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## Effect of substrates and water supply on the survival and growth of *Beilschmiedia mannii*

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### Abstract

*Beilschmiedia mannii* (spicy cedar) is an underutilized agroforestry species despite its organs being used for food, energy, and to cure various ailments. Very little effort has been made towards its domestication and the development of techniques for its production. An experiment was conducted in Benin, to evaluate the effect of substrate and water supply on *B. mannii*'s survival and growth. A factorial design with two factors was set up in a randomized complete block with three replications. Three substrate types under five watering levels were tested. Data on collar diameter, and total height were collected over 4 months and used to calculate the current growth rates, which were analyzed using two-way ANOVA. The findings indicated that the species exhibited a generally sluggish rate of growth, with height increasing by less than 1 cm per month and collar diameter expanding by under 0.4 mm each month. This trend was consistent, irrespective of the type of substrate or the frequency of watering. Although no statistically significant effect was found between the modalities of the factors in isolation and their interaction on current height growth, the combinations of a watering every two days with sandy-loamy substrate mixed with cow dung and a watering every five days with bokashi substrate exhibited the best height growth performances, with increases of 0.22 cm and 0.24 cm per week, respectively. The availability of water has proven to be crucial for both survival rates and the growth of collar diameter, highlighting how essential water is for *B. mannii*.

**Key words:** *Beilschmiedia mannii*; Water supply; Organic amendments; Growth

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## INTRODUCTION

*Beilschmiedia mannii* (Meisn.) Benth. & Hook.f. (1880), commonly referred to as spicy cedar, is a species often found in agroforestry. Its natural environment includes the moist and swampy forests of West and Central Africa (Hawthorne and Jongkind, 2006; Ebigwa and Akomoye, 2009; Ogunbanjo and Aina, 2013). This evergreen tree is a member of the Lauraceae family (Olajuyigbe and Adaja, 2020). The leaves are arranged alternately, while the fruits are elongated berries that can be black, green, or red, measuring between 1.5 to 5.5 cm or 1.5 to 2.5 cm (Figure 1), depending on the specific variety (Adaja and Olajuyigbe, 2023). When ripe, the fruit typically measures 4 to 5.5 cm and turns red, containing a single seed encased in a thin seed coat, with the cotyledons being thick and conical. This species can reach impressive heights of 10 to 35 meters and can have a diameter at breast height of 60 cm to 100 cm (Sahoré and Koffi, 2013). In Côte d'Ivoire, the fruits are harvested from October to December. The tree features a broad crown, which can vary from dense to narrow (Nyunai *et al.*, 2008).

The wood of this tree is valuable for construction and furniture (Mark *et al.*, 2014). Different parts of the plant, including the bark, leaves, and fruits, are utilized in treating dysentery and respiratory ailments, while the seeds are known for their potent antibacterial properties (Nyunai, 2008; Ahoua *et al.*, 2015; Baldé *et al.*, 2015). Additionally, in certain areas of southern Benin, the fruit is employed in treating ulcers and is reputed to act as an aphrodisiac (Yevide *et al.*, 2022). Its chemical composition provides chemopreventive benefits against cancer, establishing it as a significant anti-inflammatory source (Ahoua *et al.*, 2019). The species also holds cultural significance and is used in various religious practices, particularly during funeral rites (Yevide *et al.*, 2022). The seeds and fruits are an essential part of local diets, rich in proteins, carbohydrates, minerals, and unsaturated fatty acids (Nyunai, 2008; Sahoré *et al.*, 2012; Kouamé *et al.*, 2017). Furthermore, they are packed with antioxidants that aid in preventing oxidative damage and boosting the immune system for both humans and animals (Ahoua *et al.*, 2015). The seeds of *B. mannii* are also processed to yield edible oil (Joachim, 2017). The combination of its nutritional and medicinal properties underscores the significant socio-economic potential of this species in West Africa (Ogunbanjo and Aina, 2013; Jusu and Cuni-Sanchez, 2017).

Despite these numerous forestry, nutritional, and medicinal advantages, the species is

underutilized in Benin, where its habitat is threatened due to anthropogenic pressures, overexploitation in the past, its slow growth, and the lack of appropriate techniques for its production both in agroforestry systems and plantations. In fact, the development of proper technical guidelines is a key step in the valorization of a plant species, which involves identifying and mastering the physico-chemical, organic, and biological characteristics of the ideal substrate for nursery and plantation production. The soil structure and organic composition, determined by its mineralogical characteristics, texture, porosity, and the presence of nutrients, along with water conditions, have a significant impact on both root and aerial growth, as well as the overall productivity of the plant (Czyz, 2004; Ministère des Relations Extérieures, de la Coopération et du Développement, 2002). Additionally, water demand varies depending on the species and its developmental stages (Matthiew, 1998). The distribution of water in the soil and the amount available for plants also depend on the type of soil (Hien *et al.*, 2021). Plant species react differently to the characteristics of the soil that supports them (Mukendi *et al.*, 2017). In fact, the use of amendments and fertilizers are strategies employed to improve soil fertility and increase the productivity of the plant species that grow in it. To ensure the conservation of *B. mannii* through its domestication, which requires a better understanding and control of its reproduction and the factors contributing to its proper development, it is essential to study the effect of substrate and water supply on the growth of the species. This study, which is the first of its kind on the species aims at filling this gap.

