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Site index for *Pinus leiophylla* Schiede ex Schltdl. & Cham., plantations in Michoacan, Mexico

Índice de sitio para plantaciones de *Pinus leiophylla* Schiede ex Schltdl. & Cham., en Michoacán, México

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ABSTRACT

Simulation of dynamic growth in forest plantations (FP) is essential. The objective was to fit a dominant height growth model and generate site index (*IS*) curves for pine plantations. In *Pinus leiophylla* plantations from 4 to 24 years old in Patamban, Michoacán state, in 42 sampling sites of 400 m^2, the dominant height (*Ad*) and the age of 126 trees were obtained. Eleven statistical models were fitted to estimate the *Ad*. The best model was chosen through statistical parameters typically used in modeling *Ad* and site index (*IS*) growth. The asymptote parameter was cleared to generate the anamorphic *IS* curves, and the expression was substituted in the integral equation at a base age of 20 years. The turn of *Ad* was six years at the intersection of ICA=IMA, where FP reached an average annual increase in *Ad* of 0.86, 1.21, and 1.56 m for *IS* of 10, 14, and 18 m. The Schumacher model described *Ad* more accurately and reliably and generated anamorphic *IS* curves that properly describe the sample variation in FP of *P. leiophylla*.

KEY WORDS: Increments, mathematical models, Schumacher, station quality, shift.

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RESUMEN

La simulación del crecimiento dinámico en plantaciones forestales (FP) es esencial. El objetivo fue ajustar un modelo de crecimiento en altura dominante y generar curvas de índice de sitio (*IS*) para plantaciones de pino. En plantaciones de *Pinus leiophylla* de cuatro a 24 años en Patamban, Michoacán, en 42 sitios de muestreo de 400 m^2, se obtuvo la altura dominante (*Ad*) y la edad de 126 árboles. Se ajustaron 11 modelos estadísticos para estimar la *Ad*. El mejor modelo se eligió a través de parámetros estadísticos utilizados típicamente en la modelación del crecimiento de *Ad* e índice de sitio (*IS*). Para generar las curvas anamórficas de *IS* se despejó el parámetro de la asíntota y la expresión se sustituyó en la ecuación integral a una edad base de 20 años. El turno de *Ad* fue a seis años en la intersección de ICA=IMA, donde las FP alcanzaron un incremento medio anual en *Ad* de 0.86, 1.21 y 1.56 m para los *IS* de 10, 14, y 18 m. El modelo de Schumacher describió con mayor precisión y confiabilidad la *Ad* y generó curvas de *IS* de tipo anamórfico que describen adecuadamente la variación muestral en FP de *P. leiophylla.*

PALABRAS CLAVE: Incrementos, modelos matemáticos, Schumacher, calidad de estación turno.

Introduction

Forest ecosystems are dynamic; therefore, it is essential to simulate the variable characteristics of trees and forest stands using techniques that facilitate their management (Nava-Nava *et al.,* 2020). Productivity variances within or between species and regions are critical for applying different age-specific silvicultural treatments, as these will directly affect the financial profitability of the treatments and the obtained products (Guerra-Hernández *et al.,* 2021).

The site index (*IS*) has been widely used to evaluate site quality in forest stands and plantations (FP). It is defined as the dominant height (*Ad*) reached by the stand at a base age (B_a) (Martínez-Zurimendi *et al.,* 2015; García-Cuevas *et al.,* 2022). This indicator is the most effective for determining site productivity, as dominant height, in theory, is not affected by stand density or applied treatments (Álvarez *et al.,* 2004; Fiandino *et al.,* 2020). Additionally, the growth of *Ad* in the stand follows a determined and consistent pattern and is correlated with volume production per hectare (García-Cuevas *et al.,* 2022).

In most forestry studies, *IS* models have been used to describe productivity through site quality classifications and *Ad* labels derived from a previously fitted reference curve (Burkhart &

Tomé, 2012). Different growth trends can be generated in this context, either anamorphic, where *Ad* patterns are proportional across all classes, or polymorphic, indicating differentiated and dynamic *Ad* growth for all site classifications (Zobel *et al.,* 2022). Although mixed-effects models are currently applied to improve *Ad* estimations in FP (García-Espinoza *et al.,* 2018; Hernández-Ramos *et al.,* 2022), the required information to apply such statistical and practical enhancement approach outside the study area through parameter calibration is not always available. For this reason, the guide curve methodology continues to deliver satisfactory results, as it has been applied to conifer species such as *Pinus oocarpa* Schiede (García-Cuevas *et al.,* 2024), *Pinus pseudostrobus* var. *apulcensis* (Ramírez *et al.,* 2020), and *Pinus teocot*e Schlecht. & Cham. (Hernández-Ramos *et al.,* 2015) in various regions of Mexico.

