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ORIGINAL RESEARCH

Effect of Different Sowing Media on Seed Germination and Seedling Performance of *Ficus auriculata* L. and *F. hispida* L.

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ABSTRACT: In Bangladesh, the declining populations of *Ficus auriculata* L and *Ficus hispida* L, vital for maintaining ecosystem balance and supporting wildlife, are threatened by low germination rates and poor seedling establishment, highlighting the need for effective propagation strategies to ensure their conservation and sustainability. This experiment investigated the germination and seedling development of *Ficus auriculata* L and *Ficus hispida* L, species crucial for biodiversity and environmental stability in Bangladesh. Effective conservation and propagation require high germination rates and vigorous seedlings. This study examined the impact of different sowing media on germination and seedling growth for these two important species. The trial, conducted over two years (2019–2022), employed a completely randomized design with eight treatments, including a control and various mixtures of soil, cow dung, and sand. Seeds were obtained from the University of Chittagong and monitored daily for germination rates and growth parameters. The results showed that the different media significantly affected germination percentages. The control treatment achieved the highest germination rate for *F. auriculata* (63.66%) and showed good performance in other growth parameters. For *F. hispida*, Treatment 01 recorded the highest germination rate at 81.33%. Seedling growth was assessed by measuring shoot and root lengths, revealing significant differences among treatments. Shoot length and collar diameter were notably improved in *F. auriculata* under the control treatment, reaching 121.5 mm, compared to lower values in other treatments. The findings indicate that Treatment 7 (Sand: Soil: Dung in a 1:2:1 ratio) provided the most favorable conditions for seedling growth, promoting robust development and higher survival rates. These results highlight the importance of selecting appropriate growing conditions to enhance germination and survival rates, contributing to biodiversity conservation amid challenges like climate change and habitat degradation. Further research is recommended to explore the therapeutic and ecological benefits of these lesser-known Ficus species.

KEYWORDS: Nodal leaf cuttings, tip cuttings, Principal Component analysis, IBA, branch cutting

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1. Introduction

Bangladesh, a South Asian country, is situated between 20°34' and 26°38'N latitude and 88°01' and 92°41'E longitude. It enjoys a typical monsoon climate (Sohel et al., 2016) . The country is renowned as a storehouse of plant species, which have been extensively used for various purposes, including food, fodder, fuelwood, timber, industrial raw materials, health care, wildlife conservation (Suratman et al., 2020), carbon stock (Islam et al., 2020) and environmental protection. Biodiversity (Saimun et al., 2021), the wealth of life forms found on Earth, encompasses millions of plants, animals, and microorganisms, as well as their genes and the ecosystems they form. This diversity is considered at three levels: genetic, species, and ecosystem. Genetic diversity refers to the variability within a species, measured by the variation in genes within a particular species (Janssens et al., 2020), variety, subspecies, or breed. Species diversity is the variety of living organisms on Earth, measured by the total number of species in the world or a specific area. Ecosystem diversity is a measure of the variety of ecological complexes of organisms and is related to physical and ecological variations in an area. Biodiversity is crucial for preventing the extinction of species and preserving the balance of nature. *Ficus L.*, commonly known as 'Fig', is regarded as a keystone species in tropical rainforests (Debbarma et al., 2020). Due to its fundamental roles in the ecosystem, especially its fruits consumed by insects, birds, and other animals throughout the year. *Ficus* is also noted for being one of the most diversified genera (Raji and Downs, 2021) in terms of its habits (including deciduous and evergreen trees, shrubs, herbs, climbers, and creepers) and life forms (such as free-standing trees, epiphytes, semi-epiphytes in crevices, or lithophytes). It is one of the largest genera among angiosperms, comprising approximately 830 species (Janssens et al., 2020). The genus has a worldwide distribution, primarily in subtropical and tropical regions, with a significant concentration in the Asian-Australian region, home to about 500 species, approximately 66% of the global total (Jha et al., 2019).

Ficus auriculata Lour is a small Asian tree, 5-10 m tall, with bristle-covered branches and large round leaves up to 44 cm long. Its oblate syconium, up to 4 cm wide, bears reddish-brown fruits with prominent ridges up to 8 cm in diameter (Tamta et al., 2021). Flowering and fruiting occur from September to February (Guo et al., 2007), with nutritional and medicinal values in its consumed fruits (Ranjan Satapathy et al., 2022). *Ficus hispida* L. is a *hispid* deciduous tree (Debbarma et al., 2020), up to 15 m tall, with ovate leaves and yellowish figs. *Hypanthodia* is present in leaf axils or on leafless branchlets (Zeng et al., 2007). The figs are depressed-globose to pyriform, turning yellowish when ripe. Flowering spans April to September, and the species is native to various Asian countries, including Bangladesh(Islam et al., 2021).

