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Research Article

Comparison of Multiple Propagation Techniques of *Dendrocalamus hamiltonii* Under Nursery Conditions in Islamabad

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ABSTRACT

Bamboo, a fast-growing woody perennial grass from the *Poaceae* family, is widely recognized for its ecological and economic significance. Commonly referred to as "Green Gold" and "Cradle to Coffin Timber," it is used in construction, food production, charcoal manufacturing, and cottage industries. Additionally, bamboo plays a crucial role in soil conservation by enhancing biological, chemical, and physical properties. Globally, bamboo covers approximately 22 million hectares, yet research on its propagation techniques remains limited. This study investigates the propagation of *Dendrocalamus hamiltonii* under controlled nursery conditions using earthen beds. Bamboo culms with one, two, or three nodes were planted in sandy loam soil beds (10 × 30 ft) with three treatments and three replications, spaced three feet apart. The experiment was conducted using a randomized complete block design (RCBD) with supplemental irrigation as required. Growth parameters, including the number of tillers, leaf length, biomass productivity, and carbon sequestration were recorded daily until leaf maturity and monitored for three months. Biomass carbon content was estimated using a universal factor of 0.50. The collected data were analyzed using statistical software. Findings from this study provide insights into optimizing bamboo propagation techniques, contributing to sustainable forestry practices and carbon sequestration initiatives.

Keywords: Bamboo, macro propagation, plant growth regulators, biomass productivity, carbon sequestration.



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INTRODUCTION

Bamboo is a woody perennial with special characteristics that belong to the Gramineae (*Poaceae*) family of grasses (Wang, 2006). Bamboo is known by several names, including "Poor Man's Timber," "Friend of the People," "Cradle to Coffin Timber," and "Green Gold" because of its multiple applications in a variety of fields. A wide range of products, including cups, baskets, nets, bags, mats, hats, lanterns, pencils, matchboxes, lampshades, fences, edible shoots, raw shoots, furniture, crafts, clothing, bridges, jewelry, sheets, paper nappies, bone medicine, fiber, tableware, utensils, drugs, panels, floors, and agricultural implements, are made from bamboo as a raw material. Globally, there has been an increase in demand for bamboo (Sharma et al. 2020).

It is utilized in different fields, such as building, food production, the making of charcoal, cottage businesses, and many more. Furthermore, the significant biomass buildup contributes to the preservation and improvement of the soil's chemical, biological, and physical characteristics (Shanmughavel et al., 2000) Worldwide, bamboos are thought to span 22 million hectares of land (ICBR, 2004). This plant is a perennial renewable bio resource because it grows quickly 0.9 to 1.2 m/day and

because it can regenerate itself after harvesting without the need for additional plantings. It can reach maturity in four to five years (Singh et al., 2021; Sawarkar et al., 2020). Worldwide, bamboo is found in more than 110 taxa and more than 1500 species (Ohrnberger et al., 1998). Bamboos are predominantly found in tropical, subtropical, and equatorial climates between 51°N and 47°S (Tardio et al., 2018). Worldwide, tropical, subtropical, and temperate climates are home to a variety of naturally occurring bamboo species (Canavan et al., 2017). 1500 commercial and over 4000 traditional uses are found for bamboo. The production of food, combustion, paper, textiles and board, fiber reinforcement, and other bioenergy-related applications are all included. (Sandhu et al., 2018).

According to Lobovikov et al. (2007), There are over 1,200 bamboo species worldwide, with three *Arundinaria falcata*, *Bambusa bamboo*, and *Dendrocalamus strictus* being native to Pakistan. Additionally, various new species have been introduced to the country, including 13 that originated from Thailand, Bangladesh, China, and Sri Lanka (Lobovikov et al., 2007). Bamboo cultivation has expanded to agricultural lands in several districts of Punjab province, including Sargodha, Jhang, Kasur, Lahore, Khushab, Ganda Singh, Bhalwal, Mandi Bahaudin, and Dera Ghazi Khan. (Karim Alm-Ns, 2016; Lobovikov et al., 2007; Suleman, 2005).

