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Article

# Plantación de cuatro especies de bambú establecidas en el trópico seco de Michoacán, México

# Planting of four bamboo species established in the dry tropics of the state of *Michoacán*, Mexico

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**Resumen**

El bambú es una planta cosmopolita, de origen asiático con enormes ventajas de uso, por su rápido crecimiento y resistencia a condiciones ambientales extremas. En el presente trabajo se plantearon como objetivos: evaluar la supervivencia y crecimiento de cuatro especies de bambú establecidas en condiciones del trópico seco del estado de Michoacán; y comparar los incrementos (IMA) en altura y diámetro con otros taxones tropicales utilizados en plantaciones comerciales de la entidad. Los taxa estudiados fueron: *Guadua aculeata*, *G. inermis*, *G. amplexifolia* y *G. angustifolia.* Previo al establecimiento de la plantación se realizó un barbecho y rastreo. Se utilizó un diseño completamente al azar, con cuatro tratamientos (especies) y cuatro repeticiones por tratamiento; cada unidad experimental estaba compuesta por 25 plantas, (100 por taxón). Las variables consideradas fueron: altura total (*At*), diámetro de la base del tallo (*DBT*) y supervivencia. A los 400 días, *G. inermis* registró la mayor supervivencia con 99 %, y crecimiento en *At* y *DBT* con un promedio de 2.12 m y 21.27 mm, respectivamente. El IMAA de *G. inemis* no superó los de *Gmelina arborea, Tectona grandis, Acrocarpus fraxinifolius* y *Cedrela odorata*; sin embargo, fue mayor a los documentados para *T. grandis* y *Eucalyptus camaldulensis* en los municipios de Nuevo Urecho y Buenavista, Michoacán. Los resultados del desarrollo de *G. inermis* evidenciaron una buena adaptación a las condiciones del sitio de plantación, con una tendencia a un crecimiento mayor tanto en altura, como en diámetro durante los siguientes años, después de la plantación.

**Palabras clave:** Crecimiento y desarrollo, *Guadua* spp., plantaciones comerciales, supervivencia, riego, especies exóticas.

**Abstract**

Bamboo is cosmopolitan, of Asian origin, which offers enormous advantages of use due to its rapid growth and resistance to extreme environmental conditions. In the present work, the following were proposed as objectives: to evaluate the survival and growth of four bamboo species established in conditions of the dry tropics of the state of *Michoacán*; and to compare the increases (IMA) in height and diameter with other tropical species used in commercial plantations in the entity. The evaluated species were: *Guadua aculeata, G. inermis, G. amplexifolia* and *G. angustifolia*. Prior to the establishment of the plantation, a fallow and tracing was carried out. A completely randomized design was used, with four treatments (4 species) and 4 replications per treatment. Each experimental unit consisted of 25 plants, (100 plants per species). The assessed variables were: total height (*At*), diameter of the stem base (*DBT*), and survival. At 400 days, *G. inermis* reached the highest survival (99 %), and growth in at and *DBT*, respectively with an average of 2.12 m and 21.27 mm, compared to the other species. The IMAA of *G. inemis* did not exceed the increase shown by *Gmelina arborea, Tectona grandis, Acrocarpus fraxinifolius* and *Cedrela odorata*, however, it surpassed those reported for *T. grandis* and *Eucalyptus camaldulensis* in *Nuevo Urecho* and *Buenavista* municipalities, state of *Michoacán*. The results of the development of *G. inermis* show a good adaptation to the conditions of the planting site, with a tendency to a greater growth in height as well as in diameter, during the following years.

