International Journal of Bio-resource and Stress Management 2016, 7(6):1403-1408 HTTPS://DOI.ORG/10.23910/IJBSM/2016.7.6.1708

Review Article

Adaptive Strategy of Woody Trees and Shrubs of Tamaulipan Thorn Scrub in Xeric Environments

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Article History

Manuscript No. AR1708
Received in
Received in revised
Accepted in final form

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Keywords

Woody species, morpho-physiological, ecophysioloical traits, carbon sequestration

Abstract

Woody trees and shrubs in Tamaulipan Thorn Scrub in Northeastern Mexico are exposed to hot summer with temperature rising to 45 °C. These woody species adopt different morpho-anatomical and ecophysiological mechanism for adaptation to these xeric environments. Among these tree top crown, branching pattern, branching density help in the capture of solar radiation for photosynthesis, thereby reducing high temperature. Apart from these few anatomical traits such low or absence of stomata on adaxial surface and sunken stomata mainly on the abaxial surface prevent loss of transpiration, thereby maintaining water budget. In addition cuticular thickness, long and compact palisade cells help in better photosynthetic capacity as well as in reducing transpiration. Besides, the large variability in few ecophysiological traits such as pigments, epicuticular wax, macro-and micronutrients, and carbon sequestration (carbon fixation) help in the adaptation of woody species to xeric environments. It is recommended that the plantation of woody tree species with high carbon sequestration could reduce carbon from the atmosphere during capture of solar radiation and photosynthesis, thereby reducing high temperature and carbondioxide load in the atmosphere.

1. Introduction

The dominant vegetation in a forest ecosystem is mostly comprised of the woody trees and shrubs. The climatic conditions prevailing in a forest ecosystem have a dominating effect in governing the distribution and establishment of the various woody trees and shrubs. Woody plants are the dominant vegetation in a forest ecosystem. The Tamaulipanthorn scrub of Northeastern Mexico is predominant with a number of woody plant species. The climatic conditions as that of Coastal Mediterranean Machia Ecosystem are simulated in the Tamaulipan Thorn scrub. The woody plant species in this thorn scrub of north eastern Mexico are exposed to hot summer with temperature rising up to 45 °C and winter temperature going below 2 to 3 °C. During summer the plants were exposed and adapted to typical xeric environments.

During last few years we carried out various aspects of experimental biology of woody plant species at the experimental station of Forest Science Faculty, Universidad Autonoma de Nuevo Leon, located in the municipality of Linares (24°47´ N, 99°32´ W), at elevation of 350 m MSL. The climate is subtropical or semiarid with warm summer, monthly mean air temperature vary from 14.7 °C in January to 23 °C in August, although during summer the temperature goes up to 45 °C. Average annual precipitation is around 805 mm with a bimodal distribution. The dominant type of vegetation is the Tamaulipan Thorn scrub or subtropical Thorn scrub wood land. The dominant soil is deep, dark grey, lime-grey, vertisol with montmorillonite, which shrink and swell remarkably in response to changes in moisture content.

During the course of investigation on autoecology and ecophysiology of more than 30 woody species, the results are published in various journal and few findings are not yet published.We contemplate that each plant species possesses specific morpho-anatomical and ecophysiological characteristics contributing to the mechanism of adaptation to xeric environments. We cite here in brief the results of our research on possible adaptive strategy of woody trees and shrubs in Northeastern Mexico.We put forward few hypotheses which need to be confirmed in future studies.It is well known that few physiological mechanisms of resistance such as drought resistance such as drought escape, drought tolerance, drought resistance are found in plants for drought resistance.

Mystery of coexistence and adaptation of trees has been discussed (Maiti and Rodriguez, 2015a). Hypotheses are putforward on the biology and adaptation of the woody species (Maiti et al., 2016b). Various adaptive morpho-physiological traits of woody plants contribute to for Co-existence in a Forest Ecosystem(Maiti et al., 2016b). We make a brief summary of research findings on these aspects.

2. Methodologies Undertaken

We adopted standard protocols to study various aspects of experimental biology of woody plant species which are published. Thus the techniques followed are herewith avoided to overcome repetitions.

3. Analytical Discussion

3.1. Tree top crown

Each woody plant species possesses a typical crown architecture formed by the orientation of branches and leaves (Maiti et al., 2015a) which help in the capture of solar radiation used in the process of photosynthesis, thereby reduce temperature. Different species possess different tree top crown architecture occupying the available niches, thereby reducing the effect of high temperature in xeric environments.