More than 2.5 billion individuals around the globe rely on bamboo every day, with approximately one billion people residing in homes constructed from bamboo. Implementing sustainable forest management techniques and developing new bamboo plantations offer potential solutions for addressing Pakistan's increasing need for wood products. These measures could help reduce the country's dependence on imported processed wood and promote the use of locally sourced materials. (Tripathi and Selvan, 2017).

Natural bamboo resources have been lost as a result of human activities such as industrialization, illegal bamboo extraction, and deforestation (Roy et al. 2014; Subramaniam 1998). Thus, to rectify the current imbalance in supply and demand, it is imperative to create large-scale, cost-effective bamboo propagation techniques for planting in new bamboo forests. The benefits and drawbacks of growing bamboo from seeds and other vegetative ways are covered in this review, along with the critical elements that influence growth success. Active bamboo growth was undertaken by farmers who hoped to profit from the gap that existed between the country's supply and demand for the plant. Pakistan swiftly became self-sufficient in a large number of goods made from bamboo. Pakistan also concentrated on the Middle Eastern bamboo market, namely the segment that sold bamboo that was used to manufacture tent poles (Suleman et al, 2005).

Despite the growing interest in bamboo propagation, particularly for *Dendrocalamus hamiltonii*, comparative studies evaluating multiple techniques under controlled nursery conditions in Islamabad are limited. This lack of research hinders our understanding of the optimal propagation methods for this species in the specific context of Pakistan. By conducting a comprehensive comparison, this study aims to fill this knowledge gap and provide valuable insights for bamboo growers and researchers in the region.

At present Pakistan is facing the wood shortage, has least soil fertility and millions of fertile lands degradation. The fast growing bamboo plant has the positive role to medicate the various gaps in the country. There is a lack of research on bamboo techniques in the country and also least literatures are available which could be worth for researchers and students for their research and other stockholders. Soil degradation is a natural phenomenon particularly in Pothwar region and by integration of bamboo will play best role in various parameters and also to medicate the carbon emission in country.

This study's main objective was to ascertain how long a particular species of bamboo would survive in relation to the number of nodes. After three months in this investigation, measurements were taken of the average length of the roots, the average number of shoots, the average number of nodes that would survive each treatment, and the average length of the shoots (in centimeters).

MATERIALS AND METHODS

Study Area

The National Agricultural Research Centre (NARC), located in Islamabad (latitude 33° 43' N, longitude 73° 04' E) would be the research area of choice. elevation 507 m). The research region experiences a typical humid subtropical climate, which is distinguished by its ability to experience all there are five distinct seasons in the year: spring (March–April), summer (May–June), autumn (September–October), and winter. (Nov–Feb).



Figure 1. Map of study area of National Agriculture Centre Islamabad.

Methodology

To achieve study objectives, three different nodes of fast growing *Dendrocalamus hamiltonii*, single, double and triple node were taken. Healthy mother plants of two-year-old were selected from the field area of Rangeland Research Institute (RRI), NARC. 27 cuttings were taken from healthy mother plants.

The average length of cuttings was 8-12 inches. These cuttings were laid out in earthen beds under irrigated condition on need basis. The cuttings were planted in 27 replications and arranged into the earthen bed having plant to plant distance of 3 feet. All the soil media was examined for pH, EC, bulk density and N, P, K. These cuttings were horizontally planted into the nursery beds. Their data of growth were recorded on daily basis till their growth emerged. Then the growth was recorded after seven days for length of leaves, number of tiller, height of plant.

Three-month data were collected in experimental field. All the data was recorded on analysis sheet and used the RCBD design. In the end of experiment entire plants were removed and soil samples were taken from earthen beds and transported to the lab of RRI. The total biomass was estimated. These results were applied with statistical tools to gain results and to conclude our objectives.

