



Sustratos y fertilización para producir planta de *Swietenia macrophylla* King y *Tabebuia donnell-smithii* Rose en charolas
Substrates and fertilization to produce *Swietenia macrophylla* King and *Tabebuia donnell-smithii* Rose plants in trays

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Fecha de recepción/Reception date: 15 de enero de 2023
Fecha de aceptación/Acceptance date: 15 de mayo del 2023

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Abstract

Some forest nurseries in central and northern Mexico use substrates where the use of pine sawdust and extended release fertilizers is common; regional inputs reduce production costs and simplify plant nutrition. The objective of this study was to evaluate the growth of *Swietenia macrophylla* and *Tabebuia donnell-smithii* on two substrates: S₁ (3:1:1 peat, perlite, vermiculite) and S₂ (3:1:1 pine sawdust, perlite, vermiculite) combined with four doses (4, 6, 8, 10 g L⁻¹) of Multicote® 18-6-12 fertilizer with four-month release micronutrients. The plant was grown in 24-cavity 150 mL rigid plastic trays for a period of 3.5 months. A completely randomized design with a 2×4 factorial arrangement (two substrates and four doses of fertilizer) was used. At 3.5 months, the morphological characteristics and N, P, and K content in plant foliage were evaluated. Both species showed significant differences ($p \leq 0.05$) by substrate type and fertilizer dose on diameter, height, aerial and root dry weight, as well as nutrient concentration. Plants produced in S₁ were superior in most variables to those grown in S₂. However, the sawdust-based substrate has the potential for the production of both taxa, which renders it a viable option as a substrate for obtaining plants within the medium-quality range.

Key words: Morphological attributes, *Chiapas*, tropical rain forest, *Soconusco*, alternative substrates, tropical forest nurseries.

Resumen

En algunos viveros forestales del centro y norte del país se utilizan sustratos en los cuales es común el uso de aserrín de pino y fertilizantes de liberación prolongada; los insumos regionales reducen los costos de producción y simplifican la nutrición de las plantas. El objetivo del presente estudio fue evaluar el crecimiento de *Swietenia macrophylla* y *Tabebuia donnell-smithii* en dos sustratos: S₁ (turba, perlita, vermiculita 3:1:1) y S₂ (aserrín de pino, perlita, vermiculita 3:1:1) combinados con cuatro dosis de fertilizante (4, 6, 8, 10 g L⁻¹) *Multicote*® 18-6-12 con micronutrientes de cuatro meses de liberación. La planta se produjo en charolas de plástico rígido de 24 cavidades de 150 mL, durante un período de 3.5 meses. Se utilizó un diseño completamente al azar con arreglo

factorial 2x4 (dos sustratos y cuatro dosis de fertilizante). A los 3.5 meses, se evaluaron las características morfológicas y el contenido de N, P, K en el follaje de las plantas. Ambas especies presentaron diferencias significativas ($p \leq 0.05$) por el tipo de sustrato y dosis de fertilizante en el diámetro, altura, peso seco aéreo y de la raíz, así como en concentración de nutrientes. Las plantas producidas en S_1 fueron superiores en la mayoría de las variables a las de S_2 , sin embargo, el sustrato a base de aserrín tiene potencial para la producción de los dos taxones, por lo que es una opción como sustrato viable por el costo para obtener plantas dentro de los intervalos de calidad media.

Palabras clave: Atributos morfológicos, Chiapas, selva tropical húmeda, Soconusco, sustratos alternativos, viveros forestales tropicales.

Introduction

Intensive plant production of forest species to restore and reconvert disturbed forest land began in Mexico in 1993, and in 2011 reached a maximum of 300 million plants. This production was carried out as part of the national restoration programs known as *Solidaridad Forestal* (Forest Solidarity), *Programa Nacional de Reforestación* (National Reforestation Program, *Pronare*), *ProÁrbol* (Pro-Tree), and *Programa Nacional Forestal* (National Forestry Program, *Pronafor*) (Secretaría de Economía, 2016; Vera *et al.*, 2018). Besides, the production of plants in trays (containers) began in 2011, reaching 93.3 % by 2016, and only 6.7 % was produced in polyethylene bags and bare root (Conafor, 2019).

Plant production in trays requires the use of inert substrates with grain size ≤ 10 mm, aeration porosity ≥ 20 , slightly acidic pH (5.5 to 6.5), and electrical conductivity (*EC*) of 1 200 to 2 500 ($\mu\text{S cm}^{-1}$), with low or no fertility; consequently, it is necessary to use fertilizers with essential macro- and micronutrients (Landis *et al.*, 2014; Secretaría de Economía, 2016).

