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Translated from the original in spanish

Influence of substrate on the quality of container-grown Swietenia mahagoni (L.) Jacq. Plant

Influencia del sustrato en la calidad de la planta *Swietenia mahagoni* (L.) Jacq., cultivada en contenedores

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ABSTRACT

The objective of this study was to evaluate the effect of different organic substrates on the quality of the container-grown S. mahagoni seedling. For this purpose, an experimental trial was carried out in the technified nursery "Camarones", belonging to the Agroforestry Enterprise Baracoa. The substrates used were cocoa husk (Cc), coconut fiber (Fc) and pine sawdust (As) and volumetric mixtures of cocoa husk, coconut fiber and pine sawdust in a completely random experiment with eight treatments and five replicas. The substrates were characterized and the morphological parameters of the seedlings, destubetado characteristics, structural stability of the root ball and radical architecture were determined. The species showed a more favourable morphological response in mixtures Cc60 (Cc-60 % + Fc-20 % + As-20 %) and Cc50 (Cc-50 % + Fc-30 % + As-20 %), attributable to physical and chemical characteristics.

Keywords: container; morphological attributes; nursery.

RESUMEN

El presente estudio tuvo como objetivo evaluar el efecto de diferentes sustratos orgánicos en la calidad de la plántula *S. mahagoni*, cultivada en contenedores. Para ello se realizó un ensayo experimental en el vivero tecnificado "Camarones", perteneciente a la Empresa Agroforestal Baracoa. Los sustratos empleados fueron Cascarilla de cacao (Cc), Fibra de coco (Fc) y Aserrín de pino (As) y mezclas

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volumétricas de cascarilla de cacao, fibra de coco y aserrín de pino en un experimento completamente al azar con ocho tratamientos y cinco réplicas. Se caracterizaron los sustratos y se determinaron los parámetros morfológicos de las plántulas, características de destubetado, estabilidad estructural del cepellón y arquitectura radical. La especie mostró una respuesta morfológica más favorable en las mezclas Cc60 (Cc-60 % + Fc-20 % + As-20 %) y Cc50 (Cc-50 % + Fc-30 % + As-20 %), atribuible a las características físicas y químicas.

Palabras clave: contenedor; morfología; vivero.

INTRODUCTION

In technified nurseries, the quality of the substrates is an important factor for the successful cultivation of the plants in tubes, since the chemical, physical and biological characteristics of the same have a direct influence on the quality of the species. Thus, for Siqueira *et al.,* (2018), the substrates must offer physical support to the roots and conditions to supply the hydric and nutritional demand of the seedlings.

This implies the knowledge of the use of organic substrates to optimize the production of different forest species in nurseries, in order to obtain high quality seedlings and achieve 100% survival in plantation, and thus be able to decrease and avoid the depletion of non-renewable resources such as soil (Falcón *et al.,* 2015).

Among the species produced in forest nurseries is *Swietenia mahagoni* (L.) Jacq., known in Cuba by the common names of mahogany, Antillean mahogany or Cuban mahogany (Barroso, 1999). It is highly prized for its wood, but has been the object of irrational exploitation, which has caused the species to be hardly commercialized.

Due to its multiple uses, this species is found in the country's reforestation plans (SEF, 2018) and its cultivation in a nursery using tube technology has few research antecedents; in fact, it is the first experience of this type in Guantánamo province, using substrates made from local organic compounds.

For this reason, the objective of the present work is to evaluate the effect of different organic substrates in some parameters and morphological indexes of the species *S. mahagoni*, cultivated in tube-type containers, for its use in reforestation.

MATERIALS AND METHODS

The research was carried out in the nursery "Camarones" of the Silvicultural Unit "Cayo Güin", belonging to the Agroforestry Enterprise Baracoa, located in the geographical coordinates 20o 20' 48'' north latitude and 74o 29' 45'' west longitude, at an altitude of 23 m.a.s.l.

The climatic characteristics of the study area, with a series of data of 12 years, are given by the statistics registered in the Meteorological Station of the Territorial Delegation of CITMA, in Baracoa (Figure 1). In general, rainfall is above 100 mm per month in almost every month of the year, characteristic of the study area.

