

# Biodiversity of Leaf Traits in Woody Plant Species in Northeastern Mexico: A Synthesis

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## Abstract

Leaves play a vital role in the growth, development and productivity of woody plants in a forest ecosystem. The present paper deals first with a concise review of research advances undertaken globally on leaf traits of trees and shrubs and then a brief synthesis of results of leaf traits in Linares, Northeastern Mexico. A synthesis is made on research advances on leaf traits, leaf morphology and eco-physiology of trees and shrubs at the global levels and few studies in Northeastern Mexico. There exists a large variability in various leaf morphological traits viz. leaf dimensions and eco-physiological traits viz. leaf area, leaf specific area, leaf dry weight etc. The magnitudes of these traits vary depending on environmental conditions.

**Keywords:** Leaf traits; Variability; Morphological; Eco-physiological traits; Climatic conditions

## Introduction

### Research advances in leaf traits

Leaves play a vital role in the growth and development of the plant through the process of carbon assimilation, exchange of gases through stomata and loss of excess water through transpiration. They vary largely in size, forms, shapes, surface structure, thickness etc. Enormous research activities have been directed on leaf traits and their role in plant metabolism. A database was compiled for hundreds to thousands of species for the core 'leaf economics' traits leaf lifespan, leaf mass per area, photosynthetic capacity, dark respiration, and leaf nitrogen and phosphorus concentrations, as well as leaf potassium, photosynthetic N-use efficiency (PNUE), and leaf N : P ratio. Although mean trait values differed between plant functional types, the range observed within groups was often larger than differences among them, these relationships are very general, and are not universal, because significant heterogeneity exists between relationships fitted to individual sites. Much, but not all, heterogeneity can be explained by variation in sample size alone. PNUE can also be observed as part of this trait spectrum, whereas leaf K and N : P ratios are only loosely related [1].

In the present review is given a brief account of the research advances of leaf traits globally and finally of the few studies conducted in Northeastern Mexico.

### Leaf morphology

In Northeastern Mexico, the characterization of leaf morphology based on the qualitative and quantitative characteristics has been documented [2]. In a study, the quantitative and multivariate statistical data [3] of the leaf morphology and floral structure have been utilized on the taxonomic classification and the identification of (*Quercus*).

The patterns of foliar morphology determine the capacity of adaptation to the environmental condition [4], while the variation in morphological patterns is influenced by the availability of water, wind velocity, light intensity and intra and interspecific variation [5]. On the other hand, the variations in foliar patterns are related with the phenological variation of the leaves depending on the gradients of altitudes, latitudes and edaphic conditions [6]. However, the foliar morphology is basically determined on genetic basis but it is exposed to intense selection pressure in the environments, thereby expressing different forms and foliar size [7].

A study has been undertaken on 10 foliar morphological traits and budburst phenology in *Ulmus minor* in two successive years in northern, central and southern Italy and in France. Morphological characters seem to show a greater phenotypic plasticity with respect to phenological traits [8].

The leaf morphology may vary remarkably among species and within species with respect to structure, dimensions, types of margins, form, size of petiole, venation pattern, dry weight per unit area, moisture content, canopy, stomata density, presence of trichomes and cuticular composition.

The distinct leaf characteristics determine distinct functional trends among the communities studied. With respect to leaf traits such as leaf length, leaf breadth, petiole length, there exist wide spectrum of the foliar variations among the species studied which may vary in different environments. Nevertheless, there exist a spectrum of foliar variations within a determined community and this variation may partially explain the coexistence of the species [9] working on the leaf characteristics in *Uercus crassifolia* suggest that modifications of foliar morphology are mainly attributed basically to distinct environmental factors and conditions.

### Environments have impact on leaf variation

The dimensions and structures of leaves are highly variable under different environmental conditions such as altitude [10], latitude

[11,12] precipitation [13] temperature [14] edaphic conditions [15], quality and quantity of light [16-18].