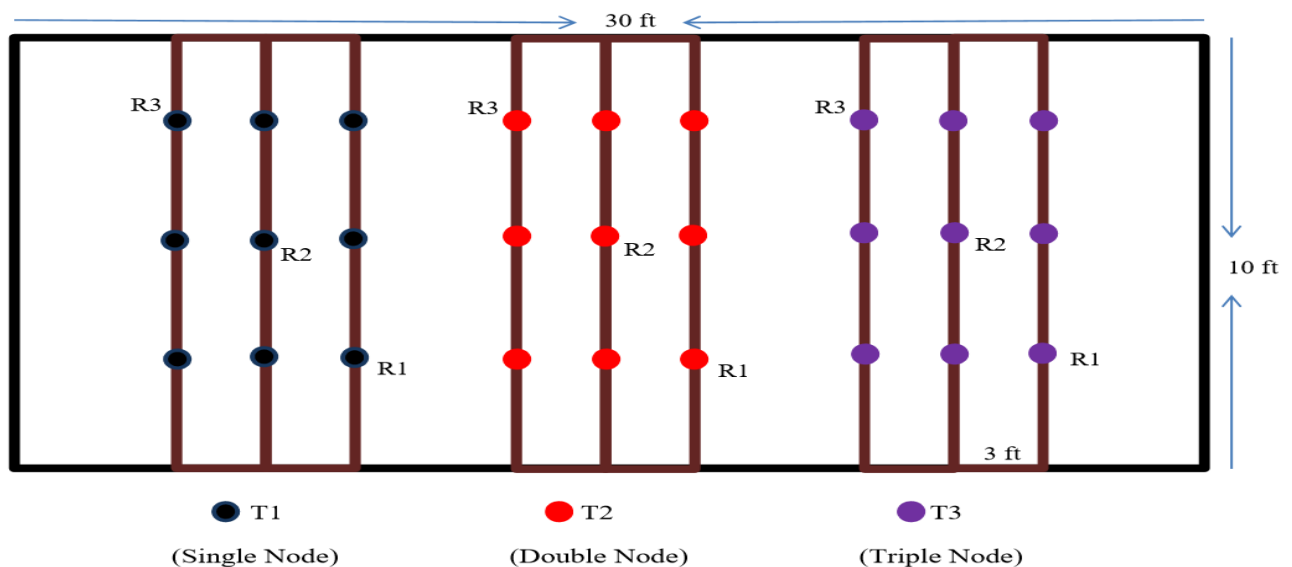


Figure 2. Layout design of the practical work.

Plant Growth Assessment

Newly arising bamboo plants were measured on a weekly basis (total of 13 weeks) for shoot height, tillers length, and number of branches and leaves. Data were recorded using a measuring scale or tape for height and other parameters.

Plant Sample Collection

Whole plants, including their roots and shoots, were pulled out of the earthen beds and cleaned with tap water first, followed by DI-H₂O to get rid of any dirt residue. Each replication was separately collected and placed in polythene zipper bags for further analysis. In total, 27 samples were collected. These samples included freshly growing shoots as well as roots of the plants. Plant samples were oven dried at 65°C for 72 hours and then measured its dried mass. The mean dry weight of the roots, shoots and entire plant were calculated of each replication.

Soil Sampling and Analysis

Soil samples weighing about 500 grams were collected from all the earthen beds and placed in zipper bags for further analysis and transported to the Rangeland Research Institute labs. For this purpose, the soil was collected about 10 to 20 and 30 inches deep from the earthen beds. For preliminary soil preparation collected samples were transferred to the laboratory whereas further chemical and elemental analysis of soil and plant was carried out from concerned laboratories of LRRRI, FSRI, and ASI, NARC. Following procedures were adopted to prepare soil samples at the Soil Head House, LRRRI, NARC. Soil samples were 1st placed in freezer to minimize the microbial activity and then left for drying at room temperature instead of sunlight by spreading a thin layer on a sheet of plastic. Stones, large aggregate, and unrecompensed organic matter were removed. After drying the samples were spread over sheet of paper and crushed with the help of a wooden pestle. Crushing was done up to the time it gave fine texture and then sieved (2-mm).

