Growth and slenderness index in sweet algarrobo, *Neltuma flexuosa*, according to the vermicompost percentage in the substrate and seed origin

Crecimiento e índice de esbeltez en algarrobo dulce, *Neltuma flexuosa*, según porcentaje de vermicompostado en sustrato y procedencia de semillas

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Nota científica

Abstract

Substrate composition and seed origin influence the morphological characteristics of future trees. This study aimed to quantify growth of sweet algarrobo plants, *Neltuma flexuosa*, obtained from seeds collected from two sites in Argentina and grown on substrates with varying vermicompost percentages. A completely randomized factorial design was used with four levels of vermicompost percentage (0; 20; 30; 70) and two levels of seed origin (Monte Comán, Mendoza and; Bolsón de Fiambalá, Catamarca) (n= 360). Height growth rate (from root neck to apex) (Delta height), root neck diameter growth rate (Delta diameter), and Slenderness index were measured for each plant. Results showed that northern sweet algarrobo specimens growing on vermicompost-enriched substrates had a significantly higher Delta height ($p<0.05$). Additionally, northern specimens growing on 30-70% vermicompost-enriched substrates and southern specimens growing on 30% vermicompost-enriched substrates had a significantly higher Delta diameter compared to those growing on vermicompost-free substrates. Moreover, northern specimens growing on vermicompost-enriched substrates had a significantly higher slenderness index than southern specimens. Based on these findings, we recommend using seeds from the northern region and substrates with a minimum addition of 20% vermicompost for sweet algarrobo cultivation.

Keywords

Prosopis flexuosa • nursery • Mendoza • Catamarca • reforestation

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Resumen

La composición del sustrato y el origen de las semillas influyen en las características morfológicas de los árboles a los que darán origen. El objetivo del presente fue cuantificar el crecimiento de plantines de algarrobo dulce, *Neltuma flexuosa*, producidos de semillas originarias de dos localidades de Argentina y cultivadas en sustratos con diferentes porcentajes de vermicompost. Se dispuso un arreglo factorial completamente aleatorizado según el porcentaje de lombricompuesto (0; 20; 30; 70) y el origen de la semilla (Monte Comán, Mendoza y; Bolsón de Fiambalá, Catamarca) (n= 360). Por cada plantín se estimó la tasa de crecimiento en altura (Delta altura), la tasa de crecimiento del diámetro del cuello de la raíz (Delta diámetro) y el Índice de esbeltez. Especímenes norteños creciendo en sustrato que contenía vermicompostado presentaron un Delta altura significativamente mayor ($p<0,05$). Además, plantines norteños creciendo en sustrato con 30-70% de vermicompostado, y sureños con 30% de vermicompostado presentaron un Delta diámetro significativamente mayor que el control. Sumado, individuos norteños en sustratos que contenían vermicompostado presentaron un Índice de esbeltez significativamente mayor al de individuos sureños. Se recomienda el uso de semilla proveniente de Catamarca, con un agregado mínimo de 20% de vermicompostado en el sustrato.

Palabras clave

Prosopis flexuosa • vivero • Mendoza • Catamarca • reforestación

Introduction

In the Monte Phytogeographic Region, the Algarrobal community has low chances of natural restoration due to faunal seed uptake and soil water deficiency after germination (21, 22). Nursery production helps increase field survival ensuring successful reforestation in reduced production times, and higher plant quality (14), but increased production costs compared with direct seeding (10).

Quality assessment of forest plants considers morphological factors such as root neck diameter, height, and Slenderness index (11, 15). Root neck diameter indicates plant ability to transport water and nutrients from roots to canopy, mechanical resistance, and heat tolerance. Height is an indicator of plant ability to photosynthesize, transpire, and compete with the surrounding vegetation (11). Furthermore, the Slenderness index, *i.e.* plant height to root neck diameter, Quiroz *et al.* (2009) characterizes plant resistance and photosynthetic capacity (18). Higher-quality forestry plants have Slenderness index values between 5 and 10 (11, 18).

