Comparative Study on Carbon Fixation, Leaf Canopy, Leaf Nutrients and Its Possible Relation to Wood Density

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Abstract

The present study was undertaken to find possible relationship between carbon fixation, leaf canopy, leaf nutrients (N, protein) and its possible relation to wood density but it needs to be confirmed in future study. It is observed that the trees and shrubs with open canopy in general produce wood with high density. The species with carbon fixation, in general, have wood with high density and trees with open leaf canopy and high carbon fixation contribute to wood with high density. Further study is needed to establish the role of these parameters, leaf canopy and carbon fixation on wood density. These tree species are also having high carbon fixation ability. These have the ability to reduce the atmospheric carbon load and reduce carbon pollution.

Keywords: Carbon fixation, leaf canopy, leaf nutrients, N protein, wood density

1. Introduction

The shrubs and trees of Tamaulipan Thornscrubs in the semiarid regions of North-eastern Mexico are of great economic importance for various uses such as timber for furniture, fences, firewood, charcoal and sources of forage for wild grazing animals for supplying various micro and macronutrients required by the grazing animals in the forest. Native trees and shrubs of this region are important sources of nutrients for wild animals in Northeast of Mexico (Ramirez, 1998; Ramirez, 2015). Leaf nutrients add forage value for wild animals. Besides, leaves contribute greatly in plant growth and productivity for photosynthesis and nutrient contents. The availability of nutrients in leaves is essential for efficient plant function in crops, therefore giving emphasis on nitrogen and phosphorus, the deficiency of which reduce crop growth (Chaplin, 1982). The nutrients present in leaves contribute to plant growth and metabolism. Sufficient research activities have been undertaken on nutrient content and metabolism in leaves (Chapman et al., 1990). There exists great diversity among plant species in growth form, leaf size, leaf shape and canopy management, as well as for carbon fixation required for photosynthesis and respiration (Wright et al., 2001). Wright et al. (2001) established a strategy shifts 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.

Maiti et al. (2014) reported variability in leaf canopy (open, close) and its possible relation with photosynthetic capacity. Recently few studies were undertaken on leaf nutrients (Rodriguez et al., 2015; Maiti et al., 2016). Rodriguez et al. (2015) studied wood density of ten native woody species and its possible relation with wood chemical composition and wood structure. Rodriguez et al. (2015) determined variability in macro and micro-nutrient contents of 25 Woody Trees and Shrubs in Northeast of Mexico.

In view of the importance of forage value, various studies have been undertaken by various workers on the analysis of leaf nutrients for nutritional values.

Plants contain nutrients useful for ruminants and wild animals in which direction research has been undertaken. Lukhele and Van Ryssen (2003) investigated chemical composition and potential value of subtropical tree species of *Combreatum* in Southern Africa for ruminants and concluded that the foliage tested would not be a suitable resource of N to supplement the protein deficiencies in low quality herbage. Rangel and Marsechner (2005) studied nutrient availability and management in the rhizosphere showing genotypic differences.

Ibrahim et al. (2011) reported the relationship of nitrogen and C:N ratio with secondary metabolites levels and antioxidant activities in three varieties of Malaysian Karcip

