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***Research***

# Survivorship and Field Growth Characteristics of Four Selected Bamboo Species for The Development of Bamboo Industry in Sarawak, Malaysian Borneo

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**ABSTRACT**

The Sarawak State Government has assigned the Sarawak Timber Industry Development Corporation (STIDC) to lead the development of the bamboo industry in Sarawak. Since bamboo research in Sarawak has received meagre attention, baseline information on the early survival rate and field growth characteristics of bamboo are essential for the development of the bamboo industry. A study to evaluate the survivorship and field growth characteristics of a three-year-old bamboo was conducted at the Sarawak Bamboo Pilot Project site in Sabal, Malaysia. Study plots were established at bamboo plantation areas with four different potential bamboo species grown in Sarawak, namely *Bambusa vulgaris* (Buluh minyak), *Gigantochloa levis* (Buluh beting), *Gigantochloa hasskarliana* (Buluh beti), and *Dendrocalamus asper* (Buluh betong). Survival rate and field growth characteristics in terms of the number of culms per clump, the number of new shoots, culm diameter, culm height, mean annual increments of diameter (MAID), and height (MAIH) were measured and quantified quarterly in the year of 2021. The findings revealed that the highest mean survival rate (88%) was found in *G. levis,* and the lowest survival rate (70%) was found in *G. hasskarliana*. However, the lowest mean culm diameter was observed in *G. levis* at 2.66 cm, and the highest was in *B. vulgaris* at 4.51 cm. Notwithstanding, *B. vulgaris* remained with the greatest mean culm height of 12.61 m. Nonetheless, *G. hasskarliana* depicted the highest number of culms per clump and shoots with 91 culms and 3 shoots, respectively. The MAID and MAIH of *B. vulgaris* were significantly higher than the other species with 1.69 cm year$^{-1}$ and 4.72 m year$^{-1}$, respectively. The scientific information and findings from this study would be useful as guidelines for bamboo industry players, managers, nursery practitioners, and policymakers to begin and carry out the development of the bamboo industry, mainly in Sarawak.

**Key words:** Bamboo, bamboo industry, growth attributes, Sarawak, survival rate

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## INTRODUCTION

Bamboo is a perennial plant belonging to the Poaceae family (Wang, 2006). It is widely distributed, mainly in the world's tropical, subtropical, and mild temperate zones, with the tropical belt having the largest number of species (Fernandez *et al*. 2003). Bamboo is renowned for being a fast-growing, highly renewable, and economical raw material. The inhabitants used it for agriculture, construction, arts and crafts, and furniture in addition to making rafts, which are an essential mode of transportation. A variety of habitats in Malaysia support the growth of bamboo, including hillslopes, riverbanks, logged-over areas, and flat land. In forested areas, bamboo can exist as either pure stands or mixed with other tree species. According to Ng and Md. Noor (1980), most Malaysian bamboo species grow gregariously in localized patches. Peninsular Malaysia is home to around

50 species of bamboo, while Sabah and Sarawak have approximately 30 and 20 species, respectively. According to Getachew *et al*. (2021) and Li *et al*. (2020), bamboo stands out as the fastest-growing plant in nature, with certain species reaching a towering 40 m in height within a few months, and some growing more than 100 cm daily. The Sarawak State Government entrusted the Sarawak Timber Industry Development Corporation (STIDC) to spearhead the development of the bamboo industry in Sarawak. To produce food, charcoal, pharmaceuticals, pulp and paper, cosmetics, textiles, handicrafts, and engineered bamboo products, Sarawak aims to develop bamboo-based industries by 2030.

Most studies are concerned with the evaluation and assessment of planted tropical tree species and the changes in the surrounding ecosystem under monoculture plantation of fast-growing exotic species (Cole *et al*., 1996; Tilki & Fisher, 1998; Norisada *et al*., 2005; MacNamara *et al*., 2006; Arifin *et al*., 2008; Mohamad Jaffar *et al*., 2018; Perumal *et al*., 2021), efforts in long-term monitoring assessment on the growth performance and survivorship of planted bamboo species in Sarawak are critical.

The bamboo industry has experienced tremendous economic growth since 2015, when the national total exports were USD 0.18 million, as opposed to USD 2.09 million in 2019 (International Bamboo and Rattan Organization (INBAR), 2021). According to INBAR's (2021) latest figures, the worldwide bamboo and rattan industry is valued at USD 60 billion in trade, primarily from domestic sales. The UN Comtrade Database data revealed that in 2017, overseas exports of bamboo and rattan goods amounted to USD 1.7 billion, covering various processed products such as flooring, panels, and cladding, as well as artisanal handwoven items.

