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Growth Performance and Economic Returns of *Schumannianthus dichotoma* (Murta/Patibet) across Elevation Gradients in the Hilly Areas of Chattogram, Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Schumannianthus dichotoma (Roxb.) Gagnep., locally known as murta or patibet and also referred to by its synonym Clinogyne dichotoma, is a perennial mat-producing shrub traditionally cultivated in wetland and hilly regions of Bangladesh. Its cultivation has gained renewed interest for its potential contribution to climate-smart agriculture (CSA) through soil stabilisation, livelihood diversification, and ecological adaptability in fragile hill environments.

This study aimed to evaluate the yield performance and economic returns of *S. dichotoma* cultivated across varying topographic elevations in the hilly Jhiri valleys of Bandarban, Bangladesh, and to assess its suitability as a climate-smart crop for sustainable hill farming systems.

Approximately 500 rhizomes were planted in a 1700 sq. ft. experimental area divided into upper, middle, and lower elevation plots. Growth performance and yield-related data were collected annually from 2017 to 2021. Plant height and income generation were compared across elevation gradients to identify spatial variation and productivity trends.

Variation in plant growth and income was observed across elevations. The lower plot exhibited comparatively better growth performance, characterised by taller plants and higher yield, which was attributed to enhanced soil moisture retention. Average annual incomes were BDT 558, BDT 1063, and BDT 1497 for the upper, middle, and lower plots, respectively, demonstrating an elevation-related yield pattern.

Schumannianthus dichotoma showed its best observed performance under moist lower-slope conditions and exhibited adaptability to the hill tract environment. The crop's low-input requirements, combined with its ecological benefits, support further evaluation of its inclusion in diversified hill farming systems.

The findings indicate the potential of *S. dichotoma* as a climate-smart, resource-efficient alternative to conventional upland crops. Long-term studies integrating climatic parameters, hydrological monitoring, and soil health assessments are recommended to validate its contribution to resilience and sustainability in hilly agroecosystems.

Keywords: Economic value; Hilly region; Murta; yield; Bangladesh.

1. Introduction

Schumannianthus dichotoma (Roxb.) Gagnep., commonly known as murta or patibet, is a rhizomatous shrub belonging to the Marantaceae family (Akter *et al*., 2023; Hooker, 1894; Prain, 1903). It is also referred to by the taxonomic synonym Clinogyne dichotoma Roxb., which appears in older floristic records. The plant is widely cultivated across Bangladesh under various local names (Hasan *et al*., 2021; Rashid & Sabah, 2005). It features oblong-lanceolate leaves (Mohiuddin & Rashid, 1988) and dichotomously branched, glossy green stems that can grow 3–5 metres high (Prain, 1903). Propagated by rhizomes or branch cuttings, murta thrives in swampy, partially shaded areas with clay or clay-loam soils (Rahman, Rahaman, *et al*., 2022; Merry *et al*., 1997; Ara *et al*., 2000; Siddiqi *et al*., 1998). It typically matures within 2–3 years and generates higher returns than traditional crops such as jute or rice (Rahman, Rahman, *et al*., 2022; Mohiuddin & Rashid, 1988), serving as the primary raw material for shital pati, a traditional mat (Chowdhury & Konwar, 2006; Choudhury & Hossain, 2011).

Murta mats are crafted from dyed strips 3–5 mm wide and are known for their aesthetic and cooling properties (Banik, 2001). As a non-wood forest product (NWFP), murta contributes significantly to local economies and forest sustainability (Myint Htun *et al*., 2023; Shamsuzzoha *et al*., 2022; Shrestha *et al*., 2020). It supports rural livelihoods, urban consumers, and growing trade sectors. A 100-hectare murta plot generates around US$ 91,783, rising to over US$ 353,012 after processing—surpassing paddy earnings by US$ 706/ha (Rashid *et al*., 1993). From 1981 to 1991, average annual revenue reached US$ 6,057 (Banik, 2001). Most products are used domestically, and 175 processing units were reported to produce *shital pati* using inputs worth US$ 37,571 and generate sales of US$ 116,714 (Rahman et al., 2010; Tasneem & Biswas, 2014).

Ecologically, murta stabilises soil by capturing silt and aiding forest regeneration (Banik, 2001). Sylhet shows higher culm production and growth than other regions (Mohiuddin & Rashid, 1988), although cultivation has declined despite rising demand (Rashid & Sabah, 2005; Banik, 2001). This calls for scientific resource management (Molla *et al*., 2025; Mohiuddin & Rashid, 1988; Chowdhury *et al*., 2007). This study was therefore conducted in the Chittagong Hill Tracts to explore traditional murta practices and evaluate the yield and economic benefits of climate-smart cultivation as a means of enhancing rural livelihoods and supporting sustainable jhum farming systems.