Pinus leiophylla Schiede ex Schltdl. & Cham. is a species widely distributed in Mexico, ranging from Chihuahua to Oaxaca, at altitudes between 1,600 and 3,000 masl (Perry, 1991). Additionally, it is a species of both timber and non-timber importance (Martínez-Trinidad *et al.,* 2002) that has gained relevance in the establishment of FP with the *Pinus* genus in Michoacán state, Mexico. Since 2010, there has been a trend of increased establishment, with approximately 16,076 ha^{-1} (CONAFOR, 2020), representing an annual timber production of around 384,679 m^3 in the state (CONAFOR, 2021).

50% of the FP are in the eastern part of the state. However, no quantitative or updated silvicultural techniques or methodologies can be implemented in the planning, establishment, monitoring, and management of FP, which poses a problem in this region. Therefore, the objective was to fit a dominant height growth model (*Ad*) and generate site index (*IS*) curves for *Pinus leiophylla* plantations established in the Purhépecha Sierra of Michoacán, Mexico.

Material and Methods

The study was conducted in *Pinus leiophylla* FP established at altitudes between 2,000 and 2,600 m in the Indigenous Community (IC) of Patamban, located in the Tangancícuaro municipality, Michoacán, Mexico (Figure 1). The IC is situated in the physiographic region of the Trans-Mexican Volcanic Belt, within the Purhépecha Sierra. It has a forested area of 11,232 ha^{-1} and is characterized by a sub-humid temperate forest ecosystem (Cw1) with summer rainfall, an average annual temperature of 12°C, a minimum of -2°C, and a maximum of 22°C. The average annual precipitation is 1,850 mm. The soils are of volcanic origin, predominantly Andosol ochric (80%), with Litosol and Cambisol chromic (20%) (INEGI, 2024).

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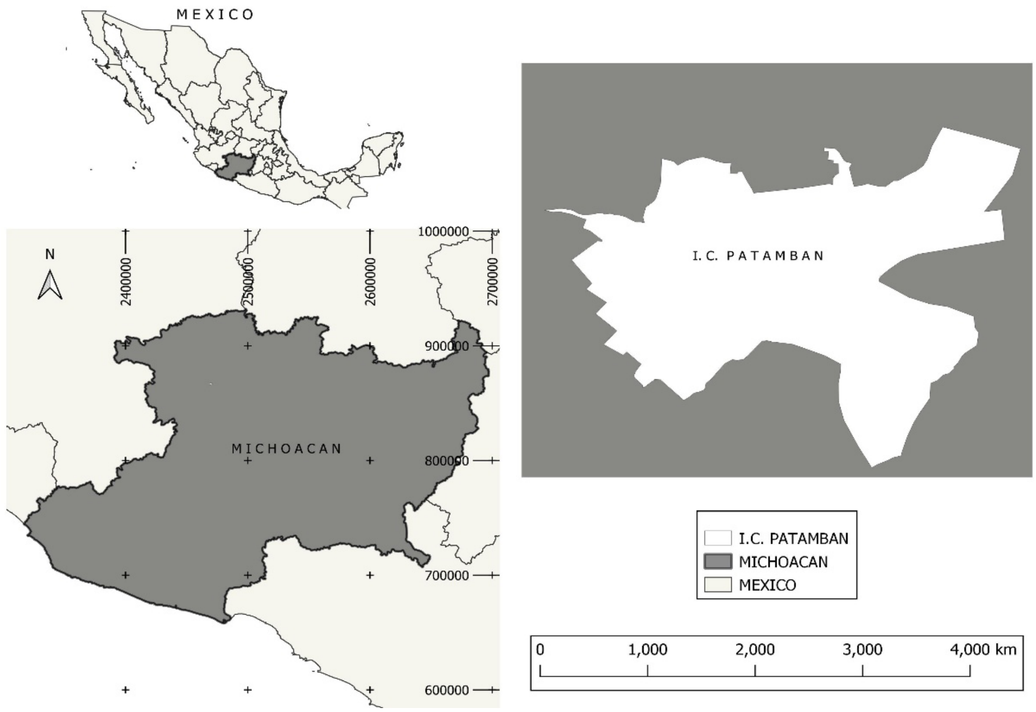

Figure 1. Geographic location of the forest plantations (FP) of *Pinus leiophylla* of the Indigenous Community of Patamban, Tangancícuaro, Michoacán, Mexico.

