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Research note

Calidad de planta de seis especies del género *Pinus* producidas en bolsas de polietileno

Seedling quality from six *Pinus* species produced in polyethylene bag

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Resumen

Los restauradores de áreas degradadas requieren de planta de calidad con atributos morfológicos ideales para lograr su establecimiento con éxito en el sitio de la plantación, aun cuando las condiciones del sitio sean adversas. Para conocer la calidad de seis especies de pino que serán empleadas durante la reforestación y restauración de terrenos forestales en el Estado de México, se realizó la evaluación de cinco atributos morfológicos con base en lo citado en la Norma Mexicana NMX-AA-170-SCFI-2016 y un artículo científico en el Vivero Forestal Héroes Bicentenario de Tecámac: diámetro al cuello de la raíz (DC), altura desde la base hasta la yema apical (Alt), índice de esbeltez (IE=Alt/DC), relación biomasa seca aérea y biomasa seca de raíz (BSA/BSR) e índice de calidad de *Dickson* (ICD). Para DC, los resultados mostraron que todas las especies, excepto *Pinus ayacahuite*, tuvieron calidad alta. En Alt, *P. greggii* y *P. leiophylla* tuvieron la mejor calidad; mientras que en IE, todos los taxones, menos *P. greggii*, presentaron alta calidad. Para la relación BSA/BSR: *P. cembroides*, *P. ayacahuite* y *P. hartwegii* fueron los mejores, y para ICD, *P. hartwegii* presentó el mayor valor de calidad. Al considerar todos los indicadores morfológicos juntos, se determinó que *P. cembroides* y *P. greggii* registraron la mejor calidad de planta. Esta información es clave para analizar la supervivencia esperada en campo y tomar decisiones oportunas en la gestión forestal.

Palabras clave: Atributos morfológicos, incremento de supervivencia, Probosque, producción de planta en vivero, reforestación, restauración forestal.

Abstract

The restorers of degraded areas require high quality plants, with ideal morphological attributes to be able to establish successfully in the plantation sites, even if the site conditions are adverse. In order to know the plant quality of six pine species that will be used for reforestation and restoration of forest lands in the state of México, five morphological attributes based on the Mexican Norm NMX-AA-170-SCFI-2016 and a paper were assessed. At the *Héroes Bicentenario* Forest Nursery of *Tecámac*, seedling's basal diameter (at the root neck (DC)), height, from the base to the apical bud (Alt), slenderness index (IE = Alt/DC), aerial dry biomass and dry root biomass ratio (BSA/BSR) and Dickson's quality index (ICD) were determined. For DC, the results showed that all species except for *Pinus ayacahuite*, had high quality. In Alt, *P. greggii* and *P. leiophylla* had the best quality; while in IE, all the species except for *P. greggii*, showed high quality. For the BSA/BSR ratio, *P. cembroides*, *P. ayacahuite* and *P. hartwegii* were the best, and for ICD, *P. hartwegii* had the highest quality value. Considering all the morphological indicators together, it was concluded that *P. cembroides* and *P. greggii* had the best plant quality. This information is crucial to analyze the seedling's survival in the field and make timely decisions in land restoration management.

Key words: Morphological attributes, increased survival, *Probosque*, nursery plant production, reforestation, forest restoration.

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During the reforestation process in degraded areas, it is necessary to use quality plants so that they have a greater ability to establish, grow and develop in the plantation sites (Muñoz *et al.,* 2015). Consequently, its use increases the survival percentage, since, once established in the field, it will be able to live and grow, even in places with low productivity.

However, it is difficult to obtain suitable plant for each site. The attributes that determine its quality refer to morphological and physiological qualities (Mexal and Landis, 1990). The former are related to the structure of the plant; while, the physiological ones to the responses it has when being planted (Rose *et al.,* 1990). The morphological criteria are more often used than the physiological ones to assess plant quality (Haase, 2008).

The main morphological attributes are stem height, neck diameter, root system, height-diameter ratio (robustness index), biomass, foliar area and presence of mycorrhizae (Escobar-Alonso and Rodríguez, 2019). In regard to the physiological ones, those used are the concentration of carbohydrates, nutritional status, water potential, electrical conductivity, stomatal conductivity, CO_2 assimilation and chlorophyll fluorescence (Escobar-Alonso and Rodríguez, 2019).

Despite the fact that there is experience on the evaluation of the plant quality parameters in Mexican forest species, the great variability in conditions and production processes in the nurseries means that knowledge in this sense is still limited, so it is necessary to carry out more research in this regard. Therefore, the present work aimed to assess the quality of the plant in the nursery of six species of the *Pinus* genus produced in polyethylene bags.

