INNSPUB

Journal of Biodiversity and Environmental Sciences | JBES
ISSN: 2220-6663 (Print); 2222-3045 (Online)
Website: https://www.innspub.net
E-mail contact: info@innspub.net
Vol. 28, Issue: 6, p. 68-79, 2026

RESEARCH PAPER | OPEN ACCESS

Vulnerability and regeneration potential of *Bambusa vulgaris* in Ebolowa, South Cameroon

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Key words: *Bambusa vulgaris* var. *vittata*, Bamboo natural abundance, Vegetative propagation, Rooting substrate, South Cameroon

Received: 20 May, 2026 **Accepted:** 04 June, 2026 **Published:** 09 June, 2026

DOI: https://dx.doi.org/10.12692/jbes/28.6.68-79

ABSTRACT

Bamboo resources play an increasingly important role in supporting rural livelihoods, ecosystem restoration, and sustainable bio-based industries in tropical regions. This study assessed the availability, vulnerability, and vegetative propagation potential of *Bambusa vulgaris* and *Bambusa vulgaris* var. *vittata* in the Municipality of Ebolowa II, southern Cameroon. Field inventories were conducted to evaluate species distribution and abundance while a propagation experiment was established to assess the influence of substrate type (soil, sand, and soil–sand mixture) on the vegetative propagation success of *B. vulgaris* var. *vittata*. Results revealed a clear dominance of *B. vulgaris*, which exhibited greater abundance, wider spatial distribution, and higher biomass contribution than *B. vulgaris* var. *vittata*. The predominance of *B. vulgaris* is attributed to its high ecological adaptability and tolerance to local environmental conditions. Utilization patterns differed markedly between species. While *B. vulgaris* was mainly subjected to destructive cutting and clearing, *B. vulgaris* var. *vittata* experienced higher exploitation pressure relative to its availability because of its ornamental, structural, and artisanal value. The propagation trial showed that substrate type did not significantly affect sprouting rate, shoot production, growth, or mortality of *B. vulgaris* var. *vittata* under controlled conditions ($p > 0.05$). However, sandy substrates tended to promote faster sprouting and higher emergence rates. These findings highlight the need for integrated bamboo management strategies combining sustainable harvesting, improved propagation techniques, and strengthened local value chains to enhance bamboo conservation and utilization in southern Cameroon.

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INTRODUCTION

Bamboo is among the fastest-growing groups of plants and is increasingly recognized for its ecological, economic, and social importance in tropical and subtropical regions. Owing to its rapid growth, extensive rhizome system, and high biomass productivity, bamboo contributes significantly to soil stabilization, watershed protection, carbon sequestration, ecosystem restoration, and the provision of renewable raw materials for construction, handicrafts, furniture production, and bioenergy (Scurlock *et al.*, 2000; Lobovikov *et al.*, 2007; Liese *et al.*, 2015). In many developing countries, bamboo also serves as an important resource for rural livelihoods and sustainable land-use systems (Lobovikov *et al.*, 2007; INBAR, 2018).

Cameroon possesses considerable bamboo resources distributed across several agroecological zones. However, despite their potential contribution to environmental conservation and local economic development, bamboo resources remain poorly documented, underexploited, and insufficiently integrated into sustainable management and restoration programs (Ingram *et al.*, 2010; Neba *et al.*, 2020; Bahru and Ding, 2021). Limited information on species distribution, resource availability, exploitation patterns, and regeneration capacity constrains the development of effective conservation and utilization strategies (Neba *et al.*, 2020; Kuate Wafo *et al.*, 2024).

Among the bamboo species present in Cameroon, *Bambusa vulgaris* var. *vittata* (yellow bamboo) is distinguished by its attractive yellow culms marked with green stripes. The species is commonly found in peri-urban landscapes, agricultural areas, home gardens, and riparian habitats within the humid forest zone of southern Cameroon (Ingram *et al.*, 2010; Mankou, 2019). Its ornamental value, structural characteristics, and potential economic applications have increased local interest in its utilization. Nevertheless, information regarding its abundance, vulnerability to anthropogenic pressures, and regeneration potential remains limited, particularly in southern Cameroon where bamboo resources are increasingly exposed to land-use changes and harvesting activities (Neba *et al.*, 2020; Bahru and Ding, 2021).