Recent reviews likewise emphasise that non-timber forest products can support rural livelihoods and ecological sustainability when their utilisation is coupled with sustainable management and market development (Verma et al., 2026; Mohale et al., 2025). Evidence from Bangladesh also identifies agroforestry as a climate-smart land-use practice with economic and environmental relevance for farming households (Ali et al., 2024). Related evidence from hilly micro-watersheds indicates that agroforestry-based systems can reduce runoff and soil loss relative to shifting cultivation under projected climate change (Choudhury et al., 2022). More broadly, recent evidence from Bangladesh links climate-smart agricultural adoption with improved household welfare among climate-vulnerable farmers (Islam & Farjana, 2024).

Despite murta's economic and ecological potential, there is a clear gap in scientifically documented cultivation trials in hilly or valley landscapes—especially under *rainfed*, low-input conditions. Most existing research addresses murta quality, processing, taxonomy, or ethnobotany, but far fewer studies examine spatial variation in growth and yield across elevation and moisture gradients under real-world hillside settings. Moreover, the integration of murta into climate-smart systems in marginal upland areas has not been empirically tested. Without such data, the case for scaling murta as a CSA-compatible crop in hill tracts remains speculative.

This study aims to evaluate the growth and yield performance of murta cultivated at different elevations and to analyse its economic viability under minimally managed, *rainfed* conditions. The central hypothesis is that murta cultivated in lower-elevation Jhiri plots yields significantly greater plant vigour and economic returns due to better soil moisture retention and reduced water stress. Additionally, the study explores murta's potential alignment with climate-smart agriculture (CSA) principles by assessing its suitability for degraded hill areas, low-input requirements, and economic benefits to marginal communities. Although climatic data such as rainfall or soil moisture were not recorded, the natural conditions and resource-conserving practices used provide a preliminary foundation for its classification as a climate-smart system.

2. Materials and Methods

2.1 Study Area

The study was conducted from 2016 to 2021 in a Jhiri valley situated between two hills on the southeastern side of the SCWMC (Soil Conservation and Watershed Management Center) administrative building in Bandarban, Chattogram. The site, located in Talukderpara village (Mouza 313), lies within the Bandarban district. Geographic coordinates range from 22°9′16″ to 22°10′32″ N and 92°11′17″ to 92°11′34″ E, with elevations varying from 92.0 to 133.0 metres above mean sea level. The location of the experimental site is shown in Fig. 1, generated using ArcGIS version 10.8 (Esri Inc., Redlands, CA, USA).

