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Biodiversity in Leaf Chemistry (Pigments, Epicuticular Wax and Leaf Nutrients) in Woody Plant Species in North-eastern Mexico, a Synthesis

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Abstract

The leaves of trees and shrubs possess various chemical components such as leaf pigments, epicuticular wax and various macro and micronutrients. These components influence the growth, development and productivity and adaptation of the species to environments. The results of studies undertaken on the more than 30 woody species in North-eastern Mexico results reveal that there exist large variations in pigments (chlorophyll, carotenoids), epicuticular wax and macro and micro nutrients Several species have been selected with high values of the pigments, epicuticular wax and various macro and micronutrients. For example, species with high Chlorophyll a were: *Ebenopsis ebano* (1.755), *Cercidium suveoleon* (0.589), *Amyrys texana* (1.66), and those with high chlorophyll b were *Ebenopsis ebano* (0.398), *Amyrys texana* (1.66) and species with high Chlorophyll total (Chl a + b) were: *Ebenopsis ebano* (2.253), *Leucaena leucocephala* (1.687). Species with high carptenoids were: Berberis chococo (0.585), Diospyros palmeri (0.433. The species showing high epicuticular wax load are *Forestiera angustifolia* (702.04 µg/cm^2), *Diospyros texana* (607.65 µg/cm^2), *Bernardia myricifolia* (437.53 µg/cm^2). There is a here is a need to conform the efficiency of these selected species for productivity and adaptation of the species to environment.

Keywords: Leaf pigments; Epicuticular wax; Leaf macro; Micronutrients; Variability

Introduction

Leaves are vital organs of a woody plant in a forest ecosystem where various physiological biochemical and metabolic reactions occur together for the growth, development and productivity and biomass and timber. Concerted research activities have been directed by the plant physiologists and biochemists to unveil the mystery of the fundamental processes and analyze these metabolic reactions and chemical components guiding different vital functions in the leases. Among these chemical components leaf pigments, epicuticular wax, and various leaf nutrients among others are important. It is essential for a forest scientist to analyse the functional activities of each of these components and chemistry for effective management of the forest. In a forest ecosystem different trees and shrubs grow together mutually sharing solar radiation and absorption of nutrients from soil horizons. Each species has its own mechanism for coexistence and adaptation in the ecosystem for different morpho-physiological traits such leaf traits, branching pattern, leaf pigments, epicuticular wax, leaf nutrients, carbon fixation, protein and other traits. Nevertheless, some species are more efficient in most of these traits over all other species.

We want to narrate here a brief accounts of research advances undertaken globally on these vital components and their respective functions in the leaves. Finally we discussed research undertaken in woody plants in North-eastern Mexico. It is necessary to select trees and shrubs with high values of leaf pigments, epicuticular wax and leaf macro and micronutrients.

Research advances in plant pigments, epicuticular wax and leaf nutrients

Leaf pigments: Plant contains various leaf pigments such as chlorophyll, carotenoids, xanthophylls, flavonoids etc., which play vital roles in plant metabolism and physiological performance of the plant. The leaf pigment contents in various plant species functions act as indices for protection. Chlorophyll and carotenoids function as key roles in photosynthetic process in higher plant. They play a vital role in capturing solar energy, which is converted to chemical energy. Carotenoids are natural fat-soluble pigments, found in plants, algae and photosynthetic bacteria, where they also play role in photosynthesis. In some non-photosynthetic bacteria, they may help as protective function against damage by light and oxygen [1,2]. Animals have no capacity to synthesize carotenoids and may incorporate carotenoids from their diets. In animals carotenoids impart bright coloration and serve as antioxidants and a source for vitamin A activity [3] In addition, they perform very important functions in plant in plant reproduction through their role in attracting pollinators and seed dispersal [4]. Seasonal variations were observed in chlorophyll a and b and carotenoids in native shrubs of North-eastern Mexico [5].

