# Adaptability of *Helietta parvifolia* to Extreme Climatic Conditions of North-eastern Mexico

**Rahim Foroughbakhch*, Jorge L. Hernández Piñero, Marco A. Alvarado Vázquez and Artemio Carrillo Parra**
Facultad de Ciencias Biológicas, Universidad Autónoma de Nuevo León, A. P. F-2, 66451 San Nicolás de los Garza, N. L., México

**Article History**
Manuscript No. 81
Received 28th October, 2010
Received in revised form 1st November, 2010
Accepted in final form 3rd November, 2010

**Correspondence to**
*E-mail: rahim.f@gmail.com

***Keywords***
*Helietta parvifolia*, adaptability, growth, firewood, yields

**Abstract**

In rural zones of Mexico, the demand for timber and forest product continues to increase. Efforts are being made to meet the demand for timber by raising compensatory man-made plantations. Presently, attention is given to growing indigenous premium hardwood species. One of the promising indigenous species among various fuelwood species is *Helietta parvifolia* which grows naturally in the dry and sub-tropical zones of north-eastern Mexico. It is a premium quality hardwood species and the wood is of high density which is used for construction and furniture. This paper describes its structure, growth characteristics and the economic yield in north-eastern Mexico. *H. parvifolia* was sampled in seven study sites of native vegetation. The average population density was 1210 plants $ha^{-1}$. Three strata were found: a low stratum along with sub-chaparral less than 3 m in height; a chaparral stratum with 3-5 m height (3-6 cm dbh), and a third stratum higher than 6 m in height and 7-12 cm in dbh (diameter at breast height). The principal component analysis indicated 75% of the biomass as wood product and 25% as foliage and debris. The economic yield was 1455 fence posts $ha^{-1}$ with a dbh superior than 7 cm, corresponding to an income of USD 1892 $ha^{-1}$.



## 1. Introduction

The screening of large number of tree species for high biomass productivity has arisen directly out of the growing recognition by the forestry research community during 1980s in arid zones (Foley and Barnard 1984; Gregersen et al., 1989). There has been a significant shift in priorities towards concentration on non-industrial species grown or managed by farmers for such products as fuelwood, poles, animal fodder and house fencing. Increase in the yields of these and other products by identifying superior genotypes is now a major thrust area of research throughout the arid and semi-arid zones (Glover and Adams, 1990).

In view of these facts, rapid deforestation often produces landscape-level changes in forest characteristics and structure, involving area, distribution, and forest habitat types (Virginia et al., 1995). Changes in landscape pattern through fragmentation or aggregation of natural habitats can alter the pattern of abundance of single species and entire communities (Quinn and Harrison, 1988; Hughes, 2000). A decrease in the size and number of natural habitat patches increases the probability of local extirpation and loss of diversity of native species, whereas a decline in connectivity between habitat patches can negatively affect regional species persistence. Thus, there is an empirical justification for managing entire landscape, not just individual habitat types, in order to ensure and maintain the native plant diversity (Andrean and Angelstam, 1988; Malcom et al., 2002).

The Tamaulipan thornscrub is a low dry forest and shrubland complex covering about 20 mha of the Gulf coastal plain in north-eastern Mexico and southern Texas, USA. The Tamaulipan thornscrub, a matorral type, has been grazed by domestic stock for about four centuries and is heavily exploited by subsistence farmers for fuel, timber and other resources (Reid et al., 1990). In order to prevent further desertification and sustain agricultural, livestock and forestry production, the matorral must be conserved, and where necessary, enriched with planting of desirable multipurpose trees and shrubs (Foroughbakhch, 1992; Foroughbakhch et al., 2006, 2007).

*Helietta parvifolia* (Rutaceae) is a native species of submountainous matorral of north-eastern Mexico, with a large range of the ecological distribution, starting from south-eastern Texas, USA, through central parts of Mexico (San Luis Potosí, Guanajuato) and concentrating in Nuevo Leon, Tamaulipas and part of Coahuila, Mexico.