Additionally, reproductive techniques and genetic components influence forestry plant quality (15). Among different reproductive techniques, container type and size, substrate characteristics, and appropriate cultural practices are important to consider (9, 14). Substrate physicochemical and nutritional properties influence morphological traits such as size, magnitude, and survival of future trees (9, 11). Substrates with a significant percentage of composted organic matter are recommended for high plant quality (9, 14).

Regarding the genetic component, considering seed origin and genetic traits is crucial (9). Whenever possible, conducting reforestation should consider using locally available seeds, usually better adapted to local environmental conditions, even at the expenses of yield (9). Northern Sweet Algarrobo species, *Neltuma flexuosa* (previously known as, *Prosopis flexuosa*) (7), is recommended for reforestation in the Monte Phytogeographic Region due to greater growth yields under the same conditions (4). However, different populations show high variability concerning morphology and growth traits, following a north-south latitudinal clinal pattern (3, 4, 8). These differences seem to relate to environmental and genetic factors (2, 4, 20). Thus, individuals from northern localities are mostly erect with a single stem, greater basal diameters, and taller than southern individuals showing less erect growth habits with several stems and lower diameter and height growth rates (2, 8, 24).

Previous growth trials for other South American *Neltuma spp.* have tested different proportions of composted organic matter. For instance, white Algarrobo, *Neltuma alba* (formerly known as *Prosopis alba*) (7), has been extensively studied for various combinations and concentrations of composted materials (6, 12, 13, 16). Salto *et al.* (2013) compared plant growth with and without addition of organic matter. Similarly, studies on black Algarrobo, *Neltuma nigra* (formerly known as *Prosopis nigra*) (7), compared growth on substrates with and without added organic matter (5, 12). To date, no such studies have been performed on *N. flexuosa*.

The present study aims to understand the effect of different proportions of composted organic material and seed origin on *N. flexuosa* growth. Plant growth of individuals originating from two localities in Argentina, Bolsón de Fiambalá (Catamarca, northern) and Monte Comán (Mendoza, southern), was estimated in terms of height, root neck diameter, and Slenderness index. The plants were grown on a substrate with varying vermicompost percentages, under nursery conditions. Increasing concentrations of vermicompost should lead to a significant increase in height, root collar diameter, and Slenderness index for *N. flexuosa* individuals from both locations. Furthermore, growth increase should be significantly higher for northern individuals under the same conditions.

Materials and methods

The present experiment was conducted between January and April 2019 at the forest nursery of EEA INTA Junín, Mendoza (34°34'17" S; 60°56'56" W). The experiment followed a completely randomized factorial arrangement with four levels of vermicompost percentage in sandy-loam soil (0, 20, 30, 70) and two levels of seed origin: (1) Monte Comán, Mendoza, and (2) Bolsón de Fiambalá, Catamarca. Each treatment had three repetitions 15 plants per treatment (n=360, figure 1). *N. flexuosa* seeds were collected from Monte Comán, Mendoza (northern), and Bolsón de Fiambalá, Catamarca (southern) between January and March 2018. Before germination, the seeds underwent a pre-germination treatment involving immersion in water at 100°C and left immersed for 24 hours at room temperature. Plant production used black polyethylene bag-pots, 8 cm in diameter and 25 cm high. Before sowing, substrate wash reduced electrical conductivity attributed to high vermicompost amounts (table 1, page 15). Plants were treated with antifungals and well irrigated.

Nomenclature is according to the origin of the seed (M) Monte Comán, Mendoza and (F) Bolsón de Fiambalá, Catamarca; and substrate vermicompost percentage.

La nomenclatura es según el origen de la semilla (M) Monte Comán, Mendoza; (F) Bolsón de Fiambalá, Catamarca; y el porcentaje de lombricompuesto en la mezcla de sustrato.