The rate of leaf emergence and its expansion influence leaf growth and its duration. In this respect a study was undertaken by Sun et al. on the effect of leaf traits on leaf emergence phenology, timing of leaf emergence, leaf expansion rate, durations of leaf emergence and expansion, leaf mass per area in temperate woody species in East-Chinese *Quercus fabri* forests. Regression analysis across species revealed the relationship between leaf phenology and the leaf traits mentioned. Small leaved species emerged earlier than the species with large leaves. Leaf expansion rate was positively correlated with leaf area and timing of leaf emergence but no significant relationship was found between leaf size and leaf emergence period.

There exists a general hypothesis for the species with wide range of distribution, that they have a greater phenotypic plasticity compared to those with limited distribution [19]. The environmental changes lead to phenotypic plasticity and physiological functions). The phenotypic plasticity is one of the mechanisms of the plant for its survival to adverse environmental conditions [20-22]. It is reported that the phenotypic plasticity is frequently represented as one form of reaction of individual plants to the environment [23].

In the case of the species with wide distribution there exist two models which tend to explain its success to colonize in new sites. One of the models pertains to ecotypes adapted locally and once established, each population of the species may exhibit differential changes as the result of change occurring frequently by local selection. Thus, due to this differentiation in ecotypes they can be accommodated in different environments among habitats exhibiting, the range of the distribution of the species locally. On the other hand, the alternative model considers that the individuals of widely distributed species have potential of phenotypic plasticity in response to wide range of environmental changes, thereby exhibiting tolerance to environmental changes [24]. Few more specific examples are cited here.

The leaves are sensitive to the environmental changes during the process of evolution and may exhibit phenotypic plasticity although not clearly known. Mello [25] undertook a simulation model to evaluate the morphological variations exposed to gradients of moisture availability and light in the leaves *Quercus acutissima* and *Robinia pseudoacacia*. Variations in size, form and venation pattern were exhibited owing to the effects of environment and or allometry. These wide morphological variations were shown along the gradients. The size of leaf reduced with decrease in moisture content.

In a study, the variation in leaf morphology in *Quercus crassifoliawas* observed at three different stages of canopy (basal, intermediate and apical) localized in National park, El Chico, Hidalgo. It was observed that each of the characteristics viz., petiole length and others showed one pattern variation in different localities [9]. Similarly, Zúñiga et al. [26] studied leaf morphological variation of *Q. laeta*, en el Parque Nacional Los Mármoles measuring 17 morphological characters in 470 leaves collected at the middle of canopy of 47 trees, all showing normal distribution. The analysis of variance in the morphological traits showed significant differences in the leaves of *Q. laeta* among localities in some morphological traits only.

Some authors report that the pattern of morphological variations in the natural populations is the products of gene flow, natural selection and phenotypic plasticity [26]. In this respect, the species of

Tamaulipan Thorn Scrub are exposed to a diversity of adverse abiotic stress factors such as extreme temperature, nutrient deficiency and others, owing to which the species develop physiological mechanisms of adaptation to these environmental stresses. In this respect, González and Oyama [27] mentioned that the leaves are the main photosynthetic organs in plants. Being highly sensitive, the leaves are continuously exposed to different environmental conditions, thereby affecting their phenological cycles and growth rates. Studies on these aspects are rare in this region. This information is of great importance for understanding the natural regeneration, and the processes of adaptation of the species to water and abiotic stresses and also for taxonomy. Similarly Quero et al. [28] working on the Mediterranean forests in the south of Iberian gulf report that there exists spectrum of leaf variations for phylogenetic diversity, which are partially determined by the climatic variation and local environmental conditions. With respect to specific leaf area, Shipley [29] undertook a study to determine the effects of specific leaf area (SLA) in growth characteristics in a wide variety of 34 herbaceous species. He observed that all species having large leaves had lower SLA though this pattern was not detected in the interspecific level. However, the recent studies demonstrate that the production of dry matter per unit of leaf area increase with an increase with the size of leaf and yield inversion (light capture) and decrease with an increase of leaf size [30]. This is valid both among and within the species through the production of biomass and growth forms [30]. This is probably attributed to the differences in biomass among productive tissues compared to the small leaves. However, studies have shown general tendency of differences of these traits among species [29] or showed intra-specific tendency [29,30].

