Revista Cubana de Ciencias Forestales

Volume 14; 2026, January-December

LIBER CIENCIA
EDITORIAL CIENTÍFICA
UNIVERSIDAD DE PINAR DEL RÍO

UNIVERSIDAD DE PINAR DEL RÍO
HERMANOS SAÍZ MONTES DE OCA

CFORES
REVISTA CUBANA DE CIENCIAS FORESTALES

ISSN: 2310-3469 RNPS: 2347
CFORES Journal, January-December 2026; Volume 14: e900

Original article

Different types of substrates in the nursery phase, in Eucalyptus globulus, in Contumazá, Cajamarca, Peru

Distintos tipos de sustratos en fase de vivero, en Eucalyptus globulus, en Contumazá, Cajamarca, Perú

Diferentes tipos de substratos na fase de viveiro, em Eucalyptus globulus, Contumazá, Cajamarca, Peru

Jerson Díaz Castillo [1] *Sergio Valdivia Vega* *, Jorge Pinna Cabrejos* [1]

[1]Antenor Orrego Private University, Trujillo, Peru.

[*] Corresponding author: jdiazc18@upao.edu.pe

Received: *02/06/2025.*
Approved: *21/01/2026.*

ABSTRACT

Eucalyptus adapts easily to the climatic conditions in Peru. This research was carried out in the department of Cajamarca. The objective was to evaluate the influence of different types of substrates (in polyethylene bags, in the open air) on the quality of the seedlings. The design was completely randomized blocks with 15 treatments, four repetitions. The number of leaves, height, and stem base diameter (DBT) were evaluated for four months. The fresh and dry mass of the aerial and root parts were evaluated, as well as quality indicators: Dickson's index, slenderness, aerial part-root part ratio, water balance of the plant and percentage of lignification. Analysis of variance was performed, and the Fisher

LSD test. No treatment had the best results for all variables. Treatment L (50 % agricultural land + 50 % black soil) ranked first in number of leaves, aerial fresh weight, total dry weight and aerial dry weight. The G treatment (15 % hill sand + 50 % agricultural land + 35 % black soil) in DBT, root dry weight and Dickson index. There was a significant difference when using river or hill sand only in some cases. There was a high correlation between the number of leaves, and the height and with the fresh and dry total weights; root and aerial, and a high correlation between the height and the fresh and dry total weight; root and aerial, Dickson index and % of lignification.

Keywords: Plant height, sand, eucalyptus, agricultural land.

RESUMEN

El eucalipto se adapta fácilmente a las condiciones climáticas peruanas. Esta investigación se desarrolló en el departamento de Cajamarca. El objetivo fue evaluar el efecto de distintos tipos de sustratos (en bolsas de polietileno, a cielo abierto) en la calidad de los plantones. El diseño fue de bloques completos al azar con 15 tratamientos, cuatro repeticiones. Se evaluó el número de hojas, la altura y el diámetro de la base del tallo (DBT) durante cuatro meses, la masa fresca y seca de la parte aérea y radicular, y los indicadores de calidad: índice de Dickson, de esbeltez, relación parte aérea-parte radicular, balance hídrico de la planta y porcentaje de lignificación. Se realizó análisis de varianza y la prueba LSD de Fisher. Ningún tratamiento tuvo los mejores resultados para todas las variables. El tratamiento L (50 % tierra agrícola + 50 % tierra negra) obtuvo el primer lugar en número de hojas, peso fresco aéreo, peso seco total y peso seco aéreo. El tratamiento G (15 % arena de cerro + 50 % tierra agrícola + 35 % tierra negra) en DBT, peso seco radicular e índice de Dickson. Existió diferencia significativa al utilizar arena de río o de cerro solo en algunos casos. Hubo alta correlación entre el número de hojas y la altura y con los pesos fresco y seco total; radicular y aéreo, y una alta correlación entre la altura y el peso fresco y seco total; radicular y aéreo, índice de Dickson y % de lignificación.

Palabras clave: altura de planta, arena, eucalipto, tierra agrícola.