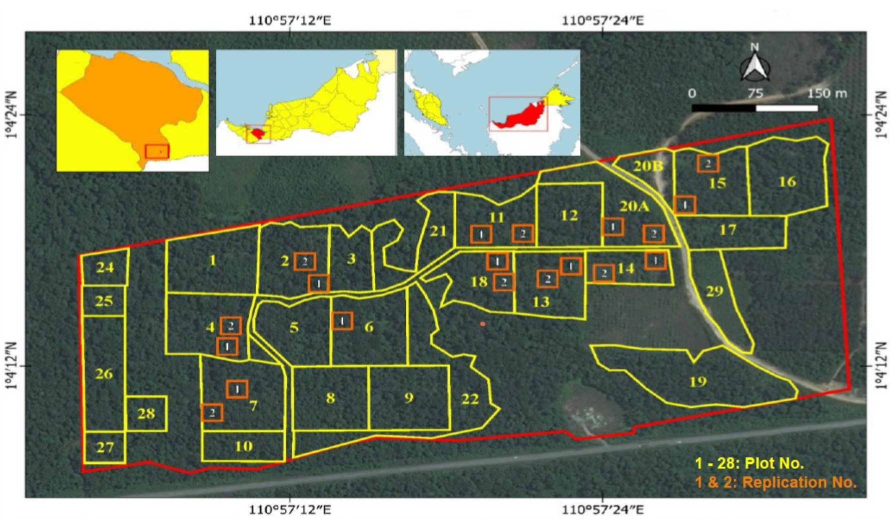
Most countries that export bamboo are found in tropical and subtropical regions. Asia, especially China, is home to the bulk of the world's bamboo-producing nations. With a value of USD 39 billion, China led the globe in the trade of bamboo in 2018, according to customs data (INBAR, 2021). However, a lot of areas that do not produce bamboo also export the material in large quantities. For instance, bamboo products are the second-largest European Union (EU) export. The EU buys bamboo intermediate items and raw materials from Asia, processes them, and then sells the finished high-value products to other nations (Amir *et al*., 2020).

Due to a lack of research on bamboo in Sarawak, Malaysia, it is pivotal to gather baseline data on the early survival rate and field growth characteristics of bamboo to support the development of the bamboo industry in the region. Thus, a study was carried out to assess the survival and field growth of a three-year-old bamboo at the Sarawak Bamboo Pilot Project located in Sabal, Sarawak, Malaysia.

## MATERIALS AND METHODS

### Study area

The research was carried out at Sabal Forest Reserve, Simunjan, Sarawak, Malaysia, specifically at Block 8406B, which is located around 51 km southeast of Serian and has an elevation of 20-35 m above sea level (Figure 1). The study sites were set up in areas of bamboo plantation with four different potential species of bamboo, namely *Bambusa vulgaris* (Buluh minyak), *Gigantochloa levis* (Buluh beting), *Gigantochloa hasskarliana* (Buluh beti), and *Dendrocalamus asper* (Buluh betong) (Figure 2). The area had an annual rainfall of 4,134.7 mm between 2011 and 2020, with a monthly mean air temperature of 26.9°C and relative humidity of 84.1% (Figure 3) (Meteorological Department, 2021).




(Source: Mohd Hassan *et al*. 2022)

**Fig. 1.** Segregation between different bamboo species at STIDC Bamboo Pilot Project area in Sabal Forest Reserve, Simunjan, Sarawak, Malaysia.

**Planting materials, preparation of growing medium, and propagation techniques**

The bamboo seedlings that were used in this research were all potential bamboo species grown in Sarawak. Except for *G. hasskarliana*, which was grown from cuttings of rhizomes while another three species were produced from branch cuttings of the mother plant (Table 1). Topsoil and river sand were mixed in a volumetric ratio of 1:1 following the standard forest nursery practice to produce seedlings in the nursery. Four-month-old seedlings were planted in the field. During planting, chicken manure-based organic fertilizer (2 kg/clump) was applied together with an inorganic fertilizer (NPK) (200 g/clump). Subsequently, after three months, the chicken manure-based organic fertilizer was applied to the planted bamboo until it reached two years of age, or for a longer period, depending on the bamboo growth development at the plantation area. During the growth period, the planted bamboo clumps were well maintained.