A study has been made on variation in leaf traits and water relations in 12 evergreen and semi-deciduous woody species in seasonal wet and dry forest of Costa Rica. Over two years an analysis has been made on leaf nitrogen (N), leaf carbon<sup>®</sup> and specific leaf area (SLA), cuticle thickness, leaf thickness and leaf lifespan (LLIS), leaf water content, canopy openness etc. The species showed large variations among these traits, but season, forest and their interactions had shown great influence on the specific leaf-trait variations. Leaf traits contributed to variation were leaf toughness, LWP and LWC. Strong season ability may cause leaf trait relationship [31].

Soil factors are driving forces in influencing spatial distribution and functional traits of plant species. Four morphological and 19 chemical leaf traits (macronutrients and trace elements and N signatures) were analyzed in 17 woody plant species. Nitrogen isotopic signatures were useful to understand different resource-use strategies in the growth of vines related to light availability. Variation in functional traits within and among plant species is dependent on elevational gradients. There is a variation in leaf phenotypes among ecosystems. Three key leaf functional traits are associated with axes of variation in both resource competition and stress tolerance: leaf mass: area ratio (LMA), leaf nitrogen content per unit mass ( $N_{mass}$ ) and N content per unit area ( $N_{area}$ ). The results reveal that environmental filtering both selects locally adapted genotypes within plant species and constrains species to elevational ranges based on their ranges of potential leaf trait values [32].

A study undertaken on the divergence and phylogenetic variation of eco-physiological traits in Lianas revealed that the mean phylogenetic distance was 1.2 times greater among liana species than among tree species. This result supported for the expected pattern of greater species divergence in lianas, but did not find consistent patterns regarding eco-physiological trait evolution and divergence. Leaf traits

govern several plant functions related to the growth and development of the plant [33].

Plant species show variability in leaf traits and in plant nutrients exposed to environmental conditions

### Leaf physiology

Various studies have been undertaken on leaf eco-physiological traits. The main functions of the leaves are photosynthesis, transpiration, respiration and storage. The leaf characteristics are found exposed to continuous process of selection under environmental changes and have capacity to adaptation to these changes.

Leaf area (LA), leaf specific area (SLA), fresh weight and dry weight are the main eco-physiological traits studied by crop physiologists and forest scientists. Several studies have been undertaken in these aspects.

The leaf area of a species at a particular stage is defined as the capacity of the plant cover for intercepting photosynthetically active radiation (PAR) required for elaboration of tissues and organic matter. Therefore, the growth and the productivity of a crop is the result of a genotype and its interaction with its environments [34]. Growth analysis is at present a tool for crop improvement, crop physiology and crop ecology.

The leaf area (LA) is a fundamental aspect of research on plant physiology in agriculture and dendrology [35]. The leaf area plays an important role in the majority of the processes in agronomy, biology, environment and physiology which include the analysis of growth, photosynthesis, transpiration, light interception, biomass estimation and water balance [36]. The plant physiologists, biologists and agronomists have demonstrated the importance of leaf area (LA) in the growth analysis, the estimation of potential biological and agronomic yield, basis of the efficient use of solar radiation and mineral nutrition [37].

### Specific leaf area (SLA)

The specific leaf area is the ratio of leaf area/dry weight which determines the adaptation of the species in a particular environment. The specific leaf area expresses the thickness of the leaves and this is sensitive to environmental factors [38]. The specific leaf area on the other hand explains to a greater extent the variation in the growth among the species. It is reported that the species with much higher growth under optimum conditions have greater specific leaf area. An increase in specific leaf area indicates that the leaf produce lower biomass per unit leaf area. This variable is strongly related with a variety of physiological and chemical parameters. The species with greater specific leaf area are considered to possess higher concentrations of cytoplasmic components such as proteins, minerals and organic acids. On the other hand, the species with lower specific area possess greater quantity of cell wall components, specifically lignin. This type of leaves is very hard and less attractive to grazing wild animals. These species are also characterized to possess greater amount of dry matter (dry weight/fresh weight), and present greater longevity in roots and leaves. It is suggested that the greater leaf area and leaf dry weight reflect a lower specific leaf area. In this respect, greater specific leaf area decrease with the lead dry weight in the leaves of pasture "mulato" (*Brachiaria híbrido*, cv).

