ISSN: 2310–3469 RNPS: 2347
Revista Cubana de Ciencias Forestales. 2020; September-December 8(3): 550-561

Translated from the original in spanish

Original article

Behavior of morphological quality parameters of the *Lysiloma sabicu* Benth. plant in nursery on organic substrates

Comportamiento de los parámetros morfológicos de calidad de la planta de *Lysiloma sabicu* Benth. en vivero sobre sustratos orgánicos

Comportamento dos parâmetros morfológicos de calidade da planta de *Lysiloma sabicu* Benth. cultivada num berçário com substratos orgânicos

Milagros Cobas López[1*] https://orcid.org/0000-0002-3785-5235

Rogelio Sotolongo Sospedra[1] https://orcid.org/0000-0003-0116-4157

Yuraimis Almora Ramos[2] https://orcid.org/0000-0002-4301-4280

[1]Universidad de Pinar del Río "Hermanos Saíz Montes de Oca". Pinar del Río, Cuba.
[2]Empresa Agroforestal Pinar del Río. Pinar del Río, Cuba.

[*]Correspondence author: mcobas@upr.edu.cu

Received: June 19th, 2020.
Approved: Octuber 19th, 2020.

ABSTRACT

The study was developed with the objective of characterizing the behavior of the morphology of the *Lysiloma sabicu* Benth. plant grown in a nursery on different organic substrates and with the use of container technology. Three combinations of substrates made from mixtures of organic compost, worm humus and cow dung were tested to determine in which way it was feasible to achieve better plant quality with the use of this technology. The morphological variables measured were: height, root collar diameter, dry biomass, as well as root system attributes. From these values, the morphological indices were calculated: Slimness, PSA/PSR Ratio, and Dickson's Quality Index. The results obtained showed that there was a differentiated effect on the plants' morphology, depending on the substrate in which they were cultivated, and that it was S1 formed by 50 % organic compost + 25 % worm humus + 25 % cattle manure (Co-50 %+Hl-25 %+Ev-25 %) which provided the best values in the parameters studied.

Keywords: *Lysiloma sabicu*; Nursery; Substrate; Morphological parameters.

RESUMEN

El estudio se desarrolló con el objetivo de caracterizar el comportamiento de la morfología de la planta de *Lysiloma sabicu* Benth. cultivada en vivero sobre diferentes sustratos orgánicos y con el empleo de la tecnología de tubetes. Se probaron tres combinaciones de sustratos elaborados a partir de mezclas de compost orgánico, humus de lombriz y estiércol vacuno para determinar en cual era factible el logro de una mejor calidad de las plantas con el empleo de esta tecnología. Las variables morfológicas medidas fueron: altura, diámetro en el cuello de la raíz, biomasa seca, así como atributos del sistema radical. A partir de estos valores se calcularon los índices morfológicos: Esbeltez, Relación PSA/PSR, e Índice de calidad de Dickson. Los resultados obtenidos demostraron que existió un efecto diferenciado en la morfología de las plantas en dependencia del sustrato en que fueron cultivadas y que fue S1 conformado por 50 % de compost orgánico + 25 % de humus de lombriz + 25 % de estiércol vacuno (Co-50 %+Hl-25 %+Ev-25 %) el que propició los mejores valores en los parámetros estudiados.

Palabras clave: *Lysiloma sabicu;* Vivero; Sustrato; Parámetros morfológicos.

RESUMO

O estudo foi desenvolvido com o objetivo de caracterizar o comportamento da morfologia da planta *Lysiloma sabicu* Benth. cultivada num berçário em diferentes substratos orgânicos e com o uso de tecnologia de canais. Foram testadas três combinações de substratos feitos de misturas de compôs orgânico, húmus de minhoca e estrume bovino para determinar de que forma era viável alcançar uma melhor qualidade vegetal com a utilização desta tecnologia. As variáveis morfológicas medidas foram: altura, diâmetro do colar de raízes, biomassa seca, bem como atributos do sistema radicular. A partir destes valores, foram calculados os índices morfológicos: Esbeltes, relação PSA/PSR, e índice de qualidade de Dickson. Os resultados obtidos mostraram que houve um efeito diferenciado na morfologia das plantas em função do substrato em que foram cultivadas e que era S1 constituído por 50 % de composto orgânico + 25 % de húmus de minhoca + 25 % de estrume bovino (Co-50 %+Hl-25 %+Ev-25 %) o que levou aos melhores valores nos parâmetros estudados.