*H. parvifolia* is a shrub with a long irregular crown which is open in the dry season and dense in the wet season. It reaches a height of 4-6 m (up to 12 m). Its diameter at breast height (dbh) ranges from 5.2 to 20 cm depending on the locality. Its branches are thin, erect and cylindrically shaped, forming a vertical crown. The bark is solid, smooth and dull brown. Its orange-brown wood is hard and heavy, with a specific density of 0.88 g $cm^3$. The leaves are opposite, trifoliate with the terminal foliate longer than the two laterals (2-5 x 1-2 $cm^2$). All parts of *H. parvifolia* are highly aromatic.

Studies on management of *H. parvifolia* in north-eastern Mexico showed that it grows best in gentle slopes and hills up to 20° with slopes in northern or north-eastern directions (10-30°)

and rocky hills of 15 to 70°. The favorable soils for this species are dark gray silty-clay vertisols, well drained, with a pH of 7-8 and a depth of more than 60 cm (Rovalo et al., 1983).

The shrub has a variety of uses, the main one being timber for house construction, fence and corral installations for animals in the rural areas. Its wood is highly valued for its durability and resistance to rotting. Its leaves are used as forage for cattle. The deep system of its root makes it an appropriate species for erosion control and soil conservation. Furthermore, due to the shape of the crown, *H. parvifolia* can be used as an ornamental plant in urban areas (Reid et al., 1989, 1990). *H. parvifolia* was selected for agro-forestry trials on the basis of its ecological importance, uses and preference by the rural population (Stewart and Dunsdon 1994; Gonzalez et al., 2005). Knowledge of their ecophysiological characteristics would facilitate the selection of the species most suitable for silvicultural management under specified conditions. In the semi-arid environment of the Gulf coastal plain, the water deficit, drought and extreme temperatures frequently limit the growth and productivity. This paper aims to provide a synthesis of the results from the evaluation of wood and leaf biomass production of *H. parvifolia* through forestry inventory in order to compare the data from seven sites of north-eastern Mexico.

## 2. Materials and Methods

### *2.1. General description of the study area*

The study was conducted in the Tamaulipan spiny matorrals situated at 35 km south-east of General Teran, Nuevo León, Mexico having the coordinates: 25°16´N latitude and 99°21´W longitude with an altitude of 200-800 msl.

The study area has a semi-dry to sub-humid climate with very low winter precipitation. It belongs to (A) C (Wo) type with two periods of summer rainfall. The long-term mean annual precipitation is 800 mm, with two peaks in the spring and late summer and drought periods in mid-summer and winter (Stienen, 1990). The mean annual temperature is 22.1°C with a large difference between winter and summer (abs. Min. 12°C, abs. Max. 45°C) and even within the same month. Hail and frosts usually occur each year even after the beginning of the growing season during February-March. The water budget is unbalanced, the ratio of precipitation on free evaporation being 0.48 and precipitation/potential evaporation 0.62 (Cavazos and Molina, 1992).

The soils of the region are basically rocky of Upper Cretaceous lutite or siltstone. The dominant soils are deep, dark grey, lime-clay vertisols which are the result of complex processes of alluvial and coluvial types. They are characterized for high clay and calcium carbonate contents (pH: 7.5-8.5) and relatively low in organic matter, phosphorus and nitrogen contents (Navar and Bryan, 1994).

### *2.2. Sampling, data collection and analysis*

In order to determine the plant density, timber and firewood volume of *H. parvifolia* in a representative area of Tamaulipan matorral (400 ha) of 5-8 m high, which consists of some 30 woody species growing in vertisol soil, 7 sites were selected with sizes of 2-3 ha each.

The selection of the sites is based on the height and the slope which are considered as factors influencing the density and growth of *H. parvifolia*. Along the length of each site a transect was established in a systematic form having 15 plots of 25 m² (5 x 5 m²) as sample size. We took a uniform sample according to Braun-Blanquet (1979), and Muller-Dombois and Ellenberg (1974).