The sustainability of bamboo resources depends largely on their capacity for regeneration. Because flowering is infrequent and often unpredictable in many bamboo species, natural regeneration through seed production is uncommon, making vegetative propagation the principal means of multiplication and resource restoration (Liese *et al.*, 2015; Banik, 2015). The success of vegetative propagation is influenced by several biological and environmental factors, including the physiological condition of planting material and the physical properties of rooting substrates (Hartmann *et al.*, 2011; Braga *et al.*, 2017; Ananfack *et al.*, 2022). Identifying suitable propagation techniques is therefore essential for large-scale production, conservation, and sustainable utilization of valuable bamboo species.

In the Ebolowa area of southern Cameroon, increasing pressure from agricultural expansion, land-use change, harvesting activities and urban development may threaten the long-term sustainability of bamboo resources. Assessing the availability, exploitation status, and regeneration capacity of *B. vulgaris* var. *vittata* is therefore necessary to support evidence-based management and promote its sustainable cultivation and utilization. This study was conducted to assess the availability, vulnerability, and vegetative propagation potential of *B. vulgaris* var. *vittata* in the Ebolowa area. Specifically, the study aimed to determine its abundance and spatial distribution, evaluate the level of exploitation pressure affecting the species, and assess the influence of different rooting substrates on the vegetative propagation performance of culm cuttings. The findings are expected to contribute to the conservation, domestication, and sustainable development of bamboo resources in southern Cameroon.

MATERIALS AND METHODS

Study area

The present study was conducted in the Ebolowa II municipality, within the Mvila Division, Southern Region of Cameroon (Fig. 1). The study area lies between 2°48′–2°55′ N latitude and 11°05′–11°15′ E longitude, with an average altitude ranging from 600 to 700 m above the sea level. The terrain of the area is characterized by alternating hills and marshy valleys (Nkeufi, 2014). Few hills have about 900 m altitude.

The climate of Ebolowa is equatorial with four seasons, characterized by two rainy seasons (March–June and September–November) and two dry seasons (December–February and July–August). The mean annual rainfall ranges between 1600 and 2000 mm, while the average annual temperatures fluctuate between 20 and 30 °C, with low thermal amplitude throughout the year (Nkeufi, 2014). The relative humidity generally remains high, often exceeding 80%, creating favorable conditions for fast-growing perennial species such as bamboo.

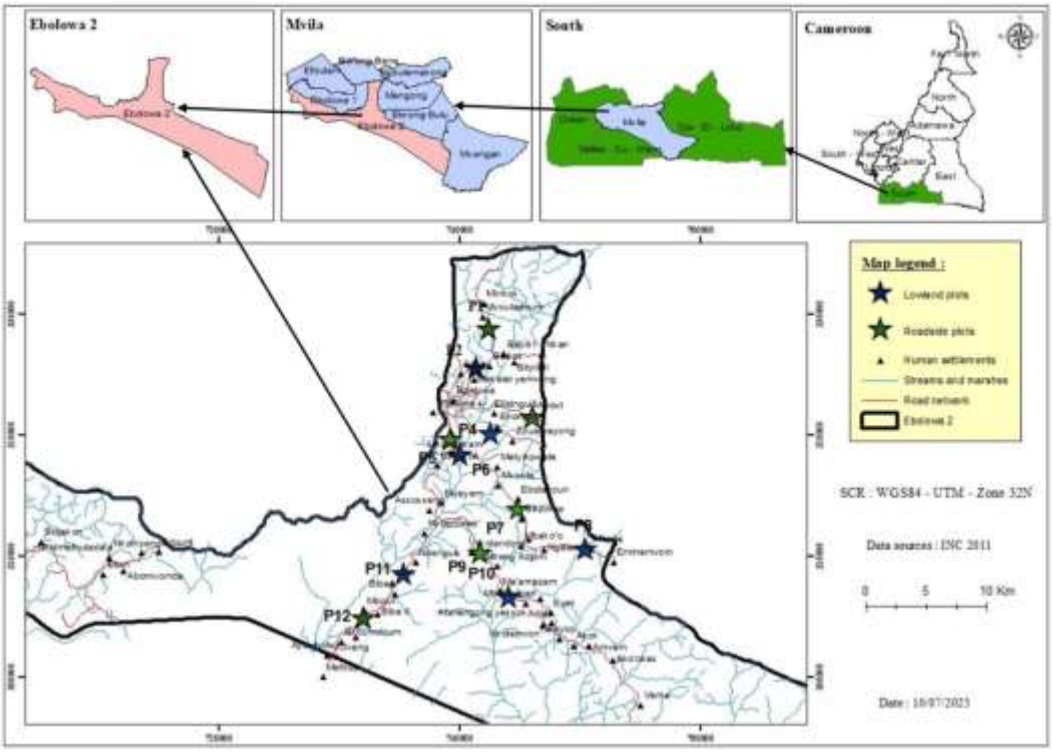

Fig. 1. Location map of the study area including surveyed villages and sampling plots

Soils in the study area are predominantly ferralitic soils, developed on precambrian crystalline basement rocks. These soils are typically deep, well drained, acidic, and moderately fertile, with high iron and aluminum oxide content (Yerima and Van Ranst, 2005). Despite their low natural fertility, such soils may be suitable for bamboo cultivation due to the species' adaptability and efficient nutrient recycling capacity.