Chlorophyll and carotenoids are responsible to absorb light energy and transfer it to the photosynthetic apparatus in chloroplast for the production of photosynthetic and finally to biomass production in plants. Therefore, the estimation of leaf pigments content serves as a valuable tool to understand the physiological and biochemical functions of leaves [6]. Plant pigments may play a role in the ecosystem productivity, but it is influenced by drought and extreme temperature prevailing during winter and summer seasons [6]. The productivity of higher plants is mediated by photosynthesis in leaves and its adaptation through leaves [7]. The effects of these environmental factors by different authors such as high temperature are well known [7,8] and low temperature during winter thereby affecting growth of the plant species. Under such conditions the production of photosynthetic may be limited by temperature, stomata control and light energy damage. The chlorophyll contents are affected by the prevailing shade characteristics [5]. There existed relationship between leaf pigment and spectral reflectance [5]. Variations in chlorophyll contents between plants are found to be related to leaf developments and senescence [5]. The chlorophyll content was higher in shade leaves, whereas carotenoid and non-photochemical quenching increased with light [7]. The carotenoid components of sunleaves of plants revealed that sun leaves contained higher amount of components of xanthophylls cycles [9]. The reduction of chlorophyll does not cause an adaptive response against the adverse condition in summer in Mediterranean summer which may be applicable in North-eastern Mexico [7]. These leaf pigment contents could be related to varying leaf structural characteristics indices for the protection. The relationship between leaf pigment content and spectral reflectance was reported by Deming-Adams [9].

Various studies have revealed the effects of environments on leaf pigments contents. The chlorophyll content and photosynthesis in young leaves were much higher than fully expanded leaves [10]; leaf orientation, photorespiration and xanthophyll cycle protect young seedlings against high irradiation in field [10]. The chlorophyll and chlorophyll derived components were studied in pistachio kernels (*Pistacia vera* L) and found 13 compounds [11]. The environmental light effect was studied by Jose Fransisco et al. on leaf on concentrations of photosynthetic pigments and chlorophyll fluorescence of Mahogany (Switinnia macrophylla Kung) and Tonka bean (*Dipteroryx odorata*). Chlorophyll contents were higher in shade leaves than in sun leaves. The seasonal fluctuations were observed in photo protective (xanthophylls cycle) and photo protective (chlorophyll) capacity in eight Mediterranean plant species belonging to two different growth forms [12].

Epicuticular wax: Leaves contain waxy coating. Environmental conditions may strongly influence the quantity, composition, and morphology of the waxy coverings of leaf surfaces. Wax and cutin function as primary components of the leaf cuticle covering the leaf epidermal cells [13]. Waxes are composed of long-chain paraffins, alcohols, ketones, esters and free fatty acids in proportions determined by both genetic capability and environmental factors [14]. 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 drought resistance of plants [15,16]. These waxes also impart resistance to plants to absorption and penetration of foliar-applied herbicides [17,18]. It has been reported that leaves of mesquite (*Prosopis* spp.) develop a thick waxy cuticle [19,20]. An increase in wax accumulation was observed with leaf maturity in velvet mesquite (*P. velutinu*), while [20] observed most rapid wax accumulation on honey mesquite (*P. glandulosa*) with early leaf development and expansion.

Researches undertaken on epicuticular wax under controlled condition have documented various factors such as, light level [21,22] photoperiod [18] temperature [22,23] and water stress [24-26] influencing the wax contents in leaves. Variations in wax properties can affect the cuticular functions such as, regulation of gas exchange and transpiration, protection against pathogens, and absorption of foliar-applied chemicals as herbicides in agriculture. Few studies are available on variation in epicuticular wax characteristics among plants growing in the field. It has been reported by Rao and Reddy [27] that the composition and quantity of epicuticular waxes of shrubs in a semiarid environment showed seasonal variations in temperature and rainfall, and both cuticular and total transpiration appeared to be affected with changes in wax composition. Ecotypic variation in the quantity and composition of waxes on leaves of salt cedar (*Tamarix pentandra* Pall.) was considered as the basis of differences among populations in sensitivity to herbicide sprays [18]. Leaves of a cabbage cultivar (*Brassica oleracea* L. var. capitata), tolerant of foliar applications of the herbicide nitrofen (2,4-dichlorophenyl-p-nitrophenyl ether) were more heavily waxed than an intolerant [28]. The heavier wax deposit on leaves of the tolerant cultivar substantially decreased the rate and extent of herbicide penetration of the cuticle. The development of leaf cuticle of velvet mesquite was investigated [29] and detected well defined crystalline wax structures on even the youngest leaves. The amount of wax appeared to increase with leaf maturity, and a dendritic-shaped wax plate was formed in July in addition to the small, linear structure already present. The epicuticular wax structure of five Prosopis species consisted of an aggregate coating of rods and dendritic platelets [30].