3.2. Branching pattern and branching density

We observed that there exists a large variability in branching pattern in woody species such as monopodial, pseudomonopodial and sympodial. These woody species with varied branching patterns are distributed in the forest ecosystem in available niches in a harmony to reduce the impact of xeric environments. Branching pattern functions as a solar pane in the capture of solar energy during the process of photosynthesis and carbon assimilation which in turn reduce high temperature. We also observed that there exists a large variability in branching density among woody specieswhich could have direct effect in reducing high temperature, and plant productivity which needs to be confirmed in future research (Maiti et al., 2015b).

3.3. Leaf traits

Woody species also exhibited a large variability in leaf shape, size, margin, apex and leaf base which also help in the co-existence and co-adaptation of the species in the ecosystem. During recent survey in the summer season (2016) we selected species with xeromorphic leaf traits suchas small size, thick, leathery leaf with shining waxy surface, highly pubescent. We are planning to study anatomy of the leaves of these selected species.

It is well documented that there exists large biodiversity in leaf traits with respect to leaf area, leaf specific weight (Maiti et al., 2014a, b; Rodriguez et al., 2015d; Rodriguez et al., 2016), which could have direct impact in co-existence, co-adaptation and productivity of the woody species, thereby maintaining harmony and congenial temperature in the xeric environments.

3.3.1. Leaf canopy

We classified two types of leaf canopy, 1) open leaf canopy where almost all leaves are exposed to solar radiation, and 2) close leaf canopy where all leaves are not exposed to solar radiation owing to overlapping. It is hypothesized that tree species with open leaf canopy have higher photosynthetic capacity (Maiti et al., 2014a) which needs to be confirmed. During the course of investigation we observed that tree species with open canopy grew taller, highly branched showing high productivity in the forest ecosystem. It is expected that they have greater photosynthetic capacity leading to the high productivity compared to those with close canopy. We observed that they have greater wood density. It is expected that tree species with open canopy having high photosynthetic capacity and high carbon assimilation will capture higher solar radiation, thereby reducing the effects of high temperature in the xeric environment.These hypotheses need to be confirmed in future studies (Maiti et al., 2014a, b).

3.3.2. Leaf anatomical traits

Apart from leaf xeromorphic traits mentioned before, few of anatomical traits (leaf surface anatomy, anatomy of lamina, petiole anatomy, leaf venation) contribute to drought resistance.

3.3.2.1. Leaf surface architecture

Stomata play an important role in water relations of the woody species. A comparative study on leaf dermal structure of 30 woody species reveals that there exists a large variability in the presence, absence and abundance of stomata. It is observed that many woody species show absence or rare presence of stomata on the adaxial leaf surface and sunken stomata on both adaxial and abaxial surface which prevents loss of transpiration, thereby conserving water budget and adaptation to xeric environments. We selected the following species having absence or rare presence of stomata on the adaxial surface showing xeromorphic leaf anatomical traits.

Berberis chococo, Celtis laevigata, Condalia hookeri, Diospyros palmeri, Diospyros texana, Ebenopsis ebano, Ehretia anacua, Forestieria angustifolia, Havardia pallens, Helietta parvifolia, Karwinskia humboldtiana, Sargentia gregii, Sideroxylon celastriana, Zanthoxylum fagara (Rodriguez et al., 2016).

Research needs to be directed to study water relation (water potential) of these species to confirm our hypothesis.

3.3.2.2. Leaf lamina anatomy

A comparative study on anatomy of leaf lamina of 26 woody species shows a large variability in cuticular thickness, epidermal cell wall thickness, length and compactness of palisade cells which could be related to conservation of water budget and drought resistance of the species. It is expected that the woody species having long compact palisade could contribute to higher photosynthetic capacity and prevent loss in transpiration. We selected the following species which could be related to high photosynthetic capacity and drought resistance (not published).

Long and compact palisade cell: *Karwinskia humboldtiana, Lantana macropoda*, *Prosopis laevigata, Zanthoxylum fagara, Helietta parvifolia, Acacia berlandieri* and *Acacia greggii.*

3.3.2.3. Petiole anatomy

Woody species having thick and strong petiole support leaf lamina against stress. A comparative study on petiole anatomy of 36 woody species shows a large variability in cuticular thickness, collenchyma layers, sclerenchyma thickness and vascular bundle area. Woody species having high cuticular and collenchyma thickness, thick sclerenchyma could function against drought stress (Maiti et al., 2016a).