In each of the 42 quadrangular 400 m^2 sampling sites established in FP aged 4 to 24 years, three dominant height trees were selected within each sampling site (CONAFOR, 2014; 126 Individuals). These were measured using a Nikon® Forestry PRO II Laser Hypsometer, while age was determined by extracting cores with a Pressler increment borer and counting the annual growth rings (Buendía-Rodríguez *et al.,* 2022), with the data cross-referenced against the plantation records of the IC. Descriptive statistics, the coefficient of skewness (CS), and kurtosis were calculated to verify the proper data distribution, with both indicators required to fall between -3 and 3 standard deviations (Martínez *et al.,* 2014).

From the specialized literature, 11 models were selected (Table 1) for fitting the *Ad* data (Martínez-Zurimendi *et al.,* 2015; Senilliani *et al.,* 2021; García-Cuevas *et al.,* 2022; Hernández-Ramos *et al.,* 2022).

Table 1. Growth models to estimate the dominant height of forest plantations (FP) of *Pinus leiophylla* in the Indigenous Community of Patamban, Tangancícuaro, Michoacán, Mexico.

Model	Expression	Equation identifier
Von Bertalanffy	$Dh = a_0[1 - e^{-a_1 E}]^3$	[1]
Chapman-Richards	$Dh = a_0[1 - e^{-a_1 E}]^{a_3}$	[2]
Monomolecular	$Dh = a_0[1 - a_1 e^{-a_2 E}]$	[3]
Gompertz	$Dh = a_0(e^{-a_1 e^{-(a_2 E)}})$	[4]
Hossfeld IV	$Dh = E^{a_2}/a_1 + E^{a_2/a_0}$	[5]
Levakovic III	$Dh = a_0(E^2/(a_1 + E^2))^{a_2}$	[6]
Cieszewski and Bella	$Dh = a_0/(1 - a_1 E^{a_2})$	[7]
Schumacher	$Dh = a_0 e^{-a_1/E}$	[8]
Verhulst-Logistics	$Dh = a_0/(1 - e^{a_1 - a_2 E})$	[9]
Allometrics	$Dh = a_0 E^{a_1}$	[10]
Korf	$Dh = e^{a_0 - (a_1/E^{a_2})}$	[11]

Where: *Ad*: dominant height (m), a_i: parameters to be adjusted, and E: age (years).

}

The growth models were fitted using the R® statistical package through the *nls* function and the maximum likelihood technique (R Core Team, 2020). The selection of the model in terms of accuracy was based on the significance of the parameter values (*α = 0.05*), the adjusted coefficient of determination (R^2_{adj}, [12]), the root mean square error (RMSE, [13]), Akaike (1974) 's Information Criterion and Bayesian Information Criterion (AIC, [14] and BIC [15]), bias [16] (Martínez-Zurimendi *et al.,* 2015; 2020; García-Cuevas *et al.,* 2022), and the relative ranking performance of each model (RRP, [17]) (Poudel & Cao, 2013). Additionally, the parsimony of the employed expressions was considered.

$$R^2_{adj} = 1 - \frac{(n-1)\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{(n-p)\sum_{i=1}^{n}(y_i - \bar{y}_i)^2} \quad [12]$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n-p}} \quad [13]$$

$$AIC = 2 \cdot p + n \cdot ln\left(\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}\right) \quad [14]$$

$$BIC = n \cdot l\left(\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}\right) + p \cdot ln(n) \quad [15]$$

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$$Bias = \sum_{i=1}^{n}\left(\frac{y_i - \hat{y}_i}{n}\right) \quad [16]$$

$$RRP = 1 + \frac{(m-1)\cdot(S_i - S_{min})}{S_{max} - S_{min}} \quad [17]$$

Where, y_i, $\hat{y}_i$ and $\bar{y}_i$ are the observed, estimated, and average values, respectively; n is the total number of data points used to fit the models; p refers to the number of parameters in the models; and m is the number of evaluated models (Table 1). Si is the selected goodness-of-fit statistic, and S_{max} and S_{min} are the maximum and minimum values of Si, respectively.

Once the best model was selected by verifying the trend of the estimates against the distribution of the observed data, as well as the average value of *RRP* for each of the goodness-of-fit statistics (R^2_{adj}, *RMSE*, AIC, BIC, and Bias; Poudel & Cao, 2013), compliance with the assumptions of normality and homoscedasticity of residuals was confirmed (Martínez *et al.,* 2014).