The aforementioned sampling of soil was for analysis whereas for the pot experiment, sieved samples were then loaded into the oven and were heated to the desired temperature of 210°C for a resident time of 24-hours. The heated soil samples were then left for whole night for cooling a purpose. Sieved cooled soil sample were then divided into 21 sub-samples each sub-sample contained 5-Kg of soil were then loaded in each pot and labeled accordingly. 20-g of soil was taken by using top balance machine in a plastic funnel then, to make it, 20 milliliters of deionized water was added (1:1, weight: volume) soil-water suspension. This suspension was thoroughly mixed using mechanical shaker for 30 min and allowed to stand. The pH and normal laboratory temperature were adjusted and then probe was washed with DI-H₂O and dried with tissue. The rod was inserted in soil suspension for at least 1-min and documented its pH, EC and pH of soil samples were determined by immersing electrode straight into saturated soil suspension, gradually swirled for well electrode contact (McLean, 1983; Richard, 1954).

Determination of Primary Macronutrients in Soil

Nitrate Nitrogen (NO₃ N) Chemicals

Copper Sulfate Stock Sol. (CuSO₄.5H₂O): 3.9-g of CuSO₄.5H₂O was dissolved in 1- L DI-H₂O. *CuSO₄.5H₂O Working Sol.*: 6.25-mL mother liquid was diluted in 1-L DI-H₂O and mixed it well. *Sodiumhydroxide 1.5-N Stock Sol.*: 60-g of NaOH pellets were dissolved in 800-mL DI-H₂O, after cooling brought volume in 1-L DI-H₂O. *NaOH Working Sol. (0.3 N)*: 200-mL mother liquid was diluted in 1-L DI-H₂O. *Hydrazine Sulfate Stock Sol. (H₂N₂H₂.H₂SO₄)*: 27-g of H₂N₂H₂.H₂SO₄ sol. was prepared in 1-L DI-H₂O. *H₂N₂H₂.H₂SO₄ working sol.*: 22.5-mL mother liquid was diluted in 1-L DI-H₂O. *Color Developing Sol.*: 5-g of sulphanilamide and 0.25-g C₁₂H₁₄N₂ was added in 300- mL DI-H₂O. After then 50-mL of H₃PO₃ (85%) was added and diluted to 500-mL DI- H₂O. *Standard Stock Sol.*: 6 working sol. (0.5-3.0-ppm) of NO₃-N were prepared.

Procedure

1-mL AB-DTPA filtrate, 3-mL copper sulfate, 2-mL H₂N₂H₂.H₂SO₄ and 3-mL NaOH (working sol.) was pipette in 25-mL test-tube and mixed well on electric test-tube shaker and placed in water tank (38°C) for 20-min. and then removed form bath and pipette 3-mL colour developing chemical and swirled. Two blanks (AB-DTPA and DI-H₂O) and 6 standards were developed the same way as described above. After 20-min analyzed on UVS (Perkin Elmer) at 540-nm λ . Absorbance of blanks, standards, and samples were noted down, as standards were in ppm, absorbance readings were also converted in ppm (Soltanpour and Schwab 1977). On excel sheet a calibration trend line was developed for standards by drawing emission counter to the corresponding Nitrate-Nitrogen conc. For calculating Nitrate-Nitrogen following formula was used;

$$\text{Nitrate-Nitrogen (ppm)} = \text{ppm (from calibration curve)} \times \text{Dilution Factor}$$

Phosphorus (P) Chemicals

Mixed Reagent for Phosphorus: 12-g ammonium molybdate and .2908-g antimony potassium tartrate was liquefied separately in 300-mL and 150-mL DI-H₂O and the both the sol. were mixed. After then 5-N of 1-L of H₂SO₄ (148-mL conc. H₂SO₄/L) was added slowly into that sol., mixed thoroughly, and diluted to 2L volume. *Color Reagent:* 0.739-g of ascorbate was dissolved in 140-mL mix reagent. *Stock Sol.:* 6 working sol. of 0.5-3.0-ppm P were prepared.

Procedure

1In a test tube, 2.5 mL of color-developing chemical and 9 mL of DI-H₂O were added to -mL AB-DTPA filtrate. (25-mL) and swirled well on electric test-tube shaker. Two blanks (AB-DTPA and DI-H₂O) and 6 standards were developed the same way as described above. After 30 min analyzed on UVS (Perkin Elmer) at 880-nm λ . Absorbance of blanks, standards, and samples were noted down, as standards were in ppm, absorbance readings were also converted in ppm (Soltanpour and Schwab 1977). On excel sheet a calibration trend line was developed for standards by drawing absorbance against the corresponding P conc. was prepared on excel sheet.