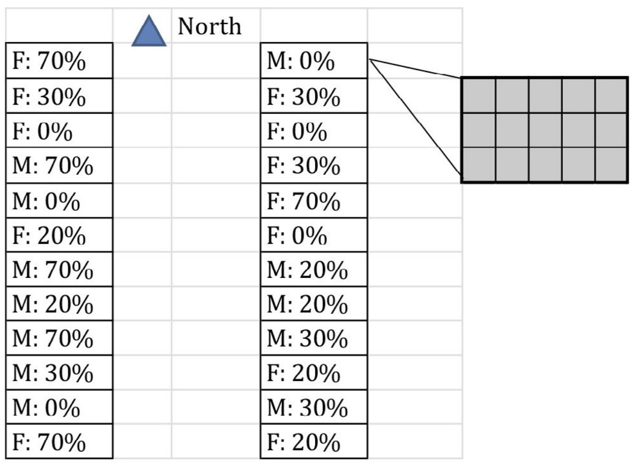

Figure 1: Demonstrative sketch of the distribution of containers in the different boxes, with thirty black polyethylene bag-pots per box.

Figura 1: Croquis demostrativo de la distribución de envases en las distintas cajas, con treinta bolsas-macetas de polietileno negro por caja.

Table 1. Electrical conductivity (EC) (in µS/cm) and pH for substrate mixtures and irrigation water.

Tabla 1. Conductividad eléctrica (EC, por sus siglas en inglés) (en µS/cm) y pH estimados en las mezclas de sustrato y en el agua de riego.

Vermicompost mixture (%)	pH	EC (µS/cm)
0	8	3.26
20	8.2	4.45
30	7.81	4.99
70	7.71	5.27
100	7.3	9.08
Irrigation water	8.09	1.71

Plant growth of one-month-old *N. flexuosa* individuals was estimated after root neck diameter, using a Vernier Caliber, and plant height from ground level to the apex, using a measuring tape. After 69 days, these measurements were repeated for each plant. Based on these data, height growth rate (Delta height), root collar diameter growth rate (Delta diameter), and Slenderness index (18) were calculated as follows:

$$\text{Delta diameter} = D_F - D_i$$

D_i: initial diameter of the one-month-old plant (in cm)
D_F: final diameter after 69 days (in cm)

$$\text{Delta height} = H_F - H_I$$

H_I: initial height of one-month-old plant (in cm)
H_F: final height after 69 days (in cm)

$$\text{Slenderness index} = H_F/D_F$$

H_F: final height after 69 days (in cm)
D_F: final diameter after 69 days (in cm)

After normality and homoscedasticity assumption tests, a two-way ANOVA test was conducted for Delta diameter, Delta height, and Slenderness index, followed by Tukey test ($p<0.05$) using Infostat/L 2020 (17).

Previous analyses

The vermicompost used had a nitrogen content of 1.51% by modified Kjeldahl Method. Additionally, table 1 shows pH and electrical conductivity (in µS/cm) in both irrigation water and vermicompost-sandy soil mixtures. As mentioned earlier, the high vermicompost-sandy soil mixture exhibited elevated electrical conductivity.

Results and discussion

The interaction between vermicompost percentage and seed origin had a significant effect on Delta height ($p=0.0014$; $F=5.30$). Individuals from Fiambalá Bolson grown on substrates with a vermicompost percentage between 20-70% exhibited significantly higher Delta height compared to other treatments (figure 2, page 16). Interestingly, increasing vermicompost percentage above 20% did not result in significant height increases. Previous studies on *Neltuma sp.* individuals testing growth and different additional composted materials (such as pine peel alone or in combination with other organic materials) reported significantly lower plant heights compared to sieved soil (12) and fertilized soil (5). These differences may be attributed to the potentially toxic effects of low pH values commonly found in pine peel, especially in proportions exceeding 50% (6, 13, 16). On the other hand, southern individuals did not exhibit a significant increase in Delta height with added vermicompost (figure 2, page 16). Similar results on southern specimens were characterized by lower heights compared to the northern individuals under natural conditions (1, 23, 24) and when growing on the same conditions in progeny-provenance trials (2, 3, 4, 8). The indifference towards increasing vermicompost concentrations in southern individuals may be attributed to lower growth potential, suggesting relatively lower physicochemical and nutritional requirements.