With the selected growth model, the guide curve for dominant height was determined by considering that, when age (E) is equal to the base age (E_b), the *Ad* equals the *IS* (García *et al.,* 2021). To generate the anamorphic curves, the asymptote parameter was isolated from the *IS* equations and substituted into the base equation, whereby the asymptotic parameter is considered implicit, and the shape parameters were common across all sites (Clutter *et al.,* 1983; García *et al.,* 2021). Meanwhile, anamorphic curves were generated by varying E and *IS* classes while keeping E_b constant.

To generate the polymorphic curves, one of the exponent parameters related to site condition was isolated from the *IS* equations and substituted into the base equation (García *et al.,* 2021). Similarly, by varying E and *IS* classes while keeping E_b constant, the polymorphic curves were generated (Clutter *et al.,* 1983; García *et al.,* 2021). A E_b of 20 years was used in constructing the *IS* curves.

For example, in the case of the Schumacher model, a_0 corresponds to $Ad = \left[\frac{SI}{e^{-a_1/Ba}}\right]\cdot e^{-a_1/E}$ [8.1] for anamorphic form, and y in a_1 the expression form representing the growth trending is $Ad = a_0 \cdot e^{-\frac{-ln\left(\frac{SI}{a_0}\right)\cdot Ba}{E}}$ [8.2] for polymorphic where the classes of site index (*IS*) were defined through the distribution of information in the established E_b to 20 years.

The technical rotations (*tt*) were determined for each generated curve to identify the point of culmination of the maximum growth rate and the point of intersection where the current annual increment is equal to the mean annual increment (ICA = IMA) (Kiviste *et al.,* 2002; Hernández-Ramos *et al.,* 2022). This can be used to determine the age at which silvicultural treatments should be applied in the FP.

Results and Discussion

The descriptive statistics for *Ad* and E of the dominant *Pinus leiophylla* trees showed no distribution issues, as the skewness coefficient and kurtosis values were both less than 1.1, with an average age of 10 years and *Ad* of nine meters (Table 2).

Table 2. Descriptive statistics of variables of the sample used from *Pinus leiophylla* forest plantations in the Indigenous Community of Patamban, Tangancicuaro, Michoacan, Mexico.

Statistic	Age (years)	Dominant height (m)
Mean	10.00	9.00
Minimum	4.00	3.00
Maximum	24.00	20.00
Standard error	0.52	0.32
Standard deviation	5.85	3.66
Sample variance	34.21	13.40
Kurtosis	0.12	0.14
Coefficient of skewness	1.05	0.50

The 11 fitted growth models showed significant parameters in all cases ($\alpha < 0.05$) and asymptote values indicating maximum dominant heights ranging from 13.0 m (Von Bertalanffy [1]) to 17.5 m (Schumacher) (Table 3).

Table 3. Value of parameters, statistics, and significance of parameters of the adjusted growth models for dominant height of *Pinus leiophylla* in the Indigenous Community of Patamban, Tangancicuaro, Michoacan, Mexico.

Model	Parameter	Estimate	Standard error	t-value	Pr>|t|
1	a_0	13.012	0.368	35.370	<0.001
	a_1	0.265	0.011	23.070	<0.001
2	a_0	13.926	0.624	22.313	<0.001

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Continuation

Table 3. Value of parameters, statistics, and significance of parameters of the adjusted growth models for dominant height of *Pinus leiophylla* in the Indigenous Community of Patamban, Tangancicuaro, Michoacan, Mexico.

Model	Parameter	Estimate	Standard error	t-value	Pr>|t|
	a_1	0.175	0.031	5.595	<0.001
	a_2	1.715	0.328	5.232	<0.001
3	a_0	14.258	0.703	20.280	<0.001
	a_1	1.227	0.107	11.431	<0.001
	a_2	0.141	0.022	6.427	<0.001
4	a_0	13.653	0.490	27.838	<0.001
	a_1	2.805	0.357	7.849	<0.001
	a_2	0.222	0.025	8.772	<0.001
5	a_0	15.343	1.101	13.933	<0.001
	a_1	1.835	0.666	2.757	0.007
	a_2	1.722	0.223	7.711	<0.001
6	a_0	14.964	0.709	21.101	<0.001
	a_1	76.019	34.932	2.176	0.032
	a_2	0.712	0.162	4.396	<0.001
7	a_0	15.343	1.101	13.933	<0.001
	a_1	28.153	8.761	3.213	0.002
	a_2	-1.722	0.223	-7.711	<0.001
8	a_0	17.484	0.637	27.440	<0.001
	a_1	5.630	0.342	16.480	<0.001
9	a_0	13.341	0.405	32.940	<0.001
	a_1	2.002	0.192	10.420	<0.001
	a_2	0.317	0.031	10.080	<0.001
10	a_0	2.413	0.221	10.940	<0.001
	a_1	0.578	0.036	16.150	<0.001
11	a_0	2.866	0.123	23.237	<0.001
	a_1	5.578	1.255	4.447	<0.001
	a_2	0.992	0.195	5.078	<0.001