RESUMO

O eucalipto se adapta facilmente às condições climáticas peruanas. Esta pesquisa foi desenvolvida no departamento de Cajamarca. O objetivo foi avaliar a influência de diferentes tipos de substratos (em sacos de polietileno, ao ar livre) na qualidade das mudas. O projeto foi de blocos aleatórios completos com 15 tratamentos, quatro repetições. Avaliou-se o número de folhas, altura e diâmetro da base do caule (DBT) durante quatro meses, a massa fresca e seca da parte aérea e radicular e os indicadores de qualidade: índice de Dickson, de esbeltez, relação parte aérea-radicular, balanço hídrico da planta e porcentagem de lignificação. Análise de variância foi realizada, e o teste LSD de Fisher. Nenhum tratamento teve os melhores resultados para todas as variáveis. O tratamento L (50% de terra agrícola + 50% de terra negra) obteve o primeiro lugar em número de folhas, peso fresco aéreo, peso seco total e peso seco aéreo. O tratamento G (15% de areia de montanha + 50% de terra agrícola + 35% de terra negra) em DBT, peso seco da raiz e índice de Dickson. Houve diferença significativa ao usar areia de rio ou colina apenas em alguns casos. Houve alta correlação entre o número de folhas, e a altura e com os pesos fresco e seco total; radicular e aéreo, e uma alta correlação entre a altura e o peso fresco e seco total; radicular e aéreo, índice de Dickson e % de lignificação.

Palavras chave: Altura da planta, areia, eucalipto, terra agrícola.

INTRODUCTION

The *Eucalytus globulus* is one of the timber species most commonly planted in reforestation projects (Balmelli *et al*., 2023). Its leaves contain essential oils used in the chemical and pharmaceutical industries (Nolazco *et al*., 2020). The density, lignin and cellulose content, and fiber length and direction of its wood make it suitable for papermaking.

The eucalyptus tree adapts very easily to the diverse climatic conditions of Peru, with 73.2 and 243.8 m3 in the production of round and sawn wood, respectively, of *Eucalyptus globulus* Labill in Peru in the year 2023 (SERFOR, 2023).

It was common practice in nurseries to use local soil to fill the containers in which the seedlings would be produced, which resulted in low productivity, and led to the formulation of mixtures for the production of potted plants and the promotion of research that would allow for quality seedlings (Kratz *et al*., 2017 ; Rodríguez-Ortega and Briceño-Yen, 2023).

Substrates are currently used in nurseries, providing water, air, nutrients, and physical support; they must have an acidity suitable for the species, a light texture, and good drainage, using, for example, organic matter, sand, or agricultural soil (Rodríguez-Ortega and Briceño-Yen, 2023). They are formulated based on the availability of their components, the producer's requirements, the species to be propagated (Quiroz *et al*., 2009); its costs, the environmental impact of their extraction, their availability, and their standardization (Gayosso *et al*., 2016).

The substrate has three fractions: 1) solid part that ensures anchorage, plant stability and maintenance of the root system; the amount of nutrients and their availability for absorption by the plants are considered (Stewart-Wade, 2020). 2) liquid fraction that provides the plant with the necessary water and nutrients; 3) gaseous part that facilitates the exchange of oxygen and carbon dioxide (Stewart-Wade, 2020).

Eucalyptus globulus is grown in nurseries with a covered root production system in pH ranges between 4.5 and 6 (Escobar, 2007); its effectiveness is limited under extreme pH conditions. Organic substrates improve structure, increase pore space, enhance moisture retention, and lower density, resulting in improved permeability. During decomposition, they release organic acids and carbon dioxide, which lower the pH and release calcium and other nutrients through the solubilization of carbonates and other primary minerals.

The exchange capacity should be between 10 and 30 meq $100g^{-1}$ of soil (FAO, 2002). A substrate should be free of phytotoxic substances, weed seeds, nematodes and other pathogens (Quiroz *et al*., 2009).

The use of peat can generate a negative environmental impact on the ecosystem; extracting agricultural soil to use as a substrate could increase erosion and cause physical deterioration of agricultural land; using urban, livestock, agricultural, forestry or industrial waste could generate a positive environmental impact (García *et al*., 2001).

Sand, due to the diameter of its particles, allows for good aeration. Its aeration decreases over time due to compaction. It has a high infiltration rate and a medium water retention capacity. It must be washed and free of silt and clay, as these will be washed away and settle at the bottom of the container during irrigation.

The production of eucalyptus seedlings in a nursery has three phases. The first phase begins with placing the seed in containers and ends with the emergence of the first two true leaves; this phase is crucial for the plant's future performance, accounts for 70% of the budget allocated to seedling production, and lasts between one and four weeks. The second phase is the full growth phase, which begins when the seedlings have two true leaves or have been inoculated with mycorrhizae and ends when the seedlings reach the desired height; it lasts between six and 24 weeks and can be shortened to between 10 and 12 weeks. The third phase is the hardening-off phase , which aims to slow the seedling's apical growth to increase its resistance to water stress before storage or transport; irrigation is limited to induce water stress in the plant, resulting in greater resistance to stress caused by transport, drought, or cold (Rodríguez, 2008).