Vegetation belongs to the Guineo-Congolian rainforest zone, dominated by semi-deciduous and evergreen forest formations (Letouzey, 1985). Agricultural activities, agroforestry systems, fallows, and settlement expansion have locally modified the natural vegetation. Bamboo stands, particularly *Bambusa vulgaris*, are found mostly in anthropogenic and semi-natural habitats such as home gardens, farm boundaries, lowlands, and along streams, where soil moisture and light conditions are favorable.

An abundant hydrographic network (Nkeufi, 2014) characterizes this area. Several watercourses, notably the Mvila River, the Bengo River, and the Mfiané River, cross the city. It also contains lakes, marshes, and natural ponds, such as Atok Bilole pond.

These biophysical conditions make the Ebolowa area ecologically suitable for bamboo growth and provide a relevant context for assessing the availability, distribution, vegetative multiplication and utilization potential of yellow bamboo (*Bambusa vulgaris* var. *vittata*) in southern Cameroon.

Assessment of availability and distribution

To achieve this goal, a bamboo (*Bambusa vulgaris* and *Bambusa vulgaris* var. *vittata*) inventory was conducted in the study area. Bamboo clumps and culms were characterized, species abundance was determined, culm volume was estimated, and the pressure exerted on each species was assessed.

Bamboo grows best under moist environmental conditions but is also capable of tolerating unfavorable conditions such as drought. Based on Ohrnberger (1999) findings, we selected two types of potential habitats of the species found in Ebolowa II (Lowlands along watercourses and Roadsides). The inventory was conducted using a random sampling approach within 4ha plots (1000 m × 40 m), established along roads (n = 6) and lowlands near watercourses (n = 6).

Density and clump area

The density and surface area of bamboo clumps were assessed, considering that each clump has an elliptical shape. Clump density (d_T) was calculated using Equation (1):

$$d_T = \frac{\Sigma_T}{S} \quad (1)$$

Where:

$\sum_T$ = total number of clumps recorded in the sample plots;

S = total sampled area (ha).

The area of each clump (S_T) was calculated using the ellipse area Equation (2):

$$S_T = \pi \times a \times b \quad (2)$$

Where:

π = mathematical constant equal to 3.14;

a = semi-major axis (half of the longest axis) of the clump (m);

b = semi-minor axis (half of the shortest axis) of the clump (m).

Bamboo abundance

Bamboo abundance was determined by calculating the percentage of bamboo clumps or culms of each species (%P) within the sampling plots using the Equation (3):

$$\%P = \frac{n}{N} \times 100 \quad (3)$$

Where:

n = number of clumps or culms of a given species;

N = total number of clumps or culms recorded in all sampled plots.

Culm characterization

Culm characterization involved measuring dendrometric parameters, including culm diameter, height, and the number of culms per clump for each bamboo species.

Culm diameter

Culm diameter was measured at 90 cm above the base using a measuring tape placed around the culm. For each clump, the mean diameter was calculated from a representative sample corresponding to 10% of the total culms. The mean culm diameter per species (D_{mean}) was then calculated using Equation (4):

$$D_{mean} = \frac{\sum_{i=1}^{N} Dm_i}{N} \quad (4)$$

Where:

Dm_i = mean culm diameters of clumps (cm);

N = total number of clumps per species.

Culm height measurement

We measured culm total height using a clinometer Suunto. For each clump, culm height was estimated by calculating the mean height of a representative sample corresponding to 10% of the culms. The mean culm height (H_{mean}) per species was calculated using Equation (5):

$$H_{mean} = \frac{\sum_{i=1}^{N} Hm_i}{N} \quad (5)$$

Where:

Hm_i = mean culm heights of clumps (m);

N = total number of clumps per species.

Mean number of culms per clump

The mean number of culms per clump ($N_{culms\ per\ clump}$) for each species was calculated using Equation (6):

$$N_{culms\ per\ clump} = \frac{n}{N} \quad (6)$$

Where:

n = total number of culms recorded per species in the sampled plots;

N = total number of clumps per species in the sampled plots.