Different letters show significant differences for α=0.05.

Circles represent the mean number and the bars are the standard error.

Las letras diferentes significan diferencias significativas para α=0,05.

Los círculos representan la media, mientras que las barras representan el error estándar.

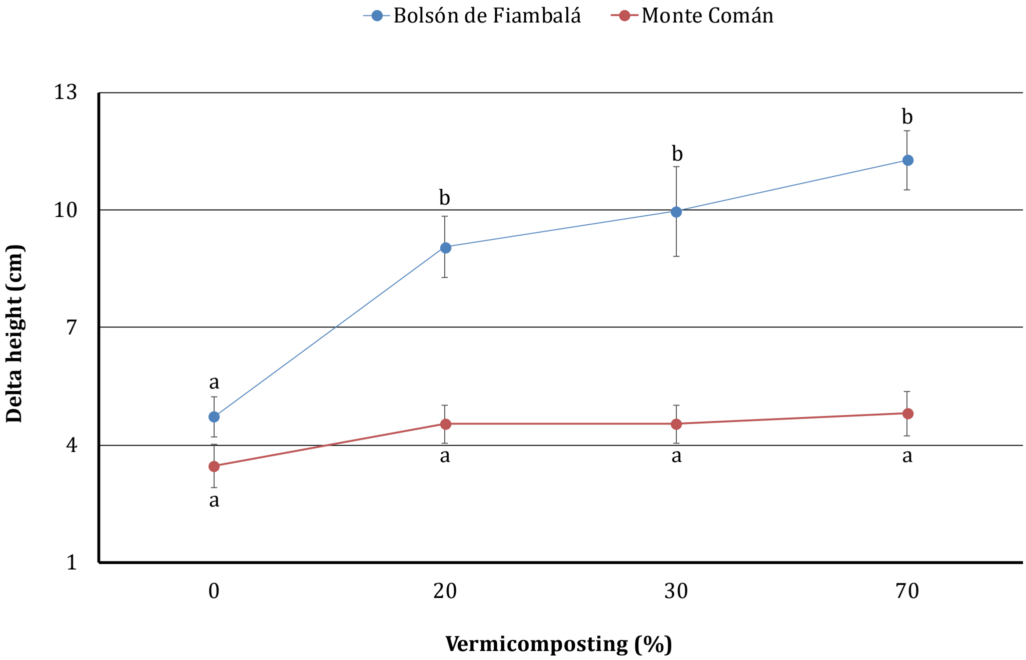

Figure 2. Interaction diagram for Delta height (in cm) according to substrate vermicompost percentage and seed origin for *N. flexuosa* interaction (n=360).
Figura 2. Diagrama de interacción para Delta altura (en cm) según el porcentaje de lombricompuesto en el sustrato y origen de semilla para *N. flexuosa* (n=360).

No significant interaction between vermicompost percentage and seed origin influenced Delta diameter (p=0.5722; F=0.67). However, vermicompost percentage had a significant effect on Delta diameter (p<0.0001; F=13.02). Individuals originating from Fiambalá Bolson and growing in a substrate enriched with 30-70% vermicompost, as well as Monte Comán individuals growing in a substrate enriched with 30% vermicompost, exhibited significantly higher Delta diameters compared to specimens from both origins without vermicompost addition (figure 3, page 17). Interestingly, no significant differences in Delta diameter occurred between northern and southern individuals grown with 0-70% vermicompost percentage. These results contrast the findings from progeny-provenance trials conducted with *N. flexuosa* individuals under similar conditions at 34 months old (4) and 23 years old (2), as well as *in situ* measurements showing significantly lower diameter growth in southern individuals compared to northern individuals (1, 23, 24). Absent significant differences in basal diameter appear to result from similar growth potentials in both seed origins at the evaluated growth stage. Furthermore, other *Neltuma* species grown on composted pine peel added to the substrate yielded different results (6, 12). For example, *N. alba* showed significantly higher root neck diameters (6), while *N. nigra* yielded significantly lower diameters (12). These differences may be attributed to *N. nigra* individuals being more sensitive to low pH levels in composted pine peel.

