

Perspectives of Branching Pattern and Branching Density in 30 Woody Trees and Shrubs in Tamulipan Thornscrub, Northeast of Mexico

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Abstract

In the context of the ecological perspectives, there is growing attention in the modelling of the morphological structure of the plants for developing the model of the functional processes of plants. The branching pattern functions as solar panel in the capture of solar radiation for the production of biomass and timber. The present study undertaken with the objective of determining the density of branching and types of branching of 30 tree species (trees and shrubs of Tamaulipan thorn scrub such; *Helietta parvifolia*, *Sargentia gregii*, *Guaicum angustifolium*, *Ebenopsis ebano*, *Harvardia pallens*, *Condalia hoockeri*, *Zanthoxylum fagara*, *Cordia boissieri*, *Acacia berlandieri*, *Diospyros texana*, *Celtis pallida*, *Forestiera angustifolia*, *Diospyros palmeri*, *Parkinsonia texana*, *Acacia farnesiana*, *Sideroxylon celastrina*, *Caesalpinia mexicana*, *Karwinskia humboldtiana*, *Croton suaveolens*, *Amyris texana*, *Leucaena leucocephala*, *Ehretia anacua*, *Gymnosperma glutinosum*, *Celtis laevigata*, *Acacia rigidula*, *Acacia shaffneri*, *Eysenhardtia polystachya*, *Prosopis laevigata*, *Bernardia myricifolia* and *Leucophyllum frutescens* located at the experimental field of Forest Science Faculty of Autónoma de Nuevo en Linares, N.L., México has shown a large variability in the density and branching patterns. The types of branching observed are; monopodial, pseudomonopodial, and sympodial. The branching density observed through animation photography in the field has revealed the presence of three types branching density i.e., high, medium and low density. There existed differences in height, biomass, basal trunk, the angle of the primary and secondary branches. With respect to branching density, a higher number of species were high density (15 species), followed by low density (9) and medium density (5 species). The architecture of the tree is the result of the activity of the apical and axial meristems. This model is a strategy for occupying the space and capture of solar radiation.

Keywords: Native species; Branching pattern; Branching density; Classification; Adaptation

Introduction

Crown architecture associated with its branching pattern of a tree plays an important role in the capture of solar radiation. In a forest ecosystem, trees exhibit a variety of forms depending on their branching patterns. The arrangement and position of the branches on a tree gives the tree a definite shape.

Various studies have been undertaken on the crown architecture and branching patterns of trees

Branching pattern is defined by branch order or its position in the hierarchy of tributaries. A study has been made on the efficiency of branching patterns, the relation of average numbers and lengths of tree branches to size of branch. A definite logarithmic relation was found to exist between branch order and lengths and numbers. This relation can be quantified in tree branching systems and can build several random-walk models in both two and three dimensions [1]. In a forest ecosystem, the shrubs do not show large difference in gross branching structure (ratio of terminal to supporting branches). It is suggested that branch angle, length and alteration of leaf orientation may exhibit significant display characters. In fact, small trees show markedly variable response to open vs closed habitats, demonstrating the expected increase in branching ratio in open environments [2]. Subsequently, a study was undertaken on the non-stationary of tree branching patterns and bifurcation ratios on four species. The results revealed that the two specific patterns of non-stationary that were directly related to morphological patterns of shoot development. Average bifurcation ratios appeared to be accurate descriptions of tree branching patterns, because they were based solely on relative branch position and ignored biologically [3].

Crown architecture plays an important role in branching pattern.

According to Isebrands and Nelson [4], the crown architecture of short-rotation and branch morphology and distribution of leaves within the crown of *Populus 'Tristis'* was related to biomass production in northern Wisconsin. The first-order branches within the trees were predominantly long shoots. Long-shoot leaves had higher specific leaf weights than short-shoot leaves attached to branches on the same height growth increment. Leaf area per tree was linearly related to the aboveground biomass of the tree. They suggest that this relationship may serve as a useful quantitative index of crown closure in poplar stands and few crown morphological criteria may be useful for selection and breeding of improved poplar trees for short-rotation intensive culture. Later, a study was undertaken on crown architecture, including branching pattern, branch characteristics and orientation of proleptic and sylleptic branches in five poplar clones (*Populus deltoides*, *P. trichocarpa* and *P. trichocarpa* × *P. deltoides* hybrids), grown under intensive culture in the Pacific Northwest, USA. Data was taken on branch characteristics viz., number, length, diameter, biomass and the angles of origin and termination. The results reveal that genotype had