At the *Héroes Bicentenario* Forest Nursery located in *Tecámac*, State of Mexico (administered by the *Protectora de Bosques* of the State of Mexico), 90 *Pinus* plants of six species were randomly chosen (15 plants per species), produced in natural ground and polyethylene bags (10 × 24 cm). The age of the plant material was different: *Pinus greggii* Engelm. ex Parl. and *P. leiophylla* Schiede ex Schltdl. & Cham., were 7 months-old; *P. pseudostrobus* Lindl., 10 months-old; *P. ayacahuite* Ehrenb.

ex Schltdl., 12 months-old; *P. hartwegii* Lindl., 14 months-old and *P. cembroides* Zucc., 15 months-old.

Each individual was evaluated for their plant quality by measuring the diameter (mm) at the root neck (DC) with a Mitutoyo 500 - 196 - 30 digital vernier, and the height (cm) from the base to the apical bud (Alt) with a Westcott H-6560 graduated ruler; the data of both variables were used to calculate the Slenderness Index (IE = Alt / DC). Substrate was removed from all plants and the stem and root were sectioned.

The plant material (aerial part and root) was placed separately in paper bags, dried in a Novatech HS35-AIA oven (50 °C, 9 days) and weighed with a Ohaus, Harvard Trip® two-plates scale to estimate aerial dry biomass (BSA, g), root dry biomass (BSR, g), total dry biomass (BST, g), BSA / BSR ratio and Dickson's quality index [ICD = BST / (IE + BSA / BSR)] (Dickson *et al.,* 1960).

To determine the quality of the plants (high, medium or low), the values obtained for DC and Alt were compared to the morphological indicators of plant quality at the nursery that are stipulated in the NMX-AA-170-SCFI-2016 Mexican Standard (Secretaría de Economía, 2016); while IE, BSA / BSR and ICD with the intervals cited by Rodríguez-Ortiz *et al*. (2020) (Table 1).

Table 1. Values and intervals of morphological indicators of plant quality.

Variable / Species	Plant quality¶		
	B = Low	M = Medium	A = High
DC† (mm)			
Pinus ayacahuite Ehrenb. ex Schltdl.	-	-	≥ 4
Pinus cembroides Zucc.	-	-	≥ 4
Pinus greggii Engelm. ex Parl.	-	-	≥ 4
Pinus hartwegii Lindl.	-	-	≥ 4
Pinus leiophylla Schiede ex Schltdl. & Cham.	-	-	≥ 4
Pinus pseudostrobus Lindl.	-	-	≥ 4
Alt† (cm)			
Pinus ayacahuite Ehrenb. ex Schltdl.	20	-	30
Pinus cembroides Zucc.	15	-	25
Pinus greggii Engelm. ex Parl.	25	-	30
Pinus hartwegii Lindl.	N/A	N/A	N/A
Pinus leiophylla Schiede ex Schltdl. & Cham.	20	-	25
Pinus pseudostrobus Lindl.	25	-	30
IE‡	≥ 8.0	(8.0 a 6.0)	< 6.0
BSA/BSR‡	> 2.5	(2.0 a 2.5)	< 2.0
ICD‡	< 0.2	(0.2 a 0.5)	> 0.5

¶B = Plants with two or more B quality values, plants that will have low survival and small development in the plantation sites; M = Accepts up to three M quality values and one variable with B quality qualification; A = Plants with minimal presence of undesirable characteristics, and that can accept up to two values with quality M, but in no case values with quality B (Rodríguez-Ortiz *et al*., 2020); † = NMX-AA-170-SCFI-2016 Mexican Standard (Secretaría de Economía, 2016); ‡ = Quality intervals (Rodríguez-Ortiz *et al*., 2020).

In regard to DC, all species, except for *P. ayacahuite*, recorded higher values than those indicated in the NMX-AA-170-SCFI-2016 (Secretaría de Economía, 2016), and thus, they were considered high quality; *P. hartwegii* in particular, was the best of all, since it more than doubled the value indicated in the Standard (Table 2).

Table 2. Average values of plant sizes and qualities of six species of pine produced in the *Héroes Bicentenario* Forest Nursery.

Species	DC¶	Alt	IE	BSA/BSR	ICD
Pinus ayacahuite Ehrenb. ex Schltdl.	3.7	16.2	4.4	1.9	0.9
Pinus cembroides Zucc.	4.6	15.9	3.5	1.5	1.1
Pinus greggii Engelm. ex Parl.	5.0	36.5	7.5	4.6	0.7
Pinus hartwegii Lindl.	9.2	18.4	2.0	2.6	2.2
Pinus leiophylla Schiede ex Schltdl. & Cham.	-	28.4	3.8	5.0	0.9
Pinus pseudostrobus Lindl.	4.8	20.7	4.4	8.3	0.5

¶DC = Neck diameter (mm); Alt = Height (cm); IE = Slenderness index; BSA = Aerial dry biomass; BSR = Root dry biomass; ICD = Dickson's Quality Index.