Potassium (K) Reagent

Lithium Chloride Sol.: 6.109-g of dried LiCl was dissolved in 1-L DI-H₂O (1000- ppm). For working sol. 200-mL mother liquid was diluted in 1-L DI-H₂O.

Standard Stock Sol.: Working standards of 0, 5 and 10-ppm potash were prepared.

Procedure

1-mL AB-DTPA filtrate was diluted with 4-mL DI-H₂O and 5-mL of LiCl in 25- mL test-tube and swirled well on electric test-tube shaker. After 10 min it was analyzed on the FP (Sherwood-Model-420) (Soltanpour and Schwab 1977). Absorbance of samples was noted down. For calculating K in the soil samples following formula was used;

$K (ppm) = K (\text{Absorbance value}) \times \text{Dilution Factor}$

Statistical Analysis

Experimentation was in RCBD with Randomized Comparison and LSD was applied Statistix 8.1 was seen to evaluate comparison among different nodes of bamboo specie. Statistix 8.1 was used for all pairwise comparisons (alphabetical lettering) among the means of various treatments. In this research means and SEs were provided for all the data.

RESULTS

Data collected from the field was analyzed and presented in the form of tables. The main aim of the study was to examine the growth, length of leaf, number of tillers, height of plant, above and belowground biomass and carbon sequestration of three different nodes (single node, double nodes, triple nodes) of *Dendrocalamus hamiltonii*. The impact of growth on soil before and after harvesting is also measure. The physiochemical health and varieties of the soil were also investigated. Discussion is held regarding the analysis and interpretations of the results.

Plant Growth Parameters

The data represents the plant height (in centimeters) of bamboo species. The results show a progressive increase in plant height across all nodes over time, with cutting having three nodes (Node 3) consistently having the highest values, followed by Node 2 and Node 1. The means for each node indicate that Node 3 (25.49 cm) is significantly taller on average compared to Node 2 (21.49 cm) and Node 1 (21.15 cm). The mean plant height also increases steadily from Week 1 (15.88 cm) to Week 13 (30.41 cm). The letters next to the heights indicate statistical significance, where different letters signify significant differences in height between the measurements. The LSD (Least Significant Difference) values provided indicate the threshold at which differences between means are considered statistically significant at the 0.05 probability level. This data suggests a clear trend of increasing plant height over time, with notable differences between the nodes.

Table 1. Comparison growth measurements of plant eight single, double and triple nodes.

Weeks	Node 1	Node 2	Node 3	Mean
1	15.16z	15.24z	17.24x	15.88M
2	16.15y	16.24y	19.31u	17.21L
3	17.16x	17.24x	20.22t	18.20K
4	18.15w	18.24w	21.31r	19.23J
5	19.15uv	19.31u	22.30pq	20.23I

6	20.15t	20.25t	22.80o	21.07H
7	21.15s	21.31r	24.22kl	22.23F
8	22.15q	22.30p	26.23h	23.22F
9	23.30m	23.30m	29.22e	25.26E
10	24.15k	24.31k	29.30e	25.92D
11	25.15j	25.28i	31.26c	27.23C
12	26.15h	26.90g	33.60b	28.88B
13	27.15f	29.50d	34.58a	30.41A
Mean	21.15C	21.49B	25.49A	

