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Research note

Contenedores y calidad de planta para Quercus crassipes Bonpl.

Containers and seedling quality for Quercus crassipes Bonpl.

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Resumen
México es el país con más especies de encinos, pero hay pocas investigaciones sobre su propagación y calidad de planta. Se estudió esta última en *Quercus crassipes*, en contenedores de 210 mL y de 150 mL. El sustrato fue composta de corteza de pino (60 %), vermiculita (30 %) y agrolita (10 %). Durante la fase de establecimiento, se aplicó fertilizante iniciador (9-45-15), 100 ppm P, 21.97 ppm N y 62.23 ppm K. En la de crecimiento: fertilizante para crecimiento (20-20-20), 150 ppm N, 66 ppm P y 123 ppm K. En el endurecimiento: fertilizante finalizador (4-25-35), 150 ppm de K, 20 ppm de N y 56.87 ppm P. Se midieron altura, diámetro, número de hojas, área foliar, peso seco foliar, longitud de raíz principal, número de raíces laterales, peso seco aéreo, de raíz y total; la relación peso seco aéreo/peso seco de raíz, coeficiente de esbeltez e índice de *Dickson*. Se empleó un diseño experimental en bloques completos al azar (cuatro repeticiones); se aplicó un análisis de varianza y la prueba de *Tukey*. A los 7 meses, las plantas del contenedor grande mostraron valores superiores para ($p \leq 0.05$) altura (19.2 y 16.0 cm), diámetro (4.3 y 3.6 mm) y longitud de raíz principal. Las demás variables no tuvieron diferencias significativas. La planta presentó calidad en sus indicadores, pero se prefiere la de mayor tamaño, ya que en otras especies presenta más supervivencia. Los contenedores grandes, sustrato y fertilización empleados, se recomiendan para producir planta de calidad y los indicadores obtenidos, como referencia.
Palabras clave: Calidad de planta, *Quercus crassipes* Bonpl.*,* indicadores de calidad, tamaño de contenedor, viveros forestales, viveros tecnificados.

Abstract
Mexico is the richest country in oak species and they span over its territory, however, there is scarce research about its propagation and its seedling quality. Was studied this last in *Quercus crassipes* Bonpl., in two sizes of containers: large (210 mL) and small (150 mL). The growing media was composted pine bark (60 %), vermiculite (30 %) and agrolite (10 %). During the establishment phase was applied starter fertilizer (9-45-15), 100 ppm P, 21.97 ppm N, 62.23 ppm K. During the growing phase, was applied growth fertilizer (20-20-20), 150 ppm N, 66 ppm P, 123 ppm K. In the hardening phase, was used finalizer fertilizer (4-25-35), 150 ppm de K, 20 ppm de N y 56.87 ppm P. Were measured height, caliper, number of leaves, foliar area, foliar dry weight, tap root length, number of lateral roots, shoot dry weight, root dry weight, and total dry weight. Were calculated shoot/root ratio, slenderness coefficient and Dickson index. Was utilized a randomized complete block experimental design (four replications) and performed an analysis of variance and the Tukey test (SAS). The larger container showed larger ($p \leq 0.05$) height (19.2 and 16 cm), caliper (4.3 and 3.6 mm) and tap root length. The other variables exhibited no significant differences. Overall the plant showed good seedling quality indicators, but is preferred the large one, for there is research evidence for other species of its higher field survival. Large containers and the growing media and fertilization employed may be used to produce quality seedlings, while the indicators obtained may be used as reference.
Key words: Seedling quality, *Quercus crassipes* Bonpl., quality indicators, container size, forest nurseries, technified nurseries.

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Development of the Topic

There are 450 species of *Quercus* on the planet, and Mexico is the richest country in this genus, of which it has 170 species (Zavala, 2007). Despite their great expanse and ecological relevance, traditional uses and economic potential, oaks are rarely used in reforestations within the national territory, and there is almost no information regarding their propagation in nurseries or their plant quality. *Quercus crassipes* Bonpl. is a taxon widely distributed in the Mexican Republic; it is found in 11 Mexican states —Mexico City*, Guanajuato, Hidalgo, Jalisco, State of Mexico, Michoacán, Morelos, Oaxaca, Puebla, Querétaro,* and *Tlaxcala—,* at an altitude of 2 400 to 2 900 masl (Zavala, 2003, Arizaga *et al*., 2009). It can reach 35 m in height and 1 m in normal diameter. The objective of this work was to evaluate the quality of the plant produced in two container sizes by means of morphological indexes.

