International Journal of Bio-resource and Stress Management 2014, 5(4):475-479
DOI:10.5958/0976-4038.2014.00604.6

Full Research Article

Variability in leaf Traits of 14 Native Woody Species in Semiarid Regions of Northeastern Mexico

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Article History

Manuscript No. AR1069b
Received in 12th November, 2014
Received in revised form 19th November, 2014
Accepted in final form 2nd December, 2014

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Keywords

Tamaulipan scrub ecosystem, leaf traits, semi-arid northeastern Mexico

Abstract

The present study was undertaken with the goal of analyzing the morphology and variability of leaf length, width, petiole length, and total leaf length, fresh and dry weight of individual leaves of 14 species native to Northern Mexico. The native species *Cordia boissieri*, *Condalia hookeri, Sargentia greggii, Diospyros texana, Zanthoxylum fagara, Sideroxylon celastrinum, Karwinskia humboldtiana, Celtis pallida, Guaiacum angustifolium, Prosopis laevigata, Celtis laevigata, Parkinsonia texana, Forestiera angustifolia* and *Havardia pallens* where chosen due to their ecological and economic importance to the rural villages as well as large variability in morphological characteristics between them. Descriptive statistical analyses showed that there was large variability in these leaf traits between the different species. Principal component analysis (PCA) revealed that it was possible to produce two axes that can explain more than 83% of the observed variation and could therefore be used in the future for separating tree species in ecological guilds and to study. Species and vegetation community level response to perturbations or individual performance in the field or under experimental conditions between the different species of this study. This suggests that similar advances are possible for other species for the same traits both in the region of study but also elsewhere.

1. Introduction

Leaves play a vital role in the growth and development of plants. They vary greatly in size, form, shape, surface structure, thickness and other relevant characteristics (Poorter et al., 2006; Read et al., 2014; Rios et al., 2013; Shucun et al., 2006; Ninenets and Kill, 2003; Wright et al., 2004). Sufficient research activities have been directed on the study of leaf traits and their role in plant metabolism and this has to a large extent been focused on identifying factors that influence plant performance and thereby predictors to be used in activities such as planting trees and woody shrubs (Laners et al., 2006; Poorter et al., 2006). Several studies have attempted to elucidate the effects of environmental conditions and overall performance in relation to leaf trait plasticity. Calagari et al. (2006) studied morphological variation in in leaf traits of natural populations of *Populus euphratica* oliv. Leaf length, maximum leaf width leaf area, distance between middle of maximum leaf width, leaf blade length, the distance between maximum leaf width and midrib, and its ratio. These were found to be good discriminating criteria for classifying various populations. In another study by Moreno and Bertlier (2012) on changes in traits of shrub canopies where examined across an aridity gradient in northern Patagonia, Argentina.They found increased diversification in the traits, species and morphotypes in shrub canopies with increasing aridity supporting the hypothesis that the variability in aridity provides ecological differentiation among shrub species facilitating their coexistence. Gotch et al. (2010) studied variation in leaf traits and water relations in 12 evergreen and semi-deciduous woody species in seasonal wet and dry forest of Costa Rica. They studied specific leaf area (SLA), cuticle thickness, leaf thickness, and leaf life span (LLIS) and leaf water content. The species showed large variations among these traits, but season, forest and their interactions had shown great influence on the specific leaf-trait variations. In a similar study, Markesteijn et al. (2007) showed that leaf trait variation was mainly related to differences among species and to a minor extent to differences in light availability in the plant community. In another study, Poorter and Bongers (2006) compared the leaf traits and plant performance of 53 co-occurring tree species in a semi-evergreen tropical moist forest community. The species showed large variations among all leaf traits such in life span, specific leaf area, nitrogen, assimilation rate, respiration rate, stomatal conductance, and photosynthetic water use efficiency. Photosynthetic traits were strongly related with leaf traits, and specific leaf area predicted mass-based rates of assimilation and respiration. Leaf traits were closely correlated with growth, survival and light requirement of the species. Leaf traits were also found to be in general good predictors of plant performance. Despite the large volume of studies, there is still a need for a set of unifying traits or set of traits that can be used to study variability in leaf morphology effectively and discover predictors of plant performance in the field. The need for such a study becomes all the more urgent for the semi-arid thorn scrub vegetation of North-eastern Mexico in particular where despite significant threats to the ecosystem (Navar et al., 2004). There have not been any detailed investigations into the variability of these traits or the mechanisms that affect them at least for several ecologically and economically important species. Thus the main objective of the present research is to determine the variability in these traits by examining these produce indicators of plant performance in the field with the goal of examining both inter and intra specific differences. Most of these species have the capacity to grow successfully under a wide range of conditions.

