LEGUMES DIVERSITY IN THE SOUTH BANK OF NAHR-IBRAHIM RIVER IN LEBANON

T. Atallah, S. Hajj, M. Mehanna, N. Aoun, T. Darwish[1] and H. Rizk
Department of Plant Production, Faculty of Agricultural Sciences, Lebanese University, Ras-Dekwaneh, Lebanon
[1]National Council for Scientific Research, Center for Remote Sensing, Beirut, Lebanon
theresea@lynx.net.lb.

(Received 29 March 2008 - Accepted 31 December 2008)

ABSTRACT

The target of studying biodiversity in the south bank of Nahr-Ibrahim valley was to study models for the rehabilitation of degraded areas, with an emphasis on the diversity of wild legumes. In an altitudinal transect, the rock substrate was limestone mostly, with a few sites on basalt. Habitats were found to be mostly oak dominated open forests. All sites on limestone were highly diverse, with Shannon index reaching 3.691. The high level of heterogeneity characterizes the relatively undisturbed sites of native vegetation. Vegetation on basalt was less diverse than on limestone. Thirty species of legumes belonging to 15 genera were identified, 23 species were annual and 7 perennial. Most dominant legume species were herbaceous, except for Calicotome villosa an abundant shrub. Legumes diversity was positively linked to the number of species, the Shannon index and the coverage by the herbaceous layer. A significant association was found between Tamus, Hordeum, Dactylocteneum, Trifolium spp, Calicotome villosa, Styrax officinalis and Quercus calliprinos. This could serve as a model for future combination of potentially useful plant species.

Keywords: Shannon index, oak dominated forest, legume diversity, humid Mediterranean, species associations

INTRODUCTION

Lebanon is regarded as very diverse, sheltering an estimated number of 4200 species. As a result of the physiography of the landscape, country's location at a crossroad between continents (Anonymous, 2003) climate and hydrography, the floristic richness of the country was estimated at 2600 plant species (cited by Zohary (1973)), 12% of them being endemic. This constitutes an important part of the Mediterranean flora especially the oriental Mediterranean.

This wealth of ecosystems and habitats is demonstrated by its many types of forests. In ancient times, Lebanese forests were the suppliers of high quality timber to the Mediterranean people (Daoud, 2003). The intensive wood cutting over several millennia, followed by the expansion of agro-pastoral activities and subsequent urbanization resulted in only relic patches and scrub vegetation remaining. The current forest surface represents 12.5% of the surface area of the country (Anonymous, 2003), while the dense forest (coverage >60%) regressed to 50,250 ha (Anonymous, 2004). Still, this remarkable diversity is actually threatened by many factors. Unless appropriate measures are taken, within several years natural areas will be replaced by bare soils and degraded lands. Till now there have been no comprehensive projects to revegetate the degraded areas.

Suitable candidates for the revegetation are native plant species, characterized by their ability to support harsh conditions, to tolerate poor and shallow soil, in particular those belonging to the legume family. The rhizobia-legume symbiosis has major environmental and agricultural importance since it is responsible for most of the atmospheric nitrogen fixation on earth (Zakhia & de Lajudie, 2001). Growing in poor soils, some legume species are pioneer plants in disrupted environments, such as *Acacia* in tropical African conditions (Zahran, 2001), *Spartium junceum* in southern Italy (Quatrini *et al*., 2002) and leguminous shrubs in semi-arid and desertified ecosystems in Spain (Requena *et al*., 2001). Leguminous shrubs are dominant in arid habitats as in Central Spain, still their fixing ability is little known compared to cultivated forages and pulses (Valladeres *et al*., 2002).

A previous study focused on the nodulation of native legume species in the grasslands and shrublands of the North bank of Nahr-Ibrahim river. Out of 36 species of legumes identified, some 15 species could be suitable candidates for use in revegetation due to their high frequency or their occurrence regardless of the sites level of degradation. The perennials *Calicotome villosa, Psoralea bituminosa* and *Spartium junceum* as well as the annuals *Onobrychis crista-galli, Hymenocarpos circinnatus, Trifolium tomentosum*, *Medicago polymorpha*, *M. orbicularis*, *Vicia hybrida* and *V. palaestina,* could be suitable legume species for the restoration of degraded sites (Atallah *et al*., 2008). In this work, field surveys were conducted in the South bank of Nahr-Ibrahim river, known for its broadleaf forests. This region was taken as the model for a better knowledge of a typical forest, its plant diversity and distribution. The main objectives were an evaluation of the diversity of relatively undisturbed ecosystems, mostly broadleaf; and identification of new possible species associations suitable for revegetation with an emphasis on legume species.