## MATERIALS AND METHODS

### Study site characterization

The experiment was conducted in the Plateau Department, specifically in the town of Ketou, located in the Ketou district, Ketou Municipality (Figure 2A). Ketou Municipality is divided into six (06) districts: Ketou, Kpankou, Odometa, Okpometa, Idigny, and Adakplame. It is situated in the southeastern part of Benin, between latitudes 7°10' and 7°41'17" North and longitudes 2°24'24" and 2°47'40" East. It covers an area of 1775 km<sup>2</sup> (INSAE, 2015), which represents 1.55% of the national territory and 54.38% of the Plateau Department. The region falls within the Pobe phytodistrict and the Guineo-Congolian zone (Akoegninou *et al.*, 2006; Tossou *et al.*, 2011). Its climate is equatorial, characterized by two rainy seasons of unequal duration (March to July and

September to October), interspersed with two dry seasons (August and November to February). Annual rainfall varies between 900 and 1100 mm, with an average annual temperature ranging from 25°C to 29°C and relative humidity between 31% and 98% (Fandohan, 2011). The area has well-drained ferruginous soils. The vegetation is dominated by wooded savannas with species such as *Daniella oliveri*, *Lophira lanceolata*, and *Parkia biglobosa*, as well as forests, including the classified forest of Ketou-Dogo, which covers approximately 42,850 hectares (Houessou *et al.*, 2019), and several sacred forests, including the Adakplamè forest. The population is about 157,352, with the Yoruba sociocultural group being the predominant group (INSAE, 2015). Ferruginous tropical soils are mainly found in the town center of Ketou, while weakly degraded ferrallitic soils are found in the rural areas of Ketou (Igue *et al.*, 2013). The main economic activities in the area are agriculture, trade, forestry, and livestock farming (Fandohan, 2011).

### Experimental design and data collection

A two-factorial experimental design in a replicated block was adopted for the experiment (Siene *et al.*, 2020) (Figure 2B). The first factor, substrate, consisted of three levels: (1) bokashi, (2) sandy-loamy substrate without cow dung, and (3) sandy-loamy substrate with cow dung. The second factor under consideration, namely the water supply, was organized into five distinct levels: (T0) a continuous water supply, (T1) irrigation every two days, (T2) irrigation every three days, (T3) irrigation every four days, and (T4) irrigation every five days (Yevide *et al.*, 2023). Due to the limited availability of seedlings and the uniqueness of the species, three seedlings of *B. mannii*, each 12 months old, were utilized for each combination of the investigated factors, culminating in a total of 135

seedlings for the experiment. These seedlings were sourced from seeds gathered from trees belonging to seed producers in the Avrankou commune, situated in the Oueme Department, where the species thrives in both agroforestry setups and natural habitats (Yevide *et al.*, 2022). The various growing mediums were placed into polyethylene bags with a diameter of 30 cm, each containing 760 g of a sandy-loamy mixture and 40 g of cow dung, totaling 800 g for the sandy-loamy substrate enriched with cow dung. Conversely, for the bokashi and the sandy-loamy substrate without cow dung, 800 g of the substrate was used to fill each bag. An electronic scale, precise to 0.1 g, was employed to measure the dry components of the different substrates. In the constant water supply group, the polyethylene bags filled with the same substrate type had holes made in the bottom and were set in containers that provided a steady water supply. For the other watering methods, each polyethylene bag was thoroughly irrigated to ensure that the substrates achieved field capacity. For each seedling, measurements were taken of the collar diameter using an electronic caliper accurate to 0.1 mm, while height was measured with a tape measure. The survival rate of the seedlings was determined by monitoring mortality via the observation of wilting plants and assessing the condition of the cambial tissue in their stems. Data collection occurred weekly in the mornings over a span of 98 days, equivalent to 14 weeks.

### Data processing and analysis

The data collected were used to compute the current growth increments in height (ACC<sub>h</sub>) and diameter (ACC<sub>d</sub>) between the start and the end of the experiment, as well as the mortality rates (Tx) using the equations below as previously recommended by Yevide *et al.*, (2011).

$$ACC_h = \frac{h_{tf} - h_{ti}}{t_f - t_i}$$

$$ACC_d = \frac{d_{tf} - d_{ti}}{t_f - t_i}$$

$$Tx = \frac{NpM \times 100}{NpT}$$

ACC<sub>h</sub>: Current growth increment in height between the beginning and the end of the experiment (cm /week)

ACC<sub>d</sub>: Current growth increment in diameter between the beginning and the end of the experiment (mm /week)

Tx : Mortality rate (%)

h<sub>ti</sub>: Initial plant height (start of the experiment)

h<sub>tf</sub>: Final plant height (end of the experiment)

d<sub>ti</sub>: Initial plant diameter (start of the experiment)

d<sub>tf</sub>: Final plant diameter (end of the experiment)

t<sub>i</sub>: Initial time (start of the experiment)

t<sub>f</sub>: Final time (end of the experiment)

NpM: Number of dead plants

NpT: Total number of plants

All the calculated parameters were processed and used to create graphs with Excel 2016. For statistical analysis, two-way analysis of variance (ANOVA) was conducted using R software version 3.6.3 to assess the isolated and combined effects of the studied factors on seedling mortality and growth. This was followed by a Tukey test, when necessary, to identify statistically significant differences between the treatments and/or treatment combinations involved



Figure 1: Picture showing *Beilschmiedia mannii*'s standing tree (A), its leaves (B), inflorescence (C), and unripe fruits (D).