### Different eco-physiological traits are closely related with the growth and development of tree and crops

A study on the anatomical and morphological leaf traits of: *Quercus ilex*, *Phillyrea latifolia* and *Cistus incanus* revealed that the specific leaf weight, (SLW) and total leaf thickness, leaf density index and leaf inclination changed according to leaf age. Leaf folding may be related to the less xeromorphic leaf structure of *Cistus incanus* (*Cistus incanus*) [39]. Although there are positive intraspecific relationships between leaf area per unit dry weight (SLA), between concentrations of P and N, and these relations are affected by soil concentration of these nutrients. It was observed that foliage physiological activity was co-limited by both P and N availability in the wood land meadow but in the bog there were positive relationships between SLA and nitrogen concentration in wood land meadow and in the bog, there was a positive relationship between SLA and P concentration but no relationship between SLA and N concentration. There was an increase in soil Nitrogen concentration with decreasing SLA. Total variation in foliar structural and chemical characteristics was similar in all sites [40]. In order to determine the suitability for afforestation different parameters such as the crop growth rate (CGR), net assimilation rate (NAR), specific leaf area (SLA) and leaf area index were calculated. CGR is better correlated with NAR. At early stage CGR and diameter could be used as selection criteria for selection for afforestation. A decline in herbage use reduced individual leaf mass, specific leaf area and shoot digestibility but increased leaf C and dry matter content.

Fresh weight is a good indicator of the physiological status of a leaf in a plant grown under different edaphic and climatic conditions. With respect to fresh weight of leaves among the species, might be attributed to water use efficiency and the anatomical properties among the leaves and the leaf area which in turn influence the process of transpiration, reflect the leaf moisture status. Besides the leaf moisture content may be related to the productivity of the root systems for absorption of greater amount of water from the soil which may reflect greater turgidity of the leaves. Besides the wax content and cuticular thickness may also influence the water status of the leaves [41]. However, each characteristic may be associated with the phylogenetic origin of each species. It is suggested that the large petiole favor greater capture of light by the leaf. On the other hand, those with short petiole or sessile were overlapped and receive lower amount of light [26]. Salisbury and Ross [41] infer that the reduction of water content is accompanied by the loss of turgour and withering, leading to the cease of cellular expansion, close of stomata, reduction of photosynthesis and the interference of many other metabolic processes. It is reported that the decrease of leaf area reduce the transpiration in the leaves exposed to strong radiations which improve water use efficiency. At the same time, the leaves with higher quantity of biomass per unit area (as observed in few species in the present study) could be more efficient in water use efficiency and nutrients in arid environments. These may be affected by nutritional variations and or moisture, light intensity, temperature, altitude, atmospheric concentration of CO<sub>2</sub>, seasonal variations and leaf age. The other variables which influence the leaf area is the leaf form which indicate that the greater length of the leaf and lower breadth of the same, reduce the transpiration. On the other hand, a leaf of more oval shape tend to present more leaf area for transpiration and subsequently lower moisture content, although this variable also depends on the density of stomata or leaf moisture and soil moisture contents. *Erica arborea* L, in the Mediterranean maquis showed variation in traits viz., leaf morphology, water relations, leaf lifespan and gas exchange, but the variation on these traits are dependent on prevalence of drought situation and recovery which may

be related to narrow root system. This could be related to variation in root tissues [42].