We selected the following species with desirable traits for adaptation to xeric environments.

Thick cuticle: A*cacia berlandieri, Celtis pallida, Condalia hookeri, Eysenhardtia texana, Gymnosperm aglutinosum*, a thick collenchyma (*Acacia farnesiana, Berberis chococo, Bernardia myricifolia, Celtis pallida, Havardia pallens*) and extra sclerenchyma bands which offer mechanical strength (*Acacia berlandieri, Ebenopsis ebano, Eysenhardtia texana, Lantana macropoda, Prosopis laevigata, Xanthoxylum fagara*).

3.3.2.4. Leaf venation pattern

Leaf venation helps to give mechanical strength and transport of water, nutrients and photosynthates in the leaf. A comparative study on the venation pattern of 30 woody species and venation density of 20 woody species reveals that there exists a large variability in venation pattern and venation density among species. The species showed large variations in venation architectures in orientation, size, shape depicting the characteristics of each species. Vein islets in few species are bounded by thin veins but traversed by thicker vein to give mechanical strength to the leaf lamina against stress, adaptive characteristics. Among the species studied *Eysenhardtia texana* had maximum vein islet density. It is expected that that the woody species with thick and strong veins offers mechanical strength, and the species with high venation density is efficient in transport of nutrients and photosynthates (Maiti et al., 2015c, Maiti et al., 2016d).

3.4. Wood anatomical traits

Wood is an important product of woody plants for wood industry and used for furniture and building construction also used for fire wood.We undertook characterization of wood anatomy of more than 30 woody species of Tamaulipan Thorn Scrub. We observed large variation in wood anatomical traits among woody species with respect to type, size of vessels, wood porosity, vessel density, type of wood parenchyma, ray cells, vessel pitting, wood fibre cell characteristics, wood compactness which could be utilized in taxonomic delimitation, wood quality and utility (Maiti et al., 2015d; Maiti et al., 2016f).

In the semiarid hot summer many species possess narrow vessels and high xylem density which could function against cavitation and embolism against hot summer and cold seasons which have been reported by various authors (the adaptive capacity of the species to environmental stresses (Baily and Tupper, 1918; Carlquist, 1983; Baas, 1982; Baas et al., 2004; Ewers and Fisher, 1991). Species with high xylem density are reported to be drought tolerant (Jacobsen et al., 2007). Few research papers are published on anatomy and its relation to taxonomy and adaptation to xeric environments (Maiti and Rodriguez, 2015a; Maiti et al., 2016f, Maiti et al., 2016).

We selected species with high xylem density and narrow vessels viz.,*Acacia wrightii*, *Berberis chococo*, *Diospyros pallens*, *Diospyros texana*, *Ehretia anacua*, *Fraxinus gregii*, *Guiacum angustifolia*, *Helietta parviflora*, *Karwinskiahum boldtiana* and others (Rodriguez et al., 2016c). Research needs to be directed to verify the capacity of these species against cavitation and drought tolerance.

3.4.1. Wood density

Wood density offers strength against stress. There exists a large variability in wood density contributing to the adaptation of the woody species to xeric stress (Maiti et al., 2016c)

3.5. Physiology and biochemistry

3.5.1. Leaf pigments

Leaf pigments (chlorophyll a, b,) play a great role in the capture of solar energy leading to photosynthesis and carbon assimilation, thereby reducing heat stress? A comparative study on leaf pigments (chlorophyll a, b and carotenoid) of 37 woody species showed a large variability in chlorophyll a and b, but little variations in carotenoids (Maiti et al., 2016). It is expected that the woody species having high total chlorophyll content such as *Leucaena leucocephala, Ebenopsis ebano, Sargentia gregii* and *Amyris texana* could be more efficient in the capture of solar radiation, high photosynthetic capacity and highly adapted to xeric environment (Rodriguez et al., 2015a). Seasonal variations in summer and winter in leaf pigments of 23 species were found showing adaptive stability to high and low temperature(Rodriguez et al., 2015c).