**Key words:** Growth and development, *Guadua* sp., commercial plantations, survival, irrigation, exotic species.

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# Introduction

Bamboo is used mainly in countries such as China and Colombia for the manufacture of furniture, handicrafts, laminates for floors, articles for the kitchen, as food, and as construction material (Cedeño and Irigoyen, 2011; Londoño and Ruiz, 2014; Zaragoza -Hernández *et al*., 2014; Maya *et al*., 2017). It offers several advantages compared to other forest species. For example, teak grows up to 30 m and is harvested after 20-25 years, depending on the planting density; on the other hand, some species of the *Guadua* genus grow up to 25-30 m in height in 5 or 6 months and are harvested after 4 or 5 years (when the stems mature) (Camargo, 2014). There are some reports that bamboo grows three times faster than eucalyptus and can be harvested from the fifth year for a period of 80 to 120 years, which is not common in timber species (Kibwage *et al*., 2008; Lárraga and Rivera, 2018). Furthermore, a production of 60 ha of bamboo is considered to be equivalent to the timber of 500 ha of valuable tropical trees (Kibwage *et al*., 2008). It also has ecological advantages, because it captures 40 % more carbon dioxide in the first three years compared to what pines and eucalyptus trees capture in a decade, to which it should be added that it produces between two and four tons of biomass per hectare (Cedeño and Irigoyen, 2011; Zaragoza-Hernández *et al*., 2014). Likewise, it contains medicinal and nutritional properties and is a source of human food and of great ornamental importance (García *et al.,* 2007).

There are eight genera and 55 native bamboo species described for Mexico: four herbaceous and 51 woody ones distributed in most of the states, with the exception of *Baja California, Coahuila* and *Tlaxcala* (Ruiz-Sánchez *et al*., 2015). The most representative genus in Mexico, Argentina, Uruguay, Peru, Cuba, Puerto Rico and Trinidad is *Guadua*, since there are 26 species that can be found between 0 and 2 200 masl, although they are more abundant below 1 500 masl (Gutiérrez and Dorantes , 2004; Gutiérrez *et al*., 2016; Lárraga and Rivera, 2018). There are five species of this genus in Mexico (*G. aculeta* Rupr. ex E. Fourn., *G. amplexifolia* Presl., *G. longifolia* (E.Fourn.) R. W. Pohl, *G. inermis* Rupr. ex E. Fourn. and *G. velutina* Londoño & L.G. Clark) and are considered the largest and most leafy of Mexican bamboos (Cedeño and Irigoyen, 2011; Maya *et al*., 2017). In addition, of the

five native species of *guaduas*, there is an exotic species, *Guadua angustifolia* Kunth (Gutiérrez *et al*., 2016); together, these species can be in production mainly in warm-sub-humid climates of the country, where they can grow up to 25 m high and reach basal diameters of 25 cm, as it happens with *G. aculeata* (Cruz, 2009; Ruiz-Sánchez *et al.*, 2015).

*G. aculeata,* called *otate*, jar, reed, or wild cane, has been declared as the most used in rural areas of the state of *Veracruz*. The stem is used as a pipe for drinking water, the reeds for fishing rods and in the manufacture of crates, cages and cradles. Also for the construction of rural houses and the elaboration of stairs, construction falsework and fencing of farms (Gutiérrez and Dorantes, 2004; Gutiérrez *et al.,* 2016).

*Guadua amplexifolia*, also known as *otate*, is characterized by its tall size and thick stems; its thorny stems have large pods up to 25 cm long and 20 cm wide. The wood is used for beams, rafters, roofs, fences for houses, living fences and for firewood; in Mexico it is recorded in the states of *Sinaloa, Tamaulipas, Hidalgo, San Luis Potosí, Hidalgo, Veracruz, Morelos, Oaxaca, Tabasco* and *Chiapas* (Juárez and Márquez, 1992; Zaragoza-Hernández *et al*., 2014).

*G. angustifolia* is considered the most important species of the genus because it is a non-timber forest product, but of great value for commercial use, and with outstanding growth rates (11 to 21 cm per day) (Deras, 2003; Ortíz, 2017; Panizzo *et al*., 2017).

*Guadua inermis* is one of the few native species in Mexico. It grows in the coastal plain to the northwest of the region of *Los Tuxtlas*, state of *Veracruz*, it has a solid cane, at least up to half of its stem, and one of its main characteristics is the absence of basal branches with thorns; in addition, they have affinity in some morphological characters with *G. amplexifolia*, with which it shares a cespitose habit (Londoño and Ruiz, 2014).