Different letters show significant differences for α=0.05.
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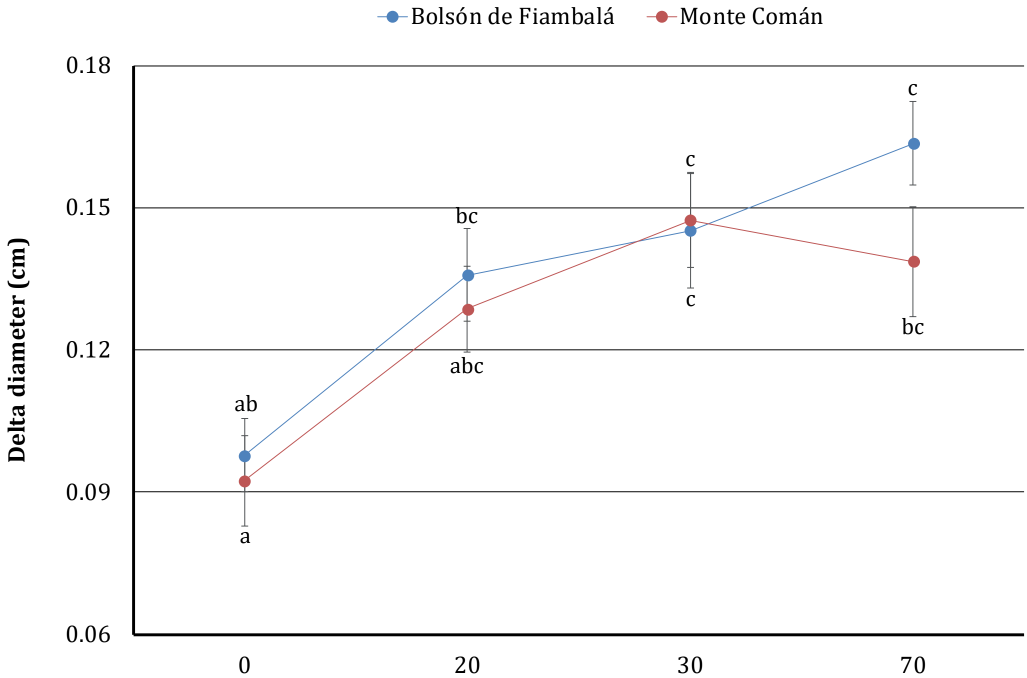

Figure 3. Interaction diagram for root neck Delta diameter (in cm) according to vermicompost percentage in substrate and seed origin for *N. flexuosa* interaction (n=360).
Figura 3. Diagrama de interacción para Delta diámetro al cuello de la raíz (en cm) según el porcentaje de lombricompuesto en el sustrato y origen de semilla para *N. flexuosa* (n=360).

The interaction between vermicompost percentage and seed origin did not significantly affect Slenderness index (p=0.082; F=2.25). However, seed origin had a significant effect on this index (p<0.0001; F=231.91). Northern individuals exhibited significant increases in Slenderness index compared to southern plants with 20-70% vermicompost addition to the substrate (figure 4, page 18). On the other hand, southern individuals did not show increased indices with vermicompost addition in the evaluated proportions. The main factor contributing to this difference is plant height, directly related to Slenderness index, and significantly higher in northern plants after amendment addition. Throughout the trial, the average Slenderness index ranged from 5 to 7 across all treatments, within the "good plant quality" indicative range (18). Similar results were observed for northern *N. flexuosa* individuals, displaying superior growth and plant quality, and becoming a recommended provenance for future reforestation efforts in the Monte Phytogeographic Region (4). A recent study on growth and survival of *N. flexuosa* individuals from different provenances in degraded areas for restoration found non-significant differences, and suggested using a mixture of provenances to increase the probability of successful restoration (19).