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When evaluating the goodness-of-fit statistics for the fitted growth models, it was observed that, according to the adjustment criteria values, the Verhulst-Logistic expression [9] was the best, followed in the same order by the Schumacher model (Table 4, [8]). However, the Schumacher expression showed better parsimony and penalized RRP resulted in the lowest value, the reason why it was selected as the most appropriate for describing the dominant height trend among the species.

Table 4. Goodness-of-fit statistics of the growth models used for the dominant height of *Pinus leiophylla* in the Patamban Indigenous Community of Tangancicuaro, Michoacan, Mexico.

ID	Coefficient of determination (R^2)	Root means square error (RMSE)	Akaike's Information Criterion (AIC)	Bayesian information criterion (BIC)	Bias (m)	Relative ranking performance (RRP)
1	0.7502	1.8377	506.8	515.3	0.0988	11485.43
2	0.7669	1.7824	500.2	511.5	0.0035	11393.85
3	0.7657	1.7870	500.8	512.1	0.0000	11408.75
4	0.7683	1.7770	499.4	510.7	0.0024	11376.47
5	0.7657	1.7871	500.8	512.1	0.0051	11408.95
6	0.7664	1.7845	500.5	511.8	0.0021	11400.68
7	0.7657	1.7871	500.8	512.1	0.0051	11408.95
8	0.7637	1.7873	499.9	508.4	0.0034	11325.21
9	0.7700	1.7708	498.6	509.9	0.0030	11356.27
10	0.7088	1.9840	525.8	534.2	-0.0472	11927.69
11	0.7637	1.7946	501.9	513.2	0.0029	11433.19

In Figure 2, the trend of the predictions is shown, where the Von Bertalanffy expression [1] overestimates the *Ad* at early ages and underestimates it at older ages, unlike the allometric expression [10], which only fits certain ages and either overestimates or underestimates at others. It is also observed that the Verhulst-Logistic [9] and Schumacher [8] expressions are practically identical, and they showed the best trend with the observed data (Figure 2).

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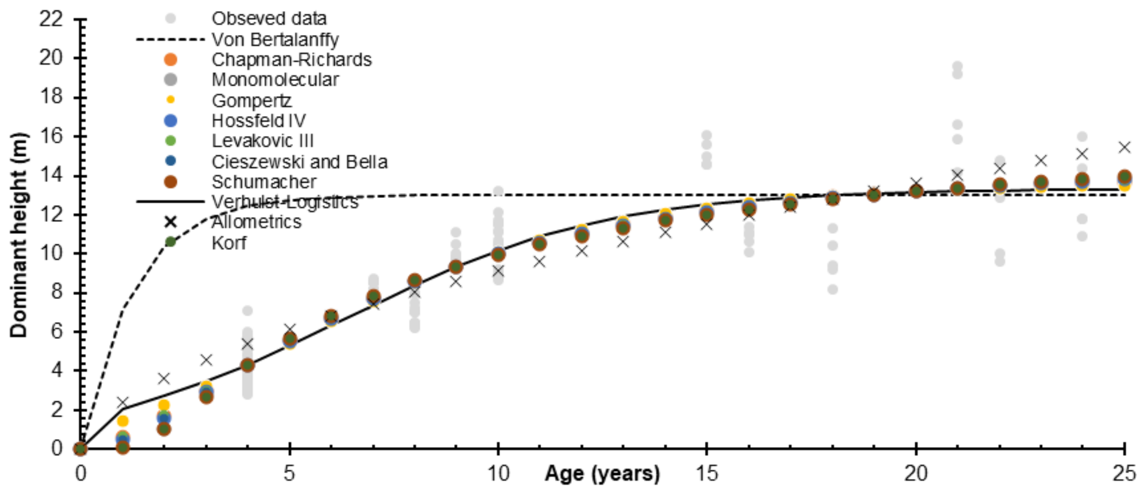

Figure 2. Distribution and estimated trend by dominant height growth model (*Ad,* m) in *Pinus leiophylla* forest plantations in the Indigenous Community of Patamban, Tangancícuaro, Michoacán.