On the basis of the vegetation characteristics and the case of determination as well as information records quadrant sampling was done. From each plot and site, the number of plants, its total height (m), basal diameter (cm), diameter at the breast height (cm) and plant canopy projection (m²), and also its importance value were recorded. The composition of the species and the response among them was determined through application of four coefficients which are explained as follows.

a) Relative frequency species$^{-1}$ (F%) = $\dfrac{\text{Number of plots with species}}{\text{Total number of plots}}$ X100

b) Relative abundance species$^{-1}$ (A%) = $\dfrac{\text{Number of plants with species}}{\text{Total number of plants}}$ X100

c) Relative dominance species$^{-1}$ (D%) = $\dfrac{\text{Canopy area of the species}}{\text{Total area of canopies}}$ X100

d) Importance value species$^{-1}$ (IV%) = $\dfrac{F\%+A\%+D\%}{3}$

For *H. parvifolia*, in addition to its annual growth, the number of stands and the volume of the same (m³ ha$^{-1}$) in each site were determined according to the Smalian formula for all cylindrical trunks (Meskimen and Franklin, 1978) as follows.

$V = S_m X L$ o $V = ½ (S_1 + S_2) x L$

Where V=Volume of the trunk in m³, $S_m$=Area of central section of the log in m², $S_1$=Area in m² at large end of the log, $S_2$=Area in m² at small end of the log, and L=Length of the log in m.

It is considered as commercial trunk as a stand with a minimum length of 1.8 m and a superficial diameter of 7 cm in both extremes.

On the basis of the population density and the calculated commercial stands, the economic return ha$^{-1}$ from the standpoint of the sale of the product was determined taking into account the unit price (Mex. $13=USD 1.0) of each stand in the regional level multiplied by total number ha$^{-1}$.

Data was analyzed statistically (SPSS, vers. 15.0) using a simple analysis of variance (one-way) to determine the differences among sites. One-way ANOVAs were conducted on all parameters under study. Mean comparisons for specific groups on each site were made using the Tukey test (Zar, 1996).

The measurement of growth parameters was done once year$^{-1}$ during a period of three consecutive years, while the volume of the firewood and the number of stands are quantified during the second year of the study.

## 3. Results and Discussion

### *3.1. Physical structure*

The analysis of physical structure reflects the composition of the matorral, number of the species and their ecological behavior.

The interactions between diverse environmental factors affect the survival and growth of every species. Thus the existence and development of the diverse plant components of the matorral need to be viewed as the results of a complex process or adaptation to the ecological conditions of the environment (Muller-Dombois and Ellinberg, 1974).

In total, 30 woody species are registered from seven sites of the study area. The results on the similarity analysis showed a clear dominance of *H. parvifolia* which accounts for 34.16% of the important vegetation (Table 1). According to these observations, *H. parvifolia* could be considered as the species of higher dominance, prevalent in deep rocky soil with inclination (10-30°), and relatively rich in nutrients with favorable water region.

The competitive capacity of a species and its utility depends largely on its height. On the basis of the growth parameters and production, *H. parvifolia* is considered a dominant timber plant of economic importance in the region.

According to Thomas (1989), physical structure analysis provides information on the plant composition, number of the species and their ecological behavior, i.e. their dynamic interaction with the environment. This analysis also generates information on parameters such as the density, height and crown area, as well as basic data on the evaluation of the usage of natural resources. The results on the population density of *H. parvifolia* as a function of different study sites are given in Table 2. These data demonstrate significant differences (ANOVA, $p<0.05$) among the study sites with a progressive increase in the density at higher elevation in each study area.

To determine the growth parameters, 25 m² plots were commonly employed in forests as well as high sub-mountainous matorral studies. In each plot, the height, diameter and crown growth of all the shrubs and trees were recorded. The increase in height and diameter of plants is normally a good index of its capacity for successful development, especially in the initial establishment phase. When other factors such as the spacing, competition, soil quality and climate begin to take effect, the absolute importance of the height increment diminishes and other criteria need to be evaluated for monitoring the growth.