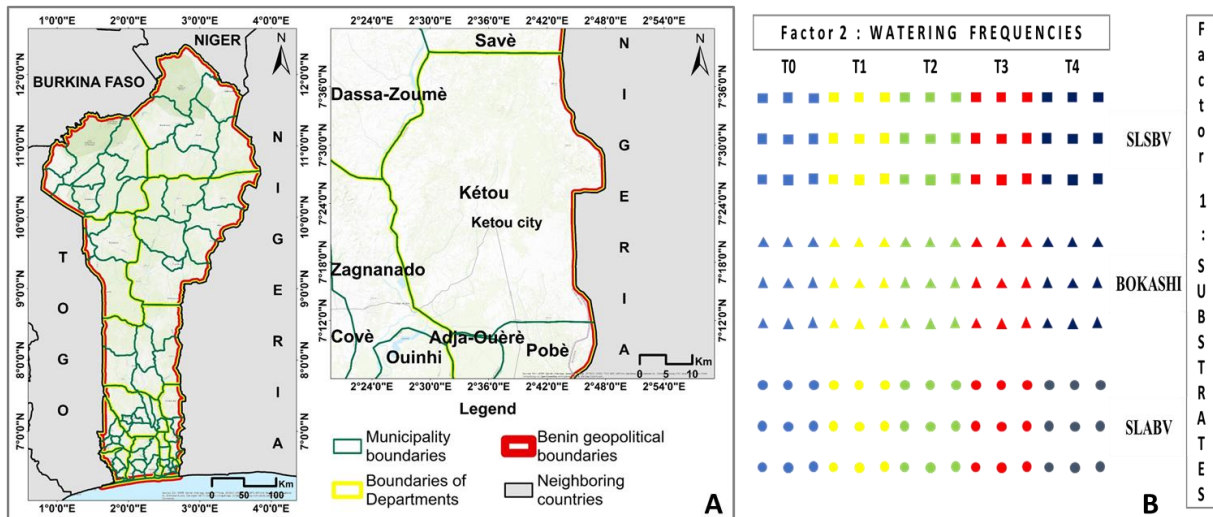


Figure 2: Map of the study area's geographical location (A) and diagram of the adopted experimental setup (B).

## RESULTS

### Seedlings mortality and survival

From the beginning of the experiment until week 6, no cases of mortality were observed. However, starting from week 7, seedling mortality was identified in treatment T4 for all substrates. In contrast to the sandy-loam substrate with cow dung (SLABV), where mortality began in week 7 for all watering frequencies, for the bokashi substrate, mortality started in week 7 for treatments T4 and T3, and progressively spread to the other watering frequencies from week 11 onwards. Among all substrates, only the sandy-loam substrate (SL

recorded a single case of seedling mortality in treatment T0 at week 8 of the experiment (Figure 3A).

At the end of the experiment, concerning seedling survival in the nursery, it was observed that when the watering frequency was reduced, i.e., as treatments changed from T1 to T4 for both the BKS (Bokashi) and SLABV (sandy-loam with cow dung) substrates, there was an overall increase in mortality cases, with mortality generally higher in the SLABV substrate. In contrast, mortality was identified only in T0 and T4 for the sandy-loam substrate without cow dung (Figure 3D).

The two-way Analysis of Variance (ANOVA) (Table 1) showed significant differences ( $p$ -value  $< 0.05$ ) in mortality rates across the substrates. Tukey's test located these differences between the SLSBV and SLABV substrates (Figure 3B). Regarding watering frequencies, the ANOVA results showed significant differences ( $p$ -value  $< 0.05$ ) in mortality rates across the watering frequencies. Tukey's test indicated that the differences were between T0 and T4 (Figure 3C). However, when considering the combined effect of the substrate and watering frequencies, the ANOVA results showed no significant difference ( $p$ -value  $> 0.05$ ) in mortality rates.

#### Current growth increments in height and diameter

In general, plants in the SLABV substrate showed the greatest height growth, whereas plants in the SLSBV substrate showed the

smallest height growth (Figure 4C). Plants in the Bokashi substrate had intermediate growth compared to the other two substrates. Regarding diameter, as watering frequencies were reduced from T0 to T4, regardless of the substrate, there was an overall reduction in current growth increments in diameter (Figure 4B).

The two-way ANOVA (Table 2) showed no significant differences between the effects of substrates and watering frequencies, nor between their combined effects on plant height growth ( $p$ -value  $> 0.05$ ). However, for diameter growth (Table 3), the two-way ANOVA showed no significant differences between the effects of substrates on plant diameter growth ( $p$ -value  $> 0.05$ ), but there was a significant difference ( $p$ -value  $< 0.05$ ) in the effects of watering frequencies on diameter growth. Tukey's test indicated that this difference was observed between treatments T0 and T4 (Figure 4A).