Fatimah (*Lobisia pumulla* Blume). Plants contribute a lot in the capture of Carbon dioxide load from the atmosphere in the process of photosynthesis, synthesis of carbohydrate and store carbon in its biomass. Variation in carbon fixation by photosynthesis is related to variation of carbon deposition in plant species. Carbon is the source of energy for plants. During photosynthesis, plants take in CO_2 and give off the oxygen (O_2) to the atmosphere. The oxygen released is available for respiration. The plants retain and use the stored carbon for growth to guide all metabolic functions. Finally, carbon is stored in plant organs and timber serving as an important source of energy. On the other hand, as a consequence of global climatic change generated, there is an eventual increase in the aerial temperature and an increase of green house gases, particularly CO_2. In order to mitigate carbon pollution, forest plantation is done to capture and retain carbon. Forests play an important role in the global C cycle (Brown, 1999). The increased global warming associated with incessant logging, illegal anthropogenic activities and conversion of forest to agriculture. These have enhanced the emission of green house gases (GHS), in particular the carbon dioxide load in the atmosphere. This particular green house gas levels were increased several folds leading to pollution and climate change (Alig and McCor, 2002). It is well known that the increased global warming is attributed to the increased concentration of various green house gases as carbon dioxide, methane, nitrous oxide, sulphur dioxide, chloroflurocarbon, ozone and water vapour (Garduno, 2004). On the other hand, the excess atmospheric carbon being released in the atmosphere can be absorbed by photosynthesis by trees and ecosystems (Rodriguez et al., 2008). Carbon fixation in trees as a micro optimization process leads to the location of carbon in plant organs. This system called as carbon sequestration can make a significant contribution to reducing global warming (Pimienta et al., 2007).

In this context, various research inputs have been undertaken to analyse carbon fixation or accumulation of carbon in different plant organs and select plants with high carbon fixation capacity (John, 1990). John (1990) developed two alternative economic-analog models of carbon fixation in trees. In the first model, the plant is modelled as a maximizer of net carbon gain (a profit analog). The second models carbon 'revenue' as the minimum of two functions that relate carbon gain to leaf and root biomass, respectively. Later, Braakman and Smith (2012) constructed the complete early evolutionary history of biological carbon-fixation, relating all modern pathways to a single ancestral form. Wang et al. (2013) studied variability of *Larix olgensis* in different organs in North-Eastern China. The carbon concentration differed significantly between tree organs, while there was no significant difference between trees with different ages. Similarly, Jimenez Perez et al. (2013) investigated carbon concentration in pine-oak forest species of the Sierra Madre Oriental. Large variation in stem, branch, bark and leaf of the species *Pinus pseudostrobus*, *Juniperus flaccida*, *Quercus laceyi*, *Quercus rysophyla*, *Quercus canbyi* and *Arbutus xalapens.* The component with the highest carbon concentration also showed variability. The species with highest carbon concentration in the leaves was *Arbutus xalapensis* (55.05%).

Though wood is an important source of carbon of high commercial value, the information with respect to the role of plant characteristics and carbon fixation capacity on wood quality such as density and wood structural characteristics is rare. The objective of the present study is to determine plant characteristics, leaf nutrients, carbon fixation and its accumulation in various native and exotic species in Mexico and its possible relation to wood quality.

2. Materials and Methods

Following 18 species of economic importance in the region were studied for analyzing their nutrient content and carbon fixation ability (Table 1).

Table 1: List of 18 species analysed under the study

Sl. No.	Scientific Name	Family
1.	*Diospyros texana*	Ebenaceae
2.	*Bumelia celastrina*	Sapotacee
3.	*Cercidium macrum*	Fabaceae
4.	*Prosopis laevigata*	Fabaceae
5.	*Condalia hoockeri*	Rhamnaceae
6.	*Celtis laevigata*	Ulmaceae
7.	*Harvadia pallens*	Fabaceae
8.	*Ebenopsis ebano*	Fabaceae
9.	*Cordia boissieri*	Boraginaceae
10.	*Acacia berlandieri*	Fabaceae
11.	*Forestiera angustifolia*	Oleaceae
12.	*Karwinskia humboldtiana*	Rhamnaceae
13.	*Acacia farnesiana*	Fabaceae
14.	*Leucophyllum frutescens*	Scrophulariaceae
15.	*Eysenhardtia polystachya*	Fabaceae
16.	*Bernardia myricifolia*	Euphorbiaceae
17.	*Celtis pallid*	Ulmaceae
18.	*Zanthoxylum fagara*	Rutaceae

The following aspects were investigated:

- Leaf nutrients (N, C:N, protein)
- Carbon fixation
- Leaf canopy architecture: Open, semi close, close depending on the mode of exposure to solar radiation (Maiti et al., 2014).
- Density: We collected 10 pieces of wood of 5 cm long from the branches of the tree of each species and then dried in an oven at 80 °C for 3 days, then cooled and weighed

in a desiccators to avoid absorption of moisture from the atmosphere.