MATERIALS AND METHODS

Region surveyed

A field survey was conducted during the spring and summer season in the South bank of Nahr-Ibrahim river, characterized by the presence of high density forests, different soil-climatic conditions and low degradation level in most sites. In ten locations chosen along the river bank, from 105 m till 1020 m above sea level, 34 sites were studied. Twenty-six of them were on limestone and 8 on basalt. The latter was selected at three altitudes comparable to locations on limestone (Table 1). The altitude was measured by the mean of an altimeter, the slope by a colloquial, latitude and longitude using a Global Positioning System Receiver (GPRS, MAGELAN MAP 330). Site physiography, the microenvironment, disturbance factors and ground coverage were estimated visually.

Each site was a square of 100 x 100 m. For individuals having only a part of them inside the square, only the included part was counted. Ground coverage was recorded according to the percentage of hard rock coverage, gravel coverage, fine gravel and vegetation coverage. The vegetation taken into consideration for the ground coverage was only the herbaceous stage, so that all factors will be at the same level.

TABLE 1

Coordinates and Major Characteristics of Target Sites

Location	Coordinates	Sites	Observed vegetation[1]	Rock	Soil type[3]
Ksar El-Kadi (I)	034 04.048 N 035 40.048 E 105 m	1-2-3	Open forest/ Scrubland	L[2]	Lithic leptosols
El Ksar (II)	034 04.046 N 035 42.490 E 220 m	4-5-6	Dense/ Open forest	L	Calcaric regosols
Ghochrye (III)	034 04.33 N 035 43.025 E 310 m	7-8-9	Scrubland/ Open forest	L	Calcaric regosols
Ayn El-Hanout (IV)	034 04.021 N 035 43.039 E 445 m	10-11-12	Dense forest	L	Endoskeletic regosols
Hay Ksar (V)	034 04.010 N 035 43.036 E 500 m	13-14-15	Scrubland/ Dense forest	L	Fluventic regosols
Esh Shwaiya (VI)	034 04.005 N 035 43.050 E 560 m	27-28-29	Open forest	B	Leptic andosols
Nabaa El-Ghara (VII)	034 03.049 N 035 44.029 E 570 m	16-17-18	Dense forest	L	Lithic leptosols
Haret El-Fawka (VIII)	034 04.007 N 035 44 001 E 590 m	30-31-32	Open forest	B	Leptic andosols
Hay El-Snawbra (IX)	034 04.002 N 035 44.049 E 695 m	19-20	Scrubland	L	Lithic leptosols
El-Baharra (X)	034 03.023 N 035 44.004 E 880 m	33-34	Dense/ Open forest	B	Leptic andosols
Hadchat (XI)	034 03.008 N 035 44.004 E 890 m	21-22-23	Scrubland/ Open forest	L	Areno-eutric leptosols
Hakl El-Rayyes (XII)	034 03.020 N 035 43.045 E 1020 m	24-25-26	Open forest	L	Lithic leptosols

1- The first habitat refers to 2 out of 3 sites; 2- L for limestone and B for basalt ;
3- Darwish (2004);

Study of the vegetation

Based on its height, the vegetation of the sites was divided into 4 layers: herbaceous (<1 m), shrub (1-2 m), small trees (2-4 m) and large trees (>4 m) layers. Within each level, the abundance, sociability and coverage were considered. For the abundance the classes were: 1- Rare; 2- Low coverage; 3- 1/5 of the total surface; 4- ¼ to ¾ of the total surface and 5- >¾ coverage of the total surface. For the sociability, the classes were: 1-isolated species, 2-slightly grouped species, 3-moderately grouped species, 4-species grouped in colonies and 5-species grouped in pure population (Faurie *et al*., 1998). Plants were identified in the field, and those that were unknown were brought to the laboratory, with their roots when possible, for their identification based on Mouterde (1970) and Davis *et al*. (1969).