Table 1: Results of the two-way analysis of variance of the effects of substrates and watering frequencies on the mortality of the seedlings.

	Df	SumSq	MeanSq	F value	Pr (>F)
Substrates	2	3703,7	1851,85	41,667	0,0253
Watering frequencies	4	6567,9	1641,98	36,944	0,01464
Substrates*Watering frequencies	8	3950,6	493,83	11,111	0,38372
Residuals	30	13333,3	444,44		

Table 2: Results of the two-way analysis of variance of the effects of substrates and watering frequencies on seedlings' height growth.

	Df	SumSq	MeanSq	F value	Pr (>F)
Substrates	2	0,020006	0,010003	1,615	0,2157
Watering frequencies	4	0,010099	0,0025248	0,4076	0,8017
Substrates*Watering frequencies	8	0,066549	0,0083186	1,343	0,2612
Residuals	30	0,185818	0,0061939		

Table 3: Results of the two-way analysis of variance of the effects of substrates and watering frequencies on seedlings' diameter growth.

	Df	SumSq	MeanSq	F value	Pr (>F)
Substrates	2	0,010019	0,005009	17,061	0,19872
Watering frequencies	4	0,03935	0,009838	33,505	0,02212
Substrates*Watering frequencies	8	0,018264	0,002283	0,7776	0,6254
Residuals	30	0,088083	0,002936		

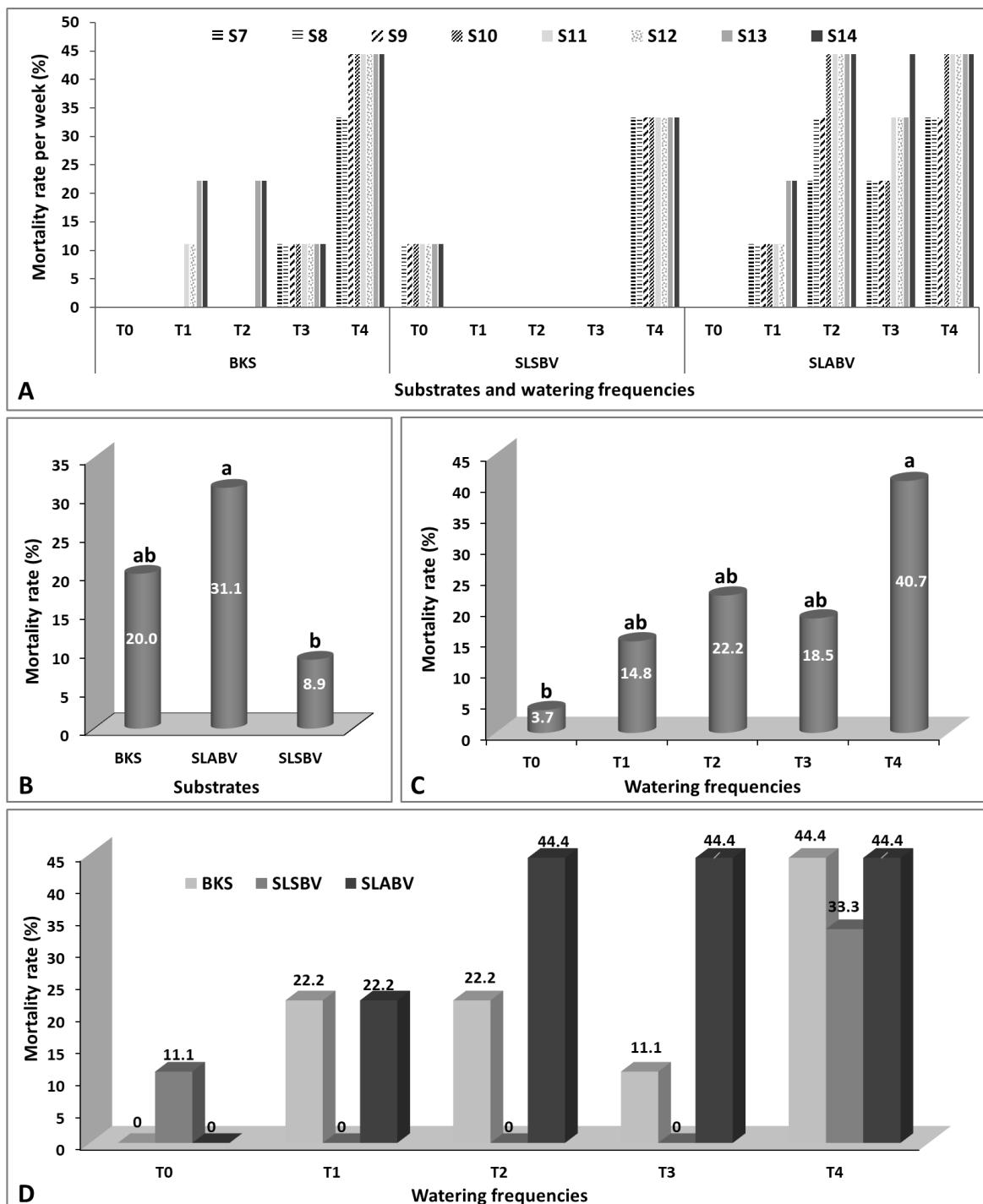


Figure 3: Shows the evolution of the mortality rate over the weeks starting from week 7 (A), effect of substrate (B), effect of watering frequencies (C) on seedling mortality, and the combined effect of substrate and watering frequencies on seedling mortality (D).