**Fig. 2.** (a) *Bambusa vulgaris* (Buluh minyak), (b) *Gigantochloa levis* (Buluh beting), (c) *Gigantochloa hasskarliana* (Buluh beti), and (d) *Dendrocalamus asper* (Buluh betong).

**Survival rate and field growth evaluation**

Study plots with the size of 20 × 20 m (two replications) with 5 × 5 m planting distance for each bamboo species (Plot No. 2, 11, 13, & 14) were established. It should be noted that the plot number was coded to represent each of the study plots; Plot No. 2 (*Bambusa vulgaris*), Plot No. 11 (*Gigantochloa levis*), Plot No. 13 (*Gigantochloa hasskarliana*), and Plot No. 14 (*Dendrocalamus asper*) (Figure 2). In the year 2021, survival rate and field growth attributes were assessed and quantified every quarter. These attributes were the number of culms per clump, number of new shoots, culm diameter, culm height, mean annual increments of diameter (MAID), and height (MAIH). In each study plot, a total of 25 clumps were measured for each replication. The culm's diameter and height were measured using a digital caliper and Vertex Haglof Transponder, respectively. The MAID and MAIH were determined based on the mean diameter and height measurements of the evaluated bamboo seedlings and the stand age of the experimental plot.

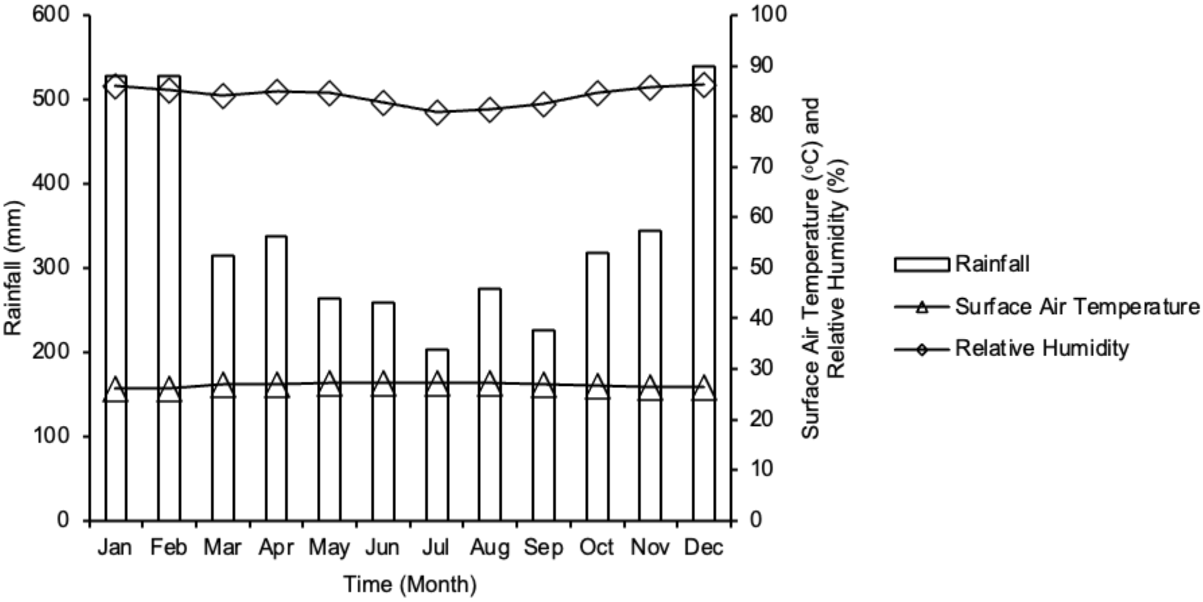



**Fig. 3.** Average monthly rainfall, surface air temperature, and relative humidity (2011-2020) in Sabal Forest Reserve, Sarawak, Malaysia (Meteorological Department, 2021).