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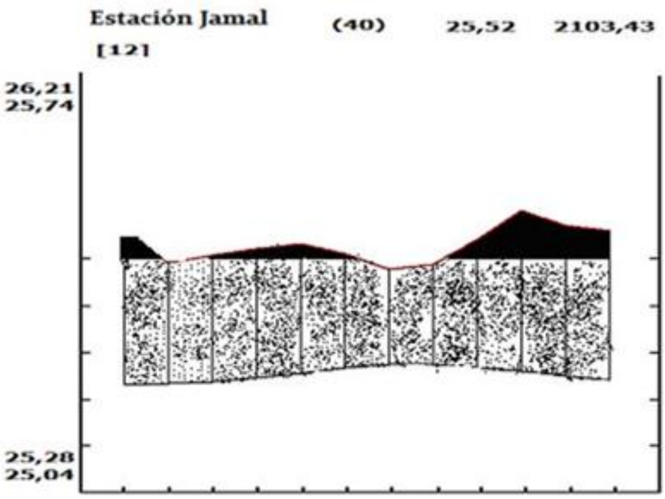

Fig. 1 - Climatic characteristics of the study area

The seeds for the production of the species *S. mahagoni* in the nursery were obtained from the seedbed of the Agroforestry Company Baracoa, which were certified in the Institute of Agroforestry Research of Baracoa, according to Cuban Standard 71-03 and 71-06.

The plants were grown in the nursery on black conical-cylindrical plastic tubes with a capacity of 200 cm^3, which are grouped in plastic trays with a capacity of 98 containers (Figure 2).

Fig. 2 - Aspects of the tube-type container and plastic tray

Cultivation in tubes-type container was performed using three substrates: cocoa husk, coconut fiber and semi-compound pine sawdust; in addition, volumetric mixtures of cocoa husk, coconut fiber and pine sawdust were used (Table 1). The substrates used are common, easily acquired and transported in the territory where the research was carried out.

Table 1. - Composition of the substrates used in the experiment

Sustrato	Abreviatura	Tratamientos	Composición (%)
Cascarilla de cacao	Cc	Cc	100
Fibra de coco	Fc	Fc	100
Aserrín de pino	As	As	100
Cascarilla de cacao + Fibra de coco + Aserrín de pino	Cc + Fc + As	Cc60	60 + 20 + 20
	Cc + Fc + As	Cc50	50 + 30 + 20
	Cc + Fc + As	Cc40	40 + 40 + 20
	Cc + Fc + As	Cc30	30 + 50 + 20
	Cc + Fc + As	Cc20	20 + 60 + 20

Experimental design

The experiment consisted of eight treatments made up of different concentrations of coconut husk, coconut fiber, pine sawdust and volumetric mixtures between them (Table 1), with five repetitions, under a completely random design. The size of the experimental unit was 10 seedlings, making a total of 50 individuals per treatment. In total, the experiment required 400 seedlings.

Chemical and physical characterization of the substrate

Chemical analysis of substrates was performed at the provincial soil laboratory of the Ministry of Agriculture in Guantánamo, based on the Cuban Standards (NC) for this type of analysis (NC-XX 2009), where it was determined: percentage of Organic Matter (MO) from the percentage of ash (Cza), content of potassium (K) and sodium (Na) by flame photometry, phosphorus (P) by colorimetry method, calcium (Ca) by volumetry method, nitrogen (N) from the percentage of organic matter, pH by potentiometric method and electrical conductivity (CE) by conductivity meter method.

The physical properties (apparent density, real density, total porosity and moisture retention) were determined from the methodology proposed by Ansorena (1994), quoted by Alonso et al. (2015). In addition to the Mean Particle Diameter (DMP), by means of granulometric analysis, with the screening method for the ASTM √2 series of sieves (ASTM E-29, 1972).