Note: Values with the same letters are not statistically different from each other at the 5% significance level.

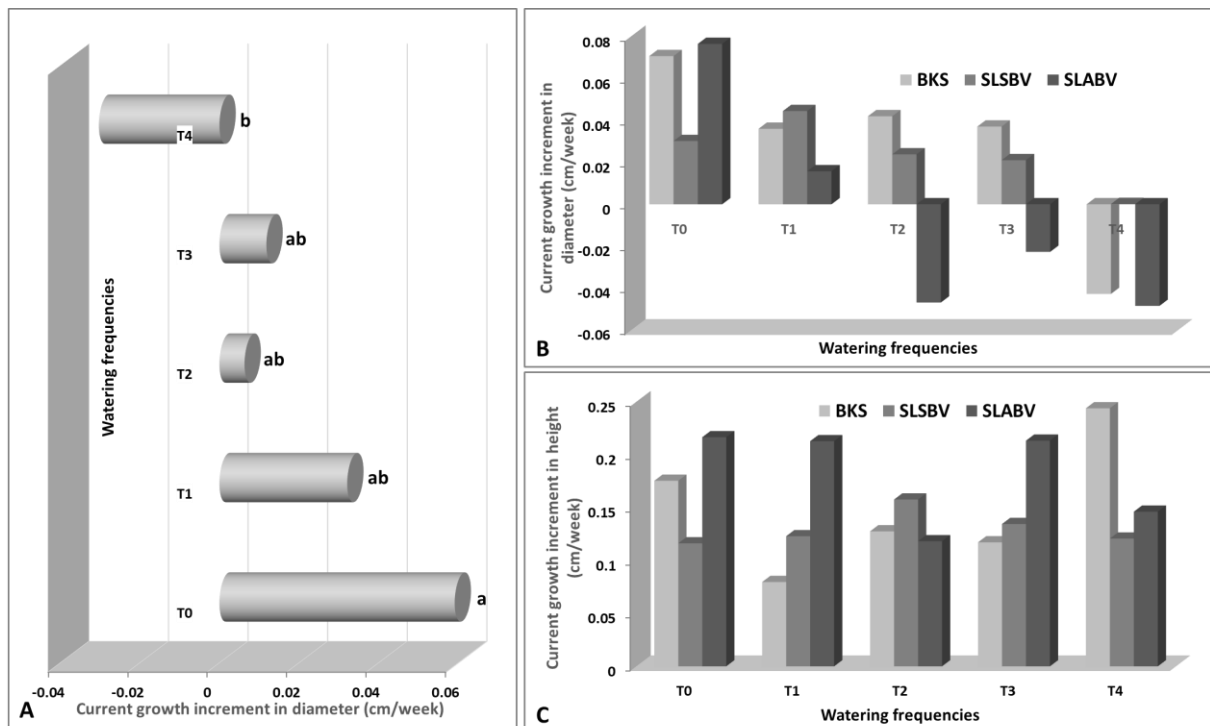


Figure 4: Shows the effect of water supply on diameter growth (A), the combined effect of watering frequencies and substrate on diameter growth (B), and the combined effect of watering frequencies and substrate on height growth (C) of *B. mannii* seedlings. Note: Values with the same letters are not statistically different from each other at the 5% significance level.

## DISCUSSION

The analysis of the effect of substrate and watering frequencies on the survival and growth of *B. mannii* seedlings in the nursery revealed that, regarding seedling survival, the sandy-loam substrate with cow dung (SLABV) in combination with treatments T4 (watering once every 5 days), T3 (watering once every 4 days), and T2 (watering once every 3 days), as well as the bokashi substrate combined with treatment T4, resulted in high mortality rates, and thus low seedling survival. In contrast, the combination of the sandy-loam substrate without cow dung (SL) and treatments T1, T2, and T3 did not have any negative impact on the survival of *B. mannii* seedlings. Therefore, it can be concluded that the addition of amendments could lead to high mortality rates for *B. mannii* seedlings. In fact, Essehi *et al.* (2016) noted that a high level of amendment could cause high mortality in plants, as seen in potato cultivation (Ngoyi *et al.*, 2020). Excessive soil amendments can adversely affect potato harvests. Hence, it is important to regulate and limit soil enhancements to prevent high nitrogen concentrations, which may hinder plant development (Mulaji, 2011). Research indicates that applying 5.16 grams of dried cow manure per 100 grams of sandy-loam soil can be quite detrimental to *B. mannii* seedlings in a nursery