The province of Contumazá, in the department of Cajamarca, Peru, has many areas with Eucalyptus plantations. Field results are not optimal due to the use of poor-quality seedlings and inadequate forest management. The solution to this problem lies in the nursery phase with the production of high-quality plants. The objective of this research is to evaluate different types of substrates currently used in the nursery phase.

MATERIALS AND METHODS

Location: The study was conducted at the nursery of the Contumazá Agricultural Agency, in the hamlet of Silacot, Contumazá district and province, Cajamarca department. Latitude: -7.365974° S; Longitude: -78.817794° W; 2546 m above sea level. A randomized complete block design was used, with 15 treatments and 4 replications (Table 1), and four plants per experimental plot. Eucalyptus (E*ucalyptus globulus* Labill) seed was used.

***Table 1.* -** *Treatments*

Treatment	River sand (%)	Agricultural land (%)	Black soil (%)
TO	15	50	35
B	20	40	40
C	30	50	20
D	50	50	0
AND	50	0	50
F	100	0	0
Treatment	**Hill sand (%)**	**Agricultural land (%)**	**Black soil (%)**
G	15	50	35
H	20	40	40
Yo	30	50	20
J	50	50	0
K	50	0	50
L	0	50	50
M	100	0	0
N	0	0	100
EITHER	0	100	0

Analysis of variance (ANOVA) was performed and, if there were statistically significant differences, grouping was performed using Fisher's LSD method with Minitab software.

Substrates:

A. Black soil. Local suppliers extract it from the hamlet of Cascabamba, calling it peat; it is believed to have physicochemical properties that influence plant growth. It was sieved to remove root fragments and clods.

B. Agricultural soil. It was extracted from a plot cultivated with peas (Pisum*). sativum),* which is located near the nursery; it was obtained from the top 40 cm of the soil. It was sieved.

C. River sand. It is extracted almost entirely from two locations: Chilete, on the Jequetepeque River, located approximately 40 km from the city of Contumazá; and the Chicama River, approximately 60 km away. It was extracted from the banks of the Jequetepeque River.
D. Sand from the hills. From a small-scale quarry located in the hamlet of Salcot. It was sieved.

Black polyethylene bags measuring 15 cm high by 3 cm in radius were used.

Seedbed: The preparation of the substrates began with the sieving and mixing of black soil and sand. The seedbeds were sterilized with a solution of formalin (250 mL) and water (16 L). The beds (10 m long, one meter wide) were filled to a height of 25 cm with the substrate and leveled. Sowing was done by broadcasting one kg of seed per bed, which was covered with half a centimeter of substrate. The beds were watered with 10 L of water using a backpack sprayer. They were covered with a double layer of plastic in a semi-tunnel shape. A *Rashel* mesh cover (50% light) was installed at a height of two meters. One week later, *Orius* (fungicide: 2 tablespoons in 6 L of water) was applied. Daily watering was carried out. Seedlings emerged ten days after sowing. Weeding was done weekly. Seedlings emerged for up to 25 days after planting.

Transplanting: Approximately one month after sowing, uniform seedlings with two to three pairs of leaves were dipped in a fungicide and then transplanted into polyethylene bags. After three days, a second transplant was performed. Five plants (2.08%) did not survive; five days later, a second transplant was carried out, resulting in the death of three plants (1.25%). One month after the experiment began, and after ensuring that the plants had acclimatized, the experiment was moved to a location with direct sunlight.

Irrigation: Initially, irrigation was carried out using a program called Soil Water Characteristics until the substrates reached field capacity. Afterward, the plants were irrigated by sheet irrigation, applying the same amount to all pots every other day. This process was carried out for two and a half months; however, to avoid variations due to the physical characteristics of the substrates, irrigation continued until each substrate reached field capacity. This process was repeated from the two-and-a-half-month mark until the end of the field phase (four and a half months).

Weeding: Weed control was done manually every 15 days, removing them from the substrate and also those adjacent to the experimental area to prevent them from hosting insects that could attack the plants.

Pest and disease control: During the slow growth phase, the presence of Ctenarytaina was observed. *eucalypti* on the young leaves at the tips; however, it gradually subsided without causing significant damage. Signs of an unidentified disease were observed causing deformation and "rosettering" of leaves and stems, as well as stunting in the plants, with a higher incidence in five plants (2.08%), so no product was applied as it did not exceed the established threshold (5%).

Evaluations: The number of true leaves on each seedling was counted. The number of branches and leaves appearing on some plants was recorded starting from the fourth evaluation (two months after transplanting). The distance from the root collar to the plant apex was measured every 15 days. The stem base diameter (SBD), also known as the root collar diameter, was measured with a digital caliper every 15 days, starting from the first month.