Shannon's index Σ (-ni/n*ln ni/n), a most common measure of diversity which takes into account the proportional abundances of different classes, was calculated. The evenness was obtained by scaling Shannon indices (Shannon/ln (ni)) between 0 and 1 (Odum, 1975). The relationship or association of plant species was assessed by the coefficient of concordance (W), calculated as:

$$W = \frac{Ri^2 - (\sum Ri)^2 / n}{M^2 (n^3 - n)/n}$$

R: rank of the variable; *M*: number of variables being correlated; *n:* number of data per variable (Zar, 1983).

RESULTS AND DISCUSSION

Sites characteristics

Nine locations out of twelve were on limestone. The habitats were mostly of open forest (coverage by large trees <60%) in 14 sites. Six sites were occupied by dense forests and five by a scrubland or a "maquis" type of vegetation, with small trees only (Table 1). Dominant species were *Quercus calliprinos* (11 sites), *Pistachia lentiscus* (5 sites), *Quercus infectoria* (4 sites) and *Styrax officinalis* (2 sites). This was quite different from the great majority of grasslands and forbs, described in the Land cover map (FAO, 1990).

Within sites, the number of species ranged from 10 (site 11) to 33 (site 16). The highest number of species found in the latter site, could be due to the little impact of urban development and to the open woodland habitat, which allowed the expansion of shrubs and grass layers. The mean number of species was 23.19 (Standard Error =1.19) with seven sites presenting less than 20 species. But high species richness does not necessarily coincide with high genetic diversity. Sites heterogeneity was assessed using Shannon index. All sites presented a relatively high Shannon index ranging from 3.691 in site 17, to 2.665 in site 1. Sensitive to the abundances of the rare species this is considered to be the best heterogeneity measure, with values falling normally between 1.5 and 3.5 (Myers & Bazely, 2003). The evenness values were narrower, between 0.961 and 0.990 (Table 2). Sites located on the North bank of the river presented smaller Shannon (Cherfane, 2002), which confirms the greater diversity of the South bank. In fact, the study was conducted on undisturbed habitats with a predominance of forests, so biodiversity should necessarily be important.

Species distribution with altitude

Species frequency varied widely. *Quercus calliprinos*, encountered in 24 out of 26 sites and *Calicotome villosa* in 20 out of 26 sites, were very frequent. *Medicago rigidula* was found in one site, while *Psoralea bituminosa* in two sites of the same location. In particular, *Sarcopoterium spinosum* that appears in degraded sites was found only in one site, as compared to 6 out of the 14 sites on the North bank (Atallah *et al*., 2008). In fact the north bank sites included medium to highly degraded areas, while those of the south bank were all of low degradation level. Of the dominant species, only the coverage of *Pistachio* presented a significant correlation with altitude. The regression equation was: $y = -0.0266\ x + 25.638$ ($r=0.602^*$ with $p<0.05$). With altitude, the coverage by this species decreased and was possibly replaced by other dominant species.

Most of these species grow well on a range of altitude, between 0-500 m or 500-1000 m (Dereix *et al*., 1999), hence the lack of response to altitude. In this study, some species were found at specific altitudes. *Hypericum*, *Myrtus communis, Asplenium trichomanis* and *Laurus nobilis* were found between 0 and 500 m. However *Laurus* is known to extend from 0 to 2000 m (Anonymous, 1996). Grasses, *Calicotome villosa*, *Securigera securidaca*, *Spartium junceum* and most of the *Trifolium* species appeared in all altitudes. Others were found in a limited range of altitude such as *Trifolium clypeatum* (220-570 m); *Ononis spinosa* present above 500 m, as well as *Medicago polymorpha* and *Vicia* sp. *Astragalus lanatus* and *Lotus corniculatus* appeared at 1020 m, while *Lotus edules* was found at 105 m.