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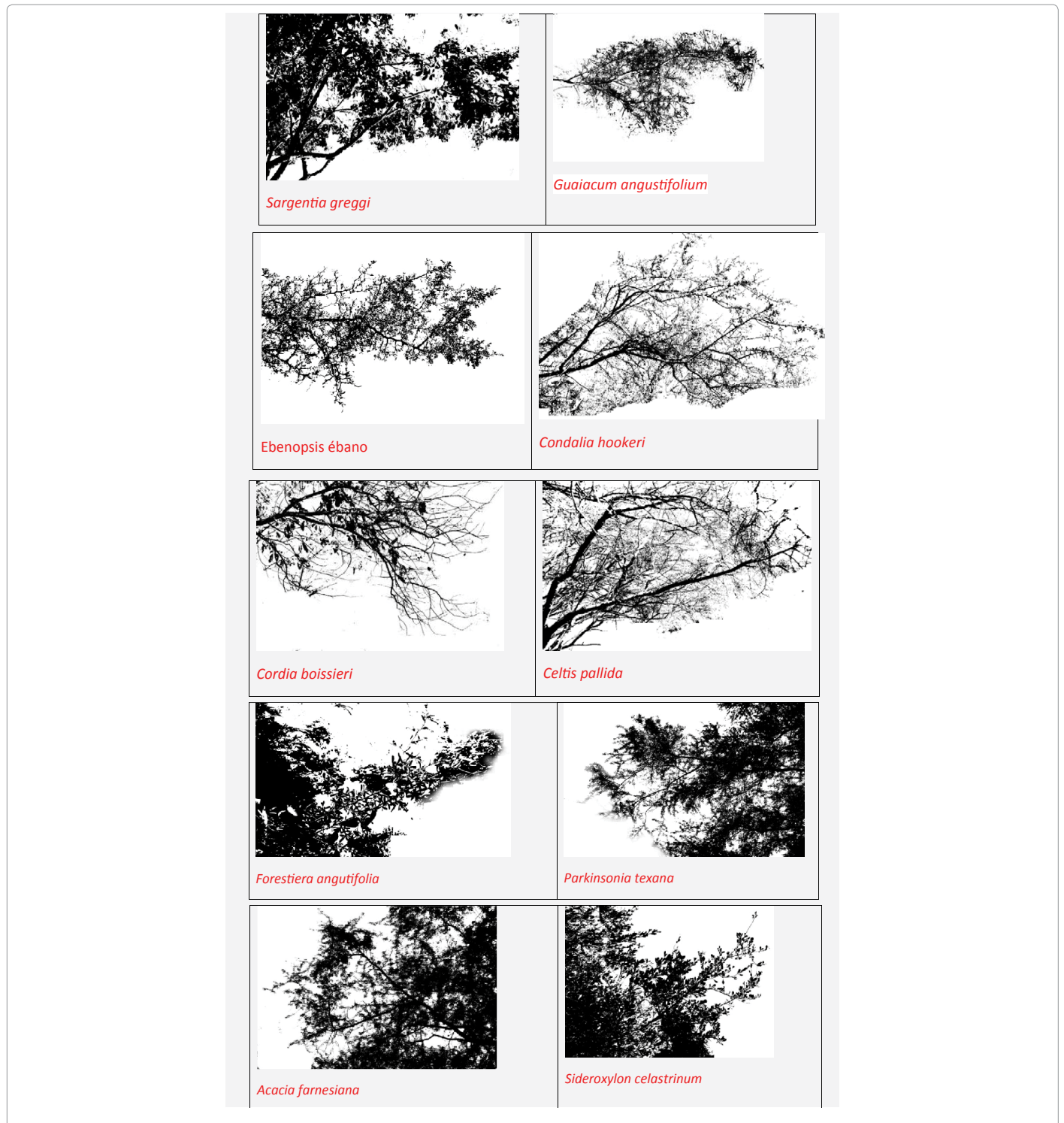
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a major influence on crown architecture in *Populus*. Clonal differences were observed in branch characteristics and branching patterns thereby leading to remarkable differences in crown form and architecture. Branch angle and curvature showed significant difference among clones and among height growth increments within clones. Branch length and diameter were significantly correlated among them in all clones [5].