The results of plant height and diameter suggest the existence of three distinct strata on the basis of the mean of these two parameters as a lower stratum between 0.1-3 m height without dbh, an intermediate stratum of 3-5 m tall with 3-6 cm dbh, and a higher stratum of over 7 m height with dbh between 7-12 cm.

One-way analysis of variance showed significant differences between the heights (F test=3.87, $p<0.01$) and dbh (F test=2.64, $p<0.05$) among the plants and sites. Mean diameter was essentially more constant ranging from 7.1 cm (200-500 msl) to 8.6 cm (800 msl).

*H. parvifolia* with a low growth rate of 0.4 cm year$^{-1}$ in dbh and 13-24 cm in height is not an adequate species to be used in mixed plantations, because a species with a rapid rate of growth can become dominant when different species in the mixture have different rates of growth.

Under normal conditions, wood production is a function of the

Table 1: Importance value of principal woody species in the Tamaulipan matorral of north-eastern Mexico

| Species | F% | A% | D% | IV% | Stratum |
|---|---|---|---|---|---|
| *Helietta parvifolia* (Gray.) Benth. | 34.9 | 36.1 | 31.5 | 34.16 | High |
| *Pithecellobium pallens* (Benth.) Standl. | 14.3 | 16.8 | 12.7 | 14.60 | Medium high |
| *Gochnatia hyperlauca* (D.C.) Gray. | 6.1 | 5.4 | 10.6 | 7.36 | Medium high |
| *Cordia boissieri* D.C. | 4.7 | 5.2 | 9.1 | 6.33 | Medium high |
| *Pistacia texana* H.B.K. | 3.7 | 2.2 | 3.4 | 3.11 | Low |
| *Diospyros texana* Scheele. | 2.4 | 3.0 | 2.9 | 2.76 | High |
| *Eysenhardtia polystachya* (Ortega.) Sarg. | 2.6 | 1.7 | 2.2 | 2.16 | Medium high |
| *Forestiera angustifolia* Torr. | 1.9 | 1.7 | 2.8 | 2.13 | Medium |
| *Diospyros palmeri* Eastw. | 1.5 | 2.2 | 1.9 | 1.86 | High |
| *Zanthoxylum fagara* (L.) Sarg | 2.2 | 1.7 | 1.6 | 1.83 | High |
| *Celtis pallida* Torr. | 2.0 | 2.1 | 1.3 | 1.80 | Medium |
| *Castela Texana* (Torr. et Gray) Rose | 1.9 | 2.4 | 0.8 | 1.70 | Medium low |
| *Condalia hookeri* M.C. Johnst. | 1.5 | 1.4 | 1.2 | 1.36 | High |
| *Leucophyllum frutescens* Benth. | 1.4 | 1.6 | 1.1 | 1.36 | Low |
| *Acacia Berlandieri* Benth. | 1.2 | 1.3 | 15 | 1.33 | Medium |
| *Acacia farnesiana* L. Wild | 0.8 | 1.2 | 1.5 | 1.26 | Medium high |
| *Amyris texana* (Buckl.) Wilson | 1.5 | 1.2 | 1.1 | 1.20 | |

F%=Relative frecuency, A%=Relative abundance, D%=Relative dominance, IV%=Importance value