The nursery where the experiment was carried out is located at the coordinates 98°53´ W and 19°23´N, at an altitude of 2 240 masl. The climate type is C (wo) (w) b (i') g: temperate sub-humid with summer rains, the temperature of the coldest month ranging between -3 and 18 °C and little thermal variation, and an average annual rainfall of 686 mm (García, 1981). Seeds (2 kg) were collected in November 2012 in the community of *San Jerónimo Amanalco*, *Texcoco*, State of Mexico, where the climate is temperate sub-humid, with an average annual temperature of 13.4 °C and an average annual rainfall of 1 156 mm, at an altitude of 2 750 m. (19°31’07” N, 98°44’14” W). Those seeds that were not damaged or plagued were selected; they were kept in fresh room conditions (approximately 10 to 15 °C) during five months. In April 2013, they were planted in portable plastic seedbeds, in a mixture of peat moss (40 %), agrolite (20 %), and vermiculite (40 %). An initial application of *Captán*® (1.5 g L^{-1}) was made after 15 days to prevent the presence of phytopathogenic fungi. The seeds remained in the greenhouse for a little over a month until germination. In June 2013, the radicle of several of the seedlings (8 cm in height) was pruned with scissors to a length of 10 cm during their transplantation to two types of black rigid polyethylene trays (treatments): 54 cavities of 210 mL (large containers, with a 5.1 × 4.8 cm square cross section and a length of 14.8 cm) and 60 cavities of 150 mL (small containers with a 4.8 × 4.8 cm square cross section and a length equal to 11 cm). Seedlings were transplanted into eight trays (four replicates per tray size).

The substrate in the trays was a mixture of pine bark compost (60 %), vermiculite (30 %), agrolite (10 %), and 3 kg m^{-3} of Osmocote© 15-9-12 slow release granular fertilizer. Inoculum of *Trichoderma harzianum* (T-22 strain, Plant Health Care *de México*®) was added for its antagonistic activity against phytopathogenic fungi.

The trays were transferred to a growth bed in order to start the establishment stage, and they were placed under a 40 % shade net (which was removed after two months), with Peters™ start fertilizer (9-45-15, containing 0. 1 % Mg, 0.007 % B, 0.05 % Fe, 0.004 % Cu, 0.025 % Mn, 0.001 % Mo, and 0.0025 % Zn) at a dose of 0.506 g L^{-1} (100 ppm P, 21.97 ppm N, and 62.23 ppm K). Also, the pH of the irrigation water was adjusted (e.g., initially from 7.3 to 5.6, using 1.38 mL of H_3PO_4). Irrigation was carried out every other day, at field capacity.

For the growth stage, Peters™ fertilizer for fast growth (20-20-20, which also includes 0.05 % Fe, 0.03 % Mn, 0.01 % B, 0.013 % Cu, 0.005 % Mo, and 0.025 % Zn) was applied at a rate of 0.75 g L^{-1} (150 ppm N, 66 ppm P, and 123 ppm K). The duration of the growth phase was four months. The hardening phase began in October 2013 and lasted two months. During this period, Peters™ finish fertilizer (4-25-35, added with 0.3 % Mg, 0.025 % B, 0.4 % Fe, 0.06 % Cu, 0.06 % Mn, 0.005 % Mo, and 0.06 % Zn), 0.52 g L^{-1} (150 ppm K, 20 ppm N, and 56.9 ppm P) was used.

The collection of the data was carried out when the plants were seven months old (November 2013); 10 plants were collected per repetition (80 plants in total), and the following variables were determined: height (*H*, ruler, cm) and diameter at root collar (*D*, digital vernier, mm), leaf area (*LA*, millimeter mesh, cm^2), number of leaves (*NL*), number of lateral roots (*NLR*), and shoot (S) and root dry weight (*R*) (dried in a *Ríos Rocha*® H-41 oven at 70 °C, until constant weight was obtained). These variables made it possible to calculate the following indices: aerial dry weight/root dry weight ratio (*S*/*R*), slenderness coefficient (*SC*=*H*/*D*), Dickson quality index (*DQI*=*TDW*/[(*S*/*R*) + *SC*)] (Landis *et al.*, 2010), as well as the total dry weight (*TDW*), leaf area to total dry weight ratio (*LA*/*TDW*), leaf area to aerial dry weight (*LA*/*S*), and leaf area to root dry weight (*LA*/*R*).