setting. Nevertheless, Sagna *et al.* (2019) found that incorporating organic amendments does not adversely affect the survival rates of plants. It was also noted that the highest death rates occurred in treatment T4, regardless of the soil type. Generally, a lack of water leads to diminished yields (Chaves, 2002), which could clarify the elevated mortality observed in treatment T4, where irrigation was done every five days. Consequently, it can be deduced that for this investigation, utilizing sandy-loam soil without cow dung combined with treatments T1 to T3 is the optimal approach to ensure the healthy survival of *B. mannii* seedlings in the nursery. When examining the growth of *B. mannii* plants, findings revealed that the bokashi substrate significantly enhanced both the height and thickness of the seedlings. This improvement may stem from bokashi's unique formulation, which facilitates the integration of biofertilizers into the soil mix (Bernal *et al.*, 2009), thereby fostering seed germination and producing robust seedlings. Bokashi also plays a role in achieving fruitful yields for various crops (de Paula Vicente *et al.*, 2020; Olle *et al.*, 2013), including amaranth (Houenou *et al.*, 2021). In contrast, cow dung appears to promote height growth more than thickness in *B. mannii* plants, likely due to its elevated nitrogen content. Nitrogen is an essential

nutrient that acts as a primary catalyst for plant vitality (Ancion *et al.*, 2009). Therefore, it can be concluded that organic matter positively influences plant growth metrics (Mukendi *et al.*, 2017). Regarding watering schedules, the results indicated that treatment T0 was more conducive to diameter growth compared to height increase and seedling survival. The findings highlight that the presence of water is crucial for the survival of *B. mannii* seedlings. Water plays a key role in processes such as photosynthesis, nutrient transport and storage, as well as temperature regulation (Reynolds *et al.*, 2004). In contrast, treatment T4 resulted in significant seedling loss, a decrease in stem diameter due to drying out, and hindered growth. Typically, a lack of water negatively influences plant development and can diminish overall yields (Chaves, 2002). For example, studies on two species from the *Acacia* and *Eucalyptus* genera (Otieno *et al.*, 2005; Gbesso *et al.*, 2023) and five key species earmarked for reforestation in Burkina Faso (Kagambega *et al.*, 2019) demonstrated that water stress adversely affected their growth. To summarize, this study emphasizes the vital importance of both water availability and substrate composition for the health and growth of *Beilschmiedia mannii* seedlings. Although bokashi has shown potential in enhancing seedling development, an overabundance of additives like cow dung can negatively impact survival rates. Therefore, effective management of water and soil conditions is crucial to foster the growth and survival of *B. mannii* in nursery settings.

## CONCLUSION

*Beilschmiedia mannii* serves as a versatile species in agroforestry, yet it encounters serious obstacles regarding habitat destruction and preservation efforts. The various experimental treatments yielded different outcomes concerning growth metrics such as height and trunk diameter. Treatment T4, which involved watering every five days alongside a bokashi substrate, and treatment T1, which entailed watering every two days with a sandy-loam substrate enriched with cow manure, both resulted in taller seedlings of *B. mannii*, though they also exhibited a significantly high mortality rate. Conversely, treatment T0, characterized by consistent water availability, paired with a sandy-loam substrate containing cow manure, as well as T0 with the bokashi substrate, produced plants with larger diameters, yet these combinations similarly led to elevated mortality rates. In contrast, utilizing a sandy-loam substrate devoid of cow manure in conjunction with treatments T1 to T3 proved to be more

conducive for successful production and enhanced seedling survival rates. However, this particular combination did not stimulate rapid growth in the seedlings. The findings underscored the critical role of water availability and organic additives in determining the growth and survival of young *B. mannii* plants. Nevertheless, it is vital to investigate further treatment options and fertilizers related to the growth of *B. mannii* seedlings, as well as to broaden the research to encompass other native species that hold significant value for local communities.

## Conflict of interest

The authors declare that they have no conflict of interest.

## Author contribution

SIAY, EECD, and GHFG: Conceptualization, data collection, data analysis, writing and correction of the original draft; SIAY and GHFG: Supervision, editing, and validation; SIAY, GHFG, and DIA: Review and editing. All authors reviewed the results and approved the final version of the manuscript.

## REFERENCES

- Adaja, A. A. & Olajuyigbe, S. O. (2023). Exploring distinctive morphological traits in *Beilschmiedia mannii* georeferenced by GPS: Implication for conservation. *Nova Geodesia*, **3** (4), 143-143.
- Ahoua, A. R. C., Konan, A. G., Bonfah, B. & Kone, M. W. (2015). Antimicrobial potential of 27 plants consumed by chimpanzees (*Pan troglodytes* versus *Blumenbach*) in Ivory Coast. *BMC Complementary and Alternative Medicine*, **15**:383.
- Ahoua, A. R. C., Monteillier, A., Borlat, F., Ciclet, O., Marcourt, L., Ebrahimi, S. N., Koné, M. W., Bonfoh, B., Christen, P., & Cuendet, M. (2019). Anti-inflammatory and quinone reductase-inducing compounds from *Beilschmiedia mannii*, *Planta Medica*, **85** (5):379-384.
- Akoègninou, A., Van Der Burg W. J., Van Der Maesen L. J. G., Adjakidjè V., Essou J. P., Sinsin B. & Yédomonhan H. (2006). Flore analytique du Bénin. Backhuys Publishers. Wageningen. Netherlands. 1034.
- Ancion, P. Y., Hoang T. T., Ton T. P., Pham K. T., Chiang C. N. & Dufey J. E. (2009). Agricultural use of aquatic plants, particularly as soil amendments, in the Thua Thien Hue province, Central