3.5.2. Leaf epicuticular wax

Epicuticular wax enhances the reflectance of visible and near infrared radiation from leaf surface thereby reducing net radiation and cuticular transpiration and seems to contribute to drought resistance of plants (Kurtz, 1950; Ebercon et al., 1977; Hull and Bleckman, 1977).

Many species in Tamaulipan Thorn Scrub possess waxy leaves owing to the presence of epicuticular wax. A study has been undertaken on epicuticular wax of 35 woody species which indicated the presence of large variations in the contents of the epicuticular wax thereby giving an opportunity to select species for future research with respect to the adaptation of these species to semiarid environment (Rodriguez et al., 2015d). We selected the species with high epicuticular wax contents viz.,*Forestiera angustifolia*(702.04 $\mu g/cm^2$), *Diospyros texana (*607.65 $\mu g/cm^2$), *Bernardia myricifolia (*437.53 $\mu g/cm^2$), *Leucophylum leucocephala* (388.50 $\mu g/cm^2$). It is expected that these species may be well adapted to the semi arid conditions. Future research needs to be directed on these selected species with special reference to their physiological function with special reference to adaptation to water stress (Maiti et al., 2016)

3.5.3. Leaf macro and micronutrients

Leaf nutrients play an important role for the growth and development of trees and are sources of nutrients for ruminants in forest. A study under taken to estimate six nutrients, three macronutrients (K, Mg, P) and three micronutrients (Cu, Fe, Zn) of twenty five woody species in Linares, Northeastern of Mexico reveals a large variability among the species. 1. *Croton suaveolens* acquired highest level of P (2.43 mg g^{-1}) and K (75.62 mg g^{-1}), whereas *Parkinsonia aculeata*for Mg (5.29 mg g^{-1}). *Cordia boissieri* for both Cu (30.71 µg gps^{-1}) and Fe (280.55 µg gps^{-1}), on the other hand, *Salix lasiolepis* for Zn (144.86 µg gps^{-1}). These species could serve as excellent sources for ruminants and could adapt well under xeric environments (Rodriguez et al., 2015b). Nutrient profile of 26 woody plants is documented (Maiti et al., 2016d).There exists a large biodiversity of leaf chemical components among woody species (Maiti et al., 2016e) which help in the adaptation of the woody species to xeric environments. Different woody species have been selected with ecophysiologically efficient traits which may be capable to adapt to xeric environments (Maiti et al., 2015b, Maiti et al., 2016b).

3.5.4. Carbon sequestration (carbon fixation)

Woody species vary in their capacity of carbon fixation (carbon sequestration) from the atmosphere during the process of photosynthesis. A study was undertaken to determine carbon and nitrogen content among 40 plant species of diverse growth habit with a view to select species with high carbon fixation (carbon content) and nitrogen content. In this study, we selected few species with high carbon fixation such as *Eugenia caryophyllata* (51.66%), *Litsea glauscensens* (51.54%), *Rhus virens* (50.35%), *Gochantia hypoleuca* (49.86%), *Pinus arizonica* (49.32%), *Eryobotrya japonica* (47.98%), *Tecoma stans* (47.79%), *Rosamarinus officinalis* (47.77%). Few of these species could be recommended for plantation in CO_2 polluted areas to reduce carbon load. In addition these with high carbon concentration in the biomass could serve as good source of energy. We selected few species with high nitrogen content such as *Mimosa malacophylla* (8.44%), *Capscicum annuum* (6.84%), *Moringa oleifer* (6.25%), *Azadirachta indica* (5.85%), *Eruca sativa* (5.46%), *Rosamarinus officinalis* (5.40%), *Mentha piperita* (5.40%). These species could serve as good sources of nitrogen for health care. We selected few species with high C/N ratio such as *Arbutus xalapensis* (26.94%), *Eryngium heterophyllum* (24.29%), *Rhus virens* (22.52%), *Croton suaveolens* (20.16%), *Cinnamomum verum* (19.89%) which may be related to high production of secondary metabolites and antioxidants (Rodriguez et al., 2015a, Maiti et al., 2015d). It is recommended that the plantation of trees with high carbon sequestration capacity in cities or carbon polluted areas could reduce carbon load in the atmosphere. This in turn will absorb solar radiation and reduce high temperature stress (Maiti et al., 2015b; Maiti et al., 2016a, e).