In order to prepare substrates with the characteristics indicated above, organic inputs such as peat moss (imported from Canada and northern Europe), composted

pine bark, raw pine sawdust, bagasse compost from plant fruits (*agave*, *lechuguilla*, sugar cane, coffee, coconut, cocoa, peanut, walnut), and, to a lesser extent, inorganic materials such as perlite, vermiculite and volcanic foam (*tepezil*, *jal*, "gravel") are used in the country's nurseries in proportions of 50 to 100 % (Abanto-Rodríguez *et al.*, 2016; Domínguez-Liévano and Espinosa-Zaragoza, 2021).

Of the organic materials, peat and pine bark are the most commonly used inputs in forest nurseries of temperate and tropical climate species, in both technified and traditional production systems (Mateo-Sánchez *et al.*, 2011), although in the last 10 years, its cost has increased considerably due to the increase in fuel and freight prices, as well as to the depreciation of the Mexican peso in relation to the U.S. dollar.

In order to reduce substrate costs and simplify plant nutrition processes, during the last decade, several forest nurseries in the center and north of the country have successfully produced coniferous and broadleaved plants in substrates with pine sawdust (not composted) combined with controlled-release fertilizers (Aguilera-Rodríguez *et al.*, 2016a; González-Orozco *et al.*, 2018; De Jesús *et al.*, 2021).

In the southeastern Mexican states, the production of forest species is mainly carried out with substrates prepared from peat, pine bark, vermiculite and agrolite, and plant nutrition is carried out with controlled-release fertilizers (added to substrates) and water-soluble fertilizers (dissolved in irrigation water) (Mateo-Sánchez *et al.*, 2011). To date, most of the studies on forest plant production correspond to conifers and hardwoods from the center and north of the country; however, for tropical timber species in the context of pine sawdust-based substrates, only one study has been cited for *Cedrela odorata* L. (Mateo-Sánchez *et al.*, 2011).

The present study, assesses pine sawdust substrate for producing mahogany (*Swietenia macrophylla* King) and roseodendron (*Tabebuia donnell-smithii* Rose) plants. These species were chosen because they are among the most widely used in

agroforestry and commercial plantations in the southeast of the country (Espinosa-Zaragoza *et al.*, 2016).

Materials and methods

Study area

The study was conducted at the *Soconusco* forest nursery, owned by the Ministry of Environment and Natural History of the state of *Chiapas*, located in *Tuxtla Chico* municipality, *Chiapas*. The nursery is located between 14°53'46.3" N and 92°13'37.6" W, at an altitude of 170 m. The climate of the area is hot and humid with summer rains, an average monthly temperature of 28 °C, an average annual rainfall of 2 326 mm, and a rainy season from March to October (SMN, 2021).

The production area has a 4 m high "shade house" type metal structure, with zenithal cover of 40 % black shade mesh, metal tables with a width of 1.5 m and a height of 80 cm for holding trays, and a manual irrigation system with a fine-drop sprinkler.

Inputs used

Containers. Rigid plastic trays measuring 21.6×35.2×10.0 cm, 24 fused cavities with a capacity of 150 mL, and with a density of 316 plants m², were utilized (BCC AB[®], Landskrona).

Substrates. Two mixtures were tested: S₁, composed of 3:1:1 peat moss, perlite, and vermiculite, and S₂, composed of 3:1:1 fresh pine sawdust (not composted), perlite and vermiculite.

Fertilizers. Multicote[®] 18-6-12 (N-P-K)+2Mg+ME four-month controlled-release fertilizer was used at a constant temperature of 21 °C (70 °F) (Haifa Chemicals Ltd., Haifa).

Germplasm. Mahogany seeds (*Swietenia macrophylla*) were collected from the forest germplasm production unit-clonal seed orchard located in *Chetumal, Quintana Roo* (18°34'25.1" N, 88°27'38.6" W) at an altitude of 32 m, and roseodendron seeds (*Tabebuia donnell-smithii*) were collected from healthy trees, free of pests and diseases located in the municipal capital of *Tuxtla Chico, Chiapas* (14°56'42.4" N, 92°09'39.7" W) at an altitude of 290 m.