After nine evaluations (four and a half months), the stem was cut, the roots were washed and weighed to obtain fresh weight in grams. For the dry weight of the root, it was placed in manila folders and placed in an oven for 1 hour at 100 °C, and then the temperature was lowered to 75 °C for 48 hours. The dry weight of the leaves and stems: The analysis was performed after the plants had been oven dried. The total dry weight was calculated by adding the weight of the root to the weight of the stem and leaves. Soil samples were taken from each material (black earth, hill sand, river sand, and agricultural soil) and transported to the laboratory to determine their physicochemical characteristics in order to identify which specific material was responsible for any improvement, if any.

Calculation of the indexs:

$$Quality\ index: \acute{I}ndice\ de\ calidad\ de\ Dickson: ICD\ =\ MST/RAD + RPAR$$

Where: MST: total dry weight (g) (aerial + root). RAD: height (cm)/diameter (mm) ratio. RPAR: dry weight ratio of aerial part (g)/dry weight of root part (g).

Biomass Index Aerial Part–Root Part (BPA/BPR): was performed by dividing the biomass of the aerial part by the biomass of the root part.

Slenderness index: Obtained by dividing the height by the stem base diameter. *Plant water balance (PWB)* = (aerial dry weight (g)/ (DBT x root dry weight (g)).

RESULTS AND DISCUSSION

Characterization of substrate components

Black soil has 2.91% organic matter, the highest among the substrates, which could provide a greater content of nutrients and increase the *buffering capacity* of the soil (Table 2).

Table 2. - *Soil Analysis*

SAMPLE	MO %	P ppm	K ppm	pH 1:1	% SATURAC.	CE $_{ES}$ dS m $^{-1}$ (Dear)	CaCO3 %
Black earth	2.91	56.30	131.30	4.10	40.0	0.32	0.20
Farmland	1.65	22.44	366.95	6.17	41.0	1.34	3.88
Hill sand	0.45	13.73	102.59	6.10	30.0	0.28	0.00
River sand	0.16	11.60	66.08	6.60	31.0	0.51	5.70

Hill sand contains more phosphorus (P) and potassium (K) than river sand; its pH is lower, as is the electrical conductivity of the saturation extract (EC_S) and the percentage of $CaCO_3$ The pH values of the materials range from 4.1 (black soil), 6.1 (hill sand), 6.17 (agricultural soil), to 6.6 (river sand). Symonds *et al*. (2001) obtained greater growth in eucalyptus seedlings in a nursery with pH values between 5.1 and 5.6. The EC of agricultural soil (1.34 dS m^{-1} is higher than that of the other components; in black soil, it is 0.32 dS $m^{1.}$ hill sand has a higher percentage of silt and clay than river sand (Table 3). Agricultural soil is classified as sandy clay loam.

Table 3. **-** *Texture analysis*

SAMPLE	PERCENTAGE OF PARTICLES			TEXTURE (USDA)
	SAND	SILT	CLAY	
Black earth	62.37	32.50	5.13	sandy loam
Farmland	54.87	25.00	20.13	sandy clay loam
hill sand	89.95	7.50	2.55	Sand
River sand	93.95	4.00	2.05	Sand

Morphological analysis (number of leaves, stem base diameter, height)

In the number of leaves (Figure 1), the ANOVA in the first evaluation indicated that it was not statistically significant. There were statistically significant differences in the second evaluation, and highly significant differences in subsequent evaluations, so Fisher's LSD test was performed. From the fourth evaluation onward, the treatments without agricultural soil (E, F, K, M, N) were statistically inferior to the others. In the fifth evaluation, hill sand was statistically superior to river sand; in the other evaluations, there were no differences in most treatments, with sporadic variations observed between the two types of sand in the different evaluations. The absence of black soil (D, J) did not statistically affect the number of leaves in most evaluations, indicating that the positive properties attributed to it in the area are not so significant. In some nurseries, the number of leaves is often used as a plant selection criterion (Escobar 2007).