Palavras-chave: *Lysiloma sabicu*; Berçário; Substrato; Parâmetros morfológicos.

INTRODUCTION

The morphological quality of a plant refers to a set of characteristics, both qualitative and quantitative in nature, about the shape and structure of the plant. The morphology of a plant grown in a container in a forest nursery is the result of the genetic characteristics of the plants, the environmental conditions of the nursery and the cultivation practices used, among others (Navarro *et al*., 2006).

The success of reforestation programs depends mainly on the quality of the plant produced in the nurseries, which can ensure a greater probability of survival and development in the plantation when they become established in the final location.

Cuba's forestry development program includes the regeneration of existing forests and the reforestation of cleared areas. Natural regeneration and reforestation by direct seeding do not seem to be sufficiently effective under the country's soil and climate conditions, so the predominant type of forest regeneration is planting (Sotolongo-Sospedra *et al*., 2017).

Lysiloma sabicu is a native species of the family Fabaceae, very useful for the quality of its wood that can be used in various uses, in addition to having a rapid growth. For both aspects, it is a prioritized species within the Forestry Development Plan until 2030.

ISSN: 2310–3469 RNPS: 2347
Revista Cubana de Ciencias Forestales. 2020; September-December 8(3): 550-561

Traditionally for the promotion of this species in Cuba, seedlings have been produced in polyethylene bags using as substrate: soil. The implementation of technified nurseries, where plastic containers are used, raises the need of characterizing the growth of the species in this kind of packaging and substituting the soil as substrate, for combinations of organic compounds that, besides guaranteeing a good development of seedlings for their contribution of nutrients and physical structure, allow an appropriate management in the nursery.

The objective of this study is to characterize the morphological behavior of the *Lysiloma sabicu* Benth. plant cultivated in a nursery on different organic substrates and with the use of the container technology, for its implementation as a way of obtaining plants with quality.

MATERIALS AND METHODS

Description of the experiment

Seeds obtained from ripe fruits collected from a mass located in the city of Pinar del Rio were used for the experiments. The fruits were processed taking into account the aspects established for their benefit by Cuban Standard 318/1978. The obtained seeds were not stored but used immediately after their processing. They were subjected to a pre-germination treatment consisting of thermal scarification during 30 seconds (Gra *et al*., 2003).

The course of germination was followed for 30 days, through daily counts as indicated in Cuban Standard 71-04: 87. Although these analyses correspond to the quality of the seed, in the end they have an impact on the quality of the plants in the nursery.

The cultivation was carried out in plastic containers of the tubular type with a capacity of 90 cm^3. After sowing and up to the first month, irrigation was done manually, twice a day, in the morning and in the afternoon. From the second month on, only one watering was done daily and one month before the end of the crop, the process of hardening of the plants was started, consisting of watering on alternate days.

As substrates, mixtures of worm humus, cow dung and organic compost, and pine bark composted in different proportions were used.

A completely randomized design was used and the substrates used were considered as a study factor, with three levels:

- S1: 50 % organic compost + 25 % worm humus + 25 % cattle manure (Co-50 %+Hl-25 %+Ev-25 %).
- S2: 50 % composted pine bark + 20 % worm humus + 30 % organic compost (Cp-50 %+Hl-20 %+Co-30 %).
- S3: 50 % organic compost + 25 % composted pine bark + 25 % cattle manure (Co-50 %+Cp-25 %+Ev-25 %,).

The number of plants per treatment was 25 and the variables evaluated were:

- Height of the plant in centimeters (cm).
- Root collar diameter in millimeters (mm).
- Length of the main root in cm.
- Number of primary roots.
- Number of secondary roots.

- Dry weight of the biomass of the aerial part in grams (g).
- Dry weight of the root part in g.

The following morphological indices were calculated from the measured variables:

- Air dry weight - radical dry weight ratio (PSA/PSR).
- Slimness or height-diameter ratio (h/d).
- Dickson Quality Index (*Qi*).

$$Qi = \frac{PT}{\left(\frac{\text{long}}{\text{Diam}} + \frac{PSA}{PSR}\right)} \quad (1)$$

Where:

PT: total dry weight in g;
Length: height of the plant in cm;
Diam: root neck diameter in mm;
PSA: air dry weight in g;
PSR: radical dry weight in g.

Two evaluations were carried out, one at two months of cultivation (intermediate control), where only the height and diameter at the root collar of the seedling were measured. The second at the end of the crop (after four months), where the magnitudes of all the variables and indices were taken into account previously.