A study has been undertaken on the crown architecture of understorey and open-grown white pine (*Pinus strobus L.*) saplings

of 15 understorey saplings and 15 open-grown saplings. Total leaf area was greater in open-grown saplings than in understorey saplings, but the ratio of whole-crown silhouette (projected) leaf area to total leaf area was significantly greater in understorey pine than in open-grown pine revealing that the crown and shoot structure of understorey trees exposed to a greater percentage of leaf area to direct incident light [6]. Subsequently a study models on crown architecture of 39 *Abies balsamea* (Figure 1) from four canopy positions. Data were taken on the





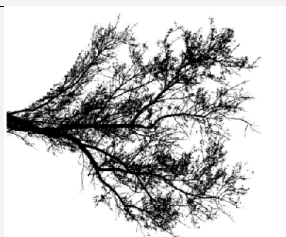
Ehretia anacua



Celtis laevigata



Acacia shaffneri



Prosopis laevigata



Bernardia myricifolia



Acacia berlandieri

Medium Density



Zanthoxylum fagara



Diospyros texana



Diospyros palmeri



Acacia rigidula

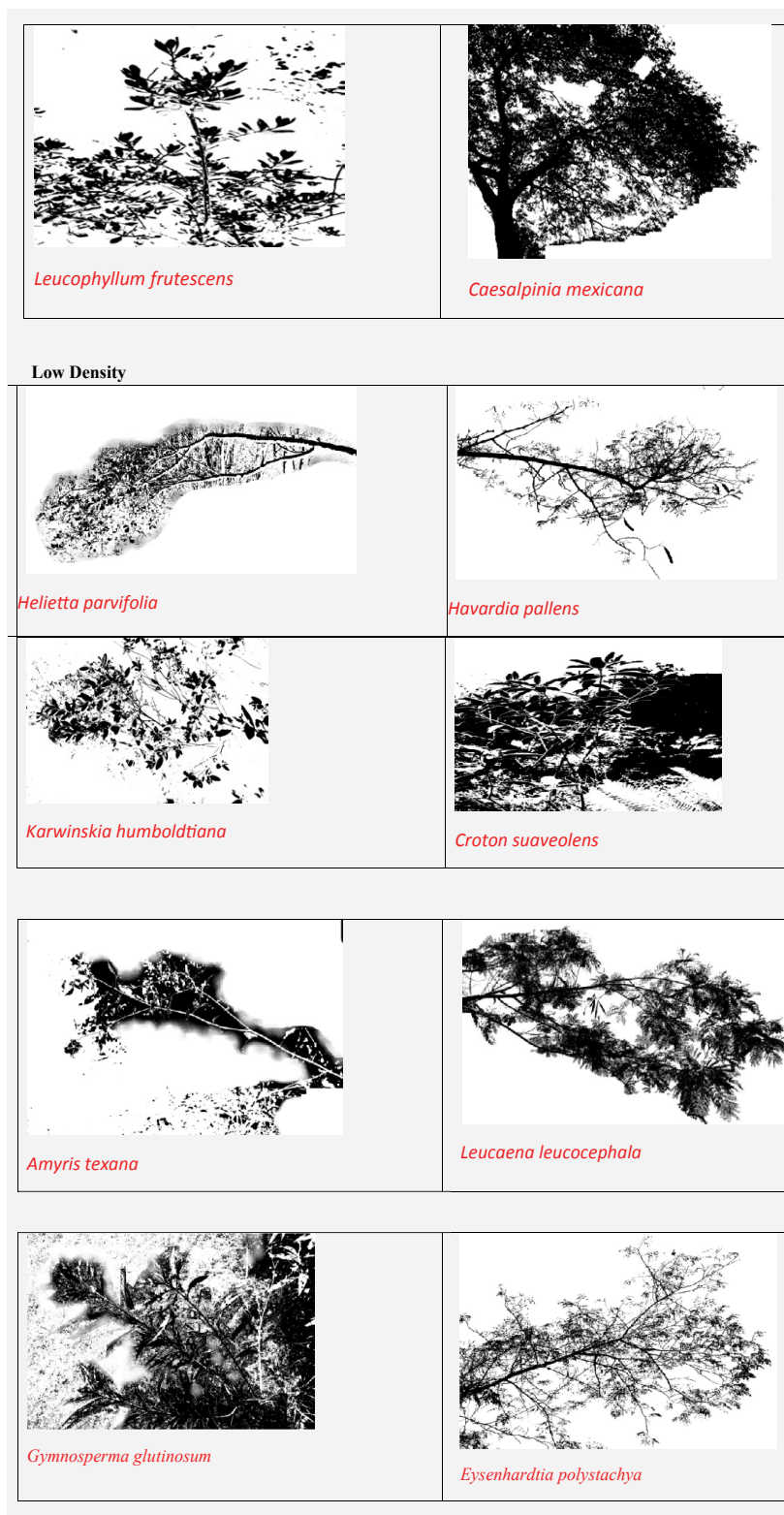


Figure 1: The characterization of branching density.