Bangladesh's diverse ecosystem, hosting 5,000 flowering plants and 1,500 fauna species (Steinbauer et al., 2017), faces imminent threats from climate change, human expansion, and economic activities. Over 94% of natural habitats have succumbed to settlements and agriculture, jeopardizing rich forests. Inadequate research on wild fruit trees, like *Ficus* species (Rudra et al., 2021), accelerates their potential extinction due to overharvesting and changing attitudes towards natural vegetation. This depletion adversely affects flagship species, leading to wildlife-human conflicts. Deforestation, illegal logging, and poor regeneration exacerbate the decline. Critical knowledge gaps exist in seed trees, propagation, and sustainable practices. This study concentrates on *F. auriculata* and *F. hispida*, addressing their germination and growth in various media to enhance wildlife habitats and biodiversity conservation. Urgent research on therapeutic and nitrogen-fixing benefits of these lesser-known species (Sengupta et al., 1981) can combat medical inefficiencies, soil degradation, unsustainable agriculture, and riverbank erosion (Sayed et al., 2020). The study aims to evaluate the germination and early growth performance of *Ficus auriculata L.* and *Ficus hispida L.* under different growing media compositions. Understanding the impact of various soil amendments, including dung and sand, on seedling establishment is crucial for optimizing nursery management practices. By comparing different soil compositions, such as control (only soil), soil-dung, soil-sand, and mixed ratios, the study seeks to identify the most suitable medium for maximizing germination rates, seedling vigor, and survival. Key germination parameters, including germination percentage, mean germination time (MGT), germination index, and germination energy, will be analyzed to determine the effectiveness of each treatment. Statistical analysis using ANOVA and Duncan's Multiple Range Test (DMRT) will help assess significant variations among treatments. The findings of this study will provide valuable insights into the best soil amendments for enhancing seedling production, contributing to more efficient and sustainable nursery practices.

2. 2. Materials and methods

2.1 Seed collection and nursery handling

F. auriculata L. and *F. hispida* L. fruits were collected from the University of Chittagong, forest area, Chattogram, Bangladesh, during February 2020. Mature seeds were collected from selected plus trees. Seeds were extracted manually from mature fruits by the de-pulping method (Vimala et al., 2018). Then, it dried in the open sun for five days (Hesami et al., 2018).

The experiment was conducted through a 2+ years period starting from 2019-2022. It was designed using CRBD methods with three replications for each treatment. A total of 4g seeds were sown in all sowing media. Each experimental plot was planned with a completely randomized design. Seven treatments were applied, including control: Seeds were planted in a nursery bed. Growing media was used in the experiment as treatment, and it was collected from the forest floor. After collection, the soil was screened well with <3 mm-sized sieve and mixed with decomposed cow-dung and coarse sand in a prospective ratio1 to prepare the soil and cow-dung media. When seedlings are grown enough to transfer to Polybags 15 cm × 10 cm (6" × 4"), they are transferred as their previous block design. Partial shade with trees was provided in the nursery bed. Seeds were selected randomly and then sown in different media. Daily weeding and two times watering were done regularly. The experiment was conducted in the average atmospheric temperature where mean annual temperature was 25.7°C, humidity 78.04% and rainfall 2,794 mm. Only in the propagator house temperature and humidity were relatively high as it was controlled, and daily sprinkling at two times was provided for required water and moisture.

2.2 Experimental design used for germination test

A simple block design was adopted for the study, with three replications for each treatment.500 (number) of each species sown on treatments. T0 = control treatment (only soil is used which collected from (≤3), T1 = Soil and Dung ratio (1:3), T2 = Dung and Soil ratio (1:3), T3 = Sand and Soil ratio (1:3), T4 = Soil and sand ratio (1:3), T5 = Sand and dung ratio (1:3), T6 = Dung and sand ratio (2:2), T7 = Sand: Soil: Dung = (1:2:1).After seed sowing, the protective measures that were adopted were the hot sun, intensive rains, birds, rodents, and pests. Insecticides (BHC) and fungicides (DithaneM45) were applied in the soil to protect the seeds and young seedlings from ants and termites and fungal attack respectively. Initially, the seeds were covered with thorn bushes to protect them from birds and rodents. Banana leaves were used to protect shade and protect seeds from excessive sun and raindrops.