Treatments

Each species was produced on both substrates (S₁, S₂) combined with four doses of controlled release fertilizer (4, 6, 8, and 10 g L⁻¹), for a total of eight treatments per species. The experimental unit consisted of 24 plants in four replicates for a total of 96 plants per treatment.

Production management

Prior to planting, the largest seeds, free of physical damage and pests or diseases, were selected. The plant was produced over a period of 3.5 months, from the third week of July to the last week of October 2020. Irrigation was carried out manually twice a week, with fine-drop watering cans. The trays with the plant were protected with a shade net cover during the first seven weeks and were placed outdoors during the last seven weeks.

Morphological variables and quality indexes evaluated

The plants of both species were evaluated at 3.5 months after planting. From each tray or replication, 15 plants were systematically extracted; a total of 60 plants per treatment were evaluated; the root ball of each one was washed with water to eliminate the substrate particles and leave the roots free.

Each plant was measured for height (m) (*H*) with a ruler graduated in mm, and the neck diameter (cm) (*ND*), with a digital vernier (Truper®); subsequently, the plant was sectioned and the aerial and root parts were placed separately in brown paper bags. The sets of bags from each repetition and treatment were dried in an electric oven at 70 °C (FELISA HORNO® FE-293A), for 72 h. At the end of drying, the dry

aerial weight (*DAW*) and of the root dry weight (*RDW*) was recorded on an 0.001 g precision analytical balance (Ohaus® AR0640). With the above values, the following qualitative morphological variables were determined: dry aerial weight/root dry weight ratio (*DAW/RDW*), robustness index (*RI*)= (H/ND) and Dickson's Quality Index (*DQI*)= $[TDW / (RI+DAW/RDW)]$, where *TDW* is the total dry weight.

Table 1 was prepared in order to determine the quality of the results obtained in the variables described above, using the data cited by Rueda *et al.* (2012), modified by Sáenz *et al.* (2010) with contributions from Santiago *et al.* (2007) and Conafor (2009) for quality plants of hardwood species.

Table 1. Quality values of hardwood species.

Variable	Plant type	Quality		
		Low	Medium	High
Height (cm)	Broadleaves	<12.0	12.0–14.9	≥15.0
Neck diameter (mm)	Broadleaves	<2.5	2.5–4.9	≥5.0
Robustness index	All ¹	≥8.0	7.9–6.0	<6.0
<i>DAW/RDW</i> ratio	All ¹	≥2.5	2.4–2.0	<2.0
Dickson's index	All ¹	<0.2	0.2–0.4	≥0.5

¹All = Non-cespítóse conifers, cespítóse conifers, and broadleaves.

N, P, K concentration in plant foliage

The concentration of N, P, and K in plant foliage was determined at the *Salvador Alcalde Blanco* Plant Nutrition Laboratory of the *Colegio de Postgraduados* (Graduate

Studies College), *Montecillo* Campus, State of Mexico. Dried foliage from the 60 plants evaluated for each treatment and species was crushed and pulverized in a 1.0 mm diameter screen mill (Yinda®-YDGS-200); three samples of each treatment were analyzed, and the results were used to obtain the average values for each nutrient.

The N content was obtained with the semi-micro-Kjeldahl method (Bremer, 1965), while for P and K the method described by Alcántar and Sandoval (1999) was used, in which the extracts were read in a plasma emission with induction spectrometry equipment (Agilent 725 Series ICP-OES). In order to compare whether the nutrient concentrations thus determined were appropriate for each species and treatment, the intervals recommended by Jacobs and Landis (2014) for healthy plants of tropical species produced in trays were used (N=1.50-3.50, P=0.10-0.25, and K=0.6-1.80 %).

Experimental design and statistical analysis

The experimental design was completely randomized with a 2×4 factorial arrangement (two substrates and four fertilizer doses), with four replicates (trays) per treatment. The response variables were subjected to an analysis of variance and to mean comparisons using Tukey's test ($P \leq 0.05$) with the InfoStat® statistical software version 2008 (InfoStat, 2008). The model used for the data analysis was as follows:

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + \varepsilon_{ijk}$$

Where:

$i = 1, 2, \dots, a$ number of factor A levels

$j = 1, 2, \dots, b$ number of factor B levels

$k = 1, 2, \dots, r$ number of replications of $A \times B$ combinations

Y_{ijk} = Value of the response variable corresponding to replication k from level i of A to level j of B

μ = Overall mean

A_i = Effect of the i level of factor A (substrates)