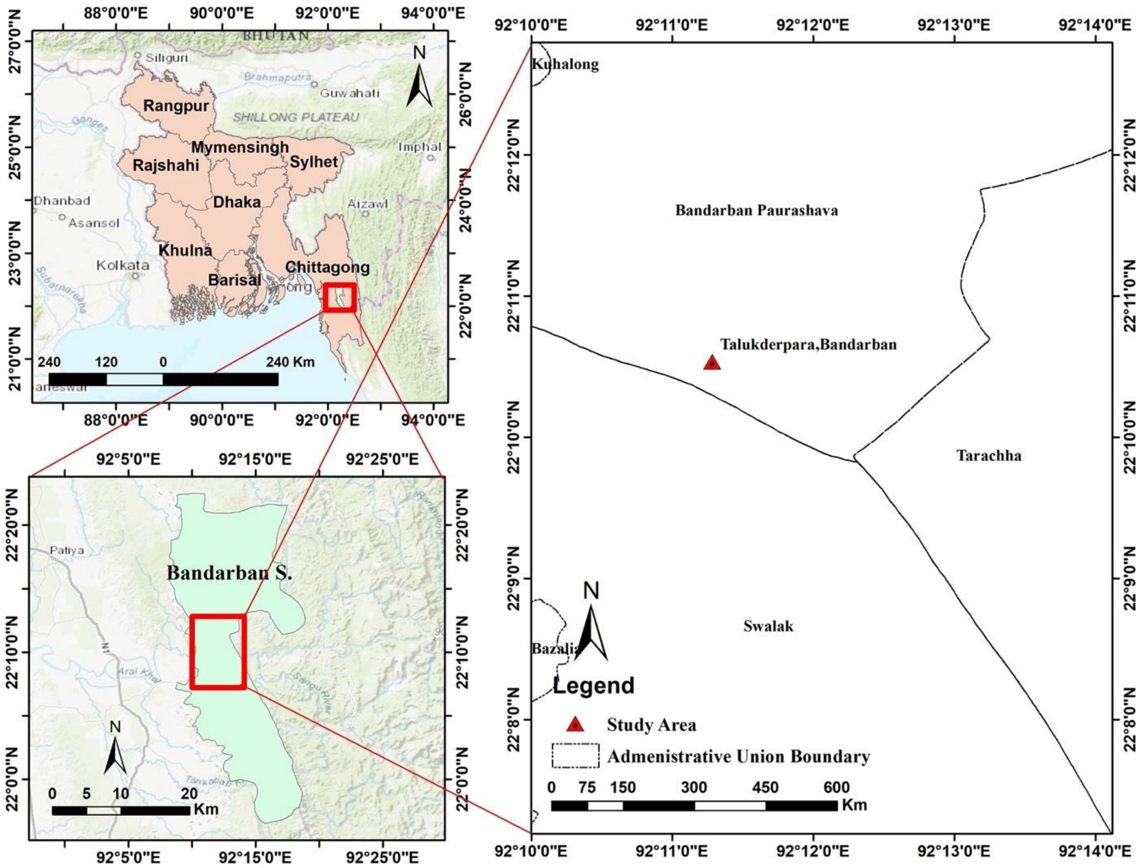

Fig. 1. Location of the study site in Talukderpara, Bandarban, Chattogram, Bangladesh. The map was created using ArcGIS version 10.8
(Esri Inc., Redlands, CA, USA; https://www.esri.com)

2.2 Climate and Weather Conditions

The Jhiri valley falls within the climatic regime of the Chittagong Hill Tracts, characterised by a tropical monsoon climate with distinct wet and dry seasons (Chowdhury, 2021).

Some key climatic features of the Bandarban region include:

I. **Annual Rainfall**: The Chittagong Hill Tracts, including Bandarban, experience substantial rainfall, often ranging from ~2,540 mm in the northern and eastern parts to over ~3,810 mm in the southern and western zones (Chowdhury, 2021).

II. **Seasonality**: The monsoon period usually extends from June through October, bringing the majority of annual rainfall; the dry-cool season spans November to March, while the pre-monsoon period (April–May) is hot and relatively dry (Chowdhury, 2021).

III. **Monthly Rainfall & Wet Days**: In Bandarban, July tends to be the wettest month, with an average of ~16.4 inches (~416 mm) of rain and about 20 rainy days in a month (WeatherSpark, n.d.-a). During the dry season (December–March), rainfall is minimal; for example, January often registers fewer than 1 rainy day and only a few millimetres of precipitation (WeatherSpark, n.d.-b).

IV. **Temperature Regime**: Mean annual temperature is approximately 25 °C in the Bandarban region (Climate-Data.org, n.d.). Seasonal extremes show that, in June, maximum temperatures of around 30–33 °C and minimum temperatures of around 24–25 °C are common (Climate-Data.org, n.d.). In winter months such as January, minimum temperatures may drop to ~13–16 °C, with daytime highs around 20–25 °C (WeatherSpark, n.d.-b).

V. **Variability & Extremes**: Extreme rainfall events have been recorded; for example, 170 mm was recorded in one 24-hour period in Bandarban in June 2018 (Nadiruzzaman et al., 2025). Longer-term analyses also suggest variability and a declining frequency of very high-intensity events in recent decades (Nadiruzzaman et al., 2025).

Given these climatic conditions, the Jhiri valley site experiences a pronounced monsoon-dominated hydrologic regime, with potential for seasonal moisture stress in the dry months and saturation or runoff challenges at the peak of the rainy season. These dynamics are expected to influence plant performance, soil moisture availability, and, ultimately, yield responses across the elevation gradient.

2.3 Experimental Layout

The experimental field, measuring 1700 sq. ft. (85' × 20'), was naturally segmented into three elevation-based plots: upper, middle, and lower. Elevation differences were 1′9″ between the upper and middle plots and 1′3″ between the middle and lower plots. Approximately 500 rhizomes of *Schumannianthus dichotoma* (murta/patibet) were planted across these plots in contour-aligned rows. Due to terrain constraints, replication and randomisation were not feasible; thus, the design serves as a quasi-experimental observational layout. Future studies should consider a randomised block design with replication to reduce environmental confounding factors.

2.4 Cultivation and Harvesting of Murta (Patibet)

The rhizomes used for planting were collected from a neighbouring Upazila within the Chattogram district. The field was prepared manually and analysed for baseline chemical and physical properties. The soil was classified as silt loam, with 26% sand, 64% silt, and 10% clay. Baseline chemical characteristics are provided in Table 1.

Informal interviews and field observations revealed a strong preference among farmers for rhizome-based propagation, attributed to higher survival rates, ease of division, and year-round availability. In contrast, seed propagation was rarely used because of low germination rates and greater management demands.

Harvesting was carried out manually using traditional curved knives (*dao*). Maturity was determined based on practical knowledge: culms exhibiting a reddish tinge and bearing 2–3 lateral branches were considered ready for harvest. Peak harvesting occurred between mid-September and late March, although minor harvesting continued year-round.