2.3 Data collection and analysis

Germination behaviors were observed daily from the date of seed sowing and continued for nine months. The germination percentage, representing the count of germinated seeds out of 100, was employed for measurement (Kumar et al., 2006). Cumulative germination percentage, indicating the total seed germination by aggregating daily germination data, was determined at the conclusion of the germination period. Germination energy was evaluated by calculating the daily germination percentage at its peak time (Dwivedi, 1993). Initial germination was approximated using the Maguire index rate (Maguire, 1962), a time-weighted cumulative germination index assessing the speed of germination (Brown and Mayer, 1988). This index is calculated as the sum of the percentage of seeds germinating each day divided by the number of days since the germination test commenced (Schrauf et al., 1995).

Mean time to germination (MGT), also referred to as speed of germination (Soleymani and Shahrajabian, 2018), serves as a measure for the rate and time spread of germination (Bewley et al., 2013). It is computed as the weighted mean of germination time, with the number of seeds germinated in specified time intervals serving as the weight (Ranal and Santana, 2006). The rate of germination is the reciprocal of MGT. The coefficient of uniformity of germination assesses the variability among seeds concerning the mean germination time of the sample (Heydecker, 1973). Survival percentage was determined by counting the total seedlings that survived at the conclusion of the experiment (Mofokeng et al., 2012). The germination value was calculated by multiplying the peak value of germination (PV) and the mean daily germination (MDG).

$$GP(\%) = \frac{\text{Number of seeds germinated} \times 100}{\text{Number of seeds sown}}$$ (Equation-1) (Kumar, 2015)

$$MGT = \frac{\sum Dn}{\sum n}$$ (Equation-2) (Almodares et al., 2007)

MGT = Mean Germination Time. Dn = number of days in which germination is observed. And n = number of seeds germinated

$$R = 1/MGT$$ (Equation-3) (Mukarati et al., 2013)

R = germination rate, and MGT = Mean Germination Time,

$$GU = \frac{\sum n}{\sum (Fn-t)2n}$$ (Equation-4) (Hasnat et al., 2020)

Where GU =Germination Uniformity, n is the number of seeds germinated, f = factor or parameter related to the germination process, and t = time point at which germination is observed. The summation process considers the distribution of seed germination times, with adjustments made using the factor F.

$$Germination\ index = \frac{No.\ of\ germinated\ seeds}{Days\ of\ first\ count}$$ (Equation-5) (Brown & Mayer, 1988)

$$Germinaion\ Value = \frac{\sum DGs}{N} \times \frac{GP}{10}$$ (Equation-6) (Hasnat et al., 2020)

The equations used to determine germination percentage (Equation 1), cumulative germination percentage (Equation 2), rate of germination (Equation 3), plant percent (Equation 4), and plant value (Equation 5)

2.4 Statistical analysis

All of the recorded data related to seed germination and seedlings growth attributes were analyzed statistically by using computer software SPSS ver.20.00. The analysis of the variance (ANOVA) and Duncan's Multiple Range test (DMRT) was tested for the analysis to explore the possible treatment variations.

3. Results

3.1. Germination performance of *F. auriculata*

In an experiment evaluating eight treatments for seed germination, Treatment 01 exhibited the highest performance in different parameters; in terms of germination energy, seeds showed the highest value in Treatment 04, followed by Treatment 07, while Treatment 03 was the lowest (Table 1). Data collection ceased at 63 days due to the halt in germination, although there was an increase in mortality rate. The effectiveness of treatments varied significantly, with notable differences in germination rates and periods observed among them. For *F. auriculata*, the highest germination percentage was recorded in the control Treatment 0 at 63.66%, followed by Treatments 05(53.3%) and 04(52.4%). These significantly differed from Treatment 01(Table 1), which had a germination percentage of 5.33%. The germination period also varied across treatments, with Treatment 0 starting at 11.6 days and Treatment 1 at 11.33 days. The longest germination period was observed in Treatment 04, beginning at 12.06 days. The daily germination rate was highest in Treatment 0 at 3.57 per day, with no significant difference observed between Treatments 04 and 05. Conversely, Treatment 01 had the lowest germination rate at 0.45 per day.