Abiotic factors influence leaf eco-physiological traits. In this context when the abiotic factors are more or less stable with respect to the quality and quantity of light, there was a reduction of leaf area when the incidence of light is reduced in the plant canopy depending on the orientation, distribution and leaf size. This which in turn contributes to determine morphotypes as a function of the type of incident light in the canopy [43]. In the case of deciduous shrubs, with respect to drought escape, the species are considered better adapted to exposure to prolonged periods of water deficit, the common strategy is the reduction of leaf area, mainly for the seasonal loss of leaves. In high humid conditions, the leaves are much finer and with greater leaf area than in dry area and high temperature for water saving [7].

Large variations are found in various morphological and eco-physiological traits. In this respect, 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 as life span, specific leaf area, nitrogen, assimilation rate, respiration rate, stomata 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 life span predicted many other leaf characteristics. Leaf traits were closely correlated with growth, survival, and light requirement of the species. Leaf investment strategies varied on a carbon gain in short term leaf against long-term leaf persistence thereby it is linked to variation in whole-plant growth and survival. Leaf traits were good predictors of plant performance. High growth in gaps is promoted by cheap, short-lived, and physiologically active leaves.

## Materials and Methods

### Variability in leaf traits of woody plant species in Northeastern Mexico

The study was undertaken in June to July in the municipality of Linares, Nuevo León in Forest Faculty of Universidad Autonoma de Nuevo Leon (24°47'N; 99°32'O), at sea level of 350 m sum. The type of climate present (cited by Gonzalez et al. [44]) is subtropical and semiarid condition with hot summer. The average monthly air temperatures oscillate between 14.7°C in January to 3°C in August, although the common temperature in summer is 45°C. The average annual precipitation is approximately 805 mm with a bimodal distribution. This site is situated in soils which are dark brown deep vertisols. The predominant vegetation is Tamaulipan Thorn Scrub or subtropical thorn scrub [45,46].

Fifty leaves from each species were taken at random from five plants (10 leaves from each plant). The species utilized in the present study are mentioned in Table 1. Fifty leaves were sampled (10 leaves from 5 plants) for measuring leaf length, leaf breadth and petiole length. The leaf area, leaf specific area and leaf dry weight were then calculated. The leaf area (cm<sup>2</sup>) is quantified using leaf area analyzer (mark LI-COR (model LI-3100, Lincoln, Ne, USA). The dry weight of leaf is taken after drying in an oven at 60°C for 72 hours. The moisture content (g) of the leaf is calculated measuring the difference of fresh weight and dry weight of leaf. The specific leaf area (cm<sup>2</sup> g<sup>-1</sup>) is calculated as a relation of leaf area (LA) / dry weight of leaf (DRWT).

We made a synthesis of the results of 3 experiments:

Variability of leaf traits in 14 species.

Variability of leaf traits of 34 species of woody plants

Seasonal variability of 23 species.

## Results

Recently few studies are undertaken in leaf traits in few North-eastern Mexican trees and shrubs. There exists variability in leaf canopy (open, close) in trees and shrubs which is expected to have greater photosynthetic capacity and productivity. Trees and shrubs having open capacity are exposed fully to solar radiation and have better capacity compared to those with close canopy. In the below table representation of large variation in leaf morphology of various trees and shrubs. Large variability is observed in the general morphology of several woody plant species with respect to leaf size, shape, apex, margin, base of the petiole size etc.

### Variability in leaf traits in 14 species

Large variations are found to occur in several leaf traits in 14 trees and shrubs in Linares, North-eastern Mexico. Besides, the principal component analyses and the attached scree plot revealed that the first three 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. This may be because of very high interspecific differences.

In addition a study was undertaken on the variability of leaf traits among 34 woody trees and shrubs. The mean values of different leaf traits are shown in Table 1.