2. Material and Methods

2.1. Description of the study area

This study was carried out during August, 2014 at the experimental station of Facultad de Ciencias Forestales, Universidad Autonoma de Nuevo Leon, located in the municipality of Linares, Northeastern Mexico (24°47″ north latitude and 99°32″ west longitude). All the area is covered by the typical semi-arid thorn scrub dominated by woody plants. The regional climate in the scheme of Koppen modified by Garcıa (2004)is defined as semi-arid and sub-humid [(A) C (Wo)] with two rainy seasons (summer and autumn) and a dry spell between November and April. Mean annual precipitation is 780 mm (Navar et al., 2004). The month with the largest mean rainfall is September (180-200 mm), and the lowest monthly registration occurs in December and January (15-20 mm). Potential evapotranspiration estimated by the Thornthwaite method is -1150 mm (Navar et al., 1994). The mean annual temperature is 22.3° C with a large difference between winter and summer (absolute minimum 12° C, absolute maximum, 45° C) and even within the same month. Hail and frosts usually occur each year even after the beginning of the growing season in March. The water budget is unbalanced. The ratio of precipitation to free evaporation is 0.48 and precipitation to potential evaporation is 0.62. Most soils of the region are of rocky type of Upper Cretaceous rich in calcite and dolomite. The dominant soils are deep, dark grey, lime-clay vertisols which are the result of alluvial and colluvial processes (FAO-UNESCO, 1974). They are characterized by high clay and calcium carbonate content (pH 7.0-8.0) and low organic matter content.

2.2. Species and sample trees

Fourteen woody perennial species (trees and shrubs) used for different purposes in the region were selected for this research. Twenty fully expanded leaves from terminal branches were selected through a stratified random sampling program from each individual belonging to one of the 14 species. Twenty mature leaves of each individual per species were selected at random for measurements to be taken. These where leaf length (cm), leaf width (cm), petiole length (cm), dry weight (mg) and fresh weight (mg). Leaves were taken to the laboratory immediately for measurements to be taken following collection. Table 1 shows information about the name, family, and the leaf characteristics of each of these species. All species are native to arid and semi-arid zones in Mexico and adjacent USA territories.

2.3. Statistical analysis

Two kinds of analyses where performed. The first was descriptive analyses consisting of the mean values and standard errors for each variable for each species. Appropriate plots were also produced as part of this procedure to check on the presence and properties of potential outliers in the datasets. The second kind of analysis was principal component (PCA) analysis of all leaf traits measured and for all species. The goal of this later analysis was to produce new composite

Table 1: Outstanding characteristics of the 14 woody plant species selected for study

Family	Species	Leaf type
Boraginaceae	*Cordia boissieri* A. DC.	Simple
Rhamnaceae	*Condalia hoockeri* M. C. Johnst.	Simple
Ebenaceae	*Diospyros texana* Scheele.	Simple
Sapotaceae	*Sideroxylon celastrina* (Kunth) Pennington	Simple
Rhamnaceae	*Karwinskia humboldtiana* (R. & S.) Zucc.	Simple
Rutaceae	*Zanthoxylum fagara* (L.) Sarg.	Compound
Ulmaceae	*Celtis pallida* Torr.	Simple
Mimosaceae	*Prosopis laevigata* (Humb. & Bonpl. Ex Willd.) M. C. Johnston	Compound
Oleaceae	*Forestiera angustifolia* Torr.	Simple
Zygophyllaceae	*Guaiacum angustifolium* (Engelm.) Gray	Compound
Rutaceae	*Sargentia greggii* S. Watson	Simple
Ulmaceae	*Celtis laevigata*	Simple
Fabaceae	*Havardia pallens*	Compound

variables the principal component axes by which to separate the different tree species and actually cluster these in groups based on this. All analyses where performed in the statistical package MINITAB (v. 17.0)