Regarding the Germination Value, Treatment 0 led, followed by Treatments 04 and 05, and it significantly differed from Treatment 01. Other treatments, such as 02, 03, 06, and 07, showed no significant differences among themselves but differed from the control. Seedling height also varied significantly among treatments, with the control showing poorer performance. Treatment 01 exhibited the lowest germination energy. Germination uniformity, measured across all treatments, indicated that Treatment 05(0.42) had the highest value, with Treatments 04 and 05 displaying similar ranges.

Table 1. Effect of different treatments on germination percentage, Germination rate, Germination energy, Germination Uniformity, Germination Value, germination Mean time of *F. auriculata.*

Treatments	GE (%)	GMT (days)	GR (seedlings /day)	GP%	GU (unitless)	GV (unitless)
T0	21b	1.10c	3.57a	63.6a	0.16bc	0.32a
T1	2e	2.52a	0.43c	5.3e	0.02c	0.00c
T2	16cd	0.76c	2.29b	38.0d	0.06c	0.12b
T3	14d	0.89c	2.10b	31.2e	0.06c	0.10b
T4	28a	0.77c	3.56a	52.4b	0.30ab	0.30a
T5	27a	0.93c	3.36a	53.3b	0.42a	0.27a
T6	14d	1.12c	2.06b	44.1c	0.05c	0.11b
T7	20bc	1.65b	2.50b	36.3e	0.41a	0.14b

Note: Alphabet is used to mean values with different Uppercase superscripts in a column are significantly different at $p<0.05$ according to DMRT. GE=Germination Energy (%), GMT= Germination Mean Time(days) GR=Germination Rate(seedlings per day), GP%=Germination Percentage, GU=germination uniformity(unitless), GV=Germination Value(unitless), GP=Germination Period, S=Start, E=End.

Table 2. Growth performance of *F. auriculata* on different treatment.

	SR%	CD (mm)	SL (mm)	RL (mm)	SFW (g)	RFW (g)	SDW (g)	RDW (g)	NL (n)
T0	54.6a	11.8a	121.5b	75.7a	6.3ab	5.5a	2.5a	2.1a	3.6a
T1	54.6a	12.8a	115.1ab	71.8a	5.2ab	5.3a	2.3a	2.3a	3.6a
T2	53.4a	11.2a	123.8b	69.3a	6.7b	5.1a	2.6a	2.6a	3.4a
T3	56.4a	11a	107.1ab	70.8a	5.2ab	4.8a	2.9a	2.7a	3.8a
T4	55.6a	13a	130.7b	71.4a	7.2b	5.7a	2.8a	2.6a	4a
T5	54.2a	11.6a	118.6ab	68.9a	7.2b	4.8a	2.8a	3.1a	3.8a
T6	57.4a	11.6a	97.1a	75.3a	3.8a	6.1a	2.9a	3.1a	4.4a
T7	54.8a	12.2a	124.2b	74.5a	5.3ab	6.2a	2.2a	2.1a	3.6a

Note: Alphabet is used to mean values with different Uppercase superscripts in a column are significantly different at $p<0.05$ according to DMRT. SR%=Survival Rate, CD(mm)=Collar Diameter, SL=Shoot Length (mm), RL=Root Length (mm), SFW(g)=Shoot Fresh Weight, RFW(g) =Root Fresh Weight, SDW(g) =Shoot Dry Weight, RDW(g) =Root Dry Weight, NL(n)=Number of leaf.

The lowest uniformity was observed in Treatments 02 and 01. Overall the experiment highlighted significant variations in germination and growth parameters across the different treatments, with a notable lack of literature to fully validate the experimental findings.

3.2. Growth Performance

The survival rate of *F. auriculata* showed no significant difference across treatments ($p < 0.08$, $\alpha = 0.05$), ranging from a minimum of 53.4% to a maximum of 57.4% (Table 2). Shoot length exhibited heterogeneity, with Treatment 06 significantly differing from Treatments 02, 04, and 07 ($p < 0.05$). However, homogeneity was observed in Treatments 0, 01, 03, and 05, showing no significant differences compared to Treatment 06 ($p<0.05$) or Treatments 02, 04, and 07 ($p <0.07$). Root length was homogeneous across treatments ($p <0.083$), indicating no significant differences. Shoot *fresh* weight displayed heterogeneity, with Treatment 06 significantly differing from Treatments 0, 02, 04, and 05 ($p < 0.05$). Homogeneity was observed in Treatments 03, 01, and 07, with no significant differences compared to Treatment 06 ($p <0.05$) or Treatments 0, 02, 05, and 04 ($p < 0.05$).