To assess the associations between a number of plant species, the coefficient of concordance (W) was calculated. For this purpose, species of the same genera were taken together. A trial was done by considering the coverage of species from the herbaceous, shrub and tree layers. As a result, the abundance of *Tamus*, *Dactylocteneum*, *Hordeum, Trifolium* spp (herbaceous), *Calicotome villosa* (shrub), *Styrax officinalis* (small tree) and *Quercus calliprinos* (large tree) presented a significant coefficient of concordance $\chi^2=62.68$ (> tabular $\chi^2_{25} = 37.65$).

Influence of the rock substrate on the vegetation

In order to see the difference in vegetation type, coverage and distribution between basalt and limestone, a survey was conducted on three different sites of basalt. As the survey was done late in the season, only large trees, small trees and shrubs were studied. It was too late to be able to identify the herbaceous layer. For the same altitude, the poor vegetation on basalt was obvious (Table 3) as forest vegetation has almost completely disappeared from such substrate in Lebanon (Anonymous, 1996). Some species such as *Pistachia lentiscus*, *Quercus calliprinos*, *Spartium* and *Calicotome* were found in both rock substrates, while *Pinus pinea* was found only on basalt and *Cercis siliquastrum* on limestone. At 570 m altitude, the dominant species for basalt was the *Pistachia lentiscus* (coverage: 15.83%) while on limestone it was *Calicotome villosa* with 20% coverage. At an altitude of 880 m, the dominant species on basalt was *Quercus calliprinos* with a coverage close to that on limestone (16.33%). The dominant species on the limestone was *Spartium junceum* with a coverage of 23.33% against 1.33% on basalt. Large patches of bare soil were present on the basalt in comparison to a very high density of vegetation and diversity in limestone. Even the coverage and abundance for the same species varied between the two rock types.

TABLE 2

Species and Legume Diversity of the Sites on Limestone

Site	Species			Legume	
	Shannon	Evenness	Number of species	Shannon	Evenness
1	2.665	0.961	14	1.083	0.781
2	3.147	0.966	23	1.427	0.887
3	2.668	0.962	14	0.868	0.790
4	3.160	0.982	18	1.083	0.986
5	3.404	0.974	25	1.895	0.974
6	3.188	0.978	21	1.321	0.953
7	3.252	0.976	25	2.025	0.974
8	3.457	0.989	28	2.111	0.961
9	3.376	0.983	30	2.206	0.958
10	3.199	0.982	25	0	
11	2.704	0.975	10	0	
12	2.756	0.973	14	1.055	0.761
13	3.117	0.981	21	1.595	0.991
14	3.342	0.973	27	2.201	0.956
15	3.526	0.976	24	2.420	0.974
16	3.525	0.976	33	2.472	0.964
17	3.691	0.981	32	2.491	0.971
18	3.412	0.967	30	1.505	0.935
19	3.354	0.977	26	1.907	0.980
20	3.463	0.990	27	2.232	0.969
23	3.286	0.966	25	1.469	0.913
24	3.314	0.974	26	1.847	0.949
25	3.343	0.973	27	2.308	0.962
26	3.400	0.990	26	2.119	0.964
27	2.891	0.965	17	1.471	0.914
28	2.757	0.973	14	1.411	0.877

Legumes diversity

Only species belonging to the sub-family Papilionidaceae will be considered, whereas *Ceratonia siliqua* and *Cercis siliquastrum* belonging to another sub-family will not be included. A total of 30 leguminous species belonging to 15 genera were found. Site 4 was the poorest with only three legume species belonging to three genera. In fact this site was a roadside, with a high coverage of large trees (mainly *Quercus calliprinos*), shading all the area and preventing the growth of the herbaceous layer. Between sites, the diversity of legumes was assessed by calculating Shannon's index for the legumes coverage. Site 10 could be considered the most diverse having an evenness of 0.93 (Table 2) while the least diverse was site 1 with a Shannon index of 0.588 and an evenness of 0.36. Legumes Shannon indices were positively correlated with the Shannon index of all species and with the coverage by the herbaceous species (Table 4). This could be linked to the fact that most legumes encountered were annuals.