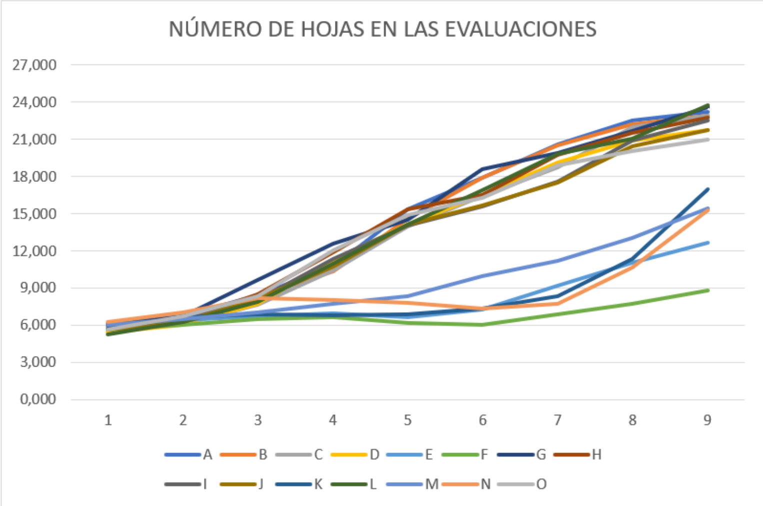

Figure 1. *- Number of leaves in the nine assessments*

In the second evaluation, the DBT (Diamond Tubercle) was measured. In all evaluations, the ANOVA registered highly significant differences, and as with the number of leaves, from the fourth evaluation onward, the treatments without agricultural soil were statistically inferior. In some evaluations, some treatments with river sand performed better than those with hill sand; in others, the opposite was true, with no sand showing superior performance. The absence of topsoil did not affect the number of leaves in most evaluations, confirming that the positive properties attributed to it in the area are not so pronounced. DBT is used to determine quality, as it is a good predictor of plant performance in the field, especially in adverse conditions. A minimum of 2.5 mm of DBT is a quality indicator (Silva *et al*., 2014). The treatments that exceeded this threshold in the 120 days evaluated were G, L, B, A, H, C, D, O, I, and Silva *et al*. (2014) obtained a DBT of 2.9.

In terms of plant height, ANOVA showed highly significant differences in all evaluations. As with the number of leaves and total dry matter (TDM), from the fourth evaluation onward, treatments without topsoil performed inferiorly to the others, with no sand showing superior performance. The absence of black soil did not affect leaf number and TDM in most evaluations, further confirming that the positive properties attributed to it in the region are not as pronounced as previously thought. Plant height shows strong correlations with leaf number (Figure 2), which determines photosynthetic processes and transpiration. Taller plants improve morphological constitution and provide greater survival and growth in the field. However, producing tall plants requires more time and space in the nursery, where the primary objective is to produce the largest number of plants in the shortest time and at the lowest possible cost. In all morphological analyses, the ANOVA shows similar results: that there were statistical differences, with the LSD test showing who is superior, finding similar behaviors in all cases, observed in Figure 1, so the numerical data of the ANOVAs are not shown.

In tropical and subtropical regions, the transplant height to the final field ranges from 15 to 30 cm, achieved within 4 to 5 months. Based on this, the treatments that could be transplanted to the final field are B, L, A, G, H, C, O, D, I, and J (using agricultural soil), considering that the last evaluation was performed 120 days after transplanting. Silva *et al*. (2014) obtained the greatest height in their experiment (28.0 cm) at 90 days.

Fresh and dry weight (total, root and aerial)

The weights are shown in Table 4. In all cases, the ANOVA shows highly significant differences. Fisher's LSD test indicates that the samples from substrates without agricultural soil, as observed in the morphological characteristic assessments, are statistically inferior. The results for the two sands are similar to those already mentioned, as are those for the black soil.

The dry weight of the entire plant (stem and leaves) is a more stable measure than the fresh weight of the plant. Ten of the 15 treatments analyzed in this experiment had a value greater than 0.67 g/plant, which may be due to the fact that the evaluation was performed at 120 days. Root weight is often used to determine the total root mass and quantify photosynthates stored by plants; however, it does not guarantee the number of absorbing roots. Both weights have a highly significant relationship with plant height (Figure 2) and (Table 4).