Name scientific	Family	type	Leaf type	Specific Leaf Area (cm <sup>2</sup> /G <sup>-1</sup> )	Length (cm)	Breadth (cm)	Petiole Length (cm)	Leaf Area (cm <sup>2</sup> )	Area	Dry Weight (G)
<i>Cordia boissieri</i>	Boraginaceae	Tree	Simple	162.027 ± 28.524	14.98 ± 1.801	8.612 ± 1.933	3.042 ± 0.616	97.479 ± 21.859		0.624 ± 0.179
<i>Ehretia anacua</i>	Boraginaceae	Tree	simple	125.487 ± 26.579	7.692 ± 1.033	4.114 ± 0.901	0.658 ± 0.143	21.981 ± 7.887		0.183 ± 0.085
<i>Helietta parvifolia</i>	Rutaceae	Shrub	compuesta	105.825 ± 25.186	4.326 ± 0.637	5.028±0.951	1.484 ± 0.264	11.002 ± 3.577		0.104 ± 0.02

<i>Fraxinus greggii</i>	Oleaceae	Tree	compuesta	59.546 ± 7.8	7.732 ± 0.942	4.306 ± 0.41	1.522 ± 0.341	17.090 ± 3.261	0.295 ± 0.079
<i>Amyris texana</i>	Rutaceae	Shrub	compuesta	138.919 ± 27.34	4.858 ± 1.624	6.548 ± 0.945	1.83 ± 0.424	12.213 ± 2.652	0.099 ± 0.075
<i>Condalia hookeri</i>	Rhamnaceae	Tree	Simple	199.191 ± 51.946	3.098 ± 0.35	1.85 ± 0.268	0.362 ± 0.107	3.283 ± 1.069	0.017 ± 0.005
<i>Leucophyllum frutescens</i>	Scrophulariaceae	Shrub	simple	115.556 ± 19.688	2.74 ± 0.371	1.22 ± 0.165	0.156 ± 0.067	2.172 ± 0.373	0.0208 ± 0.014
<i>Acacia rigidula</i>	Fabaceae	Shrub	compuesta	95.309 ± 22.101	2.95 ± 0.622	3.936 ± 0.931	0.588 ± 0.184	4.836 ± 1.605	0.052 ± 0.018
<i>Sargentia greggii</i>	Rutaceae	Tree	compuesta	100.934 ± 24.427	11.086 ± 1.756	13.674 ± 2.545	3.622 ± 0.844	66.761 ± 19.537	0.701 ± 0.22
<i>Diospyros palmeri</i>	Ebenaceae	Tree	simple	152.306 ± 22.239	5.246 ± 0.575	2.758 ± 0.455	0.348 ± 0.702	10.103 ± 2.329	0.068 ± 0.020
<i>Diospyros texana</i>	Ebenaceae	Tree	simple	151.358 ± 35.414	2.888 ± 0.353	1.326 ± 0.251	0.184 ± 0.055	2.956 ± 0.766	0.026 ± 0.033
<i>Zanthoxylum fagara</i>	Rutaceae	Shrub	compuesta	160.202 ± 34.205	5.992 ± 1.96	3.15 ± 0.973	1.414 ± 0.327	6.91 ± 3.46	0.044 ± 0.021
<i>Bumelia celastrina</i>	Sapotaceae	Tree	simple	127.756 ± 40.104	3.068 ± 0.426	1.328 ± 0.359	0.21 ± 0.097	2.757 ± 0.929	0.025 ± 0.016
<i>Karwinskia humboldtiana</i>	Rhamnaceae	Shrub	Simple	183.398 ± 42.321	6.59 ± 1.095	3.084 ± 0.514	0.702 ± 0.115	15.923 ± 4.606	0.088 ± 0.023
<i>Ebenopsis ebano</i>	Fabaceae	Tree	compuesta	158.784 ± 29.129	4.626 ± 0.803	4.444 ± 0.807	1.128 ± 0.433	13.124 ± 4.019	0.084 ± 0.026
<i>Quercus virginiana</i>	Fabaceae	Tree	simple	73.229 ± 11.667	6.208 ± 0.75	2.346 ± 0.402	0.67 ± 0.203	10.73 ± 2.176	0.150 ± 0.04
<i>Celtis pallida</i>	Ulmaceae	Shrub	simple	171.338 ± 29.263	4.182 ± 0.881	2.51 ± 0.489	0.36 ± 0.083	7.884 ± 2.782	0.046 ± 0.016
<i>Guaiacum angustifolium</i>	Zygophyllaceae	Shrub	compuesta	96.376 ± 18.987	3.866 ± 0.647	2.908 ± 0.361	0.75 ± 0.202	4.026 ± 1.210	0.043 ± 0.014
<i>Caesalpinia mexicana</i>	Fabaceae	Tree	compuesta	132.919 ± 32.288	15.69 ± 3.235	15.582 ± 2.258	4.172 ± 0.781	109.18 ± 30.995	0.837 ± 0.211
<i>Acacia berlandieri</i>	Fabaceae	Tree	compuesta	99.796 ± 28.96	15.608 ± 3.041	9.848 ± 2.124	1.978 ± 0.603	50.579 ± 18.094	0.521 ± 0.155
<i>Acacia farnesiana</i>	Fabaceae	Shrub	compuesta	108.843 ± 21.56	3.832 ± 1.061	3.12 ± 0.753	0.84 ± 0.236	3.677 ± 1.838	0.035 ± 0.017
<i>Acacia shaffneri</i>	Fabaceae	Tree	compuesta	72.658 ± 24.948	4.882 ± 6.682	3.478 ± 0.608	0.612 ± 0.396	4.611 ± 2.197	0.066 ± 0.027
<i>Lantana macropoda</i>	Verbenaceae	Shrub	simple	124.681 ± 24.62	3.352 ± 0.651	1.348 ± 1.287	0.304 ± 0.101	2.293 ± 0.667	0.019 ± 0.006
<i>Leucaena leucocephala</i>	Fabaceae	Tree	compuesta	150.015 ± 37.736	17.856 ± 2.792	13.436 ± 1.539	3.65 ± 0.671	94.742 ± 20.221	0.679 ± 0.250
<i>Prosopis laevigata</i>	Fabaceae	Tree	compuesta	81.999 ± 15.928	8.83 ± 1.767	6.126 ± 1.634	3.522 ± 0.979	14.704 ± 4.812	0.183 ± 0.060
<i>Bernardia myricifolia</i>	Euphrobiaceae	Shrub	simple	117.980 ± 28.42	2.968 ± 0.470	1.848 ± 0.325	0.486 ± 0.109	4.050 ± 1.245	0.047 ± 0.076
<i>Berberis chococo</i>	Berberidaceae	Shrub	compuesta	74.060 ± 5.255	16.05 ± 2.293	8.386 ± 1.575	5.514 ± 1.297	51.574 ± 20.073	0.694 ± 0.257
<i>Celtis laevigata</i>	Ulmaceae	Tree	simple	149.331 ± 39.169	8.26 ± 0.944	4.188 ± 0.573	1.058 ± 0.23	24.268 ± 5.624	0.176 ± 0.068