The area of commercial plantations in Mexico is small. At the end of 2018, the establishment of 349.2 thousand ha with commercial forest plantations (PFC) was registered, of which 222.9 thousand ha belong to timber PFCs, 101.3 thousand ha to non-timber PFCs and 24.9 thousand ha $^{-1}$ for dual purpose PFC. The main species that have been established in timber PFCs are: eucalyptus (42 305 ha), red cedar (37 219 ha), pine (34 050 ha), teak (30 775 ha) and melina (28 062 ha), which account for

77 % of the total surface area of timber PFCs. The rest (23 %) of non-timber and dual-purpose PFCs with species such as: candelilla (38 516 $ha^{-1}$), lechuguilla (29 299 ha) and pine nut oil (12 905 ha), group 80 % of the total and the rest with other species (includes bamboo plantations) (Conafor, 2019).

Bamboo in Mexico has been managed for different purposes since pre-Hispanic times and currently in different productive projects. It represents a wide area of opportunity for research and development due to its economic and ecological profitability; therefore, it is essential to evaluate non-timber forest plantations with bamboo species, as it has been done in *Veracruz, Tabasco* and *Chiapas* where many field works have been carried out (Juárez and Márquez, 1992; Cortés and Gilberto, 2007). In this context, the study carried out by Orozco *et al*. (2018), who studied three plantations in rainy conditions with *Guadua angustifolia* in the *Comala* municipality, state of *Colima*; their results indicate a favorable growth in height and IMMA, of 5.4 m and 0.22 m per month, respectively, four years after it was established, and 95 % survival.

Based on the foregoing, the aims of the research described below were to assess the survival and growth of four bamboo species of the *Guadua* genus established in the dry tropics of the state of *Michoacán*; and to compare the increases (IMA) and growth rates in height and diameter with other tropical species used in commercial plantations in the state. As a starting assumption, the hypothesis that bamboo species reach greater development than other woody species was proposed.

# Materials and Methods

## Study area

The plantation is within the *Apatzingán* Valley Experimental Field (CEVA) of INIFAP located in the *Apatzingán* municipality, *Michoacán*. The region to which it belongs is part of the *Sierra Madre del Sur* of the state, and the plantation itself is located between 19°00'40.6'' north and 102°13'29.3'' west, at an average altitude of 343 m (INAFED, 2019).

The climate is $Aw_o$ (w) warm subhumid with rains in summer (Köppen modified by García (1973), the mean annual precipitation is 800 to 1000 mm, with a percentage of winter rain less than 5 and temperatures that range from 14 to 36 °C.

The soil is Pelic vertisol, of calcareous, clayey origin and with a depth greater than 1.0 m (INAFED, 2019). The soil pH in the plantation is 7.58 (moderately basic) and with a sandy clay loam texture (20 % silt, 25.40 % clay and 54.605 % sand), with 1.99 % organic matter. The land is flat with an average slope of 1 % (Inegi, 2009).

The vegetation surrounding the plantation site is mainly made up of tropical deciduous forest, by species such as *zapote* (*Diospyros digyna* Jacq.), *chico zapote* (*Manilkara zapota* (L.) P. Royen.), *parota (Enterolobium cyclocarpum* (Jacq.) Griseb.), *ceiba* (*Ceiba* sp.), *ramón* (*Brosimum alicastrum* Sw. subsp. *alicastrum* C.C. Berg), *finzán* or *guamúchil* (*Pithecellobium dulce* (Roxb) Benth.), and *tepeguaje* (*Lysiloma acapulcense* (Kunth) Benth) (INEGI, 2009).