Table 1. Baseline Chemical Properties of Soil Prior to Experiment Establishment

Particulars	pH	OM%	K	Ca	Mg	TN	P	S	B	Cu	Fe	Mn	Zn
		Meq/100g soil				(%)	u gm/g soil						
Experimental Plot	5.9 Slightly Acidic	4.44 High	0.28 Opt.	8.37 V.H	2.87 V.H	0.222 Opt.	5.65 Low	9.40 Low	0.18 Low	5.20 V.H	139.60 V.H	79.60 V.H	2.04 High

Note: A culm refers to the mature, above-ground shoot of the murta plant, harvested for fibre extraction. The number of culms per plant directly correlates with economic yield, as each culm provides multiple bark strips used in shital pati production

2.5 Intercultural Operations

Intercultural practices included manual weeding and maintenance according to recommended guidelines. No synthetic fertilisers or pesticides were applied. Pest and disease incidence was minimal. Irrigation was not required, as the lower-elevation plots retained adequate soil moisture even during dry periods.

2.6 Soil Sample Collection and Analysis

Baseline soil samples were collected prior to plantation. Soil pH was measured using a Jenway glass electrode pH meter in a 1:2.5 soil–water suspension (Jackson, 1958). Organic carbon (OC) was determined by the Walkley and Black (1934) wet oxidation method and multiplied by the Van Bemmelen factor (1.724) to estimate organic matter (Piper, 1942). Total nitrogen (TN) was analysed using the Micro-Kjeldahl method (Jackson, 1958), and available phosphorus (P) was quantified using the ascorbic acid blue colourimetric method (Murphy & Riley, 1962).

Exchangeable potassium (K), calcium (Ca), and magnesium (Mg) were extracted using 1N ammonium acetate (pH 7.0) and analysed by Atomic Absorption Spectroscopy (Agilent 420 AA, Australia). Micronutrients—copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn)—were extracted and measured following Lindsay and Norvell (1978).

Available sulfur (S) was extracted by the calcium phosphate method and measured turbidimetrically as barium sulfate (Chesnin & Yien, 1951). Boron (B) was extracted with hot water and quantified colourimetrically using azomethine-H reagent (Berger & Truog, 1939). Results were expressed in mg kg^{-1} soil.

2.7 Household Survey Design and Data Collection

A semi-structured questionnaire was administered to 20 murta-growing households selected through purposive sampling based on their active involvement in cultivation. The survey aimed to capture data on land allocation, propagation methods, silvicultural practices, harvesting frequency, and murta's role in household income. Data were analysed using descriptive statistics. Inferential analysis was not performed because of the limited sample size.

2.8 Data Analysis

Observational data were recorded by year and elevation plot for key variables, including plant height, number of culms per plant, and economic returns. Although inferential statistics (e.g., ANOVA) were not applied because of the lack of plot-level replication, descriptive summaries and visual comparisons (e.g., bar charts, line graphs, and box plots) were used to identify trends. Ongoing efforts are directed towards incorporating statistical validation through replicated trials.

3. Results

The experiment revealed noticeable variation in growth characteristics and culm development among the three elevation-based plots. Plant height differed notably by location, with the lower plot consistently producing taller plants than the upper and middle plots. Plants in the uppermost plot appeared thin and pale, while those in the middle plot exhibited moderate growth with green to dark-green foliage. The lowest plot produced robust and vigorous plants with a deeper green colouration. Differences in plant appearance, leaf count, stem height, and diameter were recorded across the elevation gradient (Table 2).

A culm refers to the mature above-ground shoot of the murta plant that is harvested for fibre extraction. The number of culms per plant directly correlates with economic yield, as each culm provides multiple bark strips used in shital pati (traditional mat) production.

Table 2. Comparative growth study of *mutra/patibet* plants in different plots

Plot No	Year	Appearance	Average (Av.) plant height	Av. plants diameter (mm)	Av. leaf per plant (Nos.)	Av. plants per culm (Nos.)
1. Upper	2017-18	Yellowish green	1’-6” to 2’-0”	4- 6	4 to 6	7 to 9
	2018-19	Green	3’-6” to 6’-6”	8- 20	8 to 12	12 to 16
	2019-20	Green	3′-6′′ to 7′-0′′	10 - 22	11-20	16-20
	2020-21	Green to dark green	3′-6′′ to 7′-0′′	12 - 26	11-25	18-26
2. Middle	2017-18	Green	3’-0” to 4’-0”	5 - 8	5 to 9	10-14
	2018-19	Green	4’-0” to 7’-0”	10- 22	8 to 14	15- 20
	2019-20	Green to dark green	3′-6′′ to 7′-6′′	10-22	12-22	16-25
	2020-21	Green to dark green	3′-6′′ to 7′-6′′	14-28	14-28	16-30
3. (Lower)	2017-18	Dark green	4’-0” to 5’-0”	7 -12	9 to 14	12- 16
	2018-19	Dark Green	4’-0” to 7’-0”	12 -22	10 to 16	20- 22
	2019-20	Dark green	4′-0′′ to 7′-6′′	10-24	14-24	24-36
	2020-21	Dark green	3′-6′′ to 7′-6′′	14-28	14-28	18-35