3.3. Germination performance of F. hispida L

In the experiment, the Mean Germination Time *varied* among treatments, with Treatment 07 having the highest at 4.04 and Treatment 02 the lowest at 0.68 (Table 3). Treatment 07 exhibited the fastest germination period at 6 days. *F. hispida* showed the highest germination rate in Treatment 01 at 3.67%per day, followed by Treatment 0 at 3.19% per day, and Treatment 05 exhibited the highest Germination Value at 1.41. Germination energy was highest in Treatment 05 at 0.29. The overall experiment parameters indicated that Treatment 01 performed the best, with the cumulative day count stopping at 63 days due to halted germination and increased mortality.

Table 3. Effect of different treatments on germination percentage, Germination rate, Germination energy, Germination Uniformity, Germination Value, Germination Mean time of *F. hispida.*

	GE(%)	GMT(days)	GR(seedlings/day)	GP%	GU(unitless)	GV(unitless)
T0	17c	1.55c	3.19a	62.6b	0.57a	0.32a
T1	24b	0.68c	3.67a	81.3a	0.71a	0.47a
T2	9c	0.88c	0.83d	18.6c	0.10a	0.03a
T3	13c	0.93c	1.92b	30.6c	0.07a	0.08b
T4	9c	2.43c	1.40c	23.6c	0.28a	0.04a
T5	29a	1.14c	3.60a	52.6c	0.95a	1.41a
T6	2c	2.93b	0.33d	5.6d	0.97a	0.13a
T7	11c	4.04a	2.13b	51c	1.94a	0.79a

Note: Alphabet is used to mean values with different Uppercase superscripts in a column are significantly different at $p<0.05$ according to DMRT, GE=Germination Energy(%), GMT= Germination Mean Time(days) GR=Germination Rate(seedlings/day), GP%=Germination Percentage, GU=germination uniformity(unitless), GV=Germination Value(unitless), GP=Germination Period, S=Start, E=End.

Table 4. Growth Performance of *F. hispida* on Different treatment

	SR%	CD(mm)	SL(mm)	RL (mm)	SFW (g)	RFW(g)	SDW(g)	RDW(g)	NL(n)
T0	61.2a	10.6a	132.9a	81.9abc	6.79ab	6.56a	4.3a	2.5a	3.6a
T1	62.8a	10.6a	149.4a	72.8a	6.7ab	6.4a	4.3a	2.9a	4.4a
T2	58.6a	12.2a	136a	89.6bc	6.1a	7.3ab	4.3a	2.7a	4a
T3	61a	10.4a	129.1a	86.4abc	8.6b	8.4b	4.43a	3.7a	4a
T4	57.4a	13a	139.3a	95.8c	6.1a	7.6ab	5.2a	2.2a	4a
T5	57.2a	10.8a	144.2a	83.7abc	7.2ab	6.4a	4.1a	2.4a	3.8a
T6	54.4a	11.6a	137.6a	79.1a	7.5ab	7.3ab	4.6a	3.7a	4a
T7	63.8a	13a	134.1a	77.7a	8.1ab	8.1b	4.6a	3.3a	4a

Note: Alphabet is used to mean values with different Uppercase superscripts in a column are significantly different at $p<0.05$ according to DMRT. SR%=Survival Rate, CD(mm)=Collar Diameter, SL=Shoot Length (mm), RL=Root Length (mm), SFW(g)=Shoot Fresh Weight, RFW(g) =Root Fresh Weight, SDW(g) =Shoot Dry Weight, RDW(g) =Root Dry Weight, NL(n)=Number of leaf.

The findings also showed variations from previous studies on *A. auriculiformis* germination. For *F. hispida*, Treatment 01 had the highest germination percentage at 81.33%, significantly differing from Treatment 06(5.66%). The study emphasized significant differences in seedling height, with the control performing well in the case of *F. hispida*.

4. Discussion

Germination is a critical factor in the establishment and growth of plant species, particularly for Ficus species like *Ficus benghalensis*, *Ficus hispida*, and *Ficus auriculata*. The results of this study highlight the significant variation in germination percentages, germination periods, and seedling growth depending on the treatment conditions. These findings are consistent with previous studies, which have shown diverse germination responses in Ficus species under different environmental conditions (Raji et al., 2022; Lisci and Pacini, 1994; Tang et al., 2007). For instance, *F. benghalensis* demonstrated a germination percentage of 46% within 10 days, similar to other reports of seed germination under controlled conditions. However, in some treatments, the germination rate fell to as low as 15%, indicating that environmental factors such as soil composition and moisture availability significantly influence seedling emergence.