Leaf nutrients: Leaves contain various macro-and micronutrients absorbed by plants by roots from soil horizons, required for plant growth and development and serve as source of nutrients for grazing animals in the forest ecosystem. A large variation among species with leaf traits help in nutrient conservation and contribute short term rapid growth. Species having nutrient conservation have long life span, high leaf mass per area, low nutrient concentrations and low photosynthetic capacity. The availability of nutrients in leaves is essential for efficient plant function. Chaplin [31] reviewed the nature of crop responses to nutrient stress and compares these responses to those of specie that evolved under more natural conditions. He gave emphasis on nutritional studies of nitrogen and phosphorus because these elements most commonly limit plant growth [31]. The nutrients present in leaves contribute to plant growth and metabolism, Sufficient research activities have been undertaken on nutrient content and metabolism in leaves On the other hand, Leaf nutrient contents depends on the availability of nutrients present in the soil habitat Nutrient-poor habitats tend to be dominated by species by nutrient-conserving species, while fertile habitats tend to be dominated by species with higher short-term productivity per leaf Mass [32]. Within a given habitat, species with a range of leaf traits can coexist.

With the age of leaves, nutrient resorption occurs when nutrients are withdrawn from leaves prior to abscission and reemployed in the developing tissues (leaves, fruits, seeds. Resorption occur throughout a leaf s life particularly when the leaves are shaded [33,34]. A major phase of resorption occurs shortly before leaf abscission which is a highly ordered process of leaf senescence occurring in most species [35] is recycled via resorption (Around 50% of leaf N and P is recycled via resorption [36]. It is suggested that the presence of active nutrient sinks has control over resorption [37].

A study has been undertaken nutrient availability and management in the rhizophere showing genotypic differences. Plants exposed to nutrient deficiency activate a range of mechanism that lead to increased nutrient availability in the rhizophere compared with bulk soil plant may change their root morphology, increase affinity of nutrient transporters in the plasma membrane and exude organic compounds (carboxylates phenolic, carbohydrates enzymes etc. Chemical changes in the rhizophere lead to altered abundance and composition of microbial communities nutrient efficient genotypes are adapted to environment with low nutrient. Understanding the role of plant-microbe-soil interaction governing the nutrient availability will enhance environmental sustainability [37].

A strategy was developed in leaf physiology, structure and nutrient content between species of high- and low-rainfall and high- and low-nutrient habitats. Most plants withdraw nutrients from leaves with advance in age, The proportions of nutrients resorbed and the residual nutrient concentration in senesced leaves are different. A major spectrum of strategic variations occur in plan tin species with long life span, high leaf mass per unit area, low leaf nutrient concentrations and low photosynthetic capacity. Green- leaf and senesced leaf N and P concentration quantified revealed that leaf nutrient concentrations in green and senesced leaves were positive correlated with LL across all species. And most sites excluding nitrogen fixing species. Proportional resprption did not differ with soil nutrients. The results support the argument that a nutrient loss has affected the residual nutrient concentration rather than proportional resorption per se [38].

Plants contain nutrients useful for ruminants and wild animals in which direction research has been undertaken, Lukhele and Ryssen [39] undertook a study on chemical composition and potential value of subtropical tree species of Combreatum in southern Africa for ruminants. It was concluded that the foliage tested would not suitable resources of N to supplement protein deficiencies in low quality herbage.