- Vietnam 1. Inventory, abundance, and chemical characterization of locally available aquatic plants. *Tropicultura*, **27** (3), 144-151.
- Baldé M. A., Vandn B. D., Vlietinck A. & Pieters L. (2015). Ethnobotanical survey, antimicrobial and anticomplement activities of Guinean medicinal plants traditionally used in the treatment of inflammatory diseases in Conakry and Dubreka. *Journal of Plant Sciences*, Special Issue: *Ethnopharmacological Investigation of Medicinal Plants*, **3** (1): 11-19.
- Bernal, M. P., Albuquerque, J. A. & Moral, R. (2009). Composting of animal manures and chemical criteria for evaluating compost maturity. *Bioresource Technology*, **100**: 5444-5453.
- Chaves M. M. (2002). How plants cope with water stress in the field? Photosynthesis and growth. *Botany*, **89** (7): 907-916.
- Czyż, E. A. (2004). Effects of traffic on soil aeration, bulk density and growth of spring barley. *Soil and Tillage Research*, **79** (2):153-166.
- de Paula Vicente, T. N., Marafeli, E. A. M., de Castro Oliveira, J. A.; Tomita, J. L. C.; & Piccoli, R. H. (2020). A bibliographic review on bokashi over the last 20 years. *Research, Society and Development*, **9** (10): p. e279108339, DOI: 10.33448/rsd-v9i10.8339.
- Ebigwa, J. K. & Akomaye, F. (2009). Species diversity and regeneration potential of certain mangrove forests in the Escravos Delta State communities, Nigeria. *Journal of Forestry Research*, **8**: 34-47.
- Essehi, L. J., Trazié, B. G. J., Koffi, K. E., Soumahin, F. E., Koffi, O. M., Obouayeba, S. & Yao-Kouamé, A. (2016). Impact of organic fertilization on soil characteristics and growth parameters of rubber trees (*Hevea brasiliensis* Mull. Arg.). *International Journal of Innovation and Scientific Research*, **27**: 143-154.
- Fandohan A. B. (2011). Conservation biology of *Tamarindus indica* (Fabaceae) in Benin, West Africa. PhD Thesis, University of Abomey Calavi, Benin Republic. 227.
- Gbesso, G. H. F., Yevide, S. I. A., Gbesso, F. K. & Tonongbe, M. L. 2023. Effets du déficit hydrique sur la croissance des plantules de *Eucalyptus camaldulensis* Dehnh. et de *Acacia auriculiformis* A. Cunn. ex Benth. au Sud de la République du Bénin. *Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo*, **10** : 14-24.
- Hawthorne W. & Jongkind C. (2006). Woody plants of West African forests: A guide to forest trees, shrubs, and lianas from Senegal to Ghana. Kew: *Royal Botanic Gardens*. 320.
- Hien, M. P., Kouadio, K. K. H., Diomande, M., Nguessan, A. E. J., & Albert, Y. A. O. (2021). Estimation of water consumption and water use efficiency of *Lippia multiflora* at 30 days after transplanting in pots in Abidjan. *Revue Ivoirienne des Sciences et Technologie*, **38**: 166-186.
- Houenou, A. C. E., Koura, I. T. W., Mensah, A. I. C. G., Amonmide, I. I.; Komlan, f. A. & Dagbenonbakin, I. G. D. (2021), Production agroécologique d'amarante à base du bokashi. MAEP : Cotonou, Bénin.15.
- Houessou, L. G., Aheco, A., Adebé, Y., Yetein, M. H., & Biaou, H. S. (2019). Non-Timber Forest Products use in the Gazetted Forest of Dogo-Ketou, Benin (West Africa). *International Journal of Biological and Chemical Sciences*, **13**(6): 2824–2837.
- Igue, A. M., Saidou, A., Adjanohoun, A., Ezui, G., Attiogbe, P., Kpagbin, G., ... & Sogbedji, J. M. (2013). Evaluation de la fertilité des sols au sud et centre du Bénin. *Bulletin de la Recherche Agronomique du Bénin*, 12-23.
- INSAE. (2015). RGPH4 : What to retain from the population figures of 2013. INSAE, Cotonou, Benin. 3.
- Joachim, A. L. (2017). Physico-chemical properties of the oil extracted from the seeds of *Beilschmiedia mannii* (Lauraceae). *Journal of Agriculture and Crops*, **3** (6): 40-44.
- Jusu, A. & Cuni-Sanchez, A. (2017). Priority indigenous fruit trees in the African rainforest zone: insights from Sierra Leone. *Genetic Resources and Crop Evolution*, **64** (4):745-760.
- Kagambega, F. W., Nana, R., Bayen, P., Thiombiano, A. & Boussim, J. I. (2019). Drought tolerance of five priority species for reforestation in Burkina Faso. *Base*, **23** (4) :245-256.
- Kouamé A. M., Sahoré A. S., & Amani N. G. (2017). Fatty acid profile of *Beilschmiedia mannii* (Lauraceae) seeds oil. *International Journal of Biology and Innovation*, **6** (5): 675-700.