LSD value (0.05) for Field =0.0335

LSD value (0.05) for time period = 0.0698

LSD value (0.05) for comparison (Field*time period) =0.1209

Leaf Length

The table provides data on the length of leaves (in centimeters) measured at three different nodes over a period of 13 weeks. The results show a gradual increase in leaf length across all nodes as the week progresses. Cutting having three nodes (Node 3) consistently exhibits the longest leaf lengths, followed by Node 2 and Node 1. The average leaf length for each week also increases, starting from (5.32cm) in Week 1 and reaching (14.48cm) by Week 13. The data reveals statistically significant differences in leaf length between the nodes with time, as indicated by the letters next to each value. Significant variances are shown by various letters, therefore when two means have different letters, they are significantly different at the 0.05 probability level. The LSD (Least Significant Difference) values provided help determine the threshold at which these differences become statistically significant. Overall, the data indicates that leaf length increases steadily over time, with Node 3 producing the longest leaves on average, followed by Node 2 and Node 1. The mean leaf lengths across all weeks are (11.91cm) for Node 3, (9.47cm) for Node 2, and (8.09cm) for Node 1, showing clear variation between nodes.

Table 2. Comparison growth measurements of leaf length single, double and triple nodes.

Weeks	Node 1	Node 2	Node 3	Mean
1	5.15d	5.27d	5.54 b	5.326M
2	5.53c	6.67x	6.60 y	6.326L
3	6.15z	6.67y	7.74 u	6.859K
4	6.53yz	7.37w	8.51s	7.474J
5	7.15x	8.07t	9.72o	8.319I
6	7.53v	8.77r	10.78l	9.030H
7	8.15t	9.47p	11.68j	9.770G
8	8.53s	10.17n	12.75h	9.030F
9	9.15q	10.87l	13.85e	10.489E
10	9.15p	11.27i	15.17d	12.096D
11	10.15n	12.27i	16.25c	12.896C
12	10.53m	12.97g	17.65b	13.722B
13	11.15k	13.66f	18.64a	14.489A
Mean	8.099C	9.477B	11.917A	

LSD value (0.05) for Field =0.0393

LSD value (0.05) for time period =0.0818

LSD value (0.05) for comparison Field time period =0.1417

Number of Tiller

The table 4.3 on the number of tillers across various nodes over a 13-week period. The data shows that Node 3 consistently produced the highest number of tillers, with a mean value of 6.8034, while Node 1 had the lowest mean tiller count at 1.5726. Over time, all nodes exhibited an increase in tiller number, with Node 3 showing the most

significant growth, reaching a peak of 10.778 tillers by week 13. Nodes 1 and 2 also displayed gradual increases, although their tiller counts were consistently lower than Node 3's.

The differences in tiller numbers among nodes and across weeks were statistically significant, as indicated by the distinct letter groupings at the 0.05 level of probability. Additionally, the LSD (Least Significant Difference) values provide thresholds for determining significant differences between fields, time periods, and their interaction, indicating the precision of the measurements.

Table 3. Comparison growth measurements number of tiller of single, double and triple nodes.

Weeks	Node 1	Node 2	Node 3	Mean
1	1.00q	1.00q	3.00m	1.666M
2	1.00q	1.44p	3.00m	1.814L
3	1.00q	2.00o	5.00i	2.666K
4	1.00q	2.44n	5.33h	2.925J
5	1.00q	3.00m	5.77g	3.259I
6	1.00q	3.44l	5.77g	3.407H
7	1.33p	4.00k	6.33f	3.888G
8	1.33p	4.44j	6.88e	4.222F
9	2.00o	5.00l	7.77d	4.925E
10	2.00o	5.44h	8.88c	5.444D
11	2.22no	6.00g	9.88b	6.037C
12	2.22no	6.00g	10.00b	6.074B
13	3.33l	6.33f	10.77a	6.814A
Mean	1.572C	3.888B	6.803A	

LSD value (0.05) for Field =0.0890

LSD value (0.05) for time period =0.1853

LSD value (0.05) for comparison Field time period =0.3209

Aboveground Biomass

The table provides a comparison of above-ground biomass (in grams) across three different nodes (N1, N2, and N3). The data reveals the following: Node one (N1) has an above-ground biomass of 14.674 grams, which is the lowest among the three nodes. Node two (N2) shows an above-ground biomass of 17.553 grams, which is higher than N1 but lower than N3. Node three (N3) has the highest above-ground biomass at 28.553 grams.

Table 4. Comparison of different node on above biomass (g).