Estimation of natural resource potential

Culm and clump volume

This section aimed to quantify the available biomass in order to estimate the natural resource potential of bamboo within the municipality. Dendrometric parameters, including culm height, external diameter, and internal diameter, were measured from a representative sample corresponding to 10% of the culms per clump and per species. For each clump the internal diameter was measured from the culm having the average external diameter.

The material volume of an individual culm (V_{Mt}) was calculated using Equation (7):

$$V_{Mt} = \frac{\pi}{4} \times (D_{ex}^2 - D_{in}^2) \times h \quad (7)$$

Where:

π = mathematical constant = 3.14;

D_{ex} = external diameter of the culm (cm);

D_{in} = internal diameter of the culm (cm);

h = culm height (m).

The material volume per clump (V_{MT}) was subsequently calculated using Equation (8), based on the cumulative volume of individual culms within each clump.

$$V_{MT} = V_{Mt} \times N_{\text{culms per clump}} \quad (8)$$

Where:

V_{Mt} = material volume per culm (m³);

$N_{\text{culms per clump}}$ = mean number of culms per clump.

Clump, plot and bamboo volume estimation

The total bamboo material volume within each sampled plot (V_p) was calculated using Equation (9):

$$V_p = V_{MT} \times N_{T/V} \quad (9)$$

Where:

V_{MT} = material volume per clump (m³);

$N_{T/V}$ = total number of clumps within the sampled plots.

To estimate the total available bamboo volume at the scale of the Ebolowa II municipality (V), Equation (10) was applied:

$$V = \frac{V_p}{S_p} \times S_t \quad (10)$$

Where:

V_p = material volume within the sampled plots (m³);

S_p = area of the sampled plot (ha)

S_t= total area of suitable bamboo habitat (ha).

The surface area of our study site (roadsides and lowlands) was determined using ArcGIS by estimating the total length of roads and lowlands along the watercourses within the study site. A standard habitat width of 40 m, corresponding to the sampling plot width, was applied. In this study, the total habitat area favorable for bamboo growth was sampled and estimated by summing the surface areas associated with roads and watercourses.

Assessment of resource pressure

Resource pressure was evaluated by recording the number of clumps and culms that had been harvested or destroyed within the sampled plots. The harvesting pressure was expressed as the percentage of cut culms, calculated using Equation (11):

$$\text{Harvesting rate (\%)} = \frac{\text{Number of harvested culms (use or destruction)}}{\text{Total number of culms recorded}} \times 100 \quad (11)$$

This indicator provided an estimate of the level of anthropogenic pressure exerted on bamboo resources in the study area.

All field data were manually recorded on standardized data collection sheets.

Assessment of the optimal substrate for successful vegetative multiplication of *Bambusa vulgaris* var. *vittata*.

To carry out these assessments, several steps were undertaken:

Preparation of the rooting board

This phase involved the installation of a shade structure, acquisition of necessary materials, and construction of the rooting board (Fig. 2). A flat site located near a reliable water source was selected to facilitate maintenance and irrigation. The area was cleared of weeds, and a shade structure was constructed using bamboo stems and palm leaves to provide adequate protection from direct sunlight.

Fig. 2. Construction of the rooting board: board sizing (a), rooting board (b)

Three substrate types were used: soil, sand, and a 1:1 sand–soil mixture. The soil was collected near the experimental site, and the sand was obtained from a local quarry. All substrates were carefully sieved to remove debris such as roots, clay clods, and stones. The cleaned substrates were used to fill the rooting board compartments to a depth of 60 cm. The three substrate treatments were arranged in a randomized design with three replicates.

Collection and transportation of plant material

Plant material was collected from three *Bambusa vulgaris* var. *vittata* clumps aged 1–2 years. Culm cuttings were taken from healthy stems with diameters ranging from 8 to 8.5 cm, starting from the third node above ground level. Immediately after harvesting, the cuttings were placed in the shade and periodically moistened to prevent desiccation. Each cutting measured 60 cm in length and contained two nodes with viable buds. The cuttings were transported to the experimental site in moist bags to preserve their viability.

At the experimental site, both ends of the cuttings were treated with a fungicide solution (O.K.MIL Unik) to prevent fungal infection and sealed with a clay–soil mixture to reduce evapotranspiration and limit water infiltration. The cuttings were then planted horizontally in pre-moistened rooting boards at a spacing of 10 cm and covered with a 10 cm layer of substrate.