needle mass of individual branches, the average branch angle, branch diameter, branch length and crown radius per whorl and the average number of living branches per whorl. Using a regression model it was assessed that canopy position had an effect on the models constructed to predict needle mass, branch angle, branch diameter, branch length, crown radius and the number of living branches per whorl [7]. Later, a study was undertaken on the branching patterns and the growth units of monocyclic or bicyclic annual shoots on the main axis of 5 year old red oaks in a plantation in south-western France. The number of nodes shown by the branched zone of the growth unit of monocyclic annual shoots was stable, irrespective of the total number of nodes of the growth unit. On the contrary, the second growth unit of bicyclic annual shoots exhibited a correlation between the number of nodes in the branching zone and the total number of nodes [8]. The architecture of a tree depicts secrets of a forest. The type of branching is known as one of the components of the architecture of a plant which possess higher adaptive values [9].

Several plant characters contribute to typical crown structure and its branching pattern. A study was undertaken on field characterization of olive (*Olea europaea* L.) tree crown architecture using terrestrial laser scanning (TLS) data. Intelligent Laser Ranging and Imaging System (ILRIS-3D) data was obtained from individual tree crowns at olive (*Olea europaea*) plantations in Córdoba, Spain. From the observed 3D laser pulse returns, quantitative retrievals of tree crown structure and foliage assemblage were obtained. Best methodologies were developed to characterize diagnostic architectural parameters, such as tree height ($r^2=0.97$, $rmse=0.21$ m), crown width ($r^2=0.97$, $rmse=0.13$ m), crown height ($r^2=0.86$, $rmse=0.14$ m), crown volume ($r^2=0.99$, $rmse=2.6$ m³) and Plant Area Index (PAI) ($r^2=0.76$, $rmse=0.26$ m²/m²). This research demonstrates that TLS systems can potentially be the new observational tool and benchmark for precise characterization of vegetation architecture for improved agricultural monitoring and management [10]. There exist large variability in branching pattern and crown architecture in 30 woody species in Northeastern Mexico [11].

Crown architecture contributes to the capture of light and carbon gain by the leaf canopy. In this respect few studies have been undertaken.

A three-dimensional crown architecture model was developed for the assessment of light capture and carbon gain by the canopy of understorey, measuring the photon flux density (PFD) from the canopy openness derived from hemispherical canopy photographs and equations simulating the daily course of direct and diffuse PFD. Assimilation rate was simulated for the sunlit and shaded parts of leaves separately and then summed to give the whole-plant carbon gain. Whole-plant daily carbon gain was much higher in the forest edge site, mostly because of the additional PFD available in this site [12]. Simultaneously, a study was undertaken to establish the relationships between crown architecture and species coexistence using the diffusion model and the canopy photosynthesis model for multi-species plant communities on two species having different crown shapes [conic-canopy plant (CCP) and spheroidal-canopy plant (SCP)], for various initial mean sizes at the establishment stage and physiological parameter values (photosynthetic rate, etc.). It was assessed that there was some relationship between SCP and CCP in different leaf canopy layers. The combination of initial sizes of a CCP and an SCP at the establishment stage (i.e., establishment timing) affects the segregation of vertical positions in the canopy between the two species with different crown shape and not only species-specific physiological traits but also crown architecture greatly affects the coexistence pattern between species with different crown architectures [13].

On the other hand, crown architecture and its extension contribute remarkably to the capacity of a species on carbon capture from the atmosphere through photosynthesis. In this respect, a study has been undertaken on the role of crown architecture for light harvesting and carbon gain in extreme light environments with a realistic light capture and carbon gain by plants from low (forest understorey) and high (open Mediterranean-type ecosystems). Light environments were simulated with a 3-D model (YPLANT), in order to determine light interception and photosynthesis at the whole plant. The results show large differences between habitats in architecture depending on whether light capture must be maximised or whether excess photon flux density must be avoided. These differences were also observed both at the species level and within a species because of plastic adjustments of crown architecture to the external light [14].