For the evaluation of the air dry weight and root variables, a sample of 10 plants was used, which were taken from those that were left outside the useful plot, where the 25 plants in which the rest of the variables were measured were located.

For the measurements of the root part, the roots of each plant were washed and separated from the root ball. The weight was determined after drying in an oven for 48 hours at a temperature of 70ºC until a constant weight was achieved.

Statistical analysis

To evaluate the effect of the substrate factor, three levels were considered that corresponded to the different mixtures of substrates: S1, S2 and S3, for each of the variables. These analyses were carried out by means of the non-parametric Kruskal-Wallis test with a α=0.05, because the variables analyzed did not comply with the mathematical assumptions for parametric testing. A multiple pair comparison test was used between treatment range means as described in Conover (1999).

RESULTS AND DISCUSSION

Germination behaviour

Germination began between the third and fourth day after sowing. The percentage of germinated seeds was less than 34 %, although higher than those reported by Domínguez *et al*., (2015), which with equal pre-germination treatment to the seeds obtained 16 %. Figure 1 shows the percentages of germination achieved in each treatment. The highest values obtained in the S2 substrate could be associated to the presence of worm humus and compost that favor the conditions of humidity of the substrate and affect the germination. In this regard, Sotolongo-Sospedra *et al.*, (2017) propose that humidity exerts an environmental effect on the germination process of seeds, in the same way that Sánchez and Furrazola (2018) argue that factors such as humidity can have a marked influence on the germination response of the species.

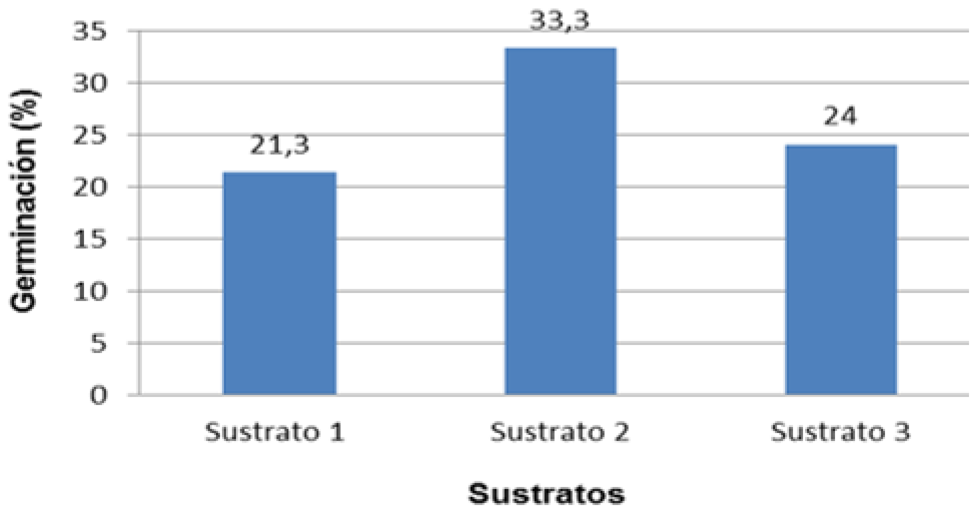

Figure 1. - Results of *Lysiloma sabicu* germination on the substrates

Results of the first evaluation (intermediate control) of *L. sabicu* seedlings after two months of cultivation

Table 1 shows the average height and diameter at the root collar reached by the seedlings in the different substrates after two months of cultivation in an intermediate quality control. The multiple comparison test reveals that the height reached in the S1 substrate is superior to the other two and differs significantly from both ($P < 0.05$). While for the variable root collar diameter, it is the substrate S3 that behaves best (Table 1).

Table 1. - Average values of height and diameter after two months of cultivation

Treatments	H (cm)	D (mm)
S1	11.73^{a}	2.26^{b}
S2	8.45^{b}	2.26^{b}
S3	8.80^{b}	2.68^{a}

Different letters indicate significant differences for $P < 0.05$ and $n = 25$ plants per treatment.

Navarro *et al*., (2006), highlight the importance of carrying out intermediate quality controls in order to avoid an increase in the length of the plant to a greater extent than the diameter of the neck of the root, which would undoubtedly lead to the production of tapered plants. Derived from the results obtained in its investigations, it suggests that the practical utility of this analysis could lead, if necessary, to the shedding of other cultivation variables such as the density of plant per m^2 in the nursery and the irrigation in order to achieve, together with the height, a more accelerated increase of the diameter.