B_j = Effect of the j level of factor B (fertilizer dosage)

AB_{ij} = $A \times B$ corresponding to level i of A and level j of B

ε_{ijk} = Experimental error corresponding to the k replication from level i of A to level j of B

Results

Effect of substrate and fertilizer on the growth of *Swietenia macrophylla*

The type of substrate generated a significant effect ($p \leq 0.05$) on the morphological variables A , RDW , and DAW . The dose of fertilizer added to the substrates induced a significant effect on all morphological variables (ND , H , RDW , and DAW) at the

doses of 8 and 10 g L⁻¹. Plants produced in substrate S₁ and doses of 10 g L⁻¹ showed higher heights and dry weights than plants produced in the other treatments (S₁ and S₂) (Table 2).

Table 2. Average plant morphological variables of *Swietenia macrophylla* King.

T	S	Dose (g L ⁻¹)	ND (mm)	H (cm)	RDW (g)	DAW (g)	RI	DAW/ RDW	ICD	
	S ₁		4.27 a [†]	33.07 a	0.64 a	1.37 a	7.82 a	2.38 a	0.20 a	
	S ₂		4.03 a	27.18 b	0.50 b	1.17 b	6.97 b	2.18 a	0.18 b	
			<i>p</i>	<0.146	<0.001	<0.001	<0.001	<0.047	<0.127	<0.041
1	S ₁	4	3.30 b	28.61 bcd	0.60 abc	1.25 ab	8.69 a	2.12 a	0.17 ab	
2		6	4.14 ab	28.10 bcd	0.63 ab	1.35 ab	6.86 ab	2.18 a	0.22 a	
3		8	4.64 a	33.89 b	0.65 ab	1.36 ab	7.34 ab	2.12 a	0.22 a	
4		10	4.99 a	41.69 a	0.67 a	1.54 a	8.38 ab	2.30 a	0.21 a	
5	S ₂	4	3.12 b	24.26 d	0.41 d	1.05 b	8.23 ab	2.59 a	0.14 b	
6		6	3.94 ab	25.83 cd	0.48 cd	1.15 b	6.72 ab	2.44 a	0.18 ab	
7		8	4.47 a	26.64 cd	0.52 bcd	1.18 b	5.92 b	2.28 a	0.21 a	
8		10	4.59 a	32.20 bc	0.58 abc	1.28 ab	7.02 ab	2.20 a	0.21 a	
			<i>p</i>	<0.001	<0.001	<0.005	<0.017	<0.013	<0.837	<0.003
			(S×Dose) <i>p</i>	<0.948	<0.091	<0.403	<0.961	<0.606	<0.464	<0.564
			RV	≥5.0	≥15.0		<6.0	<2.0	≥0.5	

T = Treatment; S = Substrate; ND = Neck diameter; H = Height of the plant; DAW = Dry aerial weight; RDW = Root dry weight; RI = Robustness index; DAW/RDW = Aerial dry weight/Root dry weight ratio; DQI = Dickson's Quality Index; RV = Recommended values (Table 1). [†]Different letters in a column indicate significant differences ($p \leq 0.05$).

The assessed quality indexes (RI and DQI) were qualitatively superior in the plant produced in S₁ with doses of 6, 8, and 10 g L⁻¹, while no statistically significant

differences were recorded for the *DAW/RDW* ratio. In the substrate vs. fertilization interaction, there was no significant effect on the variables evaluated (Table 2).

Effect of substrate and fertilizer on the growth of *Tabebuia donnell-smithii*

All treatments produced plants with neck diameters larger than 4 mm, and a greater height (≥ 30 cm). The type of substrate generated a significant effect ($p \leq 0.05$) on the variables *H*, *RDW*, and *DAW* (doses: 8 and 10 g L⁻¹). The values for both variation factors (substrate and fertilization) were higher in the substrate S₁ (Table 3).

Table 3. Average morphological variables in plants of *Tabebuia donnell-smithii* Rose.