A study was undertaken on the convergence in light capture efficiencies among tropical forest understorey plants with contrasting crown. Leaf and crown characteristics were observed for 24 tree and herbaceous species of contrasting architectures from the understorey of a lowland rainforest. Causal relationships among traits affecting light absorption at two hierarchical levels (leaf and whole crown) were quantified using path analysis. Light-capture and foliage display efficiency were found to be very similar among the 24 species studied, with most converging on a narrow range of light absorption efficiencies (ratio of absorbed vs. available light of 0.60–0.75). Differences in photosynthetic photon flux density (PPFD) absorbed per unit leaf area by individual plants were mostly estimated by site to site variation in PPFD and not by the differences in crown architecture among individuals or species. Leaf angle and to a lesser extent also supporting biomass, specific leaf area and internode length, had a significant effect on foliage display efficiency [15].

Later a study was undertaken crown architecture in sun and shade environments: assessing function and trade-offs with a three-dimensional simulation model. Sun and shade environments exhibit markedly different constraints on the photosynthetic performance of plants. This study analyse the role of architecture in maximizing light capture and photosynthesis in shaded understoreys and in minimizing exposure to excess radiation in open high light environments, using a three-dimensional structural-functional model, Y-plant. Simulations with *Psychotria* species revealed that increasing internode lengths would increase light-capture efficiencies and whole plant carbon gain. In high light environments, leaf angles and self-shading provide structural photo protection, thereby minimizing potential damage from photo inhibition [16]. The leaf canopy is expected to be related to photosynthetic efficiency of a tree [17].

In the context of the literatures no study is available on the branching pattern and branching density. The present study is directed to characterize branching pattern and branching density of some woody plants in Northeastern Mexico.

Materials and Methods

A field survey was carried out at the experimental station of Facultad de Ciencias Forestales, Universidad Autónoma de Nuevo Leon, located in the municipality of Linares (2447N.99 32 W), at elevation of 350 m. 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 change in moisture content.

We made a visual field survey using photo-animation in classifying the branching pattern and branching density of 30 trees and shrubs in the Northeast of Mexico. First we took photographs of the branch and then cause photo-animation technique.

Results

General observation

There existed a large variability in top crown architecture and branching patterns among species

On the basis of visual branch image (animation) of 30 trees and shrubs were classified into three classes viz., 1) High density, 2) Medium density and 3) Low density. The general characteristics of each of 30 species are depicted below and these are described (Table 1).

The characteristics of branching pattern and branching density

In a field survey, the characteristics and branching density pattern of thirty tree and shrub species studied are mentioned herein.

High Density

Sargentia gregii: Leaves are slightly oval to lanceolate, most of the leaves are exposed to solar radiation. Primary branch is medium thick.

Species	Type of branching	Canopy shape
<i>Helietta parvifolia</i>	pseudomonopodial	irregular
<i>Sargentia gregii</i>	pseudomonopodial	globosa
<i>Guaiaecum angustifolium</i>	monopodial	irregular
<i>Ebenopsis ebano</i>	pseudomonopodial	irregular
<i>Harvadia pallens</i>	sympodial	irregular
<i>Condalia hoockeri</i>	pseudomonopodial	irregular
<i>Zanthoxylum fagara</i>	sympodial	irregular
<i>Cordia boissieri</i>	pseudomonopodial	globosa
<i>Acacia berlandieri</i>	pseudomonopodial	irregular
<i>Diospyros texana</i>	pseudomonopodial	globosa
<i>Celtis pallida</i>	pseudomonopodial	irregular
<i>Forestiera angustifolia</i>	sympodial	irregular
<i>Diospyros palmeri</i>	pseudomonopodial	globosa
<i>Parkinsonia texana</i>	pseudomonopodial	globosa
<i>Acacia farnesiana</i>	pseudomonopodial	Globosa
<i>Sideroxylon celastrina</i>	pseudomonopodial	Globosa
<i>Caesalpinia mexicana</i>	pseudomonopodial	Irregular
<i>Karwinskia humboldtiana</i>	sympodial	Globosa
<i>Amyris texana</i>	sympodial	Irregular
<i>Leucaena leucocephala</i>	monopodial	Irregular
<i>Ehretia anacua</i>	pseudomonopodial	Irregular
<i>Gymnosperma glutinosum</i>	monopodial	Irregular
<i>Celtis laevigata</i>	pseudomonopodial	Globosa
<i>Acacia rigidula</i>	pseudomonopodial	Irregular
<i>Acacia shaffneri</i>	pseudomonopodial	Irregular
<i>Prosopis laevigata</i>	pseudomonopodial	Globosa
<i>Eysenhardtia polystachya</i>	monopodial	Irregular
<i>Bernardia myricifolia</i>	sympodial	Irregular
<i>Leucophyllum frutescens</i>	sympodial	Globosa

Table 1: Visual field survey using photo-animation in classifying the branching pattern and branching density of trees and shrubs in North-eastern Mexico.