| Table 2: Physical structure of *H. parvifolia* stands in seven permanent sites in the Tamaulipan thornscrub of north-eastern Mexico | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Site elevation (msl) | Density $ha^{-1}$ | Height (m) | | | Dbh (cm) | | | Crown growth ($m^2$) |
| | | 1 | 2 | 3 | 1 | 2 | 3 | |
| 200 | 848[e] | 6.6±0.2[c] | 3.9 ±0.3[b] | 1.7±0.6[b] | 7.1±1.3[c] | 3.8±0.3[c] | NM | 1.2-13.4 |
| 300 | 916[e] | 5.7±0.4[c] | 4.0±0.5[ab] | 1.9±0.3[ab] | 7.4±0.5[b] | 4.6±0.6[a] | NM | 1.5-12.8 |
| 400 | 1003[d] | 6.9±0.2[b] | 3.6±0.7[b] | 2.1±0.6[a] | 7.5±1.9[b] | 4.7±0.1[a] | NM | 0.9-13.1 |
| 500 | 1126[c] | 7.0±0.3[ab] | 4.2±0.1[a] | 1.9±0.8[ab] | 7.3±2.3[b] | 4.7±0.9[a] | NM | 0.5-11.6 |
| 600 | 1472[b] | 7.2±0.1[a] | 4.3±0.8[a] | 1.6±1.0[b] | 7.2±0.9[ab] | 4.6±0.7[a] | NM | 1.1-9.8 |
| 700 | 1576[a] | 7.4±0.7[a] | 3.7±0.3[b] | 2.2±0.6[a] | 8.3±2.6[ab] | 4.2±0.5[b] | NM | 0.3-8.5 |
| 800 | 1527[a] | 6.9±0.2[b] | 4.1±0.5[a] | 1.8±0.3[b] | 8.6±1.1[a] | 4.2±0.1[b] | NM | 1.3-9.2 |
| Mean | 1210 | 6.8 | 4.0 | 1.9 | 7.6 | 4.4 | | |

*Includes all individuals of different sizes and diameters; 1=Trees with 8-10 m height and 7-12 cm dbh; 2=Trees with 3-5m height and 3-6 cm dbh; 3=Trees with 0.1-3.0 m height; NM=Not measured

crown size in the arborescent dicotyledons in which the lateral branches grow more quickly than the central apex. This growth habitat gives rise to a broad dispersed canopy, especially in poor or dry sites (Daniels et al., 1979; Stienen, 1990).

Crown growth is significantly different among sites. It correlates inversely with height and dbh growth. The canopy projection showed an inverse relationship with the elevation and plant height.

The analysis of the development and environmental response of *H. parvifolia* using commonly accepted criteria such as the survival and growth in height, diameter and projected foliage cover, suggests that *H. parvifolia* has the different aspects of the growth potential as compared with other firewood species of matorral.

*3.2. Wood volume determination*

The wood resource in the developing countries can be improved by planting more trees and by better management of the existing forests.

To quantify wood volume, data on height and dbh on all primary and secondary trunks of all plants study $site^{-1}$ was taken. Stand refers to all trunks between 1.7 -2.0 m height and dbh of more than 8 cm. Wood (volume) is classified as any woody branch with thickness of more than 3 cm (3-7 cm).

Table 3 shows how trees with diameter between 8 and 12 cm have an estimated volume of 10.234 $m^3$ $ha^{-1}$, which is the most recommended size to begin harvesting of the trees (25-30 years). Based on the results, each plant commonly produces 2-3 principal trunks (primary) and 4-6 secondary stems. One hectare of *H. parvifolia* produces approximately 1455 primary trunks, corresponding to an income of USD 1892 (USD 966 $tree^{-1}$) which is considered as a very good production of wood $ha^{-1}$. Adding the incomes from the sale of firewood and other products (forage), we find a net income $ha^{-1}$ of USD 1980 for the study sites.