4. Conclusion

The synthesis from the study on more than 30 woody species showed a large variability in these traits such as tree crown architecture, branching pattern and density, variability in leaf traits which help in the capture of solar radiation, thereby reducing high temperature. Besides some of the leaf anatomical traits such as absence of stomata on the adaxial leaf surface, sunken stomata, thick cuticle, long compact palisade cells in leaf lamina prevent loss in transpiration, thereby maintaining water budget. In addition the large variability in the intensity of few ecophysiological traits such as chlorophyll and carotenoid pigment contents, epicuticular wax, nutrient profiles and carbon sequestration help in the adaptation of the woody species in xeric environments. Different woody species have been selected for high amount of the traits for determining water relation for future research. Ecophysiologically efficient woody plants have been selected to confirm their efficiency in adaptation to xeric environments.

5. References

Baas, P., 1982. Systematic, phylogenetic and ecological wood anatomy history and perspectives. In: Baas, P. (Ed.),New perspectives in wood anatomy. Nijhoff/Junk, The Hague,

23–58.
Baas, P., Ewers, F.W., Davis, S.D., Wheeler, F.A., 2004. Evolution of xylem physiology. In: Hemsley, A., Poole, I. (Eds.), The evolution of plant physiology. Elsevier, Amsterdam, 273–295.
Bailey, I.W., Tupper, W.W., 1918. Size variation in tracheary cells I. A comparison between the secondary xylem of vascular cryptogams, gymnosperms and angiosperms. Proceedings of the American Academy of Arts and Sciences 54, 149–204.
Carlquist, S., 1983. Vessel grouping in dicotiledon wood: significance and relationship to imperforate tracheary elements. Aliso 10(4), 505–525.
Ebercon, A., Blum, A., Jordan, W.R., 1977. A rapid calorimetric method for epicuticular wax content of sorghum leaves. Crop Science 17, 179–180.
Ewers, F.W., Fisher, J.B.,1991. Why vines have narrow stems: histological trends in Bauhinia. Oecologia 88(2), 233–237.
Hull, H.M., Bleckmm, C.A., 1977.An unusual epicuticular wax ultrastructure on leaves of *Prosopis tamarugo*. American Journal of Botany 64, 1083–1091.
Jacobsen, A.L., Agenbag, L., Esler, K.J., Pratt, R.B., Ewers, F.W., Davis, S.D., 2007. Xylem density, biomechanics, and anatomical traits correlate with water stress in 17 evergreen shrub species of the Mediterranean-type climate region of South Africa. Journal of Ecology 95, 171–183.
Kurtz, E.B., 1950. The relation of the characteristics and yield of wax to plant age. Plant Physiology 25(2), 269–278.
Maiti, R.K., Rodriguez, H.G., Kumari, A., 2016. Applied Biology: A model. American Academic Press (in press).
Maiti, R, Rodriguez, H.G, Kumari, A., 2016b. Adaptive morpho-physiological traits of woody plants for co-existence in a forest ecosystem. Forest Research 5, 175. doi:10.4172/2168-9776.1000175.
Maiti, R., Gonzalez R.H., Karfakis, T,N.S., 2014b. Variability in leaf traits of 14 native woody species in semiarid regions of northeastern Mexico. International Journal of Bio-resource and Stress Management 5(4), 475–479. doi:105958/0976-4038.2014.00604.6.
Maiti, R., Para, A.C., Rodriguez, H.G., Paloma, S.V., 2015d. Characterization of wood fibres of scrubs and tree species of the tamaulipanthornscrub, northeastern mexico and its possible utilization. Forest Research 4, 154. doi.org/10.4172/2168-9776.1000154.
Maiti, R., Rodriguez, H.G., 2015a. Mystery of coexistence and adaptation of trees in a forest ecosystem. Forest Research 4, http://dx.doi.org/10.4172/2168-9776.1000e120.
Maiti, R., Rodriguez, H.G., Kumari, A., 2016d. Nutrient Profile of Native Woody Species and Medicinal Plants in Northeastern Mexico: A Synthesis. Journal of Bioprocess and Biotech 6, 283. doi:10.4172/2155-9821.1000283.
Maiti, R., Rodriguez, H.G., Gonzalez, E.A., Kumari, A., Sarkar, N.C., 2016b. Variability in Epicuticular Wax in 35 Woody Plants in Linares, Northeast Mexico. Forest Research 5, 162. doi.org/10.4172/2168-9776.1000162.
Maiti, R., Rodriguez, H.G., Manue, J.J., Diaz, J.C.G., Tijerina, H.A.D., Kumari, A., 2016a. Comparative petiole anatomy of 36 woody plant species in northeastern Mexico and its significance in taxonomy and adaptation.International Journal of Bio-resource and Stress Management 7(3), 350–360. doi: 10.5958/0976-4038.2016.00055.5.
Maiti, R., Rodriguez, H.G., Diaz, J.C.G., Tijerina, H.A.D., Flores, A.A.C., Kumari, A., Sarkar, N.C., 2016f. Comparative wood anatomy of 20 woody plant species in northeastern Mexico and its significance.International Journal of Bio-resource and Stress Management7(2), 229–246. doi: 10.5958/0976-4038.2016.00035.X.
Maiti, R., Rodriguez, H.G., Mermolejo, J., Gonzalez, M.I.L., 2015c. Venation pattern and venation density of few native woody species in linares, northeast of Mexico. International Journal of Bio-resource and Stress Management 6(6), 719–727. doi: 10.5958/0976-4038.2015.00110.4.
Maiti, R., Rodriguez, H.G., Kumari, A., Diaz, J.C.G., 2015b. Perspectives of branching pattern and branching density in 30 woody trees and shrubs in tamulipanthornscrub, northeast of Mexico. Forest Research 4, 4 http://dx.doi.org/10.4172/2168-9776.1000160.
Maiti, R., Rodriguez, H.G., Sarkar, N.C., Kumari, A., 2016e. Biodiversity in leaf chemistry (pigments, epicuticular wax and leaf nutrients) in woody plant species in north-eastern Mexico, a synthesis.Forest Research 5, 170. doi:10.4172/2168-9776.1000170.
Maiti, R., Rodriguez, H.G., Karfakis, T.N.S., 2014a. Variability in leaf canopy architecture may be related to photosynthetic efficiency and carbon fixation. International Journal of Bio-resource and Stress Management 5(4), 20–25 doi: 4343543.11212.
Maiti, R.K., Rodriguez, H.G., Sarkar, N.C., Thakur, A.K., 2015a. Branching pattern and leaf crown architecture of some tree and shrubs in northeast Mexico. International Journal of Bio-resource and Stress Management 6(1), 041–050 doi:10.5958/0976-4038.2015.00009.
Rodriguez, H.G., Maiti, R., Narvaez, R.I.V., Sarkar, N.C., 2015a.Carbon and nitrogen content in leaf tissue of different plant species, northeastern Mexico. International Journal of Bio-resource and Stress Management 6(1), 113–116 doi: 10.5958/0976-4038.2015.00010.X.