Then each wood species was dipped in water in a measuring cylinder for measuring the volume of the wood. The density of wood was calculated as follows.

$$\text{Density}=\frac{\text{Weight of wood (g)}}{\text{Volume (cm}^3\text{)}}$$

2.1. Chemical analysis

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 1x1 mm^2 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 a AD 6000 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. Ashed sample is digested in a solution containing HCl and HNO_3, using the wet digestion technique (Cherney, 2000). 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 Nx6.25.

3. Results and Discussion

The leaf canopy, C%, N%, C:N, protein and wood density of 18 species has been given in Table 2. It is observed from Table 2, that the leaf canopy of the species studied varies from open, semiclosed and close. Most of these species are semiclose and open canopy types. The tree canopies are classified depending on the mode of exposure to solar radiation and probable efficiency in photosynthesis. The species with open leaf canopy is expected to be more efficient in the capture of

Table 2: Leaf canopy, C%, N%, C:N, protein and wood density of various species

Sl. No.	Scientific Name	Family	Type or leaf Canopy	%C	%N	C:N	% Protein	Density g cm^{-3}
1.	Diospyrostexana	Ebenaceae	Tree (semiclose)	40.79±1.46	1.89±0.06	21.58±24.33	11.81	0.642±0.055
2.	Bumeliacelastrina	Sapotacee	Tree (open)	49.25±1.56	2.42±0.36	20.35±4.38	15.13	0.785±0.078
3.	Cercidiummacrum	Fabaceae	Tree (open)	43.41±3.44	4.01±0.30	10.83±11.47	25.06	0.901±0.104
4.	Prosopislaevigate	Fabaceae	Tree (open)	41.64±0.71	3.85±0.21	10.83±3.38	24.06	0.954±0.077
5.	Condaliahoockeri	Rhamnaceae	Tree (semiopen)	30.07±2.81	3.06±0.41	9.83±6.85	19.13	0.851±0.143
6.	Celtislaevigate	Ulmaceae	Tree (close)	39.45±0.51	3.01±0.18	13.13±2.78	18.81	0.717±0.035
7.	Harvadiapallens	Fabaceae	Tree (open)	43.49±1.24	2.97±0.15	14.64±8.27	18.56	0.707±0.061
8.	Ebenopsisebano	Fabaceae	Tree (semiclose)	37.57±1.21	3.86±0.20	9.73±6.05	24.13	0.910±0.065
9.	Cordia boissieri	Boraginaceae	Tree (semiclose)	43.43±1.20	3.28±0.09	13.23±13.38	20.50	0.620±0.048
10.	Acacia berlandieri	Fabaceae	Tree (open)	49.18±1.25	3.82±0.14	12.88±8.89	23.88	0.876±0.063
11.	Forestiera angustifolia	Oleaceae	Shrub (semiclose)	49.47±0.43	3.00±0.41	16.47±1.04	18.75	0.634±0.033
12.	Karwinskiahum boldtiana	Rhamnaceae	Shrub (open)	31.35±0.70	2.84±0.10	11.03±6.91	17.75	0.885±0.080
13.	Acacia farnesiana	Fabaceae	Shrub (open)	46.17±2.63	3.41±0.18	13.54±14.61	21.31	0.808±0.090
14.	Leucophyllum frutescens	Scrophulariaceae	Shrub (open)	49.97±0.94	2.25±0.27	22.17±3.51	14.06	0.787±0.183
15.	Eysenhardtia polystachya	Fabaceae	Shrub (open)	36.26±0.58	4.06±0.27	8.94±2.15	25.38	0.911±0.084
16.	Bernardia myricifolia	Euphorbiaceae	Shrub (open)	42.69±1.13	4.21±0.49	10.13±2.30	26.31	0.975±0.092
17.	Celtis pallid	Ulmaceae	Shrub (open)	38.66±0.88	4.12±0.67	9.38±1.32	25.75	0.777±0.065
18.	Zanthoxylum fagara	Rutaceae	Shrub (open)	40.35±3.15	2.98±0.90	13.56±3.50	18.63	0.661±0.043