For the parameters without using tube-type container, structural stability of the root ball and radical architecture, levels of degree of complexity were analyzed as indicated in table #2. (Table 2)

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Table 2. - Levels established for the parameters without using tube-type container, structural stability of the root ball and radical development

Variable	Nivel		
	1	2	3
Destubetado	Fácil	Medio	Difícil
Estabilidad del cepellón	Alta	Intermedia	Baja
Arquitectura radical	Buena	Aceptable	Mala

Characterization of the plant in the nursery

After 25 days of germination, the measurement of morphological parameters began: height (h), for which the plants that made up the sample of 50 plants located in the center of each tray (useful plot) per treatment were taken, avoiding the edge effect. This measurement was made with a ruler graduated in centimeters, measured from the neck of the root to the apex, for the measurement of the diameter of the neck of the root (dcr) was used a caliper foot, with an accuracy of 0.002 mm.

At the fourth month (120 days), 15 samples of each treatment were selected, to which the weight of the root, stem and leaves was determined (fresh weight, radical part and fresh weight, aerial part). After separating the aerial part from the root part by the neck of the root, these were placed in the oven at 80 °C for 8 hours until a constant weight was reached; and the dry weight of each of the fractions was determined on a precision scale of 0.01 g. The dry weight of each of the fractions was determined.

The following morphological indices were calculated from the data obtained:

- Slimness (H/DCR): is the height quotient divided by the diameter in mm.
- Dickson Quality Index (DQI): the DQI was determined from the formula:

$$\text{ICD} = \left[Pst \Big/ \frac{h}{dcr} + \frac{Psa}{Psr} \right]$$

Where:
Pst: total dry weight (g);
h: high (cm);
dcr: root neck diameter (mm):
Psa: aerial dry weight (g);
Psr: radical dry weight (g)

- Vigor index: determined by the formula: IV=Log Σ 〖todas las variables morfológicas 〗

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Statistical analysis

A simple classification variance analysis and a Tukey mean comparison test were performed for a 95 % probability for parameters and morphological indices, as well as the chemical and physical properties of the substrates. The parameters destubetado, structural stability and radical development were performed a chi-square test (X2) by means of a contingency analysis (≤ 0,05). For data processing, the statistical package SPSS ver. 23 for Windows was used.

RESULTS AND DISCUSSION

The results in table #3 show differences in pH values. The highest value corresponds to the substrate Cc20 and the lowest for Fc, the latter classified as strongly acidic. Arévalo *et al.,* (2016) point out that coconut fiber presents problems related to nutrient availability due to its high acidity, but can be an acceptable substitute for peat, as it presents less compaction and volume loss. (Table 3)

Table 3. – Chemical characterization of the substrate

S	pH	MO (%)	CE($dS.m^{-1}$)	N (%)	P (%)	K^+ (%)	Ca^{2+} (%)	Na^+ (%)
Cc	$5,90^d$	$89,18^a$	$0,65^e$	$1,87^a$	$1,45^a$	$1,81^a$	$0,69^a$	$0,09^a$
Fc	$5,49^f$	$71,73^c$	$3,54^a$	$1,43^c$	$0,11^d$	$1,39^e$	$0,45^f$	$0,06^c$
As	$5,76^e$	$50,41^e$	$3,27^b$	$0,52^e$	$0,093^f$	$1,18^g$	$0,54^d$	$0,03^e$
Cc60	$6,20^c$	$77,20^b$	$3,13^c$	$1,86^a$	$1,43^b$	$1,79^a$	$0,68^b$	$0,08^b$
Cc50	$6,31^c$	$73,78^{bc}$	$2,61^c$	$1,82^a$	$1,42^b$	$1,74^b$	$0,68^b$	$0,07^b$
Cc40	$6,57^b$	$68,96^d$	$2,68^c$	$1,54^b$	$1,42^b$	$1,55^d$	$0,46^e$	$0,05^c$
Cc30	$6,66^b$	$66,66^d$	$3,08^b$	$1,33^d$	$1,36^c$	$1,59^c$	$0,68^b$	$0,04^d$
Cc20	$7,70^a$	$66,02^d$	$2,27^d$	$1,40^c$	$0,10^e$	$1,19^f$	$0,56^c$	$0,05^c$
E.S	**0,160**	**0,238**	**0,239**	**0,114**	**0,133**	**0,092**	**0,021**	**0,081**