Each compartment contained four cuttings, for a total of 36 cuttings in the experiment.

Maintenance and monitoring of cuttings

Maintenance activities included regular removal of weeds and daily watering of the substrates. Irrigation was carried out twice daily, in the morning and evening, using a watering can, with each compartment receiving approximately 6 L of water per session due to high solar exposure during the study period.

The rooting boards were cleaned daily, and dendrometric parameters of emerging shoots were recorded weekly using standardized data collection sheets. The recorded variables were grouped into two categories: cutting performance (latency period, sprouting rate, and number of shoots per cutting) and shoot growth characteristics (height, diameter, mortality rate, and height growth).

Cutting performance parameters

Latency period: Defined as the number of days required to observe the first shoot emergence in each substrate.

Sprouting rate: Calculated as the proportion of cuttings that produced at least one shoot relative to the total number of cuttings planted.

Number of shoots per cutting: Determined by dividing the total number of shoots recorded in a given substrate by the number of cuttings that successfully produced shoots, according to Equation (12):

$$\text{Number of shoots per cutting} = \frac{\text{Total number of shoots in a substrate}}{\text{Number of sprouted cuttings}} \quad (12)$$

Shoot growth parameters

Mean shoot height: Shoot height was measured weekly using a measuring tape. The mean shoot height per substrate was calculated using Equation (13):

$$\text{Mean shoot height} = \frac{\text{Sum of shoot heights}}{\text{Number of shoots per compartment}} \quad (13)$$

Mean shoot diameter: At the end of the experiment, the diameter of shoots measuring at least 20 cm in height was measured using a digital caliper. The mean shoot diameter was calculated using Equation (14):

$$\text{Mean shoot diameter} = \frac{\text{Sum of shoot diameters}}{\text{Number of shoots per compartment}} \quad (14)$$

Mortality rate: The mortality rate was determined as the proportion of shoots that died after emergence, calculated using Equation (15)

$$\text{Mortality rate} = \frac{\text{Number of dead shoots}}{\text{Total number of shoots}} \quad (15)$$

Shoot height growth according to substrate: For growth monitoring, the first emerging shoot in each substrate treatment was selected and measured weekly throughout the experimental period. This allowed the assessment of height growth dynamics and the construction of growth curves over the eight-week observation period.

Data analysis

Prior to analysis, the collected data were pre-processed to ensure quality and reliability. This process included data cleaning (identification and correction of errors and treatment of missing values) and coding, whereby responses from open-ended survey questions were grouped into thematic categories.

Field data sheets were reviewed, organized, and compiled using Microsoft Excel. Geographic coordinates recorded with the GPS were downloaded using DNRGPS software and subsequently imported into ArcGIS 10.5 for spatial visualization and mapping. These spatial data were used to analyze the distribution patterns of bamboo stands across the study area.

For the cutting experiment, descriptive statistics, including means and standard deviations, were calculated to summarize propagation performance across substrate treatments. A one-way analysis of variance (ANOVA) was used to compare the effects of the three substrate types when the assumptions of normality and homogeneity of variances were satisfied, using a significance level of 5% ($p < 0.05$). When these assumptions were not met, a non-parametric Kruskal–Wallis test was applied, particularly for variables such as mortality rate. In cases where significant differences among treatments were detected, post hoc multiple comparison tests were performed to identify pairwise differences between substrate means.

RESULTS

Availability and distribution of *B. vulgaris* and *B. vulgaris* var. *vittata* in Ebolowa II

Bamboo density

A total of 272 clumps and 14,481 culms were inventoried across 48 ha, covered by twelve sample plots located within the major bamboo habitats. Two bamboo species namely *B. vulgaris* and *B. vulgaris* var. *vittata* were identified. *B. vulgaris* was significantly more abundant and denser than *B. vulgaris var. vittata* ($p < 0.05$), accounting for 87.86±5.40% of total clumps (*239* clumps) and exhibiting a density of 4.97±1.20 clumps/ha compared to 12.14±1.00% and 0.68±0.03 clumps/ha for *B. vulgaris* var. *vittata* (33 clumps). The overall density of 5.65 clumps/ha was over the study area. The mean number of culms per clump did not differ between *B. vulgaris* and *B. vulgaris* var. *vittata* with a score of 57±48 and 26±20.18 respectively. Bamboo material volume of a culm and a clump did not differ between the two species, but the total volume par unit of area was higher for *B. vulgaris* (Table 1).