Table 2 presents a comparative assessment of plant traits over four years, while Figs. 2–4 visualise key growth and economic trends across elevation gradients. Although differences in average plant height appeared evident—especially in the middle and lower plots—ANOVA results indicated no statistically significant variation ($F = 0.48$, $p = 0.634$). Likewise, although culm production varied across plots, this difference was also not statistically significant ($F = 1.56$, $p = 0.262$). The comparatively lower values of average plant height, stem diameter, number of leaves per plant, and culm number observed in the upper and middle plots during the initial years (2017–2018) can be attributed to several ecological and physiological factors. First, these plots are situated on relatively higher and better-drained slopes, where soil moisture retention is limited, particularly during the dry months. In contrast, the lower plot—positioned in the Jhiri valley—receives both surface runoff and subsurface seepage, maintaining higher soil moisture and nutrient availability throughout the year. Second, younger murta plants typically invest early energy into rhizome establishment rather than aerial growth, resulting in shorter culms and fewer leaves in the first one to two years after planting. The middle and upper plots, where soil organic matter and fine silt deposition are lower, would therefore exhibit slower canopy development and smaller culm diameters during this establishment phase.

Additionally, the upper and middle plots likely experienced higher evapotranspiration rates and greater exposure to solar radiation and wind, increasing physiological stress and limiting early vegetative expansion. These conditions may also have caused mild chlorosis or paler foliage, as noted in field observations, due to transient water stress or nutrient dilution. Over successive years (2018–2021), however, gradual rhizome expansion, increased ground cover, and partial litter accumulation improved the microenvironment and resource retention even in the upper and middle plots, leading to better plant performance.

Overall, while the lower elevation consistently favoured vigorous growth and greater culm formation due to better hydrological and edaphic conditions, the observed improvement across years in all plots indicates the plant's adaptive potential under varied microtopographic conditions.

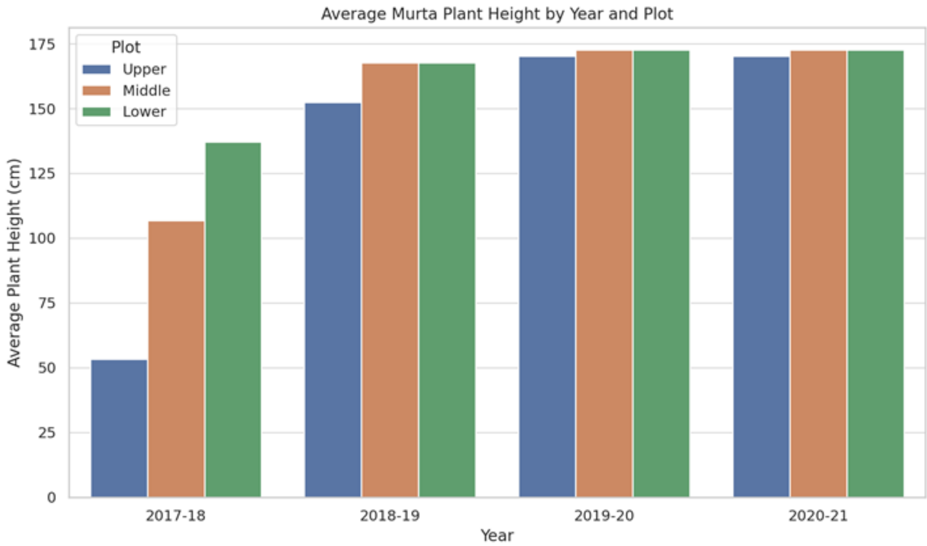

Fig. 2. Average plant height (cm) of *Schumannianthus dichotoma* across upper, middle, and lower plots during four consecutive years. Error bars represent standard deviation