For each column, different letters indicate significant differences for the Tukey test (P≤0,05) E.S-Standard Error

The combinations were found between the mean values of the individual constituents, with significant differences between the substrates of higher and lower percentages of cocoa husk (Cc), with values between slightly acidic and neutral, both considered not limiting for plant development. In this sense, Taíz and Zeiger (2006) report that values between 5.5 - 6.5 increase the availability of nutritional elements and Landis *et al.,* (2000), cited by Castillo *et al.,* (2013) state that forest species tolerate a relatively wide range of pH values. On the other hand, Guzmán (2003) exposes that, in the containers, the seedlings are very sensitive to alterations of pH, due to the slow initial development and indicated an interval of optimal pH between 5,3 and 6,5. In the studied substrates, the pH is among the intervals reported and commonly evaluated as optimal for the production of forest plants in containers, except in the compound by Fc and Cc20.

The content of Organic Matter (MO) showed a difference, being suitable for each substrate, although slightly higher in the substrate Cc, composed of the highest concentration of cocoa husk. This same trend is observed in substrates composed of higher percentages of cocoa husk (Cc60 and Cc50), which demonstrates the importance of the cocoa husk in the development of substrates for seedling development.

The organic matter is an active component of the substrate, contributes to the improvement of the structure of the porous space, decreases the density and increases the humidity, which brings with it a better permeability (Dos Santos *et al.,* 2014).

In relation to electrical conductivity, the cocoa husk (Cc) showed the lowest value and the highest value was for coconut fiber (Fc), with statistical difference between both and the rest of the substrates (Table 3). In most substrates this parameter did not reach the limits considered by Torres *et al.,* (2010) as harmful to plant development, whose value is 3.5 dS.cm-1, except 100% coconut fiber (Fc), which slightly exceeds this value.

The content of the elements nitrogen, phosphorus, potassium and sodium was lower in sawdust (As) and higher in cocoa husk (Cc), presenting the mixtures values similar to its major components, being suitable for being within the ranges advised by Landis (1989), quoted by Ribeiro *et al.,* (2016). However, the composition of calcium was similar in all substrates, which favors the growth of meristem tissues of the plant and important for the proper development of plant roots (Avellán *et al.,* 2015).

Physical characterization of substrates

Analysis of the physical properties of the substrates indicated significant differences. Mean values, in relation to the individual constituents, were found in the physical properties of the mixtures, where the influence of the coco husk in the modification of the properties was evidenced (Table 4).

Table 4. - Average values of the physical characteristics of the substrates

Sustrato	DA (g mL^{-1})	DR (g mL^{-1})	PT (%)	DMP (mm)	RH (%)
Cc	0,28^{e}	1,53^{e}	84,97^{a}	0,58^{a}	62,60^{d}
Fc	0,19^{f}	1,48^{f}	55,45^{g}	0,37^{f}	78,09^{a}
As	0,54^{a}	2,05^{a}	70,26^{f}	0,52^{b}	50,88^{f}
Cc60	0,38^{c}	1,67^{d}	82,02^{b}	0,45^{c}	65,49^{d}
Cc50	0,37^{c}	1,70^{c}	81,87^{b}	0,42^{d}	64,41^{e}
Cc40	0,42^{b}	1,72^{b}	77,60^{d}	0,44^{c}	66,33^{c}
Cc30	0,33^{d}	1,73^{bc}	78,40^{c}	0,34^{e}	71,54^{b}
Cc20	0,31^{d}	1,68^{d}	76,16^{e}	0,35^{e}	70,76^{b}
E.S	**0,010***	**0,138***	**0,126***	**0,014***	**0,128***

For each column, different letters indicate significant differences for the Tukey test (P≤0,05) E.S- Standard Error

In relation to apparent density, Abanto *et al.,* (2016) maintain that the values of this can be close to 0.4 g mL-1. The mixtures represented by the substrates (Cc60 and Cc50), where the proportion of cocoa husk is majority, are close to this value. As for the real density, the values are within the intervals recommended by Ansorena (1994), between 1.45 g mL-1 and 2.65 g mL-1.