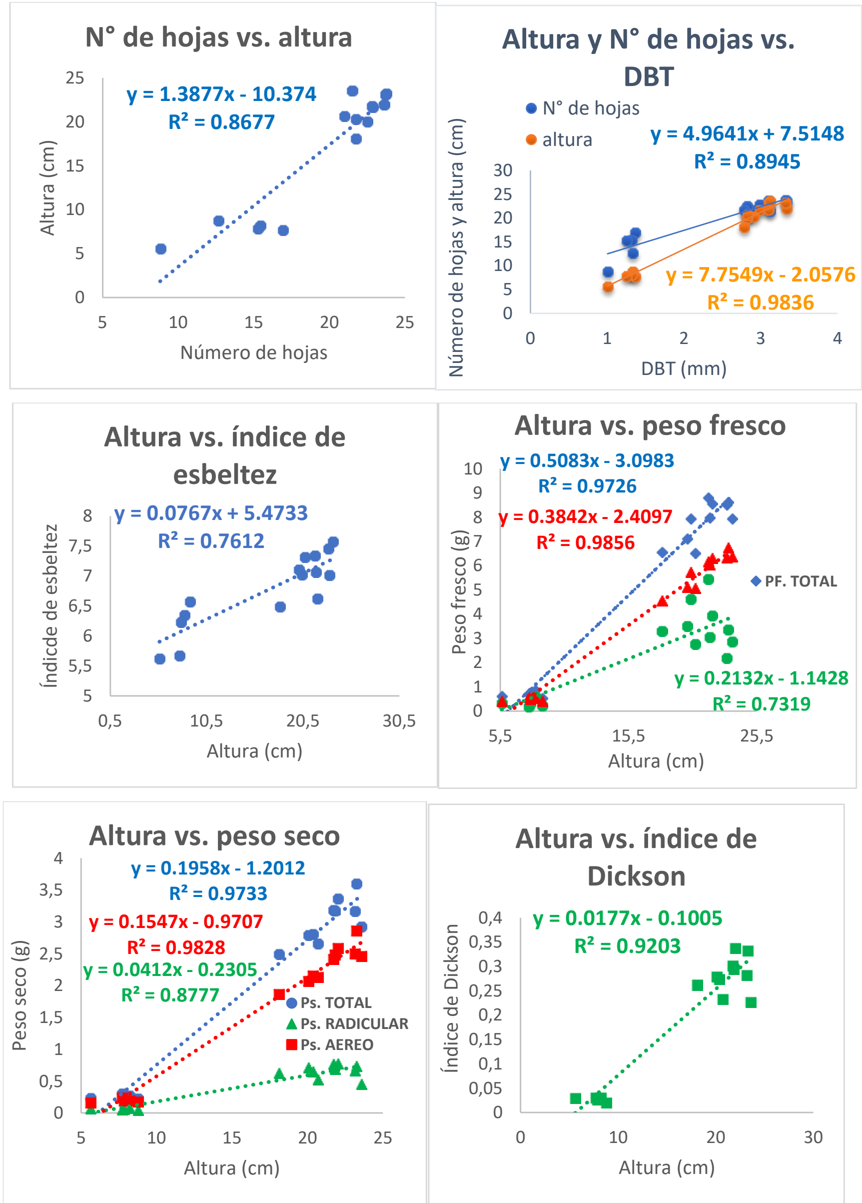

Figure 2. - *Relationship between morphological parameters and height with slenderness index, plant weight and Dickson index*

Table 4. - *Weight of the seedlings at the end of the experiment (g)*

TREATMENT	DRY WEIGHT			FRESH WEIGHT		
	TOTAL	RADICULAR	AIR	TOTAL	RADICULAR	AIR
THE	3.17	0.67	2.50	8.52	2.19	6.33
B	2.93	0.46	2.47	7.94	1.56	6.38
W	3.14	0.73	2.42	8.81	2.63	6.19
D	2.64	0.48	2.16	7,94	2,19	5,75
E	0,22	0,05	0,18	0,55	0,13	0,42
F	0,24	0,07	0,16	0,61	0,20	0,41
G	3,37	0,78	2,59	8,56	2,25	6,31
H	3,18	0,69	2,49	8,00	1,94	6,06
I	2,79	0.72	2.08	7.13	2.00	5.13
J	2.49	0.63	1.86	6.56	2.00	4.56
K	0.30	0.06	0.24	0.73	0.14	0.58
L	3.60	0.74	2.86	8.63	1.88	6.76
M	0.28	0.08	0.20	0.88	0.34	0.53
N	0.26	0.06	0.20	0.65	0.16	0.49
EITHER	2.66	0.52	2.14	6.52	1.45	5.07

Behavior of morphological index (slenderness, ratio of aerial part to root part weight -PA/PR-, plant water balance -BAP-, Dickson quality, % of lignification)

With the exception of the percentage of lignification, the ANOVA shows highly significant differences in all indices. In the slenderness index, significant differences are only found using Fisher's LSD method, with two treatments without agricultural soil (K, F), which have the lowest index, indicating smaller but more robust plants. Slenderness is an indicator that relates height to the DBT (Diamond-Better Tissue Weight), meaning that a lower slenderness value is linked to more robust plants with greater resistance to transplant stress; it also relates resistance to the plant's photosynthetic capacity (Quiroz *et al* ., 2009). Slenderness index values between 5 and 10 indicate a higher quality plant; values above 10 express a very tall plant relative to the DBT, while values below 5 indicate a low-height plant relative to its DBT (Quiroz *et al*., 2009). All treatments are within the optimal range for the slenderness index, as the highest (treatment B: 7.58) is below 10, while the lowest (F: 5.62) is above five (Figure 2).