Secondary branch branch angle ranged from 30 to 45 degree. Primary branch show bifurcation at the lower but trifurcation at the terminal end. Internodal distance is short, secondary branch is alternate at acute angle.

Guaiaecum angustifolium: Leaves small, narrow, exposed fully to solar radiation, primary and secondary branch at acute angle. Branches thin, showing profusely bi to trifurcation, extended upward.

Ebenopsis ebano: Branching pseudomonopodial. Leaves medium sized, fully exposed to solar radiation, branch mediumly thin, angle 45 to 90, horizontally extended showing frequent bifurcation, internodal distance short.

Condalia hoockeri: Branching pseudomonopodial, leaves medium sized, fully exposed to solar radiation, branch mediumly thin, alternate, angle more or less 45. The branch is horizontally extended and profusely bifurcated and secondary branch is at acute angle. Primary branch is thick, with intermediate internodal distance.

Cordia boissieri: Branching pseudomonopodial. Leaves small, oval, primary branch strong thick, terminal branch bifurcated, leaves partially exposed to solar radiation, branch horizontally extended, secondary branch at acute angle, primary branch strong, thick, bi or trifurcated at the terminal end, internodal distance is short.

Celtis pallida: Pseudomonopodial, leaves small exposed fully to solar radiation, primary branch strong, more or less horizontally extended.

Forestiera angustifolia: Branching sympodial. Leaves narrow, fully exposed to solar radiation, primary branch mediumly thin, extended to an acute angle to the main stem, alternate forming acute angle. Branch horizontally extended showing bifurcation at lower part but trifurcation at the terminal end, internodal distance is medium.

Parkinsonia texana: Branching pseudomonopodial. Leaves narrow, partially exposed to solar radiation, extended horizontally to the main stem, primary branch thin. Branch showing bifurcation at the lower part, but trifurcation at the terminal end, internodal distance is short.

Acacia farnesiana: Branching pseudomonopodial. Leaves small, narrow, exposed fully to solar radiation, primary branch dicho or trichotomously at the terminal end, primary branch medium thick, strong. Secondary branch at acute to right angle.

Sideroxylon celastrina: Branching pseudomonopodial. Leaves small, broad, fully exposed to solar radiation, primary branch mediumly thick, secondary branch forming acute angle. Branch arising from the main trunk is extended upward at an angle, branch shows bifurcation, internodal distance is short.

Ehretia anacua: Leaves small, partially exposed to solar radiation, branch thin, bifurcated at the lower part but trifurcated at the terminal end, internodal distance short.

Celtis laevigata: Branching pseudomonopodial. Leaves medium sized, lanceolate, partially exposed to solar radiation, branches thin bi or trifurcated, extended horizontally. Primary branch thick, secondary branch thin, showing bifurcation at the lower part but trifurcation at the terminal end, secondary branch alternate, at acute angle. Internodal distance is short.

Accacia shaffneri: Branching pseudomonopodial. Leaves small, not exposed fully to solar radiation, extended horizontally, branches thin.

Prosopis laevigata: Branching pseudomonopodial. Leaves narrow,

small, fully exposed to solar radiation, branches mediumly thick, strong, dichotomy or trichotomy at the terminal end, extended horizontally, primary branch thick, secondary branch thin, internodal distance is short.

Bernardia myricifolia: Branching sympodial. Leaves lanceolate, almost fully exposed to solar radiation, primary branch thin, soft, internodal distance long, bifurcation is observed.

Acacia berlandieri: Branching pseudomonopodial. Leaves small, exposed partially to solar radiation showing frequent irregular bifurcation, stem medium thick, branches extended horizontally.

Medium Density

Zanthoxylum fagara: Sympodial branching. Leaves small, fully exposed to solar radiation, branch mediumly thick, alternate, extended horizontally, showing dichotomy or trichotomy at the terminal end, acute angle, internodal distance is short.