In contrast, *Ficus hispida* and *Ficus auriculata* exhibited varying responses to the different sowing media. *F. auriculata* performed poorly in the treatment with a soil-dung combination, showing only 5.33% germination, while *F. hispida* showed a much higher rate of 81.33%. This suggests that *F. hispida* seeds may tolerate organic-rich soils better than *F. auriculata*, which is consistent with findings by Raji et al. (2022) that increasing organic matter content can benefit germination in some Ficus species, but species-specific responses must be considered. The poor germination in the soil-dung combination treatment may be attributed to excessive moisture retention, a characteristic of organic-rich media, which could hinder seedling emergence, particularly for species with lower tolerance to waterlogged conditions.

The shoot and root length results of this study also align with previous findings. In this study, shoot and root lengths for *F. benghalensis* ranged from 5 cm to 14 cm, which are consistent with reports on other Ficus species, such as *F. nalalensis* (Fujita & Yamashina, 2018) and *F. saussureana* (Guo et al., 2007), where root lengths varied from 3.5 cm to 15 cm, and shoot lengths ranged similarly. Comparatively, other species like *F. hispida* exhibited smaller root lengths between 3.2 cm and 4.5 cm, indicating that root development can vary widely depending on both the species and treatment conditions (Sparg et al., 2005).

The ability of Ficus species to thrive in different soil media—such as those containing sand, cow dung, and soil—demonstrates their adaptability and the importance of choosing the right germination medium for optimal seedling development. Sand, by improving drainage and aeration, and cow dung, by adding organic matter and enhancing microbial activity, both play vital roles in seedling growth. The soil component, providing nutrients and structure, completes the ideal mixture for propagation. As Ficus species are essential to forest ecosystems and offer both ecological and economic benefits, optimizing their propagation and germination is critical for conservation and restoration efforts.

Ficus species, particularly *F. hispida* and *F. auriculata*, are keystone species in forest ecosystems, contributing to biodiversity, supporting pollinators such as fig wasps, and providing habitat for a variety of fauna. They are also crucial for the nutrient cycle and soil stabilization, playing a key role in preventing erosion. In terms of economic value, these species offer timber, fruits, leaves, and medicinal products, supporting local economies. Understanding the germination requirements of these species, as demonstrated in this study, can help improve conservation strategies and support the sustainable management of these resources, contributing to the overall health and stability of forest ecosystems in Bangladesh and beyond.

Overall, this study underscores the importance of understanding the species-specific responses of Ficus species to different sowing media for improving germination rates and seedling growth. Tailoring propagation methods to the unique needs of each species will contribute to more successful conservation and restoration efforts, ensuring the continued ecological and economic benefits of Ficus species.

5. Conclusion

The results shows that both *Ficus auriculata* and *Ficus hispida* perform best under specific treatments. Treatment 7 (Sand: Soil: Dung in a 1:2:1 ratio) is ideal for promoting germination and seedling growth in *Ficus auriculata*, while the control treatment also shows strong results. For *Ficus hispida,* Treatment 1 (Soil and Dung in a 1:3 ratio) yields the highest germination and seedling vigor. Treatment combinations such as (T0, T1, T4) for *F. auriculata* and (T0, T1, T2, T7) for *F. hispida* are recommended for nursery management and conservation efforts. While these treatments show promise, further research is needed to assess their long-term impact on survival and growth in natural conditions. Future studies could explore the addition of organic components or growth regulators to optimize germination and seedling development. These findings have important implications for tropical ecosystem forestry, habitat restoration, and biodiversity conservation.

Author Contribution:

Conceptualization: Mohd. Imran Hossain Chowdhury, Methodology: Mohd. Imran Hossain Chowdhury, Tonima Hossain, Investigation: Mohd. Imran Hossain Chowdhury Formal Analysis, Writing—Original Draft Preparation: Mohd. Imran Hossain Chowdhury, Tonima Hossain Writing—Review and Editing: authors names Visualization,DataCuration,Project Administration:Mohd. Imran Hossain Chowdhury, Tonima Hossain. All authors have read and agreed to the published version of the manuscript.

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