In the shoot weight/root weight ratio, treatment B (5.51) achieved the highest value, statistically superior to all other treatments. The results for the remaining treatments showed no trend, likely due to a lack of arable soil or the type of soil (sand or black soil). The shoot weight/root weight ratio helps predict plant development in dry soils. The values obtained in this study were above one (the lowest F-value was 2.27), indicating poor root development. In this investigation, no rooting agent, fertilizer, or microorganism that would promote root growth was applied, nor were any agronomic practices carried out that would increase root expansion, since the objective was only to evaluate the influence of the substrate on the variables planned.

In the plant water balance (PWB), treatments without agricultural soil showed the highest results in most statistically significant treatments; only one treatment with river sand showed significant differences (B: high value), while the rest showed no difference between sand types. Black soil showed no trend. The best (lowest) value was obtained by treatment G (0.9995). PWB is expressed in terms of shoot and root mass, considering the stem base diameter (SBD); it predicts whether the plant would adapt to drought climates where water absorption by the root system is controlled by plant transpiration.

The Dickson quality index shows parameters similar to those of the morphological indices, with significant differences in the treatments without agricultural soil, which had much lower values than the other treatments (Figure 2). There was no difference between the two sands, and the black soil did not show higher quality. The best Dickson index was obtained by treatment G (0.34). The Dickson index, which shows a balance between mass distribution and robustness, helps to select more proportionate plants and avoid discarding shorter plants with higher proportions. Quiroz *et al*. (2009) recommend a minimum value of 0.2; values below this could lead to problems in the establishment of the plantation in the final field. The treatments that exceeded this parameter were G, L, C, H, A, I, D, J, O, and B.

As previously stated, the percentage of lignification does not show significant differences in the ANOVA, with values ranging between 31 and 50%.

Height is an indicator of a plant's developmental stage and is therefore correlated with the number of leaves. This experiment confirms this information, finding highly significant statistical relationships between height and the number of leaves, DBT (diameter of leaf thickness), and slenderness index; likewise, with weight and Dickson index (Figure 2); therefore, height can be used to indicate the developmental quality of eucalyptus seedlings.

Regarding the substrates to choose, those containing agricultural soil should be selected, choosing the most economical option, which in this case is the one containing only soil. However, when selecting a good substrate, the environmental impact of extracting the material used as a substrate must be considered. Extracting black or agricultural peat causes erosion and physical deterioration of the soil, making it unfeasible to produce seedlings solely with agricultural soil in Contumazá due to the environmental impact of its extraction. Furthermore, the price of this material is currently determined by the proximity of the agricultural soil extraction sites to the nursery. If extraction increases, this material will become scarce, requiring the search for more distant sources, which will increase its price.

There are no differences in substrates containing sand, whether from a river or a quarry, so the same criteria already mentioned should be followed, with the most economical option being hill sand, which is 33.33% cheaper than river sand.

CONCLUSIONS

No treatment showed better results in all variables evaluated.

Treatment L (50% agricultural soil + 50% black soil) showed the best results in the variables: Number of leaves, aboveground fresh weight, total dry weight and aboveground dry weight.

Treatment G (15% hill sand + 50% agricultural soil + 35% black soil) showed the best results for the variables: DBT, root dry weight and Dickson index.

Regarding the use of river sand vs. hill sand, there are significant differences only in some cases in the variables evaluated.

A high correlation was found between the number of leaves and height, as well as with the total fresh and dry weights, root and aerial weights.

There is a high correlation between height and total fresh and dry weight; root and shoot weight, Dickson index and % lignification.

REFERENCES

BALMELLI, G., GASPARRI, P. y MORALES OLMOS, V., 2023. Economic analysis of alternatives for second rotations in Eucalyptus globulus plantations in southeast Uruguay. Agrociencia Uruguay, vol. 27, pp. e976-e976. ISSN 2730-5066. DOI 10.31285/AGRO.27.976. https://agrocienciauruguay.uy/index.php/agrociencia/article/view/976

ESCOBAR RODRÍGUEZ, R., 2007. Manual de viverización: Eucaliptus globulus a raíz cubierta [en línea]. Chile: CORFO-INFOR. Disponible en: https://bibliotecadigital.infor.cl/handle/20.500.12220/17185.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2002. El cultivo protegido en clima mediterráneo [en línea]. Roma: FAO. Disponible en: https://www.fao.org/4/s8630s/s8630s00.htm.