Materials and Methods

Three studies were undertaken on analysis of leaf pigments, epicuticular wax and nutrients in native plant species at Linares, Northeastern Mexico. The studies were conducted during June to July, 2015 at the experimental station of Facultad de Ciencias Forestales, Universidad Autonoma de Nuevo Leon, located in the municipality of Linares (24 47 N, 99 32 W), at elevation of 350 cm. 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 Thornscrub or subtropical Thornscrub wood land. The dominant soil is deep, dark gray, lime-gray, Vertisol with montmorrillonite, which shrink and swell remarkably in response to change in moisture content.

Native shrubs and trees in semiarid region of North-eastern Mexico serve as important resources for a wide range of ruminants and white tailed deer [40]. They also supply high quality fuel and timber for fencing and construction Reid et al. [41], Fullbright [42] but the growth of these species is affected by climatic conditions which may cause differences in the production of the photosynthetic pigments, epicuticular wax and leaf nutrients.

In the following are mentioned the methodologies adopted on the estimation of leaf pigments, epicuticular wax and leaf macro and micronutrients.

Determination of chlorophyll and carotenoid contents

Five samples of leaf tissue (1.0 g of fresh weight) of each plant species were used for analysis. The chlorophyll a and b and carotenoids were extracted in 80% (v.v) aqueous acetone and vacuum filtered through a Whatman No.1 filter paper. Pigment measurements were determined spectrophotometrically using a Perkin-Elmer Spectrophotometer (Model Lamda 18). Absorbance of chlorophyll a and b and carotenoid extracts were determined at wavelengths of 669, 645 and 470 nm respectively. Carotenoids (mg/g dry weight) of pigments were calculated by equations.

Leaf epicuticular wax

Fresh leaves from different woody plant species were collected from the forest. Then leaflets were separated individually to complete a sub sample having an approximate surface area of 100 cm^2 which is determined by a leaf area meter. Sub-samples were gently rinsed in distilled water to remove foreign material, then air dried, and then placed in a beaker with 40 ml of analytical grade chloroform (99% pure) heated to 45°C. After 30s the chloroform was poured into pre-weighed foil pans which were then placed in a well-ventilated laboratory and evaporated to dryness for 24 hours. Foil pans were then reweighed to quantify the amount of residual wax. Amount of wax for a field sample was the mean of 5 laboratory replications. Wax was calculated reported on a weight per area basis (gm^{-2}) derived by dividing wax weight by the actual area of the sub-sample unit.

Leaf nutrients

The leaf samples were collected from each species and placed to dry on newspaper for a week. The leaves were separated from the rest of the plant and were passed twice through a mesh of 1 × 1 mm in diameter using a mill Thomas Wiley and subsequently dried for more than three days at 65°C in an oven (Precision model 16EG) to remove moisture from the sample and later these were placed in desiccators. A 2.0 mg of the sample was weighed in an AD6000 Perkin balance elmer in a vial of tin, bent perfectly. This was placed in Chons analyzer Perkin Elmer Model 2400 for determining carbon, and nitrogen. For estimating the mineral contents, the samples were incinerated in a muffle oven at 550°C for 5 hours. A shed sample is digested in a solution containing HCL and HNO^3, using the wet digestion technique [43]. Carbon and nitrogen foliar contents (% dry mass basis) were carried out in 0.020 g of milled dried leaf tissue by using a CHN analyser (Perkin Elemer, model 2400). Protein is calculated following N x 6.25 [44].

Mature leaf samples (1.0 g dry weight) obtained from each plant and shrub species was used for determining the contents of minerals (Cu, Fe, Zn, Mg, K and P). Mineral content was estimated by incinerating samples in a muffle oven at 550°C during 5 hours. Ashes were digested in a solution containing HCl and HNO_3, using the wet digestion technique [45], Cu, Fe, Zn, K and Mg (air/acetylene flame) were determined by atomic absorption spectrophotometry (Varian, model SpectrAA-200), whereas P was quantified spectrophotometrically using a PerkinElmer spectrophotometer (Model Lamda 1A) at 880 nm [46].