**Table 1.** Bamboo planting materials, origins, and propagation techniques used in this study

| Plot no. | Planted species | Local name | Origin | Propagation techniques |
|---|---|---|---|---|
| 2 | *Bambusa vulgaris* | Buluh minyak | Sarawak, Malaysia | Cuttings (Branch) |
| 11 | *Gigantochloa levis* | Buluh beting | Sarawak, Malaysia | Cuttings (Branch) |
| 13 | *Gigantochloa hasskarliana* | Buluh beti | Sarawak, Malaysia | Cuttings (Rhizome) |
| 14 | *Dendrocalamus asper* | Buluh betong | Sarawak, Malaysia | Cuttings (Branch) |

### Data analysis

The data was analyzed using a one-way analysis of variance (ANOVA). The experimental unit was the mean response from the sampling units for each treatment replication, and each seedling was treated as a replicate of the sampling unit for statistical purposes. Scheffe's multiple comparison tests were employed in each study to find statistically significant differences between means when the ANOVA was significant. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) (IBM, version 24.0 for Windows) (Copyright: SPSS Inc. 2016).

## RESULTS

### Survival rate and field growth characteristics

Figure 4(a) displays the percentage of planted bamboo species that have survived. The result demonstrates that all bamboo species had at least 70% survival rates. In November 2021, *G. levis* had the highest mean survival rate (88%) and *G. hasskarliana* had the lowest mean survival rate (70%). Meanwhile, *G. hasskarliana* was significantly higher than the other three bamboo species in terms of the mean number of culms per clump. It showed the highest mean number of culms per clump with 91 culms, followed by *G. levis* with 24 culms, *D. asper* with 17 culms, and *B. vulgaris* with 14 culms (Figure 4(b)). Based on Figure 4(c), there were significant differences in the mean number of new shoots between *G. hasskarliana* with *B. vulgaris*, *G. levis*, and *D. asper*. *G. hasskarliana* had the largest mean number of new shoots in November 2021, with 3 shoots and the lowest were from *D. asper*, *G. levis*, and *B. vulgaris* with 1 shoot, respectively. However, *G. levis* was significantly lower than *B. vulgaris* in terms of mean culm diameter (2.66 cm), whereas *B. vulgaris* recorded the largest mean culm diameter (4.51 cm) (Figure 4(d)). Notwithstanding, there were significant differences observed between the bamboo species for mean culm height. *G. levis* had the smallest mean culm height at 7.72

m while *B. vulgaris* had the highest mean culm height at 12.6 m (Figure 4(e)). *B. vulgaris*, on the other hand, was significantly higher and had much larger MAID and MAIH values than the other bamboo species, with 1.69 cm year$^{-1}$ and 4.72 m year$^{-1}$, respectively (Figure 4(f) & 4(g)).