## Species used and characteristics of the plant

The evaluated species were *Guadua aculeata, G. inermis, G. amplexifolia* and *G. angustifolia*. The plant was produced in the nursery of the Experimental Field of *Tecomán, Colima* of INIFAP, and later it was transferred to the *C. E. Valle de Apatzingán* for its establishment. A black polyethylene bag (1 + 1) of 5 × 20 cm and with a volume capacity of 393 ml was used, the substrate used was 60 % oak soil (decomposing litter) and 40 % red soil (topure-Andosol soil). Prior to planting, a fallow and tracing was carried out, later it was established in July 2018. A common strain of 25 × 25 × 25 cm long, high and wide, respectively, was used. Additionally, irrigation was applied (4 L of water per plant). After the establishment of the plantation, irrigation was applied every 15 days. In addition, a soil analysis was carried out that showed deficiencies of Fe and Zn; to correct it, monthly applications of foliar fertilizer were made in the four species (Quelato® of Fe and Zn) at doses of 4.11 and 0.29 ppm, respectively.

## Experimental design and assessed variables

The statistical design used was a completely randomized model, with four treatments (4 species) and 4 replications per treatment. Each experimental unit consisted of 25 plants, with a total of 100 plants per species. The variables evaluated were the total height of the plant (*At*: cm) with the help of an Apex model topographic staff graduated in cm, the diameter of the stem base (*DBT*: mm) was measured with a Neiko digital Vernier caliper and survival (dead or alive) via direct count. The variables (height, *DBT* and survival) were measured at 40, 80, 160, 360 and 400 days after planting.

With the variables *At* and *DBT*, an analysis of variance ($p = 0.05$) was made in the Statistica (2018) program 13.0 version; and the relative growth rate was estimated for each one. Survival data when not complying with the assumption of normality were transformed to natural logarithm (*ln*) to be analyzed. In the variables with significant differences, a test of multiple comparisons of Tukey means ($p = 0.05$) with confidence limits of 95 % was carried out. The mathematical model used was the following:

$$Y_{ij} = \mu + A_i + (E_{ij})$$

Where:

$Y_{ij}$ = Random variable that represents the value of the response in the $j^{th}$ observation of the $i^{th}$ treatment

$\mu$ = Constant representing the mean response of the *Y* variable

$A_i$ = Effects of the treatment *i* (*i = 4 Guadua* species)

$E_{ij}$ = Experimental error (Norman *et al*., 1996)

For the analysis of the Relative Growth Rate (TCR) of the *At* and *DBT* of each *Guadua* species, the following function was applied (Villar *et al.,* 2004):

$$TCR = [ln(height\ 2) - ln(height\ \ 1)]/[Time\ 2 - Time\ 1]$$

Where:

*TCR*= Relative Growth Rate (cm or $mm^{-day}$)

*ln (height 2)* = Height of the plant or *DBT* at 400 days (cm)

*ln (height 1)* = Height of the plant or *DBT* at 40 days

*Time 2* = 400 days

*Time 1* = 40 days

# Results and Discussion

## Survival

The differences in the survival percentage were significant ($p$ <0.05), in which the highest value obtained after one year of planting was from *G. inermis* with 99 %, followed by *G. amplexifolia* with 96 %, while *G. aculeata* and *G. angustifolia* obtained a survival of 62 %, respectively (Figure 1).