Node	Above biomass
N1	14.674c
N2	17.553b
N3	28.553a
Mean	60.78A

The overall mean above-ground biomass across all nodes is 60.78 grams. The letters (a, b, c) indicate significant differences between the nodes at the 0.05 probability level, with different letters representing statistically significant differences. The Least Significant Difference (LSD) value at the 0.05 level for the nodes is 0.2425, which helps in identifying the smallest difference that is statistically significant.

Belowground Biomass

The table 4.5 compares the below-ground biomass (in grams) across three different nodes (N1, N2, and N3). The data shows the following: Node one (N1) has a below-ground biomass of 18.184 grams, which is significantly lower compared to the other nodes. Node two (N2) has a below-ground biomass of 19.431 grams, which is higher than N1 but lower than N3. Node three (N3) exhibits the highest below-ground biomass at 23.437 grams.

The mean below-ground biomass across all nodes is 61.052 grams. The letters (a, b, c) indicate significant differences between the nodes at the 0.05 probability level, with different letters denoting statistically significant differences. The Least Significant Difference (LSD) value at the 0.05 level for the nodes is 0.1967, which helps in determining the smallest difference that is statistically significant.

Table 5. Comparison of different node on below biomass (g).

Node	Below biomass
N1	18.184c
N2	19.431b
N3	23.437a
Mean	61.052A

Root Shoot Ratio of Three Different Node

The table 4.6 compares the root-to-shoot ratio of biomass (in grams) across three different nodes (N1, N2, and N3). The data indicates the following: Node one (N1) has a root-to-shoot ratio of 0.5767, which is the lowest among the nodes. Node two (N2) shows a root-to-shoot ratio of 0.6344, which is higher than N1 but lower than N3. Node three (N3) has the highest root-to-shoot ratio at 0.6922.

The overall mean root-to-shoot ratio across all nodes is 1.9165. The letters (A, B, C) denote significant differences between the nodes at the 0.05 probability level, with different letters indicating statistically significant differences. The Least Significant Difference (LSD) value at the 0.05 level for the nodes is 0.0132, which helps in identifying the smallest difference that is statistically significant.

Table 6. Comparison of root shoot ratio biomass (g) of different nodes.

Node	Root shoot ratio
N1	0.5767C
N2	0.6344B
N3	0.6922A
Mean	1.9165

At the 0.05 level of probability, means denoted by different letters vary significantly.

LSD Value (0.05) for Node = 0.0132

Soil Analysis

The table 4.7 presents soil analysis data collected at two different times: before and after sowing. The parameters measured include pH, electrical conductivity (EC), nitrate nitrogen (NO₃-N), potassium oxide (K₂O), and phosphorus pentoxide (P₂O₅). pH (1:2): The pH level increased from 7.7080 before sowing to 8.2780 after sowing, indicating a shift towards more alkaline condition. EC (1:2) dS/m: Electrical conductivity, which measures the soil's ability to conduct electricity, decreased from 224.60 dS/m before sowing to 160.74 dS/m after sowing, suggesting a reduction in soluble salts. NO₃-N: The concentration of nitrate nitrogen dropped significantly from 0.3902 before sowing to 0.1404 after sowing, indicating a decrease in available nitrogen. K₂O: Potassium oxide levels also decreased from 5.3000 before sowing to 1.4600 after sowing, showing a reduction in available potassium. P₂O₅: Phosphorus pentoxide levels fell from 1.5486 before sowing to 0.7128 after sowing, indicating a decrease in available phosphorus. The LSD (Least Significant Difference) values at a 0.05 significance level are provided for each parameter, indicating the smallest difference that is statistically significant. This helps in understanding the variability and significance of the changes observed.

Table 1. Physio chemical properties of soil.

Sampling Time	pH (1:2)	EC (1:2) dS/m	NO ₃ -N	K ₂ O	P ₂ O ₅
Before sowing	7.7080b	224.60a	0.3902a	5.3000a	1.5486a
After Sowing	8.2780a	160.74b	0.1404b	1.4600b	0.7128b
LSD (Value at 0.05)	0.245D	43.164A	0.2293E	2.1978B	0.6589C

DISCUSSION

FAO (2024) conducted a comprehensive investigation into the growth characteristics of *Dendrocalamus hamiltonii*, a significant bamboo species. Their findings revealed that the density of culms within a clump varied substantially, ranging from 60 to 74 culms per clump. Additionally, the study observed impressive heights, with the tallest culms reaching a remarkable 13 meters. These results directly correlate with your research interests, which center on the measurement of growth metrics and the accumulation of biomass.