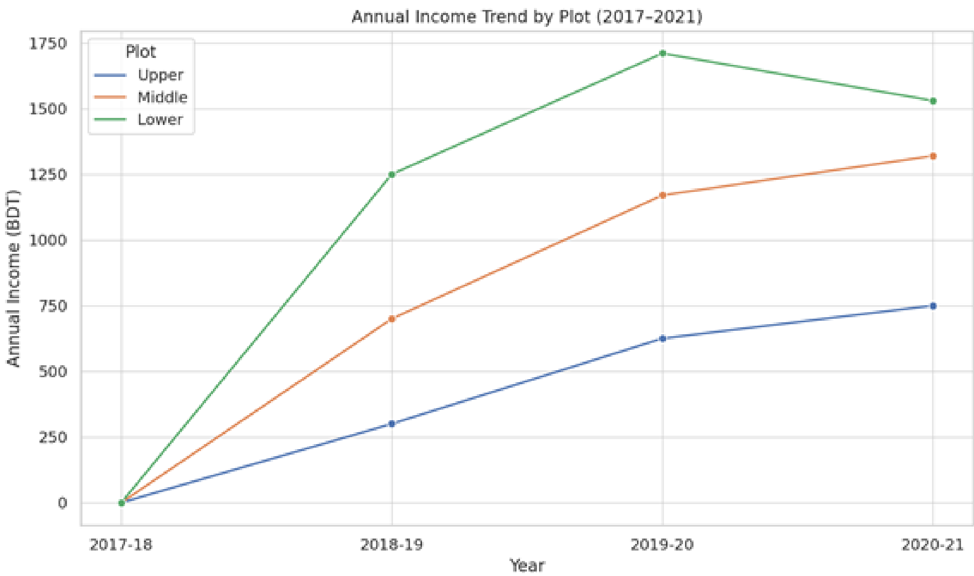

Fig. 3. Annual income (in BDT=Bangladeshi Taka) from murta cultivation in upper, middle, and lower plots over four years. The lower plot consistently produced the highest income

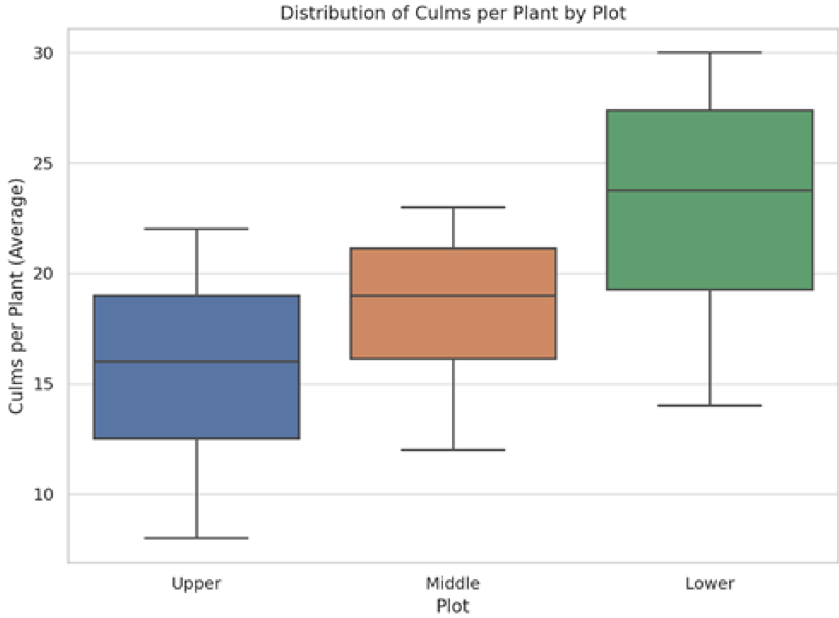

Fig. 4. Box plot showing the average number of culms per murta plant across the three plots. The lower plot shows a broader and higher distribution of culm production

3.1 Farmer Propagation Preferences and Practices

Murta can be propagated using rhizomes, branch cuttings, or seeds (Ara *et al*., 2000; Jalal *et al*., 2019; Rahman, Rahman, *et al*., 2022). In the study area, 33% of farmers relied exclusively on rhizomes, 23% used branch cuttings, and 44% employed both rhizomes and cuttings. Notably, no farmers reported using seeds. While the Bangladesh Forest Research Institute (BFRI) has developed a seed-based propagation technique (Ara *et al*., 2000; Merry *et al*., 1997), adoption remains minimal. Field observations and interviews confirmed that rhizomes and cuttings remain the preferred propagation methods because of their ease of use, availability, and reliable survival (Chowdhury et al., 2007; Rahman *et al*., 2010).

4. Discussion

4.1 Climate-Smart Characteristics of Murta Cultivation

The cultivation approach used in this study aligns with several principles of climate-smart agriculture (CSA), including: (i) optimising the use of fallow Jhiri land with high natural moisture retention to reduce irrigation dependence; (ii) enhancing vegetative ground cover on slopes to minimise soil erosion; and (iii) providing a resilient income source for marginal hill farmers, thereby increasing livelihood security. While direct environmental metrics were not collected, the reliance on low inputs, slope stabilisation through perennial planting, and use of native species contribute to environmental and socioeconomic resilience and are consistent with several climate-resilience principles (Rahaman et al., 2020).