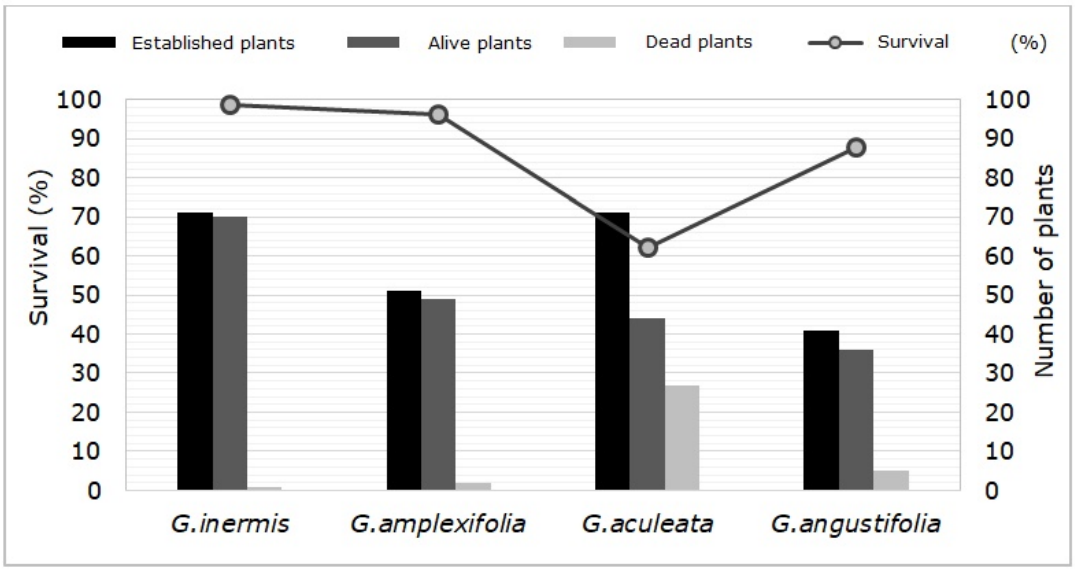


**Figure 1.** Average survival of four bamboo species under irrigation conditions at the dry tropics of the state of *Michoacán*.

The variation in the survival percentage among bamboo species is mainly due to the edaphoclimatic requirements of each *Guadua* species. In this regard, in vegetative propagation work carried out under controlled greenhouse conditions, 100 % survival was recorded; *G. angustifolia* is easy to reproduce, as long as the agroecological requirements for its optimal development are taken into account (Jiménez *et al.,* 2006). On the other hand, these results are similar to those obtained by Orozco *et al.* (2018), who evaluated three plantations under temporary conditions of *G. angustifolia* in *Comala, Colima*, since they calculated an average survival of 94 % at 40-months old.

The results of the present study are superior, compared to those of Ely *et al.* (2017), since for a plantation in Colombia with *G. angustifolia* they managed to achieve an average survival of 64 % at 44 months of age.

In another work, but with fast-growing timber species (*Gmelina arborea*, *Tectona grandis, Acrocarpus flaxinifolius* and *Eucalyptus camaldulensis*), under tropical climate conditions located in *Múgica* and *Nuevo Urecho*, *Michoacán*, Muñoz *et al*. (2010), determined survival percentages at the age of 2.5 to 7 years of planting, similar to those of this research, of between 88 and 96 % survival for *Gmelina arborea* and *Tectona grandis*, respectively.

## Height growth

The increase of this variable (*At*) showed an increasing trend for each species evaluated in regard to the last evaluation, which was maintained from 40 to 400 days after its establishment; the highest average growth for this variable was recorded by *G. inermis* with 2.12 m, followed by *G. amplexifolia* with 1.26 m; while the lowest *At* was presented by *G. angustifolia* (0.81 m) and *G. aculeata* (0.80 m) (Figure 2).