Bamboo distribution among major habitats

Lowlands accounted for approximately 80% of the total bamboo habitat area and contained the majority of bamboo resources. These areas supported significantly higher numbers of clumps and culms, as well as substantially greater harvestable biomass volume compared to roadside habitats (Table 1, $p< 0.05$). In contrast, bamboo density did not differ significantly between habitats (Table 2, $p> 0.05$).

Resource utilization

Resource utilization between the two bamboo species indicates contrasting patterns. *B. vulgaris* experienced a high level of destructive pressure, with more than 60.24% of harvested culms being destroyed without subsequent utilization. In contrast, *B. vulgaris* var. *vittata* was primarily subjected to utilitarian harvesting, with significantly high proportion of harvested culms being used (98.44%) and only a very low proportion of destroyed culms (1.56%, Table 3).

Table 1. Material volume of two Bamboo species in Ebolowa II municipality

Species	Mean culm volume (m^3)	Mean clump volume (m^3)	Total material volume (m^3/ha)
Bambusa vulgaris	0.015±0.002 [a]	0.844±0.25 [a]	4.20±0.40[a]
Bambusa vulgaris vittata	0.018±0.003 [a]	0.455±0.21 [a]	0.31±0.08[b]
Total	0.032	1.299	4.51

Values are presented as mean ± standard deviation. Means followed by different letters within a column indicate significant differences at 5% significance level.

Table 2. Bamboo stock per habitat type in Ebolowa II municipality

Habitat type	Area (ha)	Number of clumps	Density (culms/clump)	Density (clumps/ha)	Material volume (m^3/ha)
Roadsides	1,074[a]	6041± 520[a]	39.80± 3.08[a]	5.62± 0.18[a]	1.590± 0.196[a]
Lowlands	4,185[b]	23,890± 1320[b]	64.47± 3.17[b]	5.70± 0.21[a]	5.271± 0.339[b]
Total	5,259	29,931	59.49	5.66	4.519

Values are presented as mean ± standard deviation. Means followed by different letters within a column indicate significant differences at 5% significance level.

Table 3. Resource pressure on bamboo species in the study area

Species	Number of harvested culms	% Culms used	% Culms destroyed
Bambusa vulgaris	53,895	39.76	60.24
Bambusa vulgaris var. *vittata*	4,017	98.44	1.56

Table 4. Shoot emergence parameters of *B. vulgaris* var. *vittata* cuttings per substrates.

Substrates	Latency period (days)	Emergence rate (%)	Number of shoots per cutting
Soil	25±7.55[a]	50±25[a]	2.33±1.15[a]
Sand	15±9.00[a]	75±25[a]	5.33±3.21[a]
Soil /Sand	19±6.24[a]	58.30±14[a]	5.33±3.05[a]
Means	19.67±7.60[a]	61.10±621.33[a]	4.33±2.47[a]

Means followed by the same letter within a column are not significantly different at 5% significance level.

Table 5. Growth parameters of shoots according to substrate type

Substrates	Shoot height (cm)	Shoot diameter (h>20cm)	Mean height increment (cm/week)	Mortality rate (%)
Soil	33.66±13.56[a]	0.61±0.55[a]	7.50 ±5.72[a]	0[a]
Sand	45.34±20.33[a]	0.81±0.22[a]	9.88 ±6.53[a]	0[a]
Soil/sand	61.36±18.10[a]	1.04±0.10[a]	9.75 ±6.16[a]	0.37 ±0.29[a]
Mean	46.78±17.33	0.82±0.29	9.04 ±6.13	0.37 ±0.29

Means followed by the same letter are not significantly different among substrate treatments at the 5% significance level.

Effect of substrate on vegetative propagation of *B. vulgaris* var. *vittata*

Shoot emergence

The shoot emergence parameters of *B. vulgaris var. vittata* cuttings under different substrate conditions were recorded (Table 4). No significant differences were observed among substrates for latency period, emergence rate and number of shoots per cutting (All $p > 0.05$).

Weekly evolution of shoot emergence

Shoots emergence began during the second week in all substrates and increased progressively over time. The sand and sand–soil mixture substrates showed higher cumulative numbers of shoots compared to soil throughout the experimental period. By the end of the experiment, the cumulative number of shoots reached approximately 16 in both sand and sand–soil mixture substrates, compared to approximately seven shoots in the soil substrate (Fig. 3).