4.2 Growth Performance Across Elevations

One of the central goals of this study was to examine whether elevation-based microenvironments influence murta growth. While ANOVA results for plant height and culm count did not reach statistical significance, possibly because of limited replication (p = 0.634 and 0.262, respectively), visual trends indicate comparatively better growth performance in lower-elevation plots. These plots consistently exhibited taller plants and higher culm density, which aligns with existing literature on moisture-loving species thriving in Jhiri-type microhabitats (Mohiuddin & Rashid, 1988; Ara *et al*., 2000). The absence of statistical significance should therefore be interpreted cautiously, as biological trends and field observations suggest that lower elevations may offer more favourable microenvironmental conditions for murta cultivation.

The recorded mean revenues from 1700 sq. ft. of Jhiri land were BDT 558, BDT 1063, and BDT 1497 for the upper, middle, and lower plots, respectively (Table 3). Notably, the lower plot yielded better returns than the upper plot. Murta harvesting is feasible nearly every year (Ara *et al*., 2000). It is harvested at ground level, leaving minimal remnants in the clump. Each murta plant produces around seven to eight bark strands. After harvesting, sticks are bundled and manually split into strands in the yard. Some strands are dyed to enhance their appeal for use in cottage industries, while undyed bundles are directly sold (Choudhury & Hossain, 2011).

Murta plantations typically require weeding twice a year, with particular attention given to controlling vines and climbers prior to the onset of the rainy season (Choudhury & Hossain, 2011; Merry et al., 1997; Chowdhury et al., 2007). The management of dominant weeds such as Asam lata (*Eupatorium odoratum*) is most effective when integrated with harvesting activities or carried out periodically as needed.

Table 3. Annual income from *mutra/patibet* in different years

Plot No	Year	Return (inBDT=Bangladeshi Taka)	Average Return (in BDT=Bangladeshi Taka)	Remarks
1. Upper	2017-18	-		
	2018-19	300/-		150 sticks @ Tk.2/- each
	2019-20	625/-		250 sticks @ Tk.2/50 each
	2020-21	750/-	5,58	300 sticks @ Tk.2/50 each
2. Middle	2017-18	-		-
	2018-19	700/-		280 sticks @ Tk.2/50 each
	2019-20	1,170/-		390 sticks @ Tk.3/- each
	2020-21	1,320/-	1,063	440 sticks @ Tk.3/- each
3. (Lower)	2017-18	-		-
	2018-19	1250/		417 sticks @ Tk.3/- each
	2019-20	1,710	1,497	570 sticks @ Tk.3/- each
	2020-21	1,530/-		510 sticks @ Tk.3/- each

4.3 Economic Outcomes and Profitability

Murta significantly contributes to both the national economy and the rural livelihoods of hill communities (Rashid & Sabah, 2005). With proper management, it holds export potential. From 1999–2003, the government earned an average annual revenue of $4567 from murta, which was lower than in the prior decade (Bangladesh Bureau of Statistics [BBS], 2001). Enhancing returns requires intensive studies on murta's cultivation, management, and marketing (Chowdhury & Konwar, 2006; Merry *et al*., 1997). This includes examining the impact of rhizome collection on parent plants, seedling costs, and the promotion of climate-smart murta farming (Merry et al., 1997), alongside improved value chains for murta/patibet-based products (Hoque *et al*., 2012; Banik, 2001).
Income data (Table 3) indicate increasing returns over time across elevation gradients, particularly in the lower plots. The slight income decrease in the lower plots during 2020–21 likely resulted from a combination of hydrological stress, nutrient loss, plant ageing, and market instability. However, raw return values do not fully capture the profitability of murta. A basic cost-benefit framework suggests that establishment costs (e.g., rhizome procurement, land preparation, and labour) are relatively low (~BDT 3,000 over 3 years for a 1700 sq. ft. plot), with recurring harvesting possible each year. Calculated over a 4-year cycle, the estimated Return on Investment (ROI) for the lower plot exceeds 30%, with minimal maintenance beyond weeding. When compared to lowland crops such as jute or upland turmeric, murta presents higher returns per unit area in marginal or fallow land and offers added environmental benefits. Future research should apply a full Net Present Value (NPV) model, incorporating opportunity costs, labour inputs, and market fluctuations for robust economic benchmarking.

4.4 Soil Nutrient Monitoring

Soil health is critical in evaluating long-term sustainability. While baseline soil characteristics were documented before plantation establishment, post-cultivation soil analyses were not conducted. Long-term changes in nutrient status due to murta cultivation—such as organic matter build-up, cation exchange capacity, or micronutrient availability—remain unassessed. Future studies should include soil monitoring before and after multiple harvest cycles to evaluate the sustainability of nutrient cycling in murta-based agroforestry systems.