Diospyros texana: Branching pseudomonopodial. Leaves not fully exposed, terminal end bifurcated, branches extended horizontally.

Diospyros palmeri: Leaves lanceolate, small, fully exposed to solar radiation, primary branch thin, secondary branch alternate, more or less at right angle, branches extended horizontally, wide spaced, internodal length is long.

Acacia rigidula: Branching pseudomonopodial. Leaves small, fully exposed to solar radiation, primary branch mediumly thick, strong showing bifurcation at the terminal end, alternate at acute angle, branching extended upward at an angle, secondary branch alternate.

Leucophyllum frutescens: Sympodial branching. Leaves small, lanceolate, fully exposed to solar radiation, primary branch thin, erect, secondary branch alternate to opposite forming acute angle, branch extended upwards.

Caesalpinia Mexicana: Leaves small, partially exposed to solar radiation, clustered over stems. Primary branch arising from the trunk extended more or less horizontally.

Low Density

Heliatta parvifolia: Branching pseudomonopodial, leaves small, extended horizontally, frequent bifurcation is observed.

Harvardia pallens: Branching sympodial. Leaves small, fully exposed to solar radiation, horizontally extended showing dichotomy but trichotomy at the terminal end. Primary branch medium thick, secondary branch alternate forming acute angle.

Karwinskia humboldtiana: Branching sympodial, leaves lanceolate exposed fully to solar radiation, primary and secondary branch thin.

Croton suaveolens: Branching sympodial. Leaves medium sized, lanceolate, exposed fully to solar radiation, primary branch thin, delicate showing dichotomous branching.

Amyris texana: Branching sympodial. Leaves small, fully exposed to solar radiation. Horizontally extended showing dichotomous branching, secondary branch alternate forming acute angle.

Leucaena leucocephala: Branching monopodial. Leaves small, lanceolate, exposed fully to solar radiation, extended horizontally showing dichotomy and trichotomy at the terminal end, primary branch medium thick, secondary branch forming acute angle.

Gymnosperma glutinosum: Branching monopodial. Leaves

lanceolate exposed fully to solar radiation, branch arising from main stem, not branched.

Eysenhardtia polystachya: Branching monopodial. Leaves small, oval, fully exposed to solar radiation, primary branch showing dichotomy at the terminal end, extended more or less horizontally. Secondary branch are alternate, arising at acute angle.

Discussion

As mentioned above, there exist large variability in the types of branching, branching pattern, its extension, mode of branching, bifurcation, leaf canopy (open or close), leaf size etc., thereby giving opportunity to select species with desirable phenotype. And further study for the quantification of branching parameters (which are in progress).

It is expected that a large variation in branching pattern and branching density among species which could be related to their variations of solar energy. The species with high branching may block the efficient capture of solar radiation due to overlapping of leaf canopies.

It is known that the tree crown represents the top part of the tree, which consists of branches that grow out from the main trunk and offer support to the various leaves used for photosynthesis. The variability of crown architecture and its branching pattern in different species of woody plants in a forest offers beautiful landscape in a particular forest. The variability in crown architecture among tree species in a forest ecosystem confer characteristics of great interest of an aesthetic architect and assists the silviculturists for the easy identification of the species. The growth habit of the crown varies among them. In general, the trees are semierect, but its branches may be vertical, erect, extended or open. These forms are influenced by the form and diameter of the crown and the height of the plant. Other variable is the distribution of the branches as irregular, horizontal or ascending. The leaf apex varies such as obtuse, pointed, round, or apiculate. Various studies are documented on tree crown architecture, its characterization as well as the role of crown and leaf canopy in light and carbon capture

In general, most of the tree species possess open canopy leaves with mediumly narrow leaves, very few with broad leaves with ramifying branches. This may be attributed due to greater efficiency of photosynthesis and carbon accumulation in open canopy ones compared to those with close canopy ones [17]. In a recent study, 30 species in Linares, Northeastern Mexico we classified as monopodial (2), pseudomonopodial (8); and sympodial (20). Some species are selected with good landscape structures which are recommended in plantation in carbon polluted areas. We selected the species *Cordia boissieri*, *Diospyros texana*, *Ebenopsis ebano*, *Celtis pallida*, *Parkinsonia texana*, which could be planted in urban areas and parks for their beautiful landscape [11]. But the present study was directed to study branching pattern and branching density which could be related to the efficiency in the capture of solar radiation.