In relation to total porosity, composite substrates with the highest percentages of cocoa husk had the highest value; that is, as the amount of cocoa husk in the mixture increases, the total porosity increases. According to criteria of Ribeiro *et al.,* (2016), those substrates that have a total porosity in an interval of 75 to 85 %, have the appropriate characteristics, being in this range most of the substrates, except Fc and As that are below.

The lowest values of Apparent Density (DA) and Medium Particle Diameter (DMP) corresponded to coconut fiber, which conditions the highest values of Moisture Retention (RH), which is given by the presence of small particles that decrease the total porosity and increase the water retention capacity by decreasing the size of the interparticle pores (Ansorena, 1994).

According to Queiroz *et al.,* (2017), the lower DMP values characterize the substrate for its high water retention capacity. On the other hand, Salto *et al.,* (2016) with regard to moisture retention consider as adequate those substrates that retain at least 50 % humidity, according to this criterion; except **As** the rest of the materials used meet this condition, being Fc the one that retains the highest water content.

Relationship among variables destubetado, root ball stability, radical architecture and substrates

The chi-square test (X2) through the contingency coefficient showed interaction between the variable substrate, ease to destubetado, radical structure and stability of the root ball. Figure #3 shows that only As had a difficult destubetado, medium Fc and Cc20 and the rest of the substrates were easy. Dependence between the variable substrate and ease to destubetado ($P<0{,}05$) with a contingency coefficient of 0,789 was verified, therefore it is asserted that when increasing the proportion of Cc in the mixtures this influences favorably in this property (Figure 3). The chi-square test (X2) through the contingency coefficient showed interaction between the variable substrate, ease to destubetado, radical structure and root ball stability. Figure #3 shows that only As had a difficult destubetado, medium Fc and Cc20 and the rest of the substrates were easy. Dependence between the variable substrate and ease to destubetado ($P<0{,}05$) with a contingency coefficient of 0,789 was verified, therefore it is asserted that when increasing the proportion of Cc in the mixtures this affects favorably in this property (Figure 3).

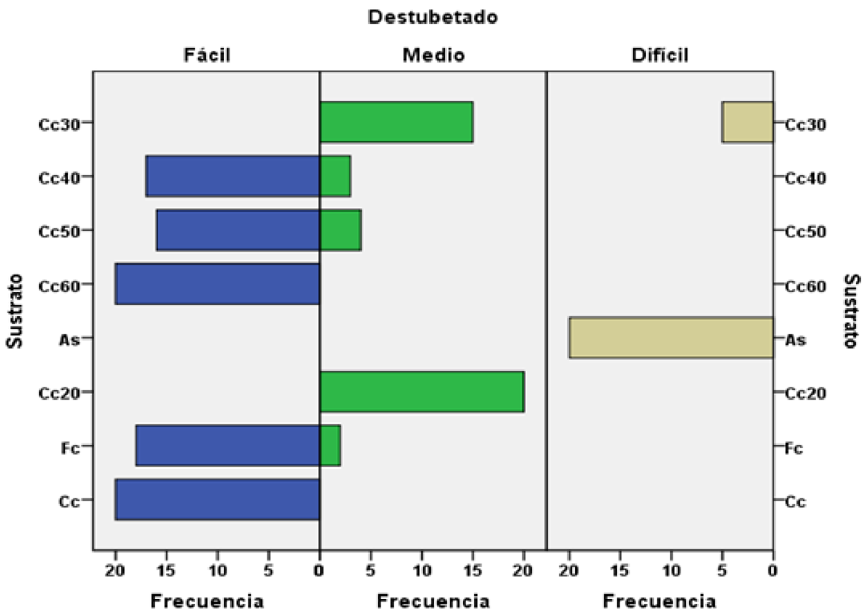

Fig. 3 - Frequency histogram showing the relationship between different levels without tube-type container and substrates

Radical architecture proved good for most substrates, except **As** which was considered bad. Substrate dependence was also found with radical architecture ($P<0.05$) for a contingency coefficient of 0.795, indicating that the presence of Cc favors the radical system (Figura.4)