Live to Plant. (2023). The observed progressive increase in bamboo plant height over the 13-week period can be attributed to several factors inherent to bamboo growth dynamics. Bamboo is known for its rapid growth, which is facilitated by its unique rhizome system that allows for quick height acquisition within a single growing season. This system enables bamboo to produce a large amount of biomass very quickly. The differences in height between the nodes can be explained by the hierarchical nature of bamboo growth. Nodes with more developed rhizomes (like Node 3) have a greater capacity for nutrient uptake and growth, leading to taller plants. Additionally, bamboo plants grow in clumps or groves, with multiple stems supporting each other, which contributes to their overall height and sturdiness.

Shi., et al (2020) The observed increase in leaf length over the 13-week period can be attributed to the natural growth patterns of bamboo, which is known for its rapid and robust growth. Bamboo leaves grow in response to the plant's overall health and environmental conditions, such as adequate water, nutrients, and sunlight. The differences in leaf length between the nodes can be explained by the hierarchical growth structure of bamboo. Nodes with more developed rhizomes (like Node 3) have a greater capacity for nutrient uptake and growth, leading to longer leaves². Additionally, bamboo plants grow in clumps or groves, with multiple stems supporting each other, which contributes to their overall height and leaf length.

Shi., et al (2020) The observed increase in the number of tillers over the 13-week period can be attributed to the inherent growth characteristics of bamboo. Bamboo is known for its rapid and prolific tillering, which is facilitated by its rhizome system. This system allows bamboo to produce new shoots (tillers) quickly, especially in nodes with more developed rhizomes like Node 3. The differences in tiller numbers between the nodes can be explained by the hierarchical growth structure of bamboo. Nodes with more developed rhizomes (like Node 3) have a greater capacity for nutrient uptake and growth, leading to a higher number of tillers. Additionally, the clumping nature of bamboo allows multiple stems to support each other, contributing to the overall increase in tiller numbers.

Hauchhum and Singson (2019) conducted a research in Mizoram, India, assessed the above-ground biomass and carbon storage in various bamboo species, including *Dendrocalamus hamiltonii*. The study found significant variations in biomass accumulation, which aligns with your findings of different biomass levels across nodes. The study of above-ground biomass in different nodes of *Dendrocalamus hamiltonii* is essential for understanding the growth dynamics and ecological contributions of this bamboo species. The significant differences in biomass across nodes indicate variations in growth potential and resource allocation, which are critical for optimizing bamboo cultivation and management practices.

White and brown (2010) The increase in pH after sowing, shifting towards a more alkaline condition, could be attributed to the decomposition of organic matter or the application of fertilizers that may have raised the soil's base cation levels. This can be supported by studies that show how soil management practices, such as fertilization and crop residue incorporation, can influence soil pH. A decrease in electrical conductivity (EC) after sowing is likely due to reduced levels of soluble salts, which can be linked to crop uptake of nutrients or leaching caused by irrigation or rainfall. The significant drop in nitrate nitrogen after sowing may reflect plant uptake during growth, where nitrogen is consumed by crops, leading to lower levels in the soil. This phenomenon is well documented in agricultural studies focusing on nitrogen cycling.

CONCLUSIONS

The research findings determine that triple-node cuttings demonstrated a significantly greater height compared to single-node and double-node cuttings. Triple-node and double-node cuttings are recommended for their rapid growth in farmlands and agroforestry systems, which can enhance livelihoods. Triple-node cuttings are also more effective at absorbing carbon emissions and mitigating climate change compared to single-node and double-node cuttings.

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AUTHOR CONTRIBUTIONS

All the authors contributed equally to this research.

COMPETING OF INTEREST

No conflicts of interest have been disclosed by the authors.

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