solar radiation and greater photosynthesis compared to those having semiclose and close canopy ones. In this context, the species showed variability in carbon fixation ranging from 30% to approximately 50%. The species with high carbon fixation are *Leucophyllum frutescens* (49.97%), *Forestiera angustifolia* (49.47%), *Bumelia celastrina (*49.25%), *Acacia berlandieri* (49.18%) and *Acacia farnesiana* (46.17%). Interestingly all these have open leaf canopy, except *Forestiera angustifolia* (semiclose, shrub), which indirectly support the hypothesis by Maiti et al. (2014). This needs to be verified with further study.

Nitrogen and protein content serve in nitrogen metabolism and enzyme function thereby contributing to forage value for animal health. Nitrogen content varied approximately from 2 to 4%, while C:N varied from 8 to 22. On the other hand protein content varied from 11 to 26%, reasonably high value from the stand point of animal nutrition. Several species have more than 20% protein. The species showing high value of protein content are *Bernardia myricifolia* (26.31%), *Celtis pallida* (25.75%)*, Eysenhardtia polystachya* (25.38%),*Cercidium macrum* (25.06%), *Ebenopsis ebano* (24.13%), *Acacia berlandieri* (23.38%),which are excellent sources of protein for animal health.

It is expected that high carbon fixation could contribute to high accumulation of carbon in wood, thereby possibly increase of wood density. In this respect wood density varied from 0.62 to 0.95). The species showing higher values of wood density are *Bernardia myricifolia* (0.97), *Prosopis laevigata* (0.95), *Ebanopsis ebano* (0.91), *Eysenhardtia polystachya* (0.91), *Cercidium Mexicana* (0.90), *Karwinskia humboldtiana* (0.88), *Cordia boissieri* (0.87), *Acacia berlandieri* (0.87), *Condalia hoockeri* (0.85), *Celtis pallida* (0.77). It is interesting to note that all these species possess open to semi open leaf canopy, thereby indicating that the species with open canopy have high carbon fixation as well as high wood density. The results of the present study coincide with few studies.

The findings of the present study coincide with the findings of few recent studies of Maiti et al. (2014) on variability in leaf canopy (open, close) and its possible relation with photosynthetic capacity; variability in leaf nutrients (Rodriguez et al., 2015; Maiti et al., 2016). Wood density of ten native woody species and its possible relation with wood chemical composition and wood structure (Rodriguez et al., 2015). Rodriguez et al. (2015) determined variability in macro and micro-nutrient contents of 25 woody trees and shrubs in Northeast of Mexico

4. Conclusion

It is concluded that the trees and shrubs with open canopy in general produce wood with high density. The species with carbon fixation in general have wood with high density. Therefore trees with open leaf canopy and high carbon fixation contribute to wood with high density. This needs to be confirmed in future studies.

5. Further Research

Further study on anatomy of wood and lignin content could confirm further the role of these parameters, leaf canopy and carbon fixation on wood density. These tree species are also having high carbon fixation ability which is evidenced through high wood densities, where the carbon is incorporated into the tree biomass. These have the ability to reduce the atmospheric carbon load and reduce carbon pollution. Apart from these, because of the presence of high protein and nitrogen contents these have an efficient nutrient feed value to the animals acting as excellent sources of protein for animal health.

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