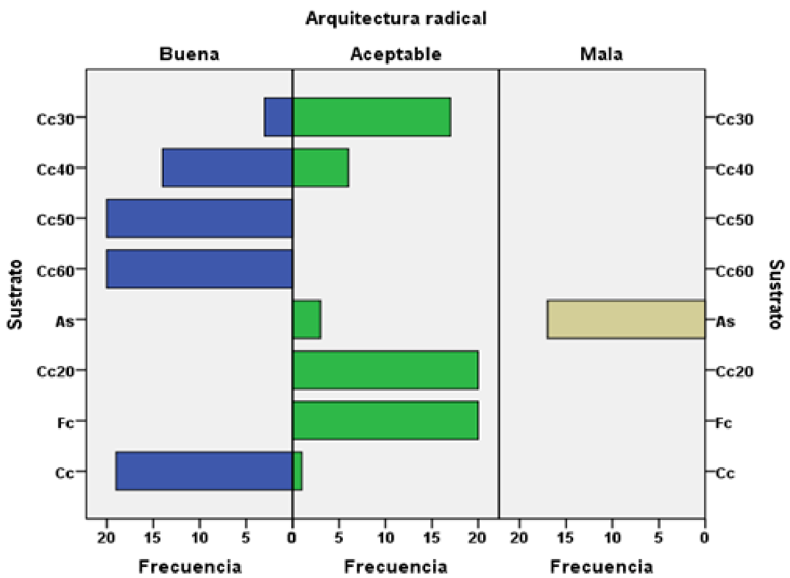

Fig. 4 - Frequency histogram showing the relationship between different levels of radical architecture and substrates

The relationship between the variable substrate and root ball stability ($P<0.05$) and a contingency coefficient of 0.768 was also demonstrated, resulting in **As** with low stability, while Cc, Cc50 and Cc60 with high stability and the rest of the substrates with intermediate stability. These results showed that the higher proportions of Cc influenced the stability of the root ball, which indicates that the radical system could easily explore and adhere to the substrates, due to the space available with respect to the others (Figure 5).

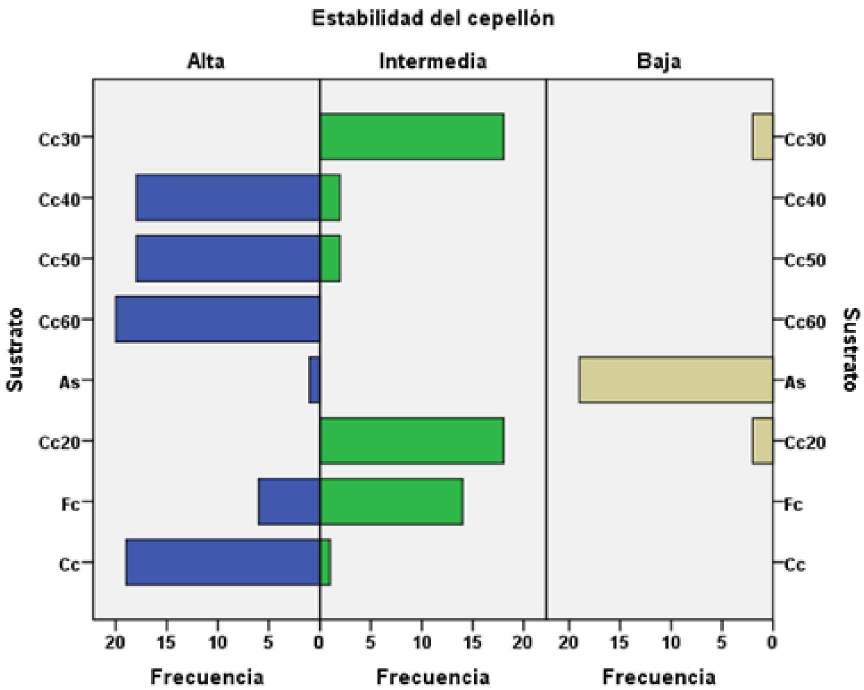

Fig. 5 - Frequency histogram showing the relationship between different levels of root ball stability and substrates

The variables without tube-type container, stability of the root ball and radical architecture are closely related to each other, which must be taken into account when studying the substrates, because the success of the plantation depends to a great extent on the good behavior of them.