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Results and Discussion

Pigment contents (Chlorophyll and Carotenoid) in 37 species of trees and chlorophyll A shrubs in northeast of Mexico during summer season

The species showed large variations in the contents of different pigments. With respect to Chorophyll a L. frutescens, A berbandieri contained minimum (around 0.6 mg), maximum was observed in Leucaena lecucocephala (nearing 1.8 mg), those with moderate value were *S. gregii, D. palmeri, A. texana, C. Mexicana* (1 to 1.2 mg). With respect to Chlorophyll b mínimum content was found in *F. angustifolia*, *A. berbandieri, A. palmeri, L. frutescens* (0.1 to 0.2 mg). *L. leucocephala* contained maximum (0.4 mg). Moderate values (around 0.3 mg) was found in *B. myricifolia*, *E. polystachya*, *S. gregii, A. rigidula* and others.

With respect to carotenoid mínimum values (around 0.2 mg) were found in *H. polystachya, G. angustifolia, L. frutescencs* and others. Maximum value was observed in C. suavelens. Moderate values (around 0.4 mg) were obtained in *E. ebano, D. plameri, A. texana*. With respect total chlorophyll mínimum values (around 0.5 mg) were obtained in *L. frutescens, H. parviflora, L. macropoda, F. angustifolia, C. suvelens*, while maximum value (around 2 mg) was obtained in *L. leucocephala*. Moderate values (nearing 1.5 mg) were observed in *S. gregii, D. palmeri, G. glutinosum.* Further, *F. angustifolia, P. aculeata* showed máximum value (around 7) followed by D. texana (around 6) with respect to chlorophyll (a,b) ratio. All the other species showed more or less similar values (ranging from 4 to 5). With respect to chlorophyll total/carotenoids *P. aculeata* showed maximum value (nearing 8), while minimum value was obtained in *E. trifoliata* (around 1). All others showed more or less similar values (around 4 to 5).

It is expected that the large variability among woody plant species in leaf pigments studied may influence the variation in growth and development, coexistence and adaptation of the species in the forest ecosystem [47].

In this study we selected the species with high pigment contents mentioned below.

Leaf pigments (in mg g^{-1} fw):

Chlorophyll a: *Ebenopsis ebano* (1.755), *Cercidium suveoleon* (0.589), *Amyrys texana* (1.66), *Leucaena leucocephala* (1.403), *Gymnosperma glutinosum* (1.228)

Chlorophyll b: *Ebenopsis ebano* (0.398), *Amyrys texana* (1.66), *Parkinsonia* (0.369), *Eysenhardtia polystachya* (0.366), *Diospyros palmeri* (0.433)

Chlorophyll total (Chl a + b): *Ebenopsis ebano* (2.253), *Leucaena, leucocephala* (1.687), *Gynosperperma glutinosum* (1.528), *Amyrys texana* (1.506), *Cercidium angustifolia* (1.497)

Carotenoids: *Berberis choco* (0.585), *Diospyros palmeri* (0.433), *Gymnosperma glutinosum* (0.33), *Amyrys texna* (0.438), *Ebenopsis ebano* (0.425)

The importance of pigments for the physiological functions is emphasized by various authors mentioned. There is a need to verify the efficiency of the species selected for high pigment contents for physiological function and productivity.

Variability in leaf epicuticular wax in 35 woody species

Considerable variation in wax accumulation was found among species showing prominent interspecific variation. Wax load varied from 11.18 to 702.04 µg/cm^2 among species studied during summer. Few species selected with high epicuticular wax viz, *Forestiera angustifolia* (702.04 µg/cm^2), *Diospyros texana* (607.65 µg/cm^2), *Bernardia myricifolia* (437.53 µg/cm^2), *Leucophylum leucocephala* (388.50 µg/cm^2), during summer which could well be adapted under semi-arid environments for their efficiency in the reflection of radiation load, reduced transpiration, gas exchange and probably impart drought resistance [48]. The large variations in epicuticular wax could be related to their physiological functions such as transpiration, gas exchange, water relations etc.