<i>Cercidium macrum</i>	Fabaceae	Tree	compuesta	146.532 ± 24.932	1.972 ± 0.589	2.994 ± 0.62	0.79 ± 0.341	2.351 ± 1.127	0.016 ± 0.007
<i>Forestiera angustifolia</i>	Oleaceae	Shrub	simple	140.201 ± 32.583	2.778 ± 0.356	0.652 ± 0.198	0.122 ± 0.042	1.334 ± 0.379	0.010 ± 0.003
<i>Parkinsonia aculeata</i>	Fabaceae	Tree	compuesta	64.532 ± 11.104	33.556 ± 5.318	1.05 ± 0.276	0.828 ± 0.295	10.182 ± 3.615	0.156 ± 0.038
<i>Croton suaveolens</i>	Euphrobiaceae	Shrub	simple	122.738 ± 14.910	5.832 ± 0.939	2.342 ± 0.334	1.172 ± 0.238	10.704 ± 3.444	0.087 ± 0.024
<i>Salix lasiolepis</i>	Salicaceae	Tree	simple	108.730 ± 7.764	9.534 ± 1.273	0.848 ± 0.149	0.594 ± 0.100	5.939 ± 1.424	0.055 ± 0.013
<i>Gymnosperma glutinosum</i>	Asteraceae	Shrub	simple	186.996 ± 31.838	16.052 ± 2.355	2.856 ± 0.515	0.436 ± 0.218	24.988 ± 7.139	0.135 ± 0.038
<i>Harvardia pallens</i>	Fabaceae	Tree	compuesta	137.918 ± 18.269	7.87 ± 1.755	7.882 ± 1.389	2.508 ± 0.561	26.649 ± 7.797	0.198 ± 0.063
<i>Acacia wrightii</i>	Mimosaceae	Tree	compuesta	98.97 ± 22.455	2.624 ± 0.509	3.266 ± 0.532	0.934 ± 0.179	3.35 ± 0.851	0.034 ± 0.008
<i>Eysenhardtia polystachya</i>	Fabaceae	Shrub	compuesta	112.428 ± 17.575	4.614 ± 0.877	1.25 ± 0.301	0.622 ± 0.189	3.180 ± 1.232	0.0285 ± 0.010