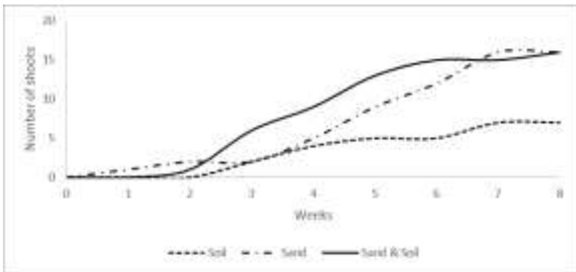

Fig. 3. Weekly changes in shoot density as a function of substrate

Shoot growth

The growth parameters of shoots produced under different substrates were recorded in Table 5. Mean shoot height, mean shoot diameter and the weekly growth rate did not show significant differences across substrates types (All $p > 0.05$). There was no shoot mortality in sand and soil substrates whereas a non-significant proportion died in sand-soil substrates.

The temporal evolution of shoot height across substrates increased steadily over time in all substrates (Fig. 4). Shoot height increment showed variability across different substrates. However, these differences were statistically non-significant across substrates ($p > 0.05$).

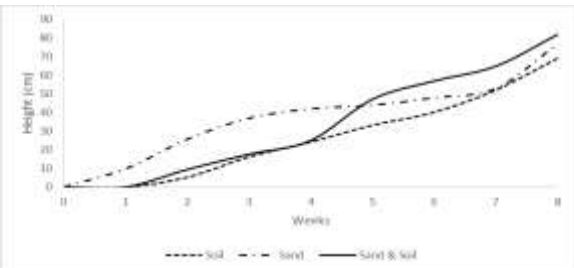

Fig. 4. Temporal dynamics of shoot height growth of B. vulgaris var. vittata across different substrates

DISCUSSION

Availability and distribution

In the municipality of Ebolowa, we observed a clear dominance of *B. vulgaris* over *B. vulgaris var. vittata*, with more clumps and culms recorded. This predominance is consistent with previous findings that identified *B. vulgaris* as the most widespread bamboo species in Africa and Cameroon (Bahru *et al.*, 2021, Ingram *et al.*, 2010, Mankou, 2019). This ecological dominance can be attributed to its strong adaptability to local environmental conditions, high ecological plasticity, and tolerance to variations in soil (structure and composition) and climatic factors, which provide a competitive advantage over *B. vulgaris var. vittata*. These findings highlight the dominant spatial coverage of *B. vulgaris* relative to *B. vulgaris* var. *vittata* and the critical importance of humid habitats as key reservoirs of bamboo biomass and resource potential in the Ebolowa II municipality, as most records were obtained in lowland areas. These observations are consistent with Liese *et al.* (2015), who highlighted the rapid growth and ecological adaptability of *B. vulgaris* under diverse environmental conditions.

In addition, anthropogenic factors such as traditional use, ease of access, and deliberate conservation by local communities have likely contributed to its widespread distribution and persistence in agroforestry landscapes. In fact, the species has been introduced in Cameroon for agricultural purpose and is mostly present in the south region including Ebolowa (Mankou, 2019).

Utilization patterns

Our findings highlight significant differences in exploitation dynamics between the two species, with *B. vulgaris* facing predominantly destructive pressure, whereas *B. vulgaris var. vittata* is mainly harvested for productive purposes. This suggests that the species may be selectively exploited due to its perceived higher economic or functional value. This selective utilization may increase the vulnerability of *B. vulgaris* var. *vittata*, particularly, given its lower abundance and limited spatial distribution in the study area.

Despite its dominance over *B. vulgaris var. vittata*, showing ecologically more adapted specie, producing more biomass, the density of *B. vulgaris* remains lower than values reported in other African regions (Lobovikov *et al.*, 2007). The low density of *B. vulgaris* in the Ebolowa area may result from a combination of factors. These factors include edaphic constraints associated with nutrient-poor ferralitic soils (Lobovikov *et al.*, 2007; INBAR, 2018; FAO, 2021), unsustainable harvesting practices (INBAR, 2018), land conversion for agriculture (FAO, 2021), and weak structuring of the bamboo value chain (Liese *et al.*, 2015).

Regarding resource pressure, the results indicate contrasting exploitation patterns between the two species. *B. vulgaris var. vittata* is subject to higher utilization pressure relative to its availability. This is likely due to its ornamental value, aesthetic appeal, and desirable mechanical properties, which increase its demand for decorative and artisanal purposes. In contrast, *B. vulgaris*, despite being more abundant and productive, is most subject to destructive cutting or clearing practices aimed at controlling its expansion. Especially in anthropogenic landscape (INBAR, 2018; FAO, 2021). This paradox highlights the influence of socio-economic factors on resource utilization, where species with higher commercial or aesthetic value are preferentially exploited despite their lower abundance. Similar exploitation dynamics have been reported by Ingram *et al.* (2010), who demonstrated that high-value bamboo species are more vulnerable to harvesting pressure in peri-urban landscapes of Cameroon.