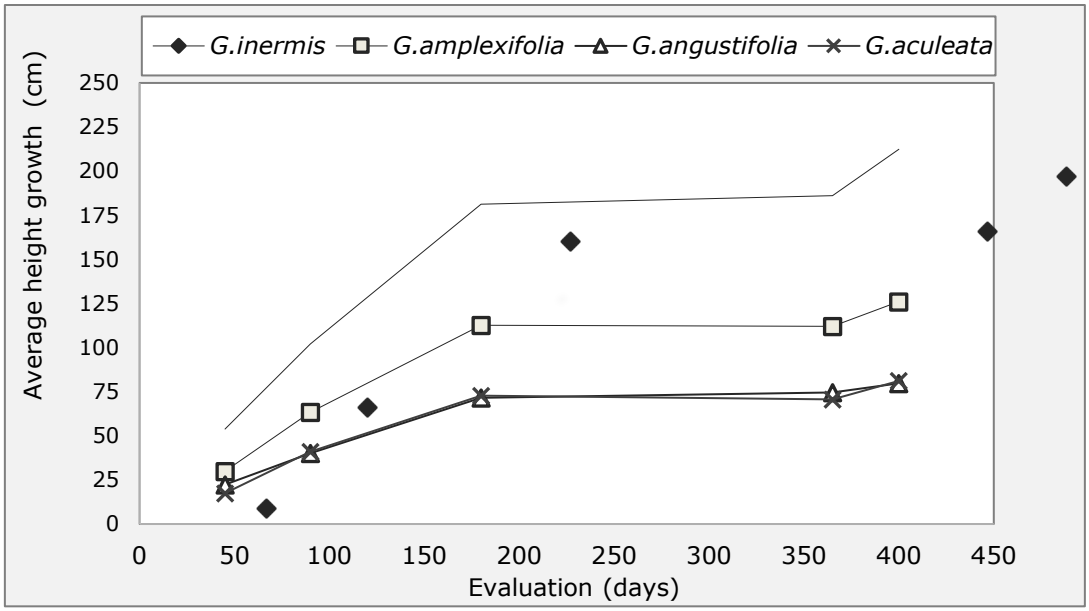


**Figure 2.** Average height growth (cm) of four bamboo species species under irrigation conditions at the dry tropics of the state of *Michoacán*.

Table 1 shows the average growth differences in *At* at 40 and 400 days of the plants ($P < 0.0001$) and the TCR of the four bamboo species, of which *G. inermis* reached the highest growth in height at 400 days from its establishment with an average height of 2.12 m, as well as the highest TCR and average annual increase (1.93 m year$^{-1}$). In contrast, the species that presented the lowest heights, relative growth rate and IMMA correspond to *G. angustifolia* (0.74 m year$^{-1}$) and *G. aculeata* (0.73 m year$^{-1}$) (Table 1). The low growth in height evidenced by *G. angustifolia*, under irrigated conditions in the dry tropics of the state of Michoacán, differs from the results obtained for this same species in three plantations established under storm conditions in *Comala, Colima* since it reached average height from 4.6 to 5.60 m at 40 months after its establishment (Orozco *et al*., 2018). They also differ from those corresponding to *Bambusa oldhamii* Munro, since by the fourth year of planting it had reached 11.8 m in height in a locality in the state of *Veracruz* (Castañeda-Mendoza *et al*., 2005).

**Table 1.** Average growth differences in total plant height (p <0.0001) and relative growth rate (TCR) of four bamboo species under irrigation conditions in the dry tropics of the state of *Michoacán*.

| Species | Height of the plant (cm) | | TCR | IMmA | IMAA |
|---|---|---|---|---|---|
| | 45 Ddp | 400 Ddp | (cm day$^{-1}$) | (cm month$^{-1}$) | (m year$^{-1}$) |
| *Guadua inermis* Rupr. ex E. Fourn. | 53.83 a | 212.41 a | 0.495 | 17.70 | 1.93 |
| *Guadua amplexifolia* Presl. | 29.93 b | 126.08 b | 0.300 | 10.50 | 1.15 |
| *Guadua angustifolia* Kunth | 22.33 c | 81.11 c | 0.179 | 6.60 | 0.74 |
| *Guadua aculeata* Rupr. ex E. Fourn. | 17.48 c | 79.74 c | 0.198 | 6.80 | 0.73 |

Ddp = Days after planting; TCR = Relative Growth Rate in height; IMmA = Monthly mean increment in height; IMMA = Annual mean increment in height.

The growth potential of *G. inermis* is largely explained by the environmental conditions. However, it should be taken into account that these growths in height shown by the four studied species correspond only to the first year of assessment, that is, to their juvenile stage, since in bamboo species the plants reach their maximum height between one and two years (Castañeda-Mendoza *et al*., 2005; Camargo, 2014) and sometimes up to 5 years (Cedeño and Irigoyen, 2011; Zaragoza-Hernández *et al*., 2014; Ortíz, 2017); therefore, the growth rates registered up to now will have a trend greater height at older age, and it could be expected that for the next few years this variable will be even taller. In this regard, in Colombia, Cruz (2009) recorded growth values in diameter and height of *G. angustifolia* that continued to increase until nine years after planting.