Results suggested that five species of pine evaluated had the potential to establish themselves in the field, since the diameter dimensions indicate well-developed root systems, resistance to physical damage, twists, tolerance to those caused by animals and to high temperatures on the soil surface (Mexal and Landis, 1990; Birchler *et al.*, 1998; Muñoz *et al.,* 2015).

When comparing the production of these pine trees with that registered in other nurseries, its superiority is evident; for example, in *P. greggii* and *P. pseudostrobus* a medium quality is reported [3.5 and 3.4 mm, respectively] (Rueda *et al*., 2012).

In regard to Alt, *P. greggii* and *P. leiophylla* were above the value suggested in the NMX-AA-170-SCFI-2016 Mexican Standard and *P. cembroides* had values within the proposed interval; however, *P. ayacahuite* and *P. pseudostrobus* had lower height than advisable (Table 2). For *P. hartwegii*, the NMX-AA-170-SCFI-2016 Mexican Standard does not include a maximum or a minimum value, as it is a cespitose species; however, the record obtained was considerably higher than that documented by Bernaola-Paucar *et al.* (2015) (4.3 cm) in 12-month-old trees.

In general, height in pines is a variable that has little value as an indicator of quality, and it does not even correlate, or it does so negatively, with survival in the field (Birchler *et al.,* 1998). However, this characteristic combined with other variables, such as the diameter of the neck (Slenderness Index), acquires greater importance.

For IE, all the species, except for *P. greggii*, recorded a value lower than six (Table 2), which indicates that the plants are more robust, of better quality, that can resist abuse from transfer maneuvers to the plantation site, to drying out by the wind, frost damage and with a better chance of survival and growth in sites with water limitations (Haase, 2008; Escobar-Alonso and Rodríguez, 2019). In the case of *P. greggii*, excessive growth in height (36.5 cm) was observed, despite the fact that its diameter corresponded to the NMX-AA-170-SCFI-2016 Mexican Standard (> 4 cm); this ratio would improve with a lower density in the growth bed during the production phase at the nursery, or with pruning to the aerial part prior to going to the field (Muñoz *et al.,* 2015).

In the BSA / BSR ratio, *P. cembroides*, *P. ayacahuite* and *P. hartwegii* recorded the lowest proportions (Table 2) which indicated high quality, from a good balance between the biomass of the aerial part and the root (Haase, 2008), as well as greater possibilities of success when planted in places with low rainfall (Thompson, 1985).

Conversely, *P. pseudostrobus*, *P. leiophylla* and *P. greggii* had the highest ratios (Table 2), which suggested that they should be planted in places where there are no water availability problems; from its poorly developed root structure, its ability to absorb nutrients and water will be limited to supply the needs of the aerial part (or of the plant) (Escobar-Alonso and Rodríguez, 2019). This can lead to stress due to lack of moisture in dry places before the roots are established, and with this occurs the supply of water and nutrients to the aerial part of the plant.

For ICD, *P. hartwegii* showed the highest value; while *P. greggii* and *P. pseudostrobus* had the lowest; *P. cembroides, P. ayacahuite* and *P. leiophylla* had intermediate values. It was determined that all species, except for *P. pseudostrobus*, show high quality, since their ICD was > 0.5 (Rodríguez-Ortiz *et al*., 2020).

When combining the values of the different evaluated, variables four species, *P. hartwegii, P. cembroides, P. leiophylla* and *P. ayacahuite* registered the best plant quality, with which it can be predicted that they will have greater development possibilities, even if they are established in sites whose conditions are unfavorable for them.

Part of the success of reforesting degraded areas lies in the use of quality plants, with morphological characteristics that allow them to survive and grow, even in unsuitable sites. However, the use of reference values, as well as the evaluation of the morphological attributes of the species produced in the nursery, are still limited in the country (Rueda *et al*., 2014). The results of the present work showed that *P. cembroides* and *P. greggii* have high plant quality; *P. ayacahuite*, low quality; *P. hartwegii*, *P. leiophylla* and *P. pseudostrobus*, medium quality. This information is crucial to analyze the survival that will be obtained in the field, depending on the characteristics of each site, and will favor timely decisions to be made in the forest management of the reforestation areas in which the plant production lots of the plants of the assessed species are intended.

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Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Tomás Pineda Ojeda: planning of the investigation, supervision of works, structuring and writing of the manuscript; Eulogio Flores Ayala: evaluation of variables, writing and discussion of the manuscript; Andrés Flores: data analysis and writing of the manuscript; Enrique Buendía Rodríguez: work planning and evaluation of variables; Vidal Guerra de la Cruz: supervision of works, evaluation of variables; Fabián Islas Gutiérrez: evaluation of variables.

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