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Revista Cubana de Ciencias Forestales. 2020; September-December 8(3): 550-561

In relation to this experiment, the plants of the substrate S1 at the time of this control at the two months of culture, were those that had the tendency to the threading; nevertheless, from that moment it began to distance the irrigation to cause the hardening, question that could have influenced in the final status of the plant.

Characteristics of the *Lysiloma sabicu* plant in nursery, at the end of cultivation

Table 2 shows the results of the average behavior of the morphological variables and quality indexes obtained by the plants in the three substrates used. As in the first evaluation it was proven that the substrate has a significant effect (P<0.05) according to the Kruskal-Wallis test and multiple comparison.

Table 2. - Mean values per substrate of morphological variables and quality indices at the end of L. sabicu cultivation in tube-type containers

Treatments	H (cm)	D (mm)	PSR (g)	PSA (g)	PST (g)	PSA/PSR	H/D	QI
S1	12.75^a	3.88^a	0.33^a	0.35^a	0.68^a	1.06^b	3.35^a	0.15^a
S2	8.98^b	2.30^c	0.16^b	0.18^b	0.34^b	2.25^a	3.93^b	0.06^c
S3	10.14^b	2.72^b	0.17^b	0.21^b	0.38^b	1.33^b	3.73^b	0.08^b

Unequal letters indicate significant differences for P < 0.05 (n=25). Plant height (H), root collar diameter (D), root dry weight (RWW), air dry weight (ASD), total dry weight (TW), Dickson Quality Index (QI).

The growth of *L. sabicu* plants varied according to the substrate in which they developed. In the case of the variables plant height and stem diameter, it was observed that the plants developed in the substrate S1 (Co-50 %+Hl-25 %+Ev-25 %) were those that reached the highest values (Figure 2).

Figure 2. - Height of the plant in the S1 treatment

Salto *et al*., (2013), state that the morphological attributes of a quantitative nature that are usually used in scientific studies or in quality control of plants in containers are the height and diameter at the height of the neck. Quiroz *et al*., (2014) agree with these criteria and mention that the morphological attributes commonly measured to determine plant quality are related to its height and diameter, hence its importance in the analyses carried out in the context of this experiment.

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Revista Cubana de Ciencias Forestales. 2020; September-December 8(3): 550-561

It should be noted that the substrates in which mixtures were made in which the compost was present in high proportions (S1 and S3) were those that presented the greatest values in height and diameter. All these benefits can be related to factors such as the improvement in the physical structure of the substrate, increase in the population of beneficial microorganisms and more probably with the increase of growth regulating substances such as hormones and humates produced by the microorganisms (Atiyeh *et al.,* 2002). In parallel to this, García *et al.,* (2010), also highlight that the addition of compost significantly influences the chemical properties of the substrate.

The diameter was the only one of the evaluated parameters that showed significant difference in the three evaluated substrates (Table 2), obtaining the highest value in the substrate S1. In relation to this, Grossnickle (2012), expressed the importance of the diameter expressing that it gives an approximation of the cross section of water transport, mechanical resistance and relative capacity to tolerate high temperatures on the soil surface, by the relationship it has with the amount of biomass and mechanical resistance. On the other hand, Muñoz *et al*., (2015) consider that the diameter is the most important quality characteristic that allows predicting the survival of the plant in the field. The diameter of the root collar is the parameter that is generally related to the amount of reserves that the plant has to begin its growth, after being planted, so the greater the diameter, the greater the initial growth in plantation.

In this case, taking into account the diameter values obtained, a high percentage of field survival can be predicted for the plants cultivated in the S1 substrate, since they will be able to counteract the effect of the adverse conditions in the stage.

Related to the production of biomass, it can be observed that there is a significant difference between the substrate S1 and the rest of the substrates (S2 and S3), with respect to the variables PSA, PSR and PST, being favored the plants of the substrate S1 that were those that reached the greater values of dry weight. Similar results were obtained by García *et al.,* (2010), with a substrate whose greater percentage was based on compost. These authors affirm that the use of compost improves some growth indicators since it increases the fertility of the substrates, caused by an increase in the availability of the nutrients, as well as it improves the structure and the capacity of water retention.

When analyzing the values obtained in the indices studied (Table 2), it can be seen that it is also in the substrate S1 where the plants show the best results. In relation to the slenderness (H/D), Villalón *et al*., (2016) point out that an improvement in the quality of the plant is achieved through a decrease in it. These authors also state that it has been demonstrated that plants with a lower height/stem diameter ratio can maintain a better water status with a more moderate water consumption in situations of water deficiency. Thus, the plant best prepared to resist adverse conditions is the one grown in the substrate S1.