- Mark J., Adrian Newton A. C., Oilfield, S. & River M. (2014). The international timber trade: A working list of commercial timber species. *Botanic Gardens Conservation International*, Descanso House, Richmond, UK.
- Mathieu, C. & Pieltain, F. (1998). Physical analysis of soils, Selected Methods. Lavoisier Tech. And Doc., ISBN:2-7430-0283-2.
- Ministère des Relations Extérieures, de la Coopération et du Développement. (2002). *Momento de l'Agronome* (7th edn). MRECD : Paris, France. 379.
- Mukendi, T. R., Tshilumba, M. T., Mpoi, B. M., Mutamba, N. B., Kabongo M. D., Ilunga, T. M., Ngoie, K. J., Ngoyi, N. D. & Munyuli, M. T. (2017). Evaluation of maize (*Zea mays* L.) productivity under organic and mineral amendments in the Lomami province, Democratic Republic of Congo. *Journal of Applied Biosciences*, **109**: 10571-10579. DOI: <http://dx.doi.org/10.4314/jab.v109i1.2>.
- Mulaji K. (2011). Use of household organic waste composts to improve fertility of acidic soils in Kinshasa province (Democratic Republic of Congo). PhD Thesis, University of Liège, Belgium. 191.
- Ngoyi, A. N., Masanga, G. K., Bila, H. M., Yashima, A. Y., Milambo, M. M., Ndjibu, L. N. & Baboy, L. L. (2020). Effect of organic amendments on growth and yield of potatoes (*Solanum tuberosum*) grown on degraded soil in the Kabinda region, Democratic Republic of Congo. *International Journal of Biological and Chemical Sciences*, **14** (5):1812-1819.
- Nyunaii N. (2008). *Beilschmiedia mannii* (Meisn.) Benth and Hook.f. In: Louppe D, Oteng-Amoako AA, Brink M (Eds). *Timbers/Bois d'œuvre 1* [CD-Rom] Wageningen, PROTA 7.1.
- Ogunbanjo, O. O & Aina, A. S. (2013). Non-timber forest products for poverty reduction in Ogun Waterside Local Government, Ogun State, Nigeria. *Journal of Agricultural Science*, **4** (1): 49-53.
- Olajuyigbe, S. O & Adaja, A. A. (2020). *B. mannii* Robyns and Wilczek: an underutilized tree crop with great socio-economic potential. Annual conference of the forestry Association of Nigeria, **3** (1): 171-177.
- Olle, M. & Williams, I. H. (2013). Effective microorganisms and their influence on plant production – A review *The Journal of Horticultural Science and Biotechnology*, **88**:380–386.
- Otieno, D. O, Schmidt, M. W. T., Adiku, S. & Tenhunen, J. (2005). Physiological and morphological responses to water stress in two *Acacia* species from contrasting habitats. *Tree Physiology*, **25** (3):361-371.
- Reynolds, J. F., Kemp, P. R., Ogle, K. & Fernandez, R. J. (2004). Modifying the 'pulse-reserve' paradigm for deserts of North America: precipitation pulses, soil water, and plant responses. *Oecologia*, **141** (2): 194-210.
- Sagna, P.Y., Diedhiou, S., Goudiaby, K. O. A, Diatta, Y., Diallo, D. M. & Ndoye Y. (2019). Effect of organic amendments on rice (*Oryza sativa* L.) development in sulfo-acidic lowlands in the south-sudanian zone in Senegal. *Journal of Applied Biosciences*, **144**:11483-114841.
- Sahore, A. D. & Kofi, L. B. (2013). Technical sheet of *Beilschmiedia mannii* (Lauraceae) seed preparation in Ivory Coast. *Journal of Pharmaceutical and Scientific Innovation*, **2** (4): 62-64.
- Sahoré, A. D., Nemlin, J. G. & Tetchi, A. F. (2012). Study of physicochemical properties of some traditional vegetables in Ivory Coast: seeds of *Beilschmiedia mannii* (Lauraceae), seeds of *Irvingia gabonensis* (Irvingiaceae), and *Volvariella volvacea*. *Food and Nutrition Sciences*, **3** (1): 17073.
- Tossou, M. G., Yedomonhan, H., Azokpota, P., Akoegninou, A., Doubogan, P. & Akpagana, K. (2011). Pollen analysis and phytogeographic characterization of honey sold in Cotonou (Benin). *Cahiers d'Agriculture*, **20** : 1-9.
- Yevide, A. S. I., Ganglo, J. C., Glèlè-Kakaï, R. L. & De Cannière, C. (2011). Effet de la densité, de l'âge et des groupements végétaux de sous-bois sur la vigueur des plantations privées de teck (*Tectona grandis* L.f.) gérées en régime de taillis au sud- Bénin (Afrique de l'Ouest). *International Journal of Biological and Chemical Sciences*, **5** (3):1215-1231.
- Yèvidé, S. I. A., Gbesso, G. H. F., Aïdjihoundé, S. V. N. & Djossa, B. A. (2022). Ethnobotanical study and conservation of *Beilschmiedia mannii* (Meisn.) Benth. et Hook. f. in the Southeast of Benin. *Revue Marocaine des Sciences Agronomiques et Vétérinaires*, **10** (2): 312-318.