Overall, these findings indicate that *B. vulgaris* constitutes the primary bamboo resource in the Municipality of Ebolowa II due to its high abundance, and greater biomass contribution, whereas *B. vulgaris* var. *vittata*, although less abundant, represents a valuable resource with higher structural and economic potential. Sustainable management strategies should therefore consider both ecological availability and socio-economic demand to ensure long-term conservation and optimal utilization of bamboo resources. Precisely, there is need to improve propagation techniques, implement sustainable clump management practices, and develop a well-structured local value chain to help enhance the availability and productive potential of the species within the studied area.

Effect of substrate on the vegetative propagation of *B. vulgaris var. vittata*

The present study demonstrated that substrate type did not significantly influence the latency period, sprouting rate, or mean number of shoots per cutting of *Bambusa vulgaris* var. *vittata*.

Although no statistically significant differences were detected among soil, sand, and soil–sand mixtures (all $p > 0.05$), sand tended to produce higher sprouting rates and faster shoot emergence. This trend is consistent with previous studies highlighting the importance of substrate physical properties in bamboo vegetative propagation (Nath *et al.*, 2009; Razvi and Nautiyal., 2011; Banik, 2015). Well-drained substrates, particularly sandy ones, improve aeration, oxygen diffusion, and drainage, thereby facilitating root initiation and reducing risks of waterlogging and microbial decay (Hartmann *et al.*, 2011).

Despite these favorable tendencies, substrate type did not significantly influence subsequent shoot growth parameters, including height, diameter, and mortality rate. Similar findings were reported by Ananfack *et al.* (2022) and Nath *et al.* (2009), who observed that while substrate composition may affect rooting initiation, later shoot development depends more strongly on environmental factors such as temperature, humidity, and light availability. In controlled conditions, where moisture and temperature are optimized, substrate effects may therefore become less pronounced (Leakey, 2004). The limited influence of substrate on growth performance may also reflect the dominant role of physiological factors inherent to the cuttings like culm age, diameter, number of nodes, and carbohydrate reserves (Hartmann *et al.*, 2011; Banik, 2015; Yadav *et al.*, 2017). However, in this study even-aged culms were used and the diameter and number of nodes of cuttings were the same. Overall, these findings indicate that the optimization of

Bamboo propagation protocols requires an integrated approach that combines appropriate substrate selection with careful management of plant physiological and environmental parameters.

CONCLUSION

This study demonstrates that *Bambusa vulgaris* constitutes the dominant bamboo resource in the municipality of Ebolowa II due to its broad ecological adaptability, greater abundance, and higher biomass production. In contrast, *B. vulgaris* var. *vittata*, although less abundant and more spatially restricted, remains highly valued for its ornamental, structural, and artisanal uses, resulting in relatively higher exploitation pressure. The contrasting utilization patterns observed between the two species highlight the strong influence of socio-economic demand on bamboo resource management and emphasize the vulnerability of species with high commercial value despite their limited availability.

The study further reveals that the relatively low density of *B. vulgaris* in the area is likely associated with multiple interacting factors, including unsustainable harvesting practices, land-use change, and the weak organization of the bamboo value chain. These findings underline the urgent need for sustainable management strategies integrating ecological conservation with socio-economic valorization.

Regarding vegetative propagation, the results indicate that substrate type did not significantly affect the propagation success of *B. vulgaris* var. *vittata* under controlled conditions.

Nevertheless, sandy substrates and soil–sand mixtures tended to favor faster sprouting and higher shoot emergence, likely due to their better aeration and drainage properties. The findings also suggest that propagation success depends not only on substrate characteristics but also on physiological attributes of the cuttings and environmental conditions. Consequently, optimizing propagation protocols for *B. vulgaris* var. *vittata* requires an integrated approach combining suitable substrates with appropriate environmental and physiological management practices.

Overall, this study provides important insights into the ecology, utilization dynamics, and propagation potential of bamboo species in southern Cameroon. It contributes valuable information for the sustainable management, conservation, and domestication of bamboo resources, while supporting the development of bamboo-based livelihoods and restoration initiatives in the region.

ACKNOWLEDGEMENTS

We express our heartfelt gratitude to M. Keponsep Yepdieu Cedric Rulair and M. Abeng Kouma Patrick who provided technical assistance during field survey and setting up the propagation trial, respectively.

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