehman, Farhatullah, H. Gul and H. Akbar. 2013. Response of soil and foliar applied nitrogen and sulfur towards Yield and yield attributes of wheat cultivars. *Pak. J. Bot*., 45(2): 435-442.

Callaway, R.M. 1995. Positive interactions among plants. *Bot. Rev*., 61: 306-349.

Callaway, R.M., R.W. Brooker, P. Choler, Z. Kikvidze, C.J. Lortie, R. Michalet, L. Paolini, F.I. Pugnaire, B. Newingham, E.T. Aschehoug, C. Armas, D. Kikodze and B.J. Cook. 2002. Positive interactions among alpine plants increase with stress. *Nature*, 417: 844-848.

Daget, P. and J. Poissonet. 1971. An ecological analysis method of prairies. Cretical's of application. *Annale agronomique,* 22: 5-41.

Derbel, S., Z. Noumi, K.W. Anton and M. Chaieb. 2007. Life cycle of the coleopter *Bruchidius raddianae* and the seed predation of the *Acacia tortilis* Subsp. *raddiana* in Tunisia. *C. R. Biologies*, 330: 49-54.

Emberger, L. 1954. Une classification biologique des climats Recueil des travaux de Laboratoire de Botanique. *Série botanique, fasc*. 7: 3-43.

Foster, M.A., C.J. Scifres and P.W.J. Jacoby. 1984. Herbaceous vegetation-lotebush [*Ziziphus obtusifolia* (T. & G.) Gray var. *obtusifolia*] interactions in north Texas. *J. Range. Manag*., 37: 317-320.

Frost, W.E. and N.K. Mc Dougald. 1989. Tree canopy effects on herbaceous production of annual rangeland during drought. *J. Range Manage*., 42: 281-283.

Holmgren, M., M. Scheffer and M.A. Huston. 1997. The interplay of facilitation and competition in plant communities. *Ecology*, 78: 1966-1975.

Jeddi, K. and M. Chaieb. 2010. Soil properties and plant community in different aged *Pinus halepensis* mill. Plantations in arid Mediterranean areas: case of southern Tunisia. *Land degradation & development*, 21(1): 40-50.

Khan, M.A., M. Sajid, Z. Hussain, A. Rab, K.B. Marwat, F.I. Wahid and S. Bibi. 2013. How nitrogen and phosphorus influence the phenology of okra. *Pak. J. Bot.*, 45(2): 479-482.

Le Houérou, H.N. 1969. La végétation de la Tunisie steppique (avec références au Maroc à l'Algérie et à la Libye). Analyses de l'INRAT (Tunisie), pp. 42-617.

Le Houérou, H.N. 1987. Aspects météorologiques de la croissance et du développement végétal dans les déserts et les zones menacées de désertification. PNUE, Nairobi et OMM, Genève.

Maestre, F.T. and J. Cortina. 2005. Remnant shrubs in Mediterranean semi-arid steppes: effects of shrub size, abiotic factors and species identity on understorey richness and occurrence. *Acta Oecologia*, 27: 161-169.

Markham, J.H. and C.P. Chanway. 1996. Measuring plant neighbour effects. *Functional Ecology,* 10: 548-549.

Pugnaire, F. and R. L´azaro. 2000. Seed bank and understory species composition in a semi-arid environment: the effect of shrub age and rainfall. *Ann. Bot*., 86: 807-813.

Samuel, D., Fred E. Smeins Fueilendorf and A. Taylor Charles. 1997. Browsing and tree size influences on Ashe juniper understory. *J. Range Manage*., 50: 507-512.

Shannon, C.E. and W. Weaver. 1949. The mathématical Theory of communication, Urbana, University of Illinois Press, (trad fr., (1975), la théorie mathématique de la communciation, Retz-CEPL, Paris), pp.69.

Skarpe, C. 1991. Dynamics of savanna ecosystems. *J. Veg. Sci*., 3: 293-300.

Stuart-hill, G.C. and N.M. Tainton. 1989. The competition interaction between *Acacia karroo* and the herbaceous layer and how this is influenced by defoliation. *J. Applied Ecology*, 26: 285-298.

Su, Y.Z. and H.L. Zhao. 2003. Soil properties and plant species in an age sequence of *Caragana microphylla* plantations in the Horqin Sandy Land, north China. *Ecological Engineering*, 20: 223-235.

Vaitkus, M.R. and L.E. Eddleman. 1991. Tree size and understory phytomass production in a western juniper wood land. *Gt. Basin Nat*., 51: 236-243.

Walker, B.H. 1987. Determinants of tropical savannas. Oxford: IRL Press.

Werner, Patricia A., B.H. Walker and P.A Stott. 1991. "Introduction". In: Patricia A. Werner. Savanna Ecology and Management: Australian Perspectives and Intercontinental Comparisons. Oxford: Blackwell Publishing.

(Received for publication 23 March 2012)