These plants also presented the lowest values of the PSA/PSR ratio. This characteristic, usually, is considered that it can contribute to improve the water economy of the plant and therefore, also, its capacity of survival and growth in dry environments (Ramírez and Rodriguez, 2004), because the smaller value of this relation, more favored is the water absorption against the losses. The plants of the S1 treatment (Co-50 %+Hl-25 %+Ev-25 %) showing a value of 1,06; present the best developed radical system, favoring the absorption of water and maintaining a level of mechanical support against the problems that they can present once they are in the field. In this sense, Álvaro *et al*., (2014), indicate that a good quality plant should present a low value of the relationship between aerial biomass and root biomass.

Sotolongo-Sospedra *et al.*, (2017), have referred to the importance of this ratio being in the range of 1.5 to 2.5 so that the plants are taken to the field in better conditions of adaptability, and can overcome certain stresses when they arrive at the site, starting from the fact that in many cases the soil preparation tasks for the forest species are not the most suitable.

As for the Dickson Quality Index (Q_i), the analysis shows that there are significant differences in all treatments, but the plants of the S1 treatment (Co-50 %+Hl-25 %+Ev-25 %) show the best quality at the end of the crop, being 0.15. According to Quiroz *et al.*, (2014), an increase in the value of Dickson's index is associated with a superior plant quality, due to a better balance between the aerial and root biomass.

In this regard, Álvaro *et al.*, (2014) conclude on the direct relationship between the value of the index and the survival of the plants, that an index lower than 0.15 means problems in the establishment for some species, therefore, the plant is favored if it reaches maximum values, this brings that, on the one hand, the total development of the plant is large, at the same time, the aerial and radical fractions are balanced. In this regard, Falcón *et al.*, (2019) agree with the previous approach and also express that the plants with higher values of this index, have greater mechanical strength during planting operations or strong winds.

Morphology of the radical system

The type of substrate did not statistically significantly influence the Kruskal-Wallis test, for the length of the main root (Lrp). The rest of the attributes of the root system are influenced by the substrate and the plant cultivated in the substrate S1 benefits from it, so that a better absorption of the substances present and indispensable for the development of the plants in the substrate is favored (Table 3).

Table 3. - Attributes of the root system at the end of the crop

Treatments	PSR (g)	Lrp (cm)	Quantity of primary roots	Quantity of secondary roots
S1	0.33^a	8.05^a	23^a	91^a
S2	0.16^b	7.9^a	15^b	67^b
S3	0.17^b	$8,05^a$	16^b	60^b

Different letters in the same column differ for $P < 0.05$ for $n = 10$ plants per treatment.

Everything could be given, according to Santiago *et al.*, (2015) because the space was better used and a greater number of secondary roots were generated, capable of colonizing the root ball faster, as is also attributed to the physical characteristics of the substrate.

In this regard, Álvaro *et al.*, (2014) and Davis and Jacobs, (2005) conclude that the abundant emission of secondary roots demonstrates high quality and ensures rapid plant growth after planting; when plants are established in favorable environmental conditions for growth, they emit new roots, which will initiate the process of water absorption; to improve their performance in the field, Davis and Jacobs (2005) also refer to the number of first-order secondary roots that have shown correlation to improve plant performance in the field.

It can be stated that the roots of the plants evaluated in this experiment completely colonized the root ball and were not deformed, which could affect future development in the plantation (Figure 3).

Figure 3. - Radical architecture of the plants in each of the substrates

In general, the plant of good quality for reforestation is associated with that which presents a good balance between the aerial part and the root, and which has an abundant and well-formed root system according to Negreros *et al*., (2010).

The results obtained at the end of the cultivation in nursery, showed that there was a differentiated effect in the morphology of the plants depending on the substrate in which they were cultivated and that it was the substrate S1 conformed by 50 % of organic compost + 25 % of worm humus + 25 % of cattle manure (Co-50 %+Hl-25 %+Ev-25 %) the one that propitiated the best values in the studied parameters.

In general it can be added that the substrates in whose composition the organic compost was found in a greater percentage (S1 and S3), were those in which representative values of good quality were obtained as far as the attributes and morphological indexes evaluated at the end of the cultivation in nursery.

These results can support decision making in reforestation activities related to *L. sabicu* species and its cultivation in nurseries with the container technology.

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Conflict of interests:

The authors declare not to have any interest conflicts.

Authors' contribution:

The authors have participated in the writing of the work and analysis of the documents.