**Table 1:** Leaf traits in different plant species used. Data are means and standard deviation (n = 5).

The results revealed that there exist large variations in leaf area (cm<sup>2</sup>), specific leaf area (cm<sup>2</sup> g<sup>-1</sup>) and leaf dry mass (g), petiole length and moisture content both in winter and summer seasons. Leaf area (cm<sup>2</sup>) ranged from 0.733 to 215.926 (cm<sup>2</sup>), leaf dry mass from 0.006 to 1.463 (g), specific leaf area from 11.833 to 1982.780 (cm<sup>2</sup>), leaf length from 0.700 to 51.00 (cm), leaf breadth from 0.400 to 22.400 (cm) and petiole length from 0.100 to 13.00 (cm). Highly significant differences were observed among the species for all the variables studied. Leaf area showed highly significant positive correlations with leaf dry weight (g) (r = 0.94), leaf length (r = 0.88), leaf breadth (r = 0.807), and petiole length (r = 0.71) while the leaf dry weight showed highly significant correlation with leaf length (r = 0.88), leaf breadth (r = 0.775), and petiole length (r = 0.734). Specific leaf area did not show any significant correlations with any of the variables studied. Therefore, leaf area, leaf length, petiole length have significant roles in plant productivity and reveals that there exists interspecific diversity among distinct leaf characteristics which in turn determine distinct functional trends among the community studied.

Another study was undertaken on seasonal variations in leaf area, leaf specific area and leaf dry weight of trees and shrubs of 23 species in Linares, North-eastern Mexico. The results reveal that there exists large variations in leaf area (cm<sup>2</sup>), specific leaf area (cm<sup>2</sup> g<sup>-1</sup>) and leaf dry mass (g) among 23 species both in Winter and Summer seasons but all these variables were higher in summer (better growth) compared to those in Winter thereby showing better adaptation in the Summer season. In consideration of leaf area and specific leaf area and or leaf dry weight, the species adapted to winter are *Cordia boissieri*, *Leucophyllum frutescens*, *Karwinskia humboldtiana*. The susceptible species were *Eysenhardtia polystachyas*, *Sideroxylon celastrinum*, *Bernardia myricifolia*. Similarly the species highly adapted in summer are *Caesalpinia mexicana*, *Leucaena leucocephalum*, *Cordia boissieri*, while the species less adapted in the summer season are *E. polystachyas*, *S. celastrina*, *B. myricifolia*. The results observed in the present study reveal that there exists interspecific diversity among

distinct leaf characteristics which in turn determine distinct functional trends among the community studied.

## Conclusion

Leaves and various leaf traits play a very important role in the growth, development and productivity of trees and shrubs in a forest ecosystem. Enormous studies have been undertaken globally on variability in various leaf traits, its roles in plant productivity. There exists large variability in both leaf morphological and eco-physiological traits. The expressions of the magnitude of traits vary widely in different edaphic and climatic conditions. These variations help in the coexistence and adaptation of the species in a forest ecosystem. The productivity of trees and shrubs is dependent on these traits mentioned. This information is needed for foresters and forest scientists for forest management and planning research projects.

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