4.5 Environmental and Microclimatic Considerations

The performance of murta is likely influenced by microclimatic variations, yet this study did not include data on rainfall, slope gradient, soil moisture, or solar radiation. These environmental variables significantly affect growth dynamics in hilly agroecosystems. For a robust understanding of elevation-based performance, future research should integrate environmental monitoring, such as automated sensors for soil moisture and ambient temperature, slope orientation, and canopy cover measurements. These indicators are important for empirically evaluating murta's climate-smart potential.

4.6 Economic Evaluation of Murta Cultivation

Income data (Table 3) indicate increasing returns over time across elevation gradients, particularly in the lower plots. However, raw return values do not fully capture the profitability of murta. A basic cost-benefit framework suggests that establishment costs (e.g., rhizome procurement, land preparation, and labour) are relatively low (~BDT (Bangladeshi Taka) 3,000 over 3 years for a 1700 sq. ft. plot), with recurring harvesting possible each year. Calculated over a 4-year cycle, the estimated Return on Investment (ROI) for the lower plot exceeds 30%, with minimal maintenance beyond weeding. When compared to lowland crops such as jute or upland turmeric, murta presents higher returns per unit area in marginal or fallow land and offers added environmental benefits. Future research should apply a full Net Present Value (NPV) model, incorporating opportunity costs, labour inputs, and market fluctuations for robust economic benchmarking.

5. Study Limitations and Future Research Directions

This study's quasi-experimental design without replication limits the statistical power of its findings. While visual trends suggest elevation-dependent differences, stronger conclusions require randomised block designs, replicated plots, and larger sample sizes. Additionally, the socioeconomic survey lacked structured analysis of household data, which could provide richer insight into adoption patterns. Future research should explore murta's scaling potential across multiple agroecological zones, with integrated environmental, economic, and social metrics.

6. Socioeconomic and Ecological Implications

Murta cultivation presents a potentially sustainable alternative to shifting (jhum) agriculture in the hill tracts, where repeated slashing and burning lead to soil degradation and biodiversity loss. The perennial nature of murta not only stabilises slopes and enhances ground cover but also contributes to ecosystem services such as erosion control and carbon sequestration through its persistent above-ground biomass. Field observations and informal farmer consultations indicate a strong preference for vegetative propagation—especially rhizome division—due to its reliability, high survival rate, and availability. In contrast, seed propagation was rarely practised, as it involves lower germination rates and greater management challenges. Scaling murta cultivation could therefore provide two potential benefits: supporting climate-resilient livelihoods for marginal communities and providing environmental co-benefits in fragile upland ecosystems.

7. Conclusion and Policy Recommendations

This study indicates that *Schumannianthus dichotoma* (murta/patibet) can be cultivated in the Jhiri valleys of the Chittagong Hill Tracts under the conditions examined. Over a four-year observation period (2017–2021), the lower-elevation plot produced the tallest plants (up to 228 cm) and the highest number of culms per plant (up to 35), compared with 26 in the upper plot. The mean annual income per 1700 sq. ft. was BDT 1,497, BDT 1,063, and BDT 558 for the lower, middle, and upper plots, respectively. With establishment costs of approximately BDT 3,000 over three years, the estimated ROI exceeded 30% in the lower plot, indicating favourable economic performance under the low-input conditions of this study.

Murta cultivation may contribute to soil erosion control, moisture retention, and livelihood diversification in marginal uplands. Its perennial canopy structure supports ecosystem functions and may complement efforts to reduce reliance on unsustainable jhum (shifting) agriculture. Farmer interviews indicated 77% reliance on rhizome-based propagation, suggesting that vegetative propagation is widely used in the study area.

8. Policy Recommendations

I. **Regional Scaling**:
   a. Integrate murta cultivation into Chittagong Hill Tracts land-use planning as a priority CSA crop.
   b. Provide targeted support (e.g., seedlings and training) through SRDI, BFRI, and the Department of Agricultural Extension (DAE).

II. **National Integration**:
   a. Include murta in national agroforestry and climate resilience strategies under the Bangladesh Forestry Master Plan (2017–2036) (Bangladesh Forest Department [BFD], 2016).
   b. Develop public–private partnerships to strengthen shital pati value chains.

III. **Regional/Global Expansion**:
   a. Promote further evaluation of murta as a potential CSA crop for humid tropical hill ecosystems in South and Southeast Asia (e.g., Nepal, Northeast India, and Myanmar).
   b. Encourage knowledge exchange and regional CSA investment programmes through platforms such as FAO and ASEAN.

IV. **Research & Monitoring**:
   a. Implement replicated trials across agroecological zones to validate elevation effects statistically.
   b. Integrate soil health monitoring (OM%, nutrients, moisture) and climate data to build long-term CSA impact evidence.

In conclusion, murta cultivation provides economic incentives and potential environmental co-benefits in hilly landscapes. Strategic investment, coordinated policy support, and scientific validation could support the scaling of this system beyond local communities and contribute to regional climate adaptation and rural economic resilience.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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