A sympodial type with narrow leaves exist in between other types of crown architecture. Sympodial types show profuse branching from the base of the plant with spreading thinner branches around. It has been interpreted that the proportion of different plant species with medium broad leaves in a forest ecosystem for detecting the mode of co-existence and adaptation as well as for their capacity in the capture of solar radiation and sharing available spaces with the neighbouring species [13].

The proactivity of trees depend on its capacity of capture of solar

radiation and photosynthesis. It is observed that in a forest ecosystem trees and shrubs attain different heights and spread their branches upwards or downwards, thereby giving opportunity to each species for the capture of solar radiation for photosynthesis. In species with low branch density and open canopy leaves all the leaves are exposed to solar radiation and probably efficient in photosynthesis, while those with high density branches and close canopy leaves, all the leaves are not fully exposed to solar radiation except the peripheral leaves and probably less efficient in photosynthesis [17]. In a recent study that the branching pattern of several woody plant species have been classified [11].

The present study was directed mainly to describe the general characteristics of branching pattern and branching species of 30 woody trees and shrubs and did not attempt to quantify the traits mentioned. Depending on the type of branching, the branching start at the top of the trunk (pseudopodial), or at the ground level (sympodial) and then grow upwards, downwards or horizontally and extend outwards depending on the available space in the understorey, thereby, giving a particular tree canopy. This in turn captures solar radiation falling vertically, laterally. In the case of open leaf canopy, all the leaves are exposed to solar radiation, thereby having photosynthetic capacity, while in the case of close canopy only the top and peripheral leaves receive solar radiation, thereby, are less efficient in photosynthesis. It is generally observed that the species with open canopy leaves grow taller and highly branched compared to those with close canopy leaves. This could be an interesting field of research for forest scientists.

Each species has specific characteristics of branching type, branching density extended to occupy the available space and the leaf canopy and leaf orientation exposed fully or partially to absorb solar radiation. In the present study, we observed large variability in branching pattern and branching density among the species studied. This variability in branching habit and density that represent a wide range of adaptative capacity in the understorey with respect to the capture of solar radiation in Tamulipan thornscrub. This also gives an opportunity in the selection of the species with its efficiency in the capture of solar radiation and also helps foresters to adopt silvicultural practice for management. In the present study we did not attempt to quantify branching variable, these species have extended leaf crown structure and branching pattern of different individual species for capture of carbon which coincide with the reports by different authors in different tree species [4-6].

Very few studies have been undertaken on the branching pattern. A study has been made by Leopold [1] on the efficiency of branching patterns, the relation of average numbers and lengths of tree branches to size of branch size on the efficiency of branching patterns, the relation of average numbers and lengths of tree branches to size of branch size of branch.

The present study coincides in general with few observations of Pickett and Kempf [2] that shrubs do not show large difference in gross branching structure (ratio of terminal to supporting branches) and suggested that branch angle, length and alteration of leaf orientation may exhibit significant display characters. Small trees show markedly variable response to open vs closed habitats, demonstrating the expected increase in branching ratio in open environments. According to Steingraeber and Waller [3], two specific patterns of non-stationary that are directly related to morphological patterns of shoot development. Average bifurcation ratios appear to be inappropriate descriptions of tree branching patterns, since they are based solely on relative branch position. Various studies documented on tree crown architecture,

its characterization, and its role in light capture and carbon gain [5,8,10,14,15].

It has been reported that these species possess open canopy leaves which have higher photosynthetic capacity compared to close canopy ones [17]. It has been documented by different authors that the Crown architecture and its branching extension contribute remarkably to the capacity of a species on carbon capture from the atmosphere through photosynthesis [12-14]. Therefore, the large variability in tree crown structure and canopy extensions depict clearly the variability in the photosynthetic capacity for co-existence in a forest ecosystem.

Conclusion

The present study shows a large variability in branching pattern and branching density of 30 woody species studied. This could be related to its variability in the capture of solar radiation and plant productivity which needs to be confirmed in future studies. It may be concluded that both the crown architecture and branching patterns are the characteristics of a tree species which can be related to the adaptation of each species to a particular environment. The organization of these feature contribute to the productivity of a particular species in a particular environment. The intensity of these traits of each species varies in understorey and open environment. Therefore, concerted research inputs need to be addresses in this aspect, in order to assess the productivity of trees. Besides, there is a necessity of the characterization of plant traits of the species in a particular forest ecosystem.

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