The species showing high epicuticular wax load are *Forestiera angustifolia* (702.04 µg/cm^2), *Diospyros texana* (607.65 µg/cm^2), *Bernardia myricifolia* (437.53 µg/cm^2), *Leucophylum leucocephala* (388.50 µg/cm^2), *Acacia farnesiana* (373.49 µg/cm^2), *Cercidium macrum* (308.63 µg/cm^2). Similarly the species showing medium epicuticular wax load are *Lantana macropoda* (294.86 µg/cm^2), *Quercus polymorpha* (199.40 µg/cm^2), *Parkinsonia aculeata* (196.20 µg/cm^2), *Acacia shaffneri* (170.04 µg/cm^2), Diospyros palmeri (163.25 µg/cm^2), *Helietta parvifolia* (151.19 µg/cm^2), *Eysenhardtia polystachya* (138.49 µg/cm^2), *Bumelia celastrina* (132.38 µg/cm^2) while the species showing minimum epicuticular wax are *Ehretia anacua* (17.58 µg/cm^2), *Karwinskia humboldtiana* (15.47 µg/cm^2), *Amyris texana* (11.18 µg/cm^2).

It has been highlighted by various authors that epicuticular wax help in the reflectance of solar radiation, thereby reducing leaf temperature and herbicide actions mentioned above. Therefore, there is a necessity to study the performance of the species with high epicuticular wax with respect to drought and water relation [49].

Leaf nutrients

The study has been undertaken to determine the variability in leaf nutrient contents (macro and micro) of 37 woody species of Northeast Mexico. Leaf nutrients play an important role for the growth and development of trees and are sources of nutrients for ruminants in forest. The study was under taken to estimate six nutrients in the leaves, three macronutrients (P, Mg, K, protein, C, N, C/N and three micronutrients (Cu, Fe, Zn). Among macronutrients P: varied from 0.78 to 243 (mg g^{-1} dw), the species containing high P are *C. suaveleons* 2.43, *E. polystachya* 1.84, *P. laveagata* 1.65, *P. aculeata* 1.56, *A. farnesiana* 1.54, Mg (mg g^{-1} dw) varied from 0.22 to 9.45 (mg g^{-1} dw). The species containing high Mg (mg g^{-1} dw) are *E. anacua* 9.45, *C. hookeri* 6.50, *P. aculeata* 5.29. K (mg g^{-1} dw) range from 11.54 to 75.62 (mg g^{-1} dw). The species containing high K are *C. suvaleolen* 75.62, *C. boissieri* 45.58, *C. pallida* 42.6. Protein % varied from 1.81 to 36.81. The species containing high protein are G. glutinosa 36.81, L. macropoda 27.69. A. shaffneri 27.0, B. myricifolia 26.3, C. pallida 25.75, E. polystachyya 25.36,8. C % varied from 30.07 to 49.97. The species containing high Carbon are *L. frutescens* 49.97, *F. angustifolia* 49.47, *B. celastrina* 49.25, *A. berlandieri* 49.18, *A. rigidula* 48.23, *G. glutinosum* 46.19, *A. farnesiana* 46.17, *C. suaveolens* 45.17, *S. gregii* 44.07, N % varied from 1.89 to 5.89. The species containing high N % are *G. glutinosum* 5.89, *L. macropoda* 4.43, *A. shaffneri* 4.32, *B. myricifolia* 2.21, *C. pallida* 4.12, *E. polystachya* 4.06, *C. macrum* 4.01.

C/N ratio ranges from 75 to 23.13. The species containing high C/N are *S. gregii* 23.13, *L. frutescens* 22.17, *Q. virginiana* 21.95, *D. texana* 21.58, *B. celastrina* 20.35, *C. suveolens* 20.16