The results of Table 2 and 3 indicate a highly positive correlation among the population density and the elevation of study site ($r$=0.95 and $p$=0.001). Greater number of seedlings were observed in sites with elevation of 600-800 msl result ing from

| Table 3: Average dbh, growth height, estimated number of the fence posts and the economic yield of *H. parvifolia* trees at different study sites | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Site elevation (msl) | Average dbh as fence post (cm) | Average stem height (m) | Average volume ($m^3$) | | Average number of fence posts | | Income (USD) | |
| | | | $Tree^{-1}$ | $ha^{-1}$ | $Tree^{-1}$ | $ha^{-1}$ | $Tree^{-1}$ | $ha^{-1}$ |
| 200 | 7.1 | 6.6 | 0.008[a] | 7.465[e] | 6.7 | 1687 | 11.39 | 2193 |
| 300 | 7.4 | 5.7 | 0.0085[a] | 7.894[d] | 6.3 | 1565 | 10.71 | 2034 |
| 400 | 7.5 | 6.9 | 0.0089[a] | 8.991[bc] | 6.8 | 1616 | 11.56 | 2100 |
| 500 | 7.3 | 7.0 | 0.0077[c] | 8.428[c] | 4.6 | 1246 | 7.82 | 1619 |
| 600 | 7.2 | 7.2 | 0.0075[c] | 9.024[b] | 4.2 | 1486 | 7.14 | 1931 |
| 70 | 8.3 | 7.4 | 0.0081[b] | 10.164[a] | 5.4 | 1348 | 9.18 | 1752 |
| 800 | 8.6 | 6.9 | 0.0072[d] | 10.234[a] | 4.6 | 1242 | 7.82 | 1614 |
| Mean | 7.63 | 6.81 | 0.0081 | 8.886 | 5.5 | 1455 | 9.66 | 1892 |

the natural regeneration as compared to the plain sites. Nevertheless, this relation changes inversely with the volume of the wood ha$^{-1}$ ($r$=-0.76 and $p$=0.04) and the number of fence posts ($r$=-0.81 and $p$=0.02) as a function of the elevation. On the other hand, the sites with lower density present highly developed plants with a higher production of wood and fence posts.

## 4. Conclusion

There is no control or evaluation to determine how many trees can be cut and, how many young trees should be planted cut$^{-1}$ tree. Proper management of the vegetation is needed, as this approach will aid in the sustained and rational management of *H. parvifolia*. In this context, we must involve other species of rapid growth and commercial value, in order to prevent damage both to the ecological balance and to the economic activity in these areas where *H. parvifolia* plays a decisive role with the probable negative impact on the economic status of many families which depend on the products of this dwindling species. From the ecological as well as management perspectives, an important observation that emerges from this investigation is that the Tamaulipan matorral of north-eastern Mexico has been extremely dynamic. This suggests that attempts to preserve the stand structure at this stage may not be an appropriate or practical conservation objective. Rather, priority should perhaps be placed on protecting a sufficient range of the community types so that the disturbance of any particular site may be considered acceptable as a functional process in the preservation of the natural area.

## 5. References


Andrean, H., Angelstam, P., 1988. Elevation of predation rates as an edge effect in habitat islands: experimental evidence. Ecology 69, 544-547.

Braun-Blanquet, J., 1979. Fitosociología: Bases Para El Estudio de las Comunidades Vegetales. H. Blume, Madrid.

Cavazos, M.T., Molina, V., 1992. Registros Climatológicos de la Región Citrícola de Nuevo León. Facultad de Ciencias Forestales, Universidad Autónoma de Nuevo León. Boletín Técnico 1, 1-65.

Daniels, P.W., Helms, U.E., Baker, F.S., 1979. Principles of Silviculture (2nd Ed.). McGraw-Hill Book Company, USA.

Foley, G., Barnard, G., 1984. Farm and Community Forestry. Earthscan Energy Information Programme Technical Report 3, International Institute for Environment and Development, London, 236.

Foroughbakhch, R., 1992. Establishment and growth potential of fuel wood species in north-eastern Mexico. Agroforestry Systems 19, 95-108.

Foroughbakhch, R., Alvarado, M.A., Hernández-Piñero, J.L., Guzman, M.A., 2006. Establishment, growth and biomass production of 10 tree woody species introduced for reforestation and ecological restoration in northeastern Mexico. Forest Ecology and Management 235, 194-201.