Behavior of morphological parameters and indices at the end of the crop

Statistically, there are no significant differences between the substrates Cc60 and Cc50 for the variables height, diameter and dry weight, although the substrate Cc60 showed the highest averages. These values can be conditioned by a correct or abundant supply of nutrients from the substrates, so these combinations favored to a greater extent the development and growth of the plants (Table 5).

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Table 5. - Parameters and morphological indices of the plants after three months of cultivation

Sustratos	H (cm)	DCR (mm)	PSA (g)	PSR (g)	H/DCR	ICD	IV
Cc	18,89^{c}	3,87^{d}	0,62^{b}	0,43^{c}	4,88^{b}	0,16^{d}	2,27^{c}
Fc	14,81^{g}	3,16^{f}	0,50^{d}	0,30^{e}	4,68^{d}	0,12^{g}	2,23^{f}
As	15,65^{f}	3,15^{f}	0,34^{e}	0,22^{f}	4,96^{a}	0,09^{h}	2,25^{e}
Cc60	25,10^{a}	5,91^{a}	0,75^{a}	0,53^{a}	4,34^{f}	0,21^{b}	2,31^{b}
Cc50	24,20^{a}	5,56^{a}	0,74^{a}	0,52^{a}	4,26^{g}	0,22^{a}	2,33^{a}
Cc40	20,38^{b}	4,10^{b}	0,64^{b}	0,47^{b}	4, 47^{c}	0,18^{c}	2,26^{d}
Cc30	18,28^{d}	3,98^{c}	0,58^{c}	0,29^{e}	4,60^{e}	0,13^{f}	2,23^{f}
Cc20	16,78^{e}	3,75^{e}	0,57^{c}	0,35^{d}	4,68^{d}	0,14^{e}	2,22^{fg}
E.S	**0,174***	**0,048***	**0,006**	**0,005***	**0,012***	**0,002***	**0,002***

For each column, different letters indicate significant differences for the Tukey test (P≤0,05) (n= 25 plants per treatment).

These increases are considered to be due to the concentrations of nitrogen, phosphorus and potassium present in the substrates Cc60 and Cc50 (Table 3). Da Ros *et al.,* (2015) and Valkinir *et al.,* (2017) indicated that the presence of nitrogen in the initial phase of seedling production increased the growth rate of stem mass.

Regarding the Fc and Fc20 treatments, corresponding to the mixtures with the highest percentages of coconut fiber, these produced a lower growth in height and biomass than the other treatments used, differing with Klein (2015), who describes a good development of the plants when coconut fiber is used as substrate. The unfavorable results can be explained by analyzing the inadequate total porosity, delivered by the physical-chemical analysis, which shows a low DA and small DMP, which makes the substrate retain a high amount of water, which together with the climatic characteristics of the area affect the development of the postures (Figure 2).

In relation to the evaluated indices, such as: Esbeltez (H/DCR), Dickson quality index (ICD) and Vigor Index (IV), the best results were obtained in the substrates Cc60 and Cc50, from which it is inferred that they are plants that present greater mechanical resistance during planting operations or strong winds, that on the one hand the total development of the plant is large and that at the same time the aerial and radical fractions are balanced (Santil *et al.,* 2018).

In general, the values of the evaluated indices are within the positive ranges recommended by Rueda *et al.,* (2014), although the worst values are obtained by using 100 % coconut fiber (Fc) and sawdust (As) as substrate. These, as they are not mixed with other components, have lower physical and chemical characteristics than the other substrates used, coinciding with what was stated by Queiroz *et al.,* (2017), who express that modern growth media are prepared with two or more components, to provide the desirable physical, chemical or biological properties (Table 3 and Table 4).

The best chemical and physical properties in the substrates Cc60 and Cc50 indicate that they are the potential substrates for use in containers in the cultivation of the species *S. mahagoni.* The *S. mahagoni* species showed the best morphological response in substrates Cc60 and Cc50, attributable to the chemical-physical characteristics of the substrates.

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