T	S	Dose (g L⁻¹)	ND (mm)	H (cm)	RDW (g)	DAW (g)	RI	DAW/RDW	DQI
	S ₁		4.35 a [†]	40.47 a	0.77 a	1.32 a	9.33 a	1.82 a	0.19 a
	S ₂		4.17 a	38.69 b	0.56 b	1.00 b	9.26 a	1.75 a	0.14 b
	<i>p</i>		<0.054	<0.014	<0.001	<0.001	<0.812	<0.526	<0.001
1	S ₁	4	4.09 ab	36.96 cd	0.68 ab	1.13 abc	9.05 a	1.75 a	0.17 a
2		6	4.24 ab	39.37 bc	0.75 ab	1.36 ab	9.32 a	1.76 a	0.19 a
3		8	4.42 ab	41.38 abc	0.79 ab	1.38 ab	9.40 a	1.88 a	0.20 a
4		10	4.65 a	44.19 a	0.88 a	1.41 a	9.55 a	1.62 a	0.20 a
5	S ₂	4	4.06 b	33.54 d	0.48 b	0.82 c	8.28 a	1.76 a	0.13 a
6		6	4.08 b	38.58 bc	0.55 b	0.99 bc	9.46 a	1.87 a	0.14 a
7		8	4.22 ab	40.26 abc	0.54 b	1.10 abc	9.55 a	2.02 a	0.14 a
8		10	4.35 ab	42.39 ab	0.68 ab	1.10 abc	9.77 a	1.64 a	0.16 a
	<i>p</i>		<0.010	<0.001	<0.038	<0.009	<0.079	<0.392	<0.305

(S×Dose) <i>p</i>	<0.738	<0.534	<0.983	<0.964	<0.574	<0.838	<0.960
RV	≥ 4.0	25-35			≤8.7	1.5-2.5	≥2.0

T = Treatment; S = Substrate; *ND* = Neck diameter; *H* = Height of the plant; *DAW* = Dry aerial weight; *RDW* = Root dry weight; *RI* = Robustness index; *DAW/RDW* = Aerial dry weight/Root dry weight ratio; *DQI* = Dickson's Quality Index; RV = Recommended values (Table 1). †Different letters in a column indicate significant differences ($p \leq 0.05$).

As for the quality indexes evaluated, there were significant differences in the *DQI* only for the type of substrate, and there were no significant differences in terms of the fertilization rate and the interaction of the factors (Table 3).

Effect of substrate and fertilizer on nutrient assimilation

The percentage values for N, P, and K concentrations were higher in plants produced with *S*₁, compared to those produced with *S*₂. In all treatments, the percentage concentration of these nutrients was within the ranges recommended by Jacobs and Landis (2014) for healthy plants of tropical species. In general, increasing the fertilizer dose generated a greater proportional increase of nutrients in the foliage of both species (Table 4).

Table 4. N, P, and K concentrations in the foliage of *Swietenia macrophylla* King (Mahogany) and *Tabebuia donell-smithii* Rose (Roseodendron) plants.

S	Dose	Mahogany	Roseodendron
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	(g L ⁻¹)	N	P	K	N	P	K
S ₁	4	2.64	0.18	0.88	2.84	0.21	0.93
	6	2.80	0.24	1.04	2.99	0.21	0.93
	8	3.33	0.25	1.01	3.36	0.24	0.95
	10	4.35	0.30	1.15	3.83	0.27	1.04
Average		3.28	0.24	1.02	3.26	0.23	0.96
S ₂	4	2.58	0.16	0.67	2.72	0.17	0.48
	6	2.86	0.19	0.66	2.75	0.17	0.55
	8	3.24	0.20	0.69	3.24	0.19	0.64
	10	3.45	0.23	0.72	3.43	0.19	0.64
Promedio		3.03	0.20	0.69	3.04	0.18	0.58
RV		1.5-3.4	0.2-0.3	0.6-1.8	1.5-3.5	0.2-0.3	0.6-1.8

S = Substrate; RV = Reference values by Jacobs and Landis (2014).

Input costs

The costs per plant were determined based on the average costs of the inputs used in each treatment as of April 2023: 5.5 ft³ bale of peat (250 L without compaction)= \$ 970.00, equivalent to \$ 3.88 L⁻¹; pine sawdust without compost (freight included)= \$ 150.00 m³, i.e., \$ 0.015 L⁻¹; perlite (100 L bag)= \$ 216.00, equivalent to \$ 2.60 L⁻¹; vermiculite (100 L bag)= \$ 514.00, \$5.40 L⁻¹; and Multicote® (25 kg bag)= \$ 2 251.00, \$ 0.09 g⁻¹. The cost per plant was calculated based on the value of 200 mL of substrate with fertilizers necessary to fill each cavity of 150 mL, as the substrate is compacted during this activity. The cost per plant in U.S. dollars was calculated considering an exchange rate of \$ 20.00 MN

per dollar, as of April 2023. For the S_1 , the cost varied from 0.041 to 0.047 USD, and for S_2 , from 0.018 to 0.024 USD.