The trend of estimates was compared with themselves and the distribution of information, where the Von Bertalanffy [1] and Allometric [10] models showed the most evident biases in the average estimation of *Ad* as a function of age (E) for the FP (Table 4 and Figure 3).

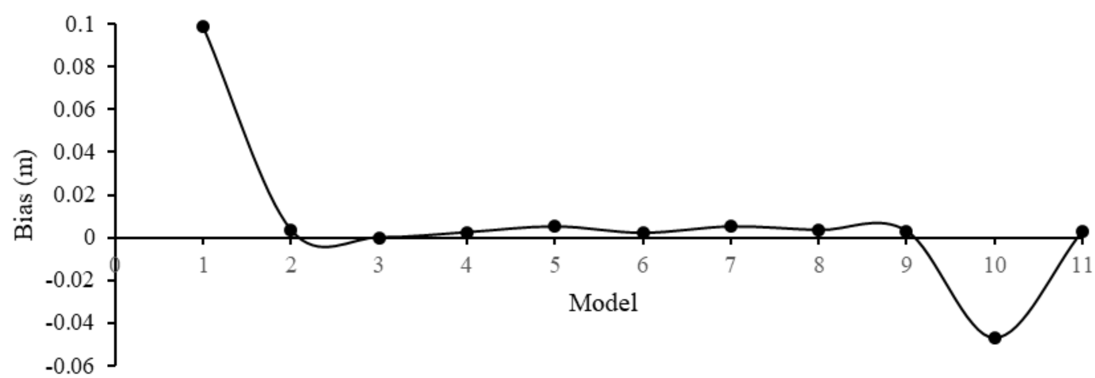

Figure 3. Biases of predictions of dominant height growth models (*Ad*, m) in *Pinus leiophylla* plantations in the Indigenous Community of Patamban, Tangancícuaro, Michoacán.

Revista Bio ciencias
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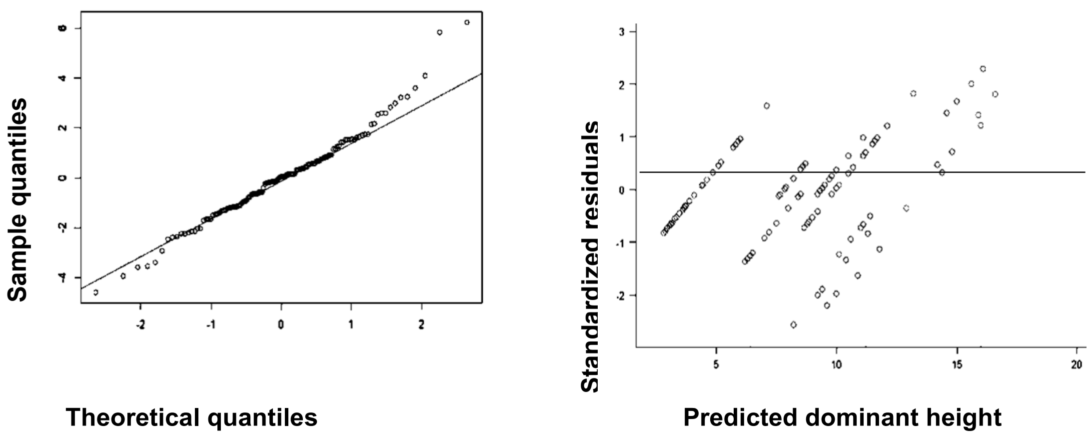
When graphically verifying the regression assumptions of normality in residual distribution (Figure 4a) and homoscedasticity of variance (Figure 4b), no global distribution issues were observed in either case, which was confirmed by the Shapiro-Wilk test. In the first case, although a slight deviation was observed at both ends, a trend toward the straight line was obtained in the theoretical quantiles *versus* the sample, while the standardized residuals showed a tendency toward zero (<3).



a) *Q-Q plot*: W = 0.9773, *p*-valor = 0.0345   b) Distribution of residuals.

Figure 4. Tests of normality (a) and homoscedasticity of variance (b) of the Schumacher model were selected as the best.