GARCÍA, O., ALCÁNTAR, G., CABRERA, R.I., GAVI, F. y VOLKE, V., 2001. Evaluación de sustratos para la producción de Epipremnum aureum y Spathiphyllum wallisii cultivadas en maceta. Terra Latinoamericana, vol. 19, no. 3, pp. 249-258. Disponible en https://www.redalyc.org/pdf/573/Resumenes/Resumen_57319306_1.pdf

GAYOSSO RODRÍGUEZ, S., BORGES GÓMEZ, L., VILLANUEVA COUOH, E., ESTRADA BOTELLO, M.A. y GARRUÑA HERNÁNDEZ, R., 2016. Sustratos para producción de flores. Agrociencia, vol. 50, no. 5, pp. 617-631. ISSN 1405-3195. Disponible en https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-31952016000500617

KRATZ, D., NOGUEIRA, A.C., WENDLING, I. y MELLEK, J.E., 2017. Physic-chemical properties and substrate formulation for Eucalyptus seedlings production. Scientia Forestalis, vol. 45, no. 113, pp. 63-76. Disponible en https://www.ipef.br/publicacoes/scientia/nr113/cap06.pdf

NOLAZCO CAMA, D., VILLANUEVA QUEJIA, E., HATTA SAKODA, B. y TÉLLEZ MONZÓN, L., 2020. Extracción y caracterización química del aceite esencial de eucalipto obtenido por microondas y ultrasonido. Revista de Investigaciones Altoandinas, vol. 22, no. 3, pp. 274-284. ISSN 2306-8582. DOI 10.18271/ria.2020.661. Disponible en https://huajsapata.unap.edu.pe/index.php/ria/article/view/99

QUIROZ MARCHANT, I., GARCÍA RIVAS, E., GONZÁLEZ ORTEGA, M., CHUNG GUIN-PO, P. y SOTO GUEVARA, E., 2009. Vivero forestal: Producción de plantas nativas a raíz cubierta [en línea]. Chile: INFOR Sede Bío-Bío. Disponible en: https://bibliotecadigital.infor.cl/handle/20.500.12220/17366.

RODRÍGUEZ TREJO, D.A., 2008. Indicadores Calidad Planta [en línea]. México: Editorial Mundi Prensa. [consulta: 4 agosto 2025]. Disponible en: https://www.researchgate.net/publication/349119937_Indicadores_Calidad_Planta.

RODRÍGUEZ-ORTEGA, G. y BRICEÑO-YEN, H., 2023. Efecto de Sustratos Enriquecidos con Materia Orgánica en Parámetros de Crecimiento de Bolaina Blanca (Guazuma Crinita C. Martius) en Vivero-Puerto Inca. Folia Amazónica, vol. 32, no. 1, pp. e32665-e32665. ISSN 2410-1184. DOI 10.24841/fa.v32i1.665. Disponible en: https://www.researchgate.net/publication/374597972_EFECTO_DE_SUSTRA

TOS_ENRIQUECIDOS_CON_MATERIA_ORGANICA_EN_PARAMETROS_DE_CRECIMIENTO_DE_BOLAINA_BLANCA_Guazuma_crinita_C_Martius_EN_VIVERO-_PUERTO_INCA

SERVICIO NACIONAL FORESTAL Y DE FAUNA SILVESTRE, 2023. Anuario forestal y de fauna silvestre [en línea]. Perú: SERFOR. Disponible en: https://drive.google.com/file/d/1O04sKBJmMj1r1AqAhRHlgUgyY1lCEWi1/view.

SILVA, R.B.G. da, SILVA, M.R. da y SIMÕES, D., 2014. Substrates and controlled-release fertilizations on the quality of eucalyptus cuttings. Revista Brasileira de Engenharia Agrícola e Ambiental, vol. 18, pp. 1124-1129. ISSN 1415-4366, 1807-1929. DOI: https://doi.org/10.1590/1807-1929/agriambi.v18n11p1124-1129.

STEWART-WADE, S.M., 2020. Efficacy of organic amendments used in containerized plant production: Part 1 – Compost-based amendments. Scientia Horticulturae, vol. 266, pp. 108856. ISSN 0304-4238. DOI 10.1016/j.scienta.2019.108856. Disponible en: https://www.sciencedirect.com/science/article/abs/pii/S0304423819307423

SYMONDS, W.L., CAMPBELL, L.C. y CLEMENS, J., 2001. Response of ornamental Eucalyptus from acidic and alkaline habitats to potting medium pH. Scientia Horticulturae, vol. 88, no. 2, pp. 121-131. ISSN 0304-4238. DOI 10.1016/S0304-4238(00)00202-8. Available in: https://www.researchgate.net/publication/223706835_Response_of_ornamental_Eucalyptus_from_acidic_and_alkaline_habitats_to_potting_medium_pH

***Conflicts of interest*:**

The authors declare no conflicts of interest.

Authors' contribution:

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