3. Results and Discussion

3.1. Descriptive statistics

Large variations in leaf traits among the species where observed that where undoubtedly due to inherent species specific differences (Table 2). Leaf length on average varied from 2 to 9.37 cm. Highest leaf length was observed in *Sargentia greggi* and *Celtis laevigata* (9.37 and 7.53 cm, respectively) while *Prosopis laevigata* and *Zanthoxylum fagara* also showed high values (7.36 and 6.70 cm, respectively). Leaf width ranged from 2 to 4.5 cm. *Prosopis lavaegata* and *Sargentia gregii* had the maximum width observed (7.56 and 4.40 cm, respectively). Petiole length ranges from 0.1 to 2.7 cm. Maximum petiole length was found in *Prosopis laevigata* (2.69 cm). Minimum petiole length was observed in *Forestiera angustifolia* (0.1 cm) and *Zanthoxylum fagara* (0.20). Total leaf length varied from 2.7 to 10 cm. greatest leaf length was observed in *Sargentia gregii* (10 cm), and *Prosopis lavaegata* (10 cm). Minimum leaf length was observed in *Parkinsonia texana* (2.79 cm) and *Sideroxylon celastrinum* (3.49 cm). As far as maximum leaf area this was observed for *Sargentia greggii* (29.580 cm^2), and *Celtis laevigata* (19.38 cm^2). Minimum leaf area was in *Forestenia angustifolia,* (1.75 cm^2) and *Sideroxylon celastrinum* (3.03 cm^2). With respect to leaf dry weight highest dry weight was observed in *Sargentia greggi* (0.38 mg) *Celtis laevigata* (0.19 mg) and *Prosopis laevigata* (0.16 mg). Minimum dry weight was observed in *Forestiera angustifolia* (0.01 mg) and *Condalia hookeri* (0.02 mg). Specific leaf area (SLA) varied from 77.39 cm^2mg^{-1} (*Cordia boisierii*) to 215.35 cm^2 mg^{-1} (*Karwinskia humboldtiana)*. Leaf fresh weight varied on average from 0.02 (*Forestiera angustifolia*) to 0.78 mg (*Sargentia gregii*). Similar observations to the ones of this study have been made elsewhere for a similar vegetation community it was found that the height, blade length and blade area increased significantly with shrub cover (Moreno et al., 2010; Gratani and Bombelli, 2000; Gratani and Varone, 2004; Louault et al., 2005; Dominguez et al., 2012). The large variations in leaf traits among these ecologically important woody species of the Tamaulipan thornscrub are therefore very likely to contribute to species diversification, co-existence and adaptation to the semi-arid condition as has been reported elsewhere (Laners et al., 2006; Moreno and Bertlier, 2012; Louault et al., 2005; Read et al., 2013; Rios et al., 2014).

3.2. Principal component analysis

The principal component analyses (Table 3) and the attached scree plot (Figure 1) revealed that the first two PCA axes accounted for the largest proportion of the observed variation and hence we can keep these for examining further hypotheses. The outlier plot for the PCA analysis reasserted the significant presence of outliers (Figure 2). This may be because of very high interspecific differences simply. These results indicate that it is possible to address questions regarding leaf Eco physiology for individual species for specific scientific hypotheses using the two PCA axes found significant using these as predictor variables of response. This very importantly includes areas like leaf physiological response to perturbations

Table 2: Statistical mean for all respective leaf traits for the 14 woody plant species selected for study

Species	Leaf length, (cm)	Leaf width, (cm)	Petiole length, (cm)	Total leaf legth, (cm)	Leaf area, (cm^2)	Leaf dry weigh (mg)	Specific leaf area (cm^2 mg^{-1})	Leaf fresh weight (mg)
Cordia boissieri	6.26	3.26	1.28	7.35	14.94	0.18	77.39	0.34
Condalia hookeri	3.88	2.06	0.37	4.25	5.07	0.02	186.21	0.07
Sargentia greggii	9.37	4.40	0.69	10.06	29.58	0.38	82.02	0.78
Diospyros texana	3.94	2.03	0.25	4.19	6.19	0.05	134.59	0.10
Zanthoxylum fagara	6.70	2.39	0.22	6.92	6.86	0.06	116.61	0.14
Sideroxylon celastrinum	3.18	1.48	0.31	3.49	3.03	0.03	127.20	0.09
Karwinskia humboldtiana	5.12	2.31	0.60	5.73	9.80	0.05	215.35	0.12
Celtis pallida	3.54	2.06	0.35	3.89	5.84	0.04	128.62	0.12
Guaiacum angustifolium	3.71	2.68	0.77	4.48	3.75	0.03	120.08	0.06
Prosopis laevigata	7.36	7.56	2.69	10.05	13.78	0.16	86.17	0.33
Celtis laevigata	7.53	3.72	1.31	8.84	19.38	0.19	100.72	0.34
Parkinsonia texana	2.05	2.86	0.74	2.79	2.73	0.02	127.22	0.05
Forestiera angustifolia	3.68	0.59	0.10	3.78	1.75	0.01	152.31	0.02
Havardia pallens	3.33	4.18	1.34	4.67	5.44	0.03	141.47	0.08