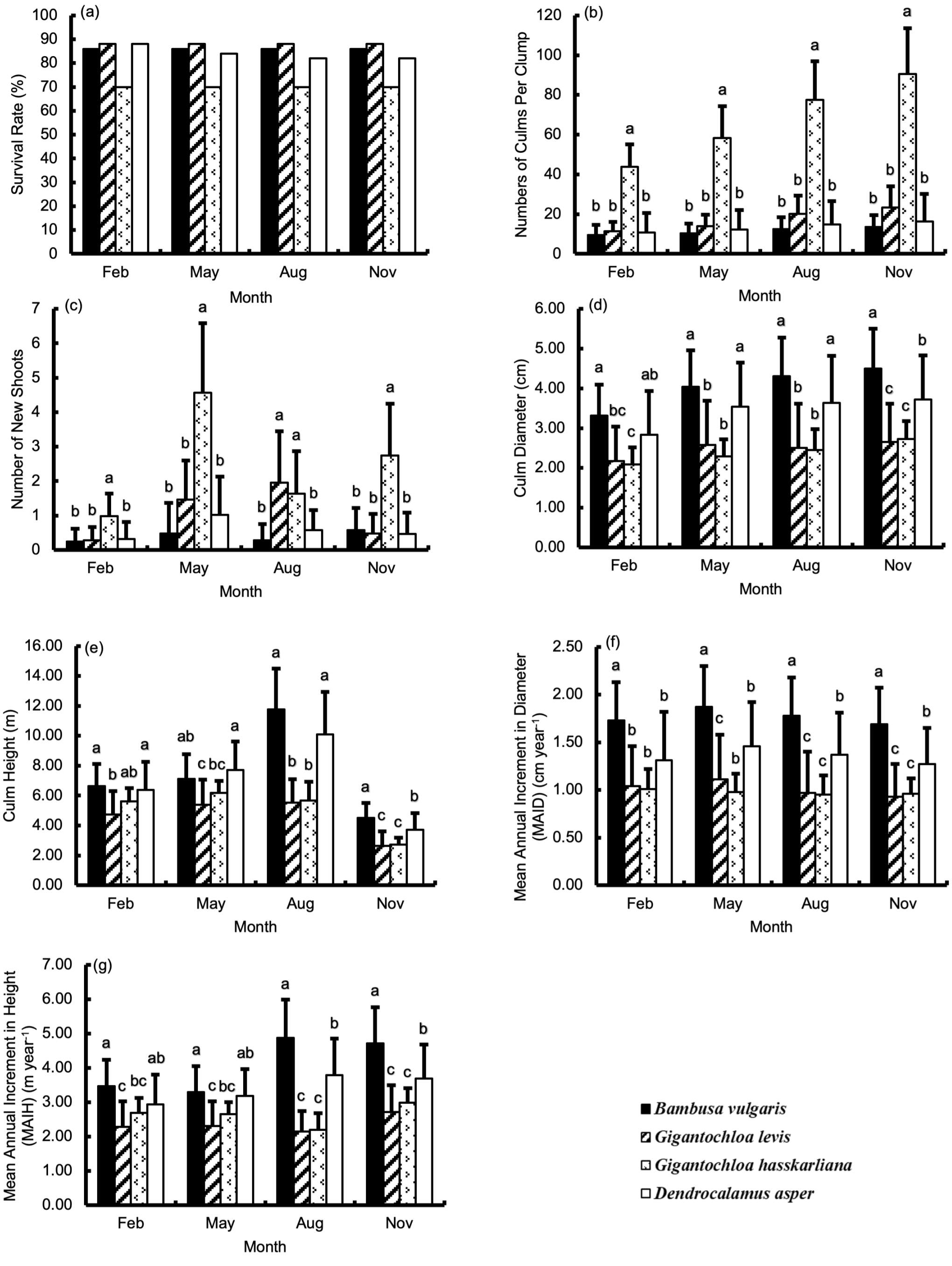



Fig. 4. (a) Survival rate, (b) numbers of culms per clump, (c) number of new shoots, (d) culm diameter, (e) culm height, (f) mean annual diameter increment (MAID), (g) mean annual height increment (MAIH) among different bamboo species. Bars are means and error bars are standard deviations. Bars with different letters are significantly different at the 5% level using Scheffe's multiple comparison test.

**Relationship among different bamboo growth quality attributes**

Table 2 presents the correlations among all potential combinations of growth quality attributes in this study so that future research can utilize them to reduce the number of attributes for observations based on the degree of relationship. Based on Table 2, the results show that the number of new shoots of different bamboo species was significantly ($P$<0.01) correlated ($r$=0.706) with the number of culms per clump. There was also a significant ($P$<0.05) negative correlation between culm diameter ($r$=-0.247) and mean annual increment in diameter (MAID) ($r$=-0.254) with the numbers of culms per clump. Nonetheless, a significant ($P$<0.01) strong positive correlation ($r$=0.846) between the culm height and culm diameter of different bamboo species in this study was observed. High significant ($P$<0.01) strong positive correlations ($r$=0.994) between mean annual increment in diameter (MAID) with culm diameter as well as with culm height ($r$=0.846) were also detected. Moreover, strong positive correlations ($P$<0.01) were found between mean annual increment in height (MAIH) with culm diameter ($r$=0.849), culm height ($r$=0.993), and mean annual diameter increment (MAID) ($r$=0.861), respectively.

**Table 2.** Relationship among different bamboo growth quality attributes

| Growth quality attributes | Numbers of culms per clump | Number of new shoots | Culm diameter (cm) | Culm height (m) | Mean annual increment in diameter (MAID) (cm year$^{-1}$) | Mean annual increment in height (MAIH) (m year$^{-1}$) |
|---|---|---|---|---|---|---|
| Numbers of culms per clump | 1.000 | | | | | |
| Number of new shoots | 0.706** | 1.000 | | | | |
| Culm diameter (cm) | -0.247* | -0.191 | 1.000 | | | |
| Culm height (m) | -0.145 | -0.086 | 0.846** | 1.000 | | |
| Mean annual increment in diameter (MAID) (cm year$^{-1}$) | -0.254* | -0.189 | 0.994** | 0.846** | 1.000 | |
| Mean annual increment in height (MAIH) (m year$^{-1}$) | -0.161 | -0.088 | 0.849** | 0.993** | 0.861** | 1.000 |