TABLE 3

Number of Perennial Species and their Ground Coverage (%), in Three Locations of Comparable Altitude on Limestone or on Basalt Bedrock

Limestone				Basalt			
Altitude (m)	**Site**	**Shrubs**	**Trees**	**Altitude (m)**	**Site**	**Shrubs**	**Trees**
500	**13**	32	40	560	**27**	0	37
	14	3	17		**28**	3	40
	15	20	62		**29**	6	45
570	**16**	34	95	590	**30**	7	27
	17	59	106		**31**	20	10
	18	37	56		**32**	0	24
890	**21**	55	40	880	**33**	12	68
	22	31	34		**34**	19	30
	23	55	7				

Generally, 23 annual and 7 perennial species were described. The frequency of these species varied from 76.9 % for *Calicotome villosa* to 7.69 % for *Psoralea bituminosa, Astragalus lanatus, Lotus cytisoides* and others. *Calicotome* was by far the most frequent species, comparable to that on the grasslands and shrublands of the north bank (Atallah *et* *al*., 2008). Elsewhere, a relatively rare perennial species *Coronilla emeroides* was found. Encountered first on sandstone and later on limestone too, it seemed to prefer shaded and humid areas.

Trifolium were the most frequent annual followed by *Lathyrus* then by *Medicago*. *Lathyrus aphaca* was the most frequent (46.15 %), similar to the North bank where this species was very abundant (Atallah *et al*., 2008). The frequency of *Trifolium campestre* was 53.84 % and that of *Medicago polymorpha* 30.76 %. Some frequent species, such as *Trifolium stellatum* (38.46 %), grew on fertile soils only. This is consistent with the results of Cherfane (2002), indicating its unsuitability for the rehabilitation of degraded soils.

Mean ground coverage was the highest for *Calicotome villosa* (11.38%), followed by *Spartium junceum* (8.05 %) and *Lathyrus aphaca* (7.99 %). *Lotus edules* had the least coverage percentage (1 %). In the grasslands of the North bank, *Hymenocarpus* had the highest coverage (16 %), compared to 1.33 % in the sites of the South bank. *Trifolium purpureum* had a high ground coverage (20 %) in the high-degraded sites, as well as the sites of the South bank (7.6%), which indicates its ability to grow on all sites irrespective of the degradation level. A special attention should be given to the threatened species *Lathyrus digitatus* and *Lotus cytisoides*, with a higher danger for *Lotus* than for *Lathyrus* (Anonymous, 1996). This fact was made clear in this study, since *Lotus cytisoides* was found only in one site, while *Lathyrus digitatus* was found in 4 sites.

TABLE 4

Correlation Matrix between the Diversity Components of the Sites on Limestone

	Shannon index	Herbaceous coverage	Shrubs coverage	Small trees coverage	Large trees coverage	Legume – Shannon index
Species	0.937**	0.592*	-0.002	-0.114	-0.027	0.711*
Shannon index		0.620*	-0.034	-0.072	0.049	0.738*
Herbaceous coverage			0.300	0.067	0.052	0.472*
Shrubs coverage				0.385	-0.337	-0.106
Small trees coverage					-0.065	-0.089
Large trees coverage						-0.306

*significant at the 5% level, ** significant at the 1% level.

CONCLUSION

The majority of surveyed sites consisted of relatively undisturbed ecosystems, with a predominance of open forests. Two types of rock substrates were encountered: limestone and basalt. All sites on limestone were highly diverse, Shannon index reached 3.691 in the most diverse site. The high level of heterogeneity characterizes the relatively undisturbed sites of native vegetation. Basalt was less diverse than limestone. For the same altitude, the vegetation and dominant species differed between basalt and limestone. Thirty species of legumes belonging to 15 genera were identified, 23 species were annual and seven perennial. Most dominant legume species were forbs, except for *Calicotome villosa,* an abundant shrub. Legumes diversity was linked to the general number of species, the high Shannon index and the herbaceous coverage. A significant association was found between the following species *Tamus*, *Hordeum, Dactylocteneum, Trifolium* spp, *Calicotome villosa, Styrax officinalis and Quercus calliprinos.*

REFERENCES

Anonymous 1996. *Etude de la diversité biologique du Liban, flore terrestre*. République Libanaise, Ministère de l'Agriculture, Programme des Nations Unies pour l'Environnement, 147 pages.