Once the best-fit equation was defined, a generic *Ad* curve was created with the expression: $Dh = 17.484e^{-5.630/E}$[8]. From the *Ad* equation, the structure of the expressions to generate anamorphic curves with *IS* classes of 10, 14, and 18 m were derived through algebraic treatment. In the case of polymorphic curves, they did not adhere to the data trend.

Anamorphic curves: $$Dh = SIe^{5.630(1/B_a - 1/E)} \quad [8.1]$$

Polymorphic curves: $$Dh = 17.484\left(\frac{SI}{17.484}\right)^{\left(\frac{B_a}{E}\right)} \quad [8.2]$$

As shown in Figure 5a, the anamorphic curves cover the entire range of observed data dispersion for the *Ad* in *Pinus leiophylla* individuals established in FP. On the other hand, the polymorphic curves overestimate or underestimate the dominant height at younger ages and in poorer site qualities, and at older ages, the *IS* labels must be modified to prevent exceeding the

Revista Bio ciencias
ISSN 2007-3380

natural asymptote of the model (Figure 5c). The rotation for dominant height for this species was determined to be approximately at six years, at the point of intersection where ICA = IMA, where the FP reached an average annual increment in *Ad* of 0.86, 1.21, and 1.56 m for the site indexes of 10, 14, and 18 m (Figure 5a), respectively. The highest current increment occurred at four years with increments of 1.21, 1.70, and 2.19 m (Figure 5b). The increments related to the polymorphic growth trend did not a*dh*ere to the logical trends of the plant species, thus they were discarded (Figure 5d).

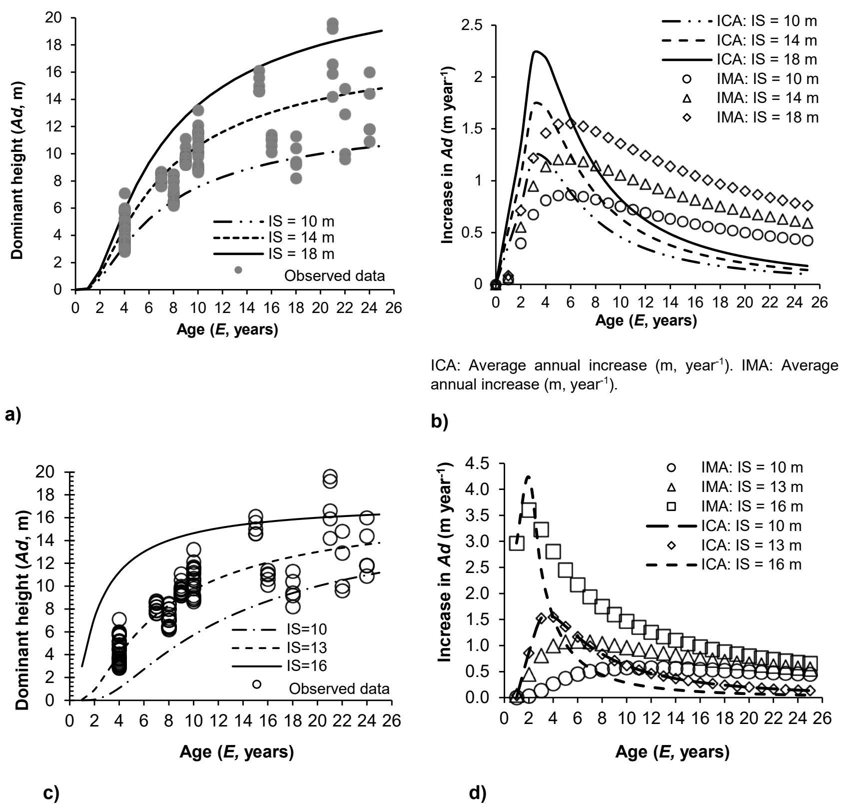


Figure 5. Dominant height growth of anamorphic (a) and polymorphic (c) type and increases (c and d) by site index (*IS*) classes for FP of *Pinus leiophylla* in the Indigenous Community of Patamban, Tangancicuaro, Michoacan, Mexico.

The classification of forest zones according to their productivity is fundamental for planning silvicultural activities (Díaz *et al.,* 2018; Senilliani *et al.,* 2021; García-Cuevas *et al.,* 2022). For this purpose, the determination of site quality through *IS* labels and the guide curve as a reference is the most widely used technique to establish productivity levels in forest areas (Martínez-Zurimendi *et al.,* 2015; García *et al.,* 2021; García-Cuevas *et al.,* 2024). Therefore, it is important to define the

Revista Bio ciencias
ISSN 2007-3380

equation that best describes the growth behavior in *Ad*, since, when integrated into a growth and yield system, it allows for predicting production volumes and optimal harvest age of the plantation (Nava-Nava *et al.,* 2020).