At the nursery, a randomized complete block experimental design with four replications was established. The factor was the size of the container —large and small. 240 large container plants and 216 small container plants were used, for a total of 456 plants. The statistical model was:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijk}$$

Where:

Y_{ijk} = Response of the k^{th} plant to the j^{th} block and the i^{th} level of the container size effect

μ = Overall average

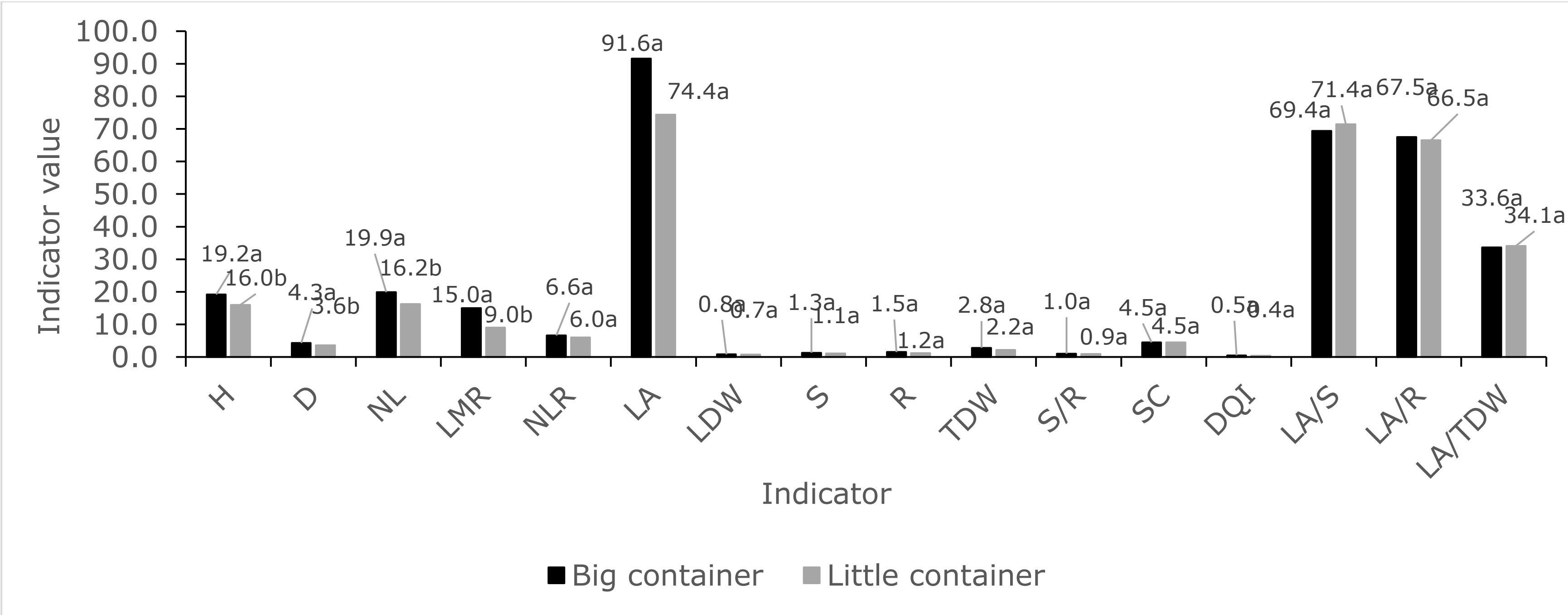
αi = Effect of the i^{th} level of the container size factor

β_j = Effect of the j^{th} block

ε_{ijk} = Experimental error

An analysis of variance and Tukey's mean comparison test were performed (both with $p < 0.05$, when the former was significant). The PROC ANOVA procedure of the SAS V.9 statistical analysis software (SAS Institute, 2002) was utilized for this purpose.

Large containers produced plants with a greater height (19.2 *vs*. 16.0 cm, respectively; $P = 0.0344$), diameter (4.3 and 3.6 mm, $P = 0.0249$), and main root length (15.0 and 9.0 cm, $P = 0.0127$) than small ones, but without significant differences for the rest of the variables ($P > 0.05$). This indicates that the total, aboveground and underground biomass, as well as the ratios between different biomasses were proportional, regardless of the size of the container (Figure 1).



H = Height (cm); *D* = Diameter (mm); *NL* = Number of leaves; *LMR* = Length of main root (cm); *NLR* = Number of lateral roots; *LA* = Leaf area (cm^2); *LDW* = Leaf dry weight (g); *S* = Aerial dry weight (g); *R* = Root dry weight (g); *TDW* = Total dry weight (g); *S/R* = Aerial dry weight/root dry weight; *SC* = Slenderness coefficient, *DQI* = Dickson quality index; *LA*/S = Leaf area/air dry weight (cm^2 g^{-1}); *LA*/*R* = Leaf area/root dry weight (cm^2 g^{-1}); *LA*/*TDW* = Leaf area/total dry weight (cm^2 g^{-1}). Pairs of bars with different letters had significant differences (*Tukey*, $P \leq 0.05$).