Discussion

According to the reference values (Table 1), medium to high quality mahogany and roseodendron plants were produced; based on the results, the treatments of S_1 and 10 g L^{-1} of Multicote[®] exhibited the best reference values of plant quality for both species, and this mixture is recommendable for standardizing a substrate for tropical species. These results prove that it is possible to produce tropical forest species in substrates with pine sawdust and controlled-release fertilizers. Mateo-Sánchez *et al.* (2011) produced *Cedrela odorata* plants in trays with 140 cm^3 cavities and substrates with different proportions of sawdust, combined with 8 g L^{-1} of Multicote[®] (18-6-12) of 8 months of release; three and a half months after planting, the plant produced in the substrate composed of pine sawdust, peat, vermiculite, and perlite (60:24:08:08) developed average values in diameter, height, and *DQI* of 4.5 mm, 31 cm, and 0.30, respectively.

The production period of three and a half months, from planting to plant evaluation, was appropriate for the mahogany plant, which exhibited diameters and heights within the recommended ranges (Table 1). On the other hand, the roseodendron plant registered greater heights. On average, for both species, robustness indexes (*RI*) were high or above the reference interval, and Dickson's quality indices (*DQI*) were low or below those recommended. The use of cavities with a higher volumetric capacity or of controlled-release fertilizers with less N and more P may contribute to the production of more robust plants with higher root biomass and, consequently, higher *DQIs*.

Regarding the effect of the substrate and the fertilizer on nutrient assimilation, for both species, the values corresponding to the plants produced in S_1 with the 6, 8, and 10 g L⁻¹ doses, and in S_2 with the 8 and 10 g L⁻¹ doses, were similar to those reported by Rueda-Sánchez *et al.* (2014) in four nurseries in the state of *Nayarit*. This authors produced mahogany (*Swietenia humilis* Zucc.) and roseodendron plants in polystyrene trays with 170 cm³ cavities, in which he used a substrate composed of peat, perlite and vermiculite (3:1:1) and added 4 g L⁻¹ of controlled-release fertilizer, in addition to water-soluble fertilizers. The plants were assessed at 4 and 3.5 months of age, respectively, exhibiting the following average values of N, P, and K: mahogany had 1.9, 0.2 and 0.9 %, and roseodendron had 2.1, 0.2, 0.9 %.

Escobar and Buamscha (2012) indicate that, in the production of quality plants, the best substrate will be that which is available close to the nursery, in order to reduce labor efforts, and has the lowest cost. Based on these characteristics, S_2 allows obtaining (with the use of sawdust) plants suitable for establishment in the field for reforestation purposes, exhibiting no sanitary issues and producing a saving of 50 %. Sawdust has a potential for mahogany and roseodendron production; therefore, this substrate is a viable option, given its low cost, and yields plants grown within the average quality range.

Conclusions

It is possible to produce *Swietenia macrophylla* and *Tabebuia donnell-smithii* plants with morphological and nutritional characteristics appropriate for reforestation in the substrate prepared with 60 % fresh pine sawdust (S_2), with doses of Multicote® of 8

and 10 g L⁻¹, and in the substrate composed of peat (S₁) and Multicote® at doses of 6, 8, and 10 g L⁻¹, for a period of 3.5 months, in rigid plastic trays with cavities with a capacity of 150 mL. The percentage values for N, P, and K concentrations were higher in plants produced with S₁, compared to those obtained with S₂. The average cost of substrate with peat and Multicote® is twice as expensive as substrate with pine sawdust and Multicote®.

Acknowledgments

The authors wish to thank the managers of the *Soconusco* nursery of the Ministry of the Environment and Natural History (*Secretaría del Medio Ambiente e Historia Natural*) of the State of *Chiapas*, and Eng. Hernán Ichimura Pérez (nursery manager).

Conflict of interest

The authors declare that they have no conflict of interest.

Contribution by author

Alexis Domínguez Liévano: design, structure and drafting of the article; Manuel Aguilera Rodríguez: structure and drafting of the article; Saúl Espinosa Zaragoza: information processing and drafting of the article; Arnulfo Aldrete: structure and drafting of the article; Arnoldo Wong Villarreal: revision of the literature and drafting of the article; Nidia Bélgica Pérez De la O: revision of the article.

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