Rodriguez, H.G., Maiti, R., Kumari, A., 2015c. Seasonal influence on pigment production in nine species of trees and shrubs in linares, northeast of Mexico. International Journal of Bio-resource and Stress Management 6(3), 346–351. doi:10.5958/0976-4038.2015.00059.7.

Rodriguez, H.G., Maiti, R., Tijerina, H.A.D., Kumari, A., Sarkar, N.C., 2015b.Macro and Micronutrient Contents of 25 Woody Trees and Shrubs in Northeast of Mexico. International Journal of Bio-resource and Stress Management6(4), 478–483. doi: 10.5958/0976-4038.2015.00070.6.

Rodriguez, H.G., Maiti, R., Tijerina, H.A.D., Gonzalez, M.I.L., Diaz, J.C.G., Kumari, A., 2015d. Variation in leaf traits of 34 trees and shrubs in summer season in linares, north-eastern Mexico. International Journal of Bio-resource and Stress Management 6(6), 707–718. doi: 10.5958/0976-4038.2015.00109.8.

Rodriguez, H.G., Maiti, R., Sarkar, N.C., Kumari, A., 2016c.Variability in wood density and wood fibre characterization of woody species and their possible utilityin northeastern Mexico. American Journal of Plant Sciences 7, 1139–1150. doi.org/10.4236/ajps.2016.77109.

Rodriguez, H.G., Maiti, R., Kumari, A., 2016. Biodiversity of leaf traits in woody plants in northeastern mexico: a synthesis. Forest Research 5(2), 1–7. doi: 10.4172/2168.9776.1000169.