Table 3: Eigenvalues and respective probabilities of the principal component analysis

Eigenvalue	Proportion	Cumulative
5.5534	0.694	0.694
1.1566	0.145	0.839
0.7961	0.100	0.938
0.2913	0.036	0.975

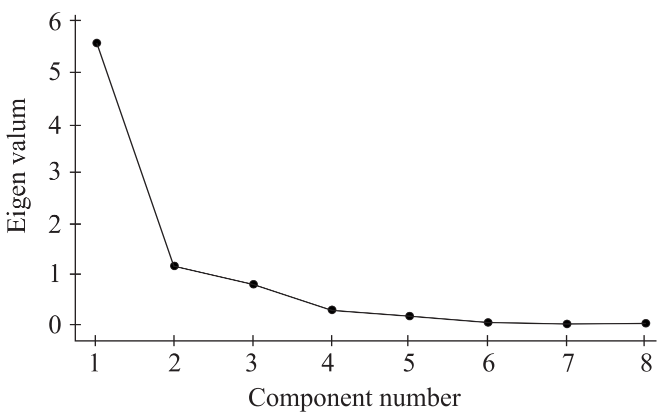

Figure 1: Scree plot of the principal components relative to the original variables

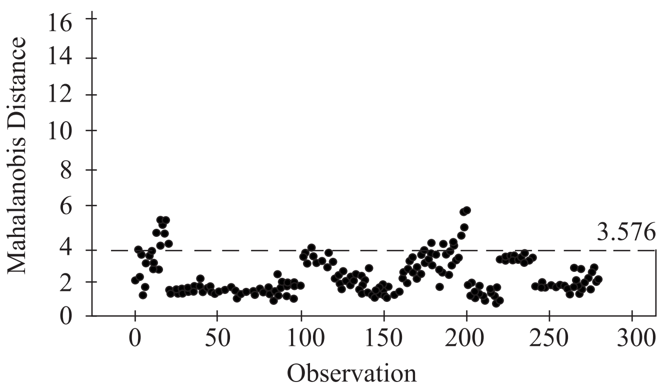

Figure 2: Outlier plot of the principal components of the analysis

Table 4: Principal component axes coefficients for the analysis

Variable	PC1	PC2	PC3	PC4
Fresh weight (mg)	0.398	0.248	0.038	-0.340
Leaf length (cm)	0.385	0.200	-0.196	0.564
Breadth (cm)	0.313	-0.541	-0.075	-0.324
Petiole length (cm)	0.259	-0.694	-0.072	0.050
Total length (cm)	0.402	-0.029	-0.188	0.495
leaf area (cm^2)	0.395	0.250	-0.160	-0.261
Dry weight (mg)	0.399	0.244	0.073	-0.331
SLA (cm^2 mg^{-1})	-0.226	0.047	-0.940	-0.189

such as atmospheric pollution and animal browsing among other things. These results also show that specific variables describing leaf physiology are highly important in determining differences and thereby response to environmental stresses. It is also possible to describe interspecific differences in terms of leaf Eco physiology using the two PCA axes deemed as statistically important in the future for the species used in this study. Finally it is possible to use the first two PCA axes found significant (Table 4) for future examinations of hypotheses regarding ecosystem functional responses to perturbations or examining forest dynamics in communities composed of these or similar species it is possible. These results are in agreement with other similar studies looking at large woody shrubs and tree species in other parts of the World (Calagari et al., 2006; Read et al., 2013; Rios et al., 2014; Gotsch et al., 2010; Jones et al., 2011).

4. Conclusions

There was an obviously very large inter-specific diversity among the species studied. It was possible however to address the issue of finding a methodology for examining differences in leaf morphology between the different species through the new variables(axes) produced by the principal component analysis. It was also possible to limit the inherently large variability using these and produce variables that where considerably more amendable to statistical analysis. More species need to be added through additional sampling to the continuum and redo the PCA analyses in the future with these included in order to see if this relationship holds for other species and for a broader range of leaf morphological characteristics. Following this final analysis it will be possible to address more diverse issues in the endangered Tamaulipan scrub ecosystem like response to anthropogenic perturbations and climate change. Until that time using the species in this study as indicator species it is possible to address the above ecologically important issues with an acceptable level of accuracy for issues requiring both temporary and permanent sampling programs.

5. Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

6. Acknowledgments

We are grateful to Jeffrey Christopher Gonzalez Diaz of the Faculty of forest sciences of the University of Nuevo Leon for valuable help and assistance with respect to field and laboratory work for this research.

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