Foroughbakhch, R., Alvarado-Vazquez, M.A., Guzman-Lucio, M.A., Hernandez-Piñero, J.L., 2007. Ecological Characteristics and Productive Potential of the Mesquite (*Prosopis glandulosa*) Communities in Northeastern Mexico. In: Verne, N.C. (Ed.), Forest Ecology Research Horizons, Nova Publishers, 77-145.

Gonzalez, M., Jurado, E., Navar, J., González, M.S., Villanueva, J., Aguirre, O., Jiménez, J., 2005. Tree-rings and climate relatoinships for Douglas-fir chronologies from the Sierra Madre Occidental, Mexico: a 1681-2001 rain reconstruction. Forest Ecology and Management 213, 39-53.

Glover, N., Adams, N., 1990. Tree Improvement of Multipurpose Species. Multipurpose Tree Species Network Technical Series (vol. 2), Winrock International Institute for Agricultural Development, Arlington, VA, 112.

Gregersen, H., Draper, S., Elz, D., 1989. People and Trees: The Role of Social Forestry in Sustainable Development. Economic Development Institute Seminar Series, World Bank, Washington D.C., 273.

Hughes, L., 2000. Biological consequences of global warming: is the signal already apparent? Trends in Ecology and Evolution 15(2), 56-61.

Malcom, J.R., Markham, A., Neilson, R.P., Garaci, M., 2002. Estimated migration rates under scenarios of global climate change. Journal of Biogeography 29(7), 835.

Meskimen, G., Franklin, E.C., 1978. Spacing *Eucalyptus grandis* in southern Florida. Southern Journal of Applied Forestry 1(1), 3-5.

Muller-Dombois, D., Ellenberg, H., 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons. Inc., New York, USA.

Navar, J., Bryan, R.B., 1994. Fitting the analytical model of rainfall interception of gash to individual shrubs of semi-arid vegetation in northeastern Mexico. Agriculture, Forestry and Meteorology 68, 133-143.

Quinn, J.F., Harrison, S., 1988. Effects of habitat fragmentation and isolation on species richness: evidence from biogeographic patterns. Oecologia 75, 132-140.

Reid, N., Stienen, H., Hempel, H., 1989. Timber and Fences Uses of Shrubs of Snipy Matorral. Department of Ecosystem and Management, University of New England, Armidale NSW 2351, Australia.

Reid, N., Marroquín, J., Bayermunzel, P., 1990. Utilization of shrubs and trees for browse fuelwood and timber in the tamaulipan thornscrub, northeastern Mexico. Forest Ecology and Management 36, 61-69.

Rovalo, M., Graue, B., González, M.E., Rojas, D.B., Covarrubias, M.L., Magallanes, E., 1983. La Barreta o barreto [*Helietta parvifolia* (Gray.) Benth.] Recurso Vegetal Desaprovechado del Semidesértico del Noreste de México, Jalapa, Veracruz, Mexico. Bol. Técnico INIREB 1,1-9.

Stewart, J.L., Dunsdon, A.J., 1994. Performance of 25 Central

American dry zone hardwoods in a pantropical series of species elimination trials. Forest Ecology and Management 65, 183-193.
Stienen, H., 1990. The agroforestry potential of combined production systems in northeastern Mexico. Agroforestry Systems 11, 45-69.
Thomas, T.H., 1989. Economic evaluation methodologies for agroforestry (silvopastoral) systems. Forestry Sciences Faculty, UANL, Linares, México. Scientific Reports 5, 1-30.
Virginia, H.D., Offerman, H., Frohn, R., Garder, R.H., 1995. Landscape Characterization and Biodiversity Research. In: Boyle, T.J.B. and Boontawee, B. (Ed.), Measuring and monitoring biodiversity in tropical and temporate forests. Center for International Forestry Research (CIFOR), Bogor, Indonesia, 395.
Zar, J.H., 1996. Biostatistical **A**nalysis. (3rd Ed.). Printice-Hall Inc, New Jerssey, Englewood, 662.