On the other hand, Camargo *et al.* (2010) described average heights of 10.10 m at the seven years of the plantation establishment with the same species in *Pereira*, Colombia, with an IMAA of 1.44 m year$^{-1}$, in sites located at 1 200 masl, in Andosols,

with neutral pH, high content of organic matter and slightly limited by clay content and an average annual rainfall of 1 900 mm and average temperature of 24 °C; Duarte *et al.* (2016) that *G. angustifolia* grows in all types of soils, but those with a sandy loam texture (53 % sand, 28 % silt and 19 % clay) are not suitable for the successful development and structural quality of the species.

The growth differences in height are possibly due to the edaphoclimatic conditions in which the plantations with *Guadua* species were made; Such is the case of the *Colima* plantations, since despite the fact that the climate is similar (not the same) to that of *Michoacán*, the type of soil in the locality of the plantation is Pelic vertisol and in *Comala, Colima*, it is Regosol and this species prefers well-drained alluvial soils (Mercedes, 2006).

This is an important point that should be considered: that the soils where plantations with these species are established must have good drainage, to avoid flooding (Camargo, 2014; Duarte *et al.,* 2016; Ortiz, 2017), since the factors of site directly influence the growth and development of *Guadua* species. On the other hand, Camargo (2006) maintains that due to the wide geographic distribution of *G. angustifolia*, and its adaptability to different climates and soils, it may be different in terms of its development and growth, determined by the quality of the planting site, the precipitation and temperature of the place (Giraldo and Sabogal, 1999).

In other works such as the one carried out by García *et al.* (2008) and García and Camargo (2010), mention that the *Guadua* species in Colombia show the best growth rates in height, between 1 200 and 1 500 m of altitude, with temperatures of 19.6 to 21.3 °C and slopes of up to 18 %. Likewise, the ideal soil conditions are given by low planting densities and high aluminum content. It is worth mentioning that the best soils in which *G. angustifolia* grows are those with a clay-silty loam texture, but it also thrives on soils with a silty-loam, clay-loam and sandy-loam texture (Camargo, 2006; Camargo, 2014; Duarte *et al.,* 2016).

The growth of *G. inermis* showed good adaptation to the plantation site in the dry tropics of the state of *Michoacán*, with a tendency to greater height and diameter,

due to the fact that the soil conditions are clay loam and sandy loam and with 1.99 % organic matter. This growth behavior is expected to continue during the following years, as to consider this species with potential enough to establish commercial non-timber plantations in the state.

When comparing the IMAA of *G. inemis* (1.93 m year$^{-1}$), with the results of the evaluation of 12 commercial plantations of timber species in the dry tropics of the entity (Muñoz *et al*., 2010), the increases were higher than favor of timber species, since *Gmelina arborea* reached increases of 8.58 to 4.65 m year$^{-1}$, *Tectona grandis* from 3.33 to 2.35 m year$^{-1}$, *Acrocarpus fraxinifolius* of 3.20 and 2.79 m year$^{-1}$, and *Cedrela odorata* with 3.14 m year $^{-1}$.

However, it also refers that the species of *T. grandis* and *E. camaldulensis* showed the lowest IMAA with 1.57 to 1.65 m year$^{-1}$ and from 1.52 to 1.81 m year$^{-1}$ in the *Nuevo Urecho* and *Buenavista* municipalities in the state of *Michoacán*. Respectively, where these are slightly exceeded by those obtained for *G. inermis* (± 15 cm on average). These results agree with some of the advantages of bamboo species, compared with any forest species, in this particular case with *T. grandis,* and *E. camaldulensis* (Camargo, 2014).

## Diameter at the base of the stem

The results of the analysis of variance for *DBT* were significant; the growth differences in this variable ($p$ <0.0001) and the relative growth rate at 40 and 400 days, stood out for *G. inermis* with an average growth of 9.26 mm and 21.27 mm respectively and higher than the *DBT* growths shown in regard to *G. amplexifolia* (6.8-12.76 mm), *G. aculeata* (4.91-10.32 mm) and *G. angustifolia* (4.48-5.93 mm) (Table 2). The highest mean annual increase in *DBT* was exhibited by *G. inermis* with 19.41 mm year$^{-1}$, followed by *G. amplexifolia* with 11.64 mm year$^{-1}$, *G. aculeata* with 9.42 mm year$^{-1}$ and finally *G. angustifolia* with 5.41 mm year$^{-1}$ (Table 2).