Different letters show significant differences for α=0.05.

Circles represent the mean number and the bars are the standard error. Las letras diferentes significan diferencias significativas para α=0,05.

Los círculos representan la media, mientras que las barras representan el error estándar.

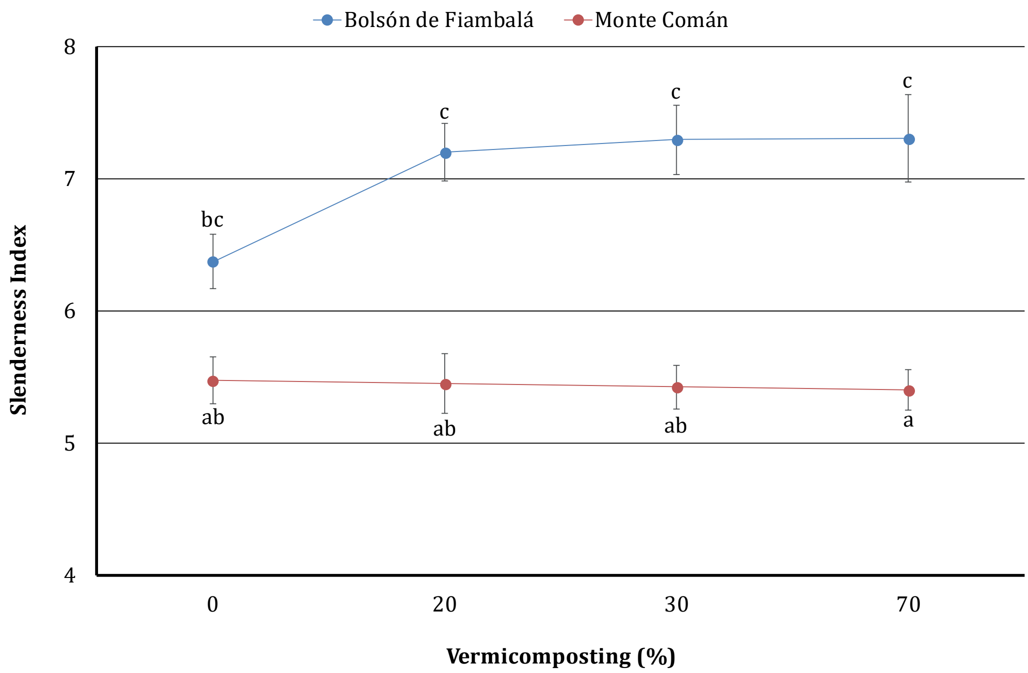

Figure 4. Interaction diagram for Slenderness index according to substrate vermicompost percentage and seed origin for *N. flexuosa* (n=360).

Figura 4. Diagrama de interacción para el Índice de esbeltez según el porcentaje de vermicompost en el sustrato y el origen de la semilla para *N. flexuosa* (n=360).

Conclusion

The study assessed growth in height, root neck diameter, and Slenderness index of *N. flexuosa* individuals from two different locations in Argentina: Bolsón de Fiambalá, Catamarca (northern), and Monte Comán, Mendoza (southern), growing in substrates with varying percentages of vermicompost under nursery conditions. The results showed that vermicompost addition had a significant positive impact on height and Slenderness index of northern individuals, but showed non-significant differences in basal diameter between seed origins when the same vermicompost proportion was applied.

High-quality *N. flexuosa* plants resulted from northern seeds, grown with 20% vermicompost. Future studies should focus on assessing field survival of different treatments in the medium and long-term ensuring successful reforestation of the Algarrobal Community in the Monte Phytogeographic Region.

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