The growth trend of the anamorphic type in *Ad* of this research is in line with what was reported by Castillo *et al.* (2013) for *Pinus leiophylla* stands in the Santiago Papasquiaro forest region, Durango state, Mexico, at a base age of 50 years. However, these authors describe the dynamics of forests of this species. Benavides (1991) determined through *IS* that in natural stands of *Pinus leiophylla* in the Sierra de Tapalpa, Jalisco state, at a base age of 45 years, the greatest growth in *Ad* occurs compared to *Pinus devoniana*, *Pinus oocarpa*, and *Pinus lumholtzii*. Similarly, as in this work, the anamorphic curves provided the best prediction and fit with the Schumacher model, yielding a determination coefficient of 0.94. It is important to highlight that the observed differences in growth are due to the species' habits, site quality, or the differentiated management of plantations or natural stands.

In the Michoacán state, areas with potential for establishing plantations of *Pinus leiophylla* have been reported (CONABIO, 2019), with a technical rotation of 12 years on Andosol-type soils (García and Muñoz, 1993). However, there is no additional information for the Sierra Purépecha region of Michoacán that could contribute to the planning and management of forest plantations of this economically important species.

In a similar study with *Pinus oocarpa* in Michoacán, García-Cuevas *et al.* (2024) indicate that the point of intersection of ICA and IMA (technical rotation in dominant height) occurred at the same age as in this study (9 years). Additionally, the representation through anamorphic curves for all evaluated site qualities and at different ages with polymorphic curves (5, 8, 11, and 15 years) shows that the inflection points are associated with better-quality station areas. This is also the case in this study, with the culmination of the increase around 3, 6, and 11 years.

In plantations with *Pinus patula* var. longipedunculata established in Oaxaca, the *IS* was modeled and as a result, polymorphic curves were generated, since, as in this study, when overlaying the observed and predicted data, the latter overestimated the projected dominant height (Nava-Nava *et al.,* 2020). However, although the model parameter results were significant, the coefficient of determination was low (0.58) compared to *Pinus leiophylla* (0.76). Knowledge of the site index allows for determining at what age the trees will reach a specific height and expected production based on age (Ramírez *et al.,* 2020); therefore, choosing the location and condition for establishing a forest plantation of any species will be decisive when determining its yield and the type of management. In this regard, the particular conditions provided by the site are essential for the growth, annual mean increment, and current annual increment of the species (Pompa-García & Domínguez-Calleros, 2015; García-Aguilar *et al.,* 2017; Hernández-Ramos *et al.,* 2022).

The equation proposed for modeling the site index of the plantations and their respective *IS* labels can be included in a growth and yield system so that they can form the basis for forest management focused on classifying forest areas according to their timber productivity, aligned with the particular growth conditions (Castillo-López *et al.,* 2018; Hernández-Ramos *et al.,* 2022).

Revista Bio ciencias
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Therefore, the different growth trends in dominant height, the *IS* classes, and the increments obtained can be used in decision-making for the forest management of *Pinus leiophylla* plantations or as a tool to classify forest areas according to their timber productivity in the IC of Patamban, Michoacan state, or to define the cutting rotations for this type of forest crop (García-Espinoza *et al.,* 2018; Hernández-Ramos *et al.,* 2022).

Conclusions

The adjustment of the Schumacher model [8] allowed for a more precise and reliable description of dominant height and the generation of anamorphic site index curves that adequately describe the sample variation of dominant height in *Pinus leiophylla* forest plantations, which can be used to classify forest plantations according to the site productivity level.

The proposed expressions can be included in a growth and yield system with acceptable accuracy. The generated dominant height equations describe the dispersion of obtained data, fulfilling the desirable characteristics of a prediction model, such as a sigmoidal behavior, an inflection point, a horizontal asymptote, and the three site index classes presenting growth culmination.

The technical rotation in dominant height for the anamorphic curves occurs at approximately six years for the site index labels of 10, 14, and 18 meters.

Author Contributions

Conceptualization and work development, Author 1 and 2; Methodology development, Author 1 and 2; Software management, Author 2; Experimental review and validation, Author 2 and 4; Results analysis, Author 1 and 2; Data management, Author 1, 2, and 3; Manuscript writing and preparation, all authors; Review and editing, all authors.

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Conflict of Interest

"The authors declare that they have no conflict of interest."

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