With respect micronutrients Cu (μg g^{-1} dw) varied from 2.8 to 30.71. The species containing high Cu (mg g^{-1} dw) are *C. boissieri* 30.71, *C. suveleons* 26.87, *C. pallida* 25.98, *B. celastrina* 23.24, *A. farnesiana* 24.62. Fe (μg g^{-1} dw) varied from 48.47 to 280.55. The species containg high Fe (μg g^{-1} dw) are *C. boissieri* 280.55 to *C. pallida* 276.89, *A. farnesiana* 259.76, *C. laevaegata* 234.09, *A. rigidula* 252.33, *B. celastrina* 249, *C. suveolens* 229.19, *G. glutinosum* 167.4, *P. aculeata* 165.63. Zn (μg g^{-1} dw) varied from 10.23 to 144.86. The species containing high Zn are *S. lasiolepis* 144.86, *S. boissieri* 51.87, *P. acueata* 51.66, *E. polystachya* 51.39, *F. angustifolia* 48.56, *P. laevaegata* 48.47, *A. shaffneri* 44.60, *C. lavaegata* 42.28, *D. texana* 41.45, *E. anacua* 40.07 (μg g^{-1} dw). The species selected for the highest macro and micronutrients may be utilized for confirming their physiological efficiency and probable better growth and productivity. The species having high nutrients could serve as good source for the plants during nutrient deficiency to sustain growth and good sources of nutrients for grazing wild animals [50].

Leaf nutrients contribute to the physiological functions of trees and also serve as sources of nutrients for ruminants.

Cu: *C. boissieri*, (30.71), *Croton suaveolens* (26.67), *Celtis pallida* (25.98), *Blumia celastrinum* 25.24), *Acacia farnacia* (24.62)

Fe: *C. boissieri* (280), *A. farnaciana* (259.79), *A. rigidula* (252.33), *Blumelia celastriana* (249.09) *Croton suaveolens* (229.13), *Celtis lavaegata* (254.09)

Zn: *Salix lasiolepis* (144.86), *C. boissieri* (51.87), *Parkinsonia aculeate* (51.86), *Eysenhardtia polystachya* (51.39), *Berberis choco* (5068), *Prosopis lavaegata* (48.47)

K: *Croton suveolens* (75.62), *C. boisiieri* (45.58), *Celtis pallida* (49.60), *Acacia rigidula* (38.75), *Diospyros texano* (36.55)

Mg: *Ehretia anacua* (9.45), *Condalia hookeri* (6.50), *Parkinsonia aculeate* (5.29), *Hellieta parviflora* (3.15), *Guaiacum Virginia* (2.60)

P: *Croton suaveolens* (2.45), *Prosopis laveagata* (1.65), *Celtis laveagata* (1.57), *Parkinsonia aculeate* (1.56)

(%) Protein: *Gymnospermum glutinosum* (36.81), *Diospyros texana* (36.55), *Bermardia celastrina* (33.02), *Celtis pallida* (25.75), *Ebenopsis ebano* (24.13), *Cordia boissieri* (20.5)

(%) C: *Leucophylum frutescens* (49.97), *Forestieria angustifolia* (49.47), *Blumelia celastrianum* (49.29), *Acacia berlandieri* (49.29), *A. rigidula* (48.23), *Sargantia greggii* (44.07), *C. boissieri* (44.43)

(%) N: *Gymnospermum glutinosum* (5.89), *Blumelia celastrinum* (4.21), *Celtis pallida* (4.12), *Acacia berlandieri* (3.82), *Acacia texana* (3.71)

C/N ratio: *Sargantia greggii* (23.13), *Quercus Virginia* (21.51), *Croton suveolens* (20.16), *Diospyros palmeri* (17.36), *Blumelia celastrina* (15.17)

In the context of the above results it may be stated that the species show large variation in the contents of six macro (P, Mg, K, protein, N, C/N) and three micronutrients (Cu, Fe and Zn, P) and micronutrients (Cu, Fe, Zn), thereby offering opportunity to select species for high macro and micronutrients

Conclusion

Studies undertaken in North-eastern Mexico reveals that there exist a large variation in leaf pigments, epicuticular wax and leaf nutrients which have impact on the growth, development and adaptation of the species in forest ecosystem. Several species have been selected for having high values of thee chemical components. It is expected that the woody species selected for high values of different plant pigments, epicuticular wax and leaf nutrients are more efficient in physiological function, plant productivity as well as could serve as good sources of nutrients and forage for wild animals. These hypothesis needs to be confirmed in future studies. These species could also serve as model sample for various research projects in forest science.

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