**Table 2.** Average growth differences in base diameter ($p$ <0.0001) and relative growth rate of four bamboo species under irrigation conditions in the dry tropics of the state of *Michoacán*.

| Species | Base diameter of the plant (mm) | | TCR (mm day$^{-1}$) | IMmD (mm month$^{-1}$) | IMAD (mm year$^{-1}$) |
|---|---|---|---|---|---|
| | 45 Ddp | 400 Ddp | | | |
| *Guadua inermis* Rupr. ex E. Fourn. | 9.26 a | 21.27 a | 0.034 | 1.773 | 19.41 |
| *Guadua amplexifolia* Presl. | 6.28 b | 12.76 b | 0.018 | 1.064 | 11.64 |
| *Guadua aculeata* Rupr. ex E. Fourn. | 4.91 c | 10.32 c | 0.006 | 0.500 | 9.42 |
| *Guadua angustifolia* Kunth | 4.48 c | 5.93 d | 0.015 | 0.860 | 5.41 |

Ddp = Days after planting; TCR = Relative Growth Rate in height; IMmA = Monthly mean increment in diameter; IMAD = Annual mean increment in base diameter.

In this regard, Camargo *et al*. (2010) reported similar growth results in average *DBT* of 5.1 (± 1.7) cm, seven years after the establishment of *G. angustifolia* plantations in *Pereira*, Colombia. However, the dimensions in diameter and height were lower (up to 50 %) than those recorded in natural forests of *Guadua* (Camargo *et al*., 2010; Camargo and Arango, 2012); this means that the plants have not yet reached their maximum growth, as mentioned by Castañeda-Mendoza *et al.* (2005), Daquinta *et al.* (2007) and Cruz (2009) in their respective works, due to the fact that bamboo species continue to increase in height and diameter as time goes by for up to nine years after being planted.

In another contribution with timber species such as that of Muñoz *et al*. (2010), for *E. camaldulesis* established under storm conditions, the IMA of the stump diameter was 16.30 mm year$^{-1}$ at seven years in *Buenavista* municipality, *Michoacán.* These results were surpassed by the IMA of the stump diameter of *G. inermis* with 19.41 mm year$^{-1}$, at the first year of its establishment; therefore, it is considered that *G. inermis* has an opportunity for plantations in the dry tropics of *Michoacán*. However, it is necessary

to carry out a soil analysis prior to its establishment, in order to buffer the nutrient deficiency that may exist, as was done in this research, since as mentioned by Maya *et al.* (2017), site conditions influence the physical-mechanical properties (density and hardness) of culms and provide different growth characteristics. Therefore, the appropriate selection of planting sites should be considered, according to the intentions for which it is desired to orient their use.

# Conclusions

The edaphoclimatic factors and the precipitation present in the plantation site in *Michoacán* apparently influenced the growth in height and diameter of the four evaluated bamboo species, since these registered lower yields compared to other timber species in commercial plantations in the state. However, the *Guada inermis* species one year after its establishment, showed a good adaptation to the conditions of the planting site that correspond to the dry tropics of the state of Michoacán, with a survival of 99 % and a trend towards a greater growth in height and diameter during the following years. Therefore, this species could be considered with potential for the establishment of commercial plantations in sites with similar conditions in the state.

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**Conflict of interests**

The authors declare no conflict of interests.

## Contribution by author

H. Jesús Muñoz Flores: field work and writing of the manuscript; J. Trinidad Sáenz Reyes: review and correction of the manuscript; Jonathan Hernández Ramos: general review and correction of the manuscript; Gabriela Orozco Gutiérrez: general review and correction of the manuscript; Rubén Barrera Ramírez: data statistical analysis.

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