Anonymous 2003. National program to combat desertification. Lebanon, Ministry of Agriculture, 47-57.

Anonymous 2004. *Atlas agricole du Liban*. Ministère de l'Agriculture, Direction des études et coordination, CD format.

Atallah, T., Rizk, H., Cherfane, A., Bou Daher, F., El-Alia, R., De Lajuide, P. and Hajj, S. 2008. Distribution and nodulation of spontaneous legume species in grasslands and shrublands in Mediterranean Lebanon. *Arid Land Research and Management,* 22: 109-122.

Cherfane, A.R. 2002. *Ecogeographical distribution of wild legumes in degraded areas.* Lebanese University, Faculty of Agricultural Sciences, graduation project, 54 pages.

Daoud, A. 2003. Sauver le cèdre du Liban - un symbole culturel. *Unasylva,* 54 (2) : 50-51.

Darwish, T. 2004. New soil map of Lebanon at 1:50 000, sheet Jbeil and Qartaba. Assessment of soil resources using remote sensing for soil studies, CNRS, Beirut, Lebanon.

Davis, P.H., Chamberlain, D.F., Phil, D. and Mathews, V.A. 1969. *Flora of Turkey and East Aegean Islands.* University of Edinburgh, Volume III, 627 pages.

Dereix, C., Ohannessian-Charpin, A., Khouzami, M., Safi, S., Zreik, R., El Hann, C., Hanna, K., Assaf, N., El Riachy, R., Habr, A., Munz, M.H., Fourtunat, L. 1999. *Du gestionnaire des forêts et d'espaces naturels au Liban, comment établir un plan de gestion durable*. Union Européenne, Ministère de l'Agriculture, Projet d'assistance à la protection de la couverture végétale au Liban. 102 pages.

Faurie, C., Ferra, C., Médori, P., Dévaux, J. 1998. *Ecologie, Approches scientifiques et pratiques*. Editions TEC et DOC, Paris, pp. 41- 68.

FAO 1990. Lebanon land cover map (1:50 000), Sheet 4.

Mouterde, P. 1970. *Nouvelle flore du Liban et de la Syrie.* Dar el Machrek éditeurs, Beyrouth, Tome II, 727 pages.

Myers, J.H. and Bazely, D.R. 2003. *Ecology and control of introduced plants.* Cambridge University Press, Cambridge, UK, 313 pages.

Odum, E.P. 1975. *Ecology*. 2nd edition, Holt-Saunders international edition, London, 233 pages.

Quatrini, P., Scaglione, G., Cardinale, M., Caradonna, F. and Puglia, A.M. 2002. *Bradyrhizobium* sp. nodulating the Mediterranean shrub Spanish Broom (*Spartium junceum* L.). *Journal of Applied Microbiology*, 92 : 13- 21.

Requena, N., Perez-Solis, E., Azcon-Anguilar, C., Jeffries, P. and Barea, J. 2001. Management of indigenous Plant-Microbe symbioses aids restoration of desertified ecosystems. *Applied and Environmental Microbiology,* 67(2): 495- 498.

Valladares, F., Villar-Salvador, P., Dominguez, S., Fernandez-Pascual, M., Penuelas, J.-L. and Pugnaire, F.I. 2002. Enhancing the early performance of the leguminous shrub *Retama spaerocarpa* (L.) Boiss.: fertilization versus *Rhizobium* inoculation. *Plant and Soil,* 240 : 253- 262.

Zahran, H.H. 2001. Rhizobia from wild legumes: diversity, taxonomy, ecology, nitrogen fixation and biotechnology. *Journal of Biotechnology*, 91 : 143- 153.

Zakhia, F. and de Lajudie, P. 2001. Taxonomy of Rhizobia. *Agronomie,* 21: 569- 557.

Zar, J. 1984. *Biostatistical analysis*. 2nd edition, Prentice-Hall International Editions, New Jersey, 715 pp.

Zohary, M. 1973. *Geobotanical foundations of the Middle East*. Gustav Fischer Verlag, Stuttgart, Germany, 2 volumes (x, 738 pages).