Figure 1. Comparison of means of quality indicators.

Although this work was limited to the nursery stage, for any species a larger diameter entails various advantages, such as a root system with greater biomass, the possibility of storing water and carbohydrates, mechanical resistance, and abundance of buds for resprouting, as well as greater survival in low humidity sites (Rodríguez-Trejo, 2008; Landis *et al*., 2010).

Like most species, *Quercus rugosa* Née produced in nursery with a greater height (16 to 24 cm) tends to have better survival in the field (Ramírez and Rodríguez, 2004; Cuesta *et al.*, 2010). Thus, for *Q. ilex* L. in Spain, at low humidity sites, Del Campo *et al.* (2010) report that the large plant (height = 15 cm and diameter = 4 mm) competes better than wild plants and is more resistant to drought. According to Del Campo *et al*. (2010), in dry years, the height (12-17 cm) and diameter (3.5-4.8 mm) predict 2-year survival for *Q. ilex*. Ramírez and Rodríguez (2004) observed the same tendency for *Q. rugosa* produced in plastic bags; the larger plants (16-24 cm in height and 2-4 mm in diameter) had higher percentages of survival (63 %) in the field and growth in height and diameter than the smaller ones at low humidity sites; in particular, if the former are planted in NE exposures and at microsites (NE of a rock). Also, large plants can grow larger, such as *Q. rubra* L. and *Q. alba* L. in the U.S., whose height and diameter were good predictors for these same variables two years after planting (Jacobs *et al.*, 2005).

A study with *Picea mariana* Kuntze shows that the plant with lower slenderness coefficient maintains a better water status and moderate water consumption under drought conditions (Stewart and Bernier, 1995). The biomass variables and their ratios did not show differences between container sizes, which may be due to the fact that for these variables there was no significant difference in the available growing space; also, fertilization was adequate for both container sizes, although this was not evaluated, since only one fertilization treatment was used.

A research study on the production of *Q. crassipes* in plastic bags (Velázquez *et al.,* 1996) tested different shade levels throughout the production cycle and compared variables with the full-sun treatment. With the larger growing space available in the bag (8 cm diameter and 18 cm length, 905 cm^3 capacity), the height (26 cm), the diameter (5 mm), the number of leaves (71.4), and the shoot (5.3 g), root (8.5 g) and total dry weights (13.8 g) surpassed those of the present study, as did the *R*/S ratio (8.5). However, in addition to the larger growing space, the production time in bag —16 months— was slightly more than twice that of the experiment documented herein. Dickson's index had an acceptable mean value of 0.45, which is similar to the 0.5 obtained by De Jesús *et al.* (2021) for *Q. rugosa* in 135 mL containers.

According to Landis *et al.* (2010), the *S*/*R* ratio with a low value (0.95 on average) is indicative of a quality plant that is suitable for low humidity sites; the same applies to the SC (4.5 on average). Based on the former indicator, the plant has a balance between aboveground and underground parts that minimizes the likelihood of dehydration, which is much higher when the root biomass is less than the aboveground mass.

Pine plants with a SC of less than 6 are considered to be well proportioned (Prieto-Ruiz *et al*., 2009; Landis *et al*., 2010; Bello, 2012; Rueda *et al.*, 2012).

We conclude that plants grown in the large container offer morphological characteristics that in other species have been found to be related to survival and resistance to field stress. Based on the diameter and *S*/*R* ratio obtained, the utilized substratum —which includes composted bark—, as well as the fertilization regime and shade provided in the early stages of cultivation, proved to be suitable for the production of *Q. crassipes*. Although the planting and evaluation of survival in the field are still pending, as well as a better timing to planting season, the morphological quality standards obtained in the present study serve as a reference for the production of quality *Q. crassipes* plants.

Conflict of interests

The authors declare that they have no conflict of interest.

Contribution by author

Roselia Venancio Nabor: conception of the study, cultivation of trees, laboratory work, literature review, statistical and results analysis, writing; Dante Arturo Rodríguez Trejo: conception of the study, experimental design, supervision of culture and laboratory work and experiment, in general, statistical analysis and results, writing and review of the writing; Leopoldo Mohedano Caballero and Edgar Arturo Sánchez Moreno: experimental design, supervision of culture and laboratory work, and of the experiment, in general, review of the writing.

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