**Correlation is significant at 1% ($P$<0.01), *Correlation is significant at 5% ($P$<0.05)

## DISCUSSION

Understanding the mechanisms that influence the dynamics of the bamboo population and effectively managing the population and its habitat depends greatly on the survival rate percentage. In this study, generally, the survival rate of several bamboo species was moderately high, over 70%. Five bamboo species (*B. blumeana*, *B. bambos*, *B. vulgaris*, *D. asper*, and *D. membranaceus*) after two years of planting except for *D. birmanicus* demonstrated a survival rate of 100% in Kenya, according to a study published by Were *et al*. (2017). A study reported by Azmy *et al*. (2009) in Bukit Saga, Johor, Malaysia indicated that all four commercial bamboo species namely *D. asper*, *G. levis*, *B. vulgaris*, and *Gigantochloa* '*Brang*' planted using branch cuttings had a survival rate of more than 80%. Branch cutting is a simple and effective method for obtaining numerous propagules with a high survival rate (Abd. Razak *et al*., 1990, Chu & Chen *et al*., 1991, Sharma, 1991 & Shanmughavel *et al*., 1997). Additionally, Abd. Razak and Hashim Md. Nor (1992) recommended that *B. vulgaris*, *D. asper*, and *G. levis* be propagated using branch cutting due to their favorable survival rates. This corresponded to the bamboo species trial at Sabal Forest Reserve, Sarawak, Malaysia.

The number of culms per clump varied depending on both internal and external factors. The plant's robust system, species, and place of origin were among the internal variables. External factors included the type of fertilizer used, the slashing techniques, and other maintenance programs for the plantations (Mohd Hassan *et al*., 2022). According to our research, all species' early culm growth largely fell within the expected range of results. A study by Krishnakumar *et al*. (2017) found that *B. balcooa* (32.37) slightly outperformed *B. vulgaris* (31.94) and *B. bambos* (25.03) by producing the most culms in the fifth year.

Careful study of the growth of bamboo shoots is necessary to determine which bamboo species are the most active in terms of bamboo growth. Young bamboo shoots are the first bamboo products that can be marketed to the food sector. The use of bamboo in various industries, such as furniture and charcoal production is altered when the shoots are not harvested because they develop into bamboo culms. In this study, *G. hasskarliana* showed active shoot growth as compared to other bamboo species. *B. vulgaris*, on the other hand, showed the largest growth increment when measured in terms of the MAID and MAIH. It can be inferred that this potential species might be suggested for planting in Sarawak, Malaysia, for larger-scale activities geared toward the development of the bamboo industry. *B. balcooa* had the largest mean growth increment in diameter (1.84 cm year$^{-1}$) and height (4.35 m year$^{-1}$) according to a recent study by Mohd Hassan *et al*. (2022) at Sabal Forest Reserve, Sarawak, Malaysia. According to a study by Azmy *et al*. (2009) in Bukit Saga, Johor, Malaysia, it was found that the height of two species of bamboo namely *B. vulgaris* and *Gigantochloa* 'Brang', tends to be higher than the other two species, *D. asper* and *G. levis*. However, the study also reports that *D. asper* and *G. levis* had fewer culms on average compared to *B. vulgaris* and *G.* 'Brang'.

Singh and Rai (2012) reported a significant positive correlation between biomass production and clump circumference in their study. In addition, positive correlations were found between the biomass of the culms and various culm param such as clump diameter, plant height, inter-node length, culm diameter, and hollowness (Singh & Rai, 2012). Thus, in this study, it can be deduced that almost all the growth quality attributes are crucial in monitoring the outplanted bamboo growth development.

## CONCLUSION

Different bamboo species exhibit varying growth patterns in terms of survival rates and field growth characteristics. In this study, it is clearly shown that *B. vulgaris* depicted rapid growth in terms of culm diameter, culm height, MAID, and MAIH as compared to other bamboo species. This study's scientific data and findings can serve as guidance for stakeholders in the bamboo industry, nursery managers, and policymakers to begin and carry out the development of the bamboo industry, particularly in Sarawak. A long-term monitoring period is advised to be necessary before developing a commercial bamboo industry plantation operation in Sarawak. More in-depth research is required to determine the edaphic factors that can impact the survival and growth of planted bamboo using the line planting technique in Sarawak.

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## ETHICAL STATEMENT

Not applicable.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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