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Research Article

Seed Population Dynamics and Early Seedling Growth of *Albizia chinensis* (Osbeck) Merr. in the Forests of Humid Subtropics of India

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Understanding seed population dynamics is essential for recognizing shifts in species composition during ecosystem restoration. *Albizia chinensis* (Osbeck) Merr. is a tropical fast-growing tree species, widely cultivated in community forests and plantations, and is well adapted to a low fertility soil. This study aimed at estimating seed production, dispersal, and fate of the seed population (disappearance and germination at varying distance from the mother tree) and related early seedlings growth performance to microclimate variables. The findings revealed that seed production of *A. chinensis* varied significantly ($p < 0.001$) among individual trees and showed a positive correlation between number of branches, inflorescences, crown height, and crown diameter with seed production. However, seed dispersal exhibited a strong negative correlation with dispersal distance from the mother tree ($r = -92$) with significant differences among individual trees ($p < 0.05$). We found that most seeds fell directly beneath the mother tree and seed disappearance declined as distance from the mother tree increased. Seedling height showed strong positive correlations with soil temperature, moisture, and humidity, and these variables also exhibited positive correlations with seedling diameter. We found that seedling growth (height and diameter) increments significantly varied between months ($p < 0.05$). The findings of this study could help in restoration, management and conservation of *A. chinensis* in tropical areas. Importantly, this research represents the first comprehensive study on seed production dynamics and microclimate seedling interaction of *A. chinensis* in Northeast India, thereby filling a critical knowledge gap. Future research should focus on understanding the alternative seed production strategies in the species and their relation to biotic and abiotic factors.

Keywords: fate of seed population; microenvironments; regeneration ecology; seed dispersal; seed production; soil seed bank

1. Introduction

Albizia chinensis (Osb) Merr., a member of Fabaceae family, is fast-growing tree species and wildly cultivated in community forests and plantations, also well adapted to low soil fertility [1, 2]. It occurs naturally in India, Myanmar, and China [2, 3]. *A. chinensis* is a multipurpose tree species highly suitable for restoration of degraded lands [4], often planted for shade in tea gardens, for protecting sloping land [1, 4]. Because of its nitrogen fixing ability, it is commonly used for reforestation and afforestation to improve soil quality and fertility [5–8] and has economic importance [2].

Seed production in the tree species is often different between years [9]. Understanding seed production patterns is also extremely valuable in forest conservation and management; a large and consistent supply of viable seeds is

required for planting and regeneration of forest [10]. Once seeds are dispersed, various physical and biotic factors act as selective forces, influencing which seeds will germinate and get established [11, 12]. The seed soil bank is also important to ensure the conservation of species as a fraction of seeds remains viable in soil until the next seed dispersal event, also contributing to the resilience of tree population even when no seeds are produced in given year [12]. This seed bank thus plays a significant role in afforestation and reforestation effort [13]. Conversely, the future of many tree species is at risk due to rapid decline of the world's forest cove owing to overexploitation for timber, and other uses [12]. The regeneration of the forest is particularly susceptible to climate change affecting various processes such as seed production, germination, and development of seedlings and saplings [14]. In the meantime, seed germination data of the tree species are limited [15, 16].

Although economically valuable, *A. chinensis* has received limited attention for conservation and improvement [2], and the survival of tree is affected due to poor seed germination [17] and excessive felling and germination percentage not documented [3, 4]. Notwithstanding, the germinant and young seedling life stage of tree species has the highest mortality rate [18], and the seedling establishment pattern is affected by landscape feature and forest topography as well as microclimatic factors [19]. Therefore, studies on assessing the early seedling growth performance are important to understand the seedling behavior and its relation to microclimate variables. However, despite its ecological and economic importance, there remains a lack of comprehensive studies on the seed population dynamics and early seedling growth of *A. chinensis*. Seed population dynamics including production, dispersal, germination, and seedling establishment is crucial in determining the regeneration potential of any tree species in a given ecosystem. Understanding these factors in *A. chinensis* will provide insights into its natural recruitment and growth potential, offering valuable information both sustainable forestry practice and conservation efforts.

Although, a few studies have examined *A. chinensis*, particularly on germination pretreatment [1, 3, 4, 17, 20] and radiosensitivity of seedling at early stage [2], no comprehensive ecological study has addressed its natural regeneration. This research represents the first comprehensive study on seed population dynamics and microclimate seedling interactions of *A. chinensis* in Northeast India, filling a critical ecological knowledge gap. Therefore, our study aims to provide a detailed analysis of seed production, dispersal mechanisms, fate of seed population, and early seedling growth in relation to microclimatic variables such as soil temperature, moisture, humidity, and soil pH under natural forest condition in the humid subtropics of India. The findings have significant implications for biodiversity conservation, forest restoration, and the sustainable management of subtropical ecosystems.

2. Materials and Methods

2.1. Study Area. Mizoram University (MZU) campus is located 15 km away from Aizawl town [21]. It encompasses roughly 980 acres of land and geographically located between 23°39′52″– 23°48′43″N and 92°39′49″–92°46′39″E (Figure 1) and elevation ranging from 300 m to 880 m above sea level [21, 22]. The campus contains regenerating tropical wet evergreen and semievergreen forests, including a protected forested water catchment reserve in the north and a small biodiversity park. Several streams flow through the campus [21–23]. The area is home to 384 plant species belonging to 290 genera and 107 families [23] interspersed with tall grass [21].

The region receives an average annual rainfall of approximately 1850 mm, influenced heavily by the southwest monsoon, with most precipitation occurring between May and September. The mean annual temperature is about 21.6°C, with summer highs reaching 30°C and winter lows ranging between 10°C and 12°C (Meteorological data of Mizoram, Aizawl, 2023).

2.2. Data Collection

2.2.1. Seed Production. Seed production of *A. chinensis* was assessed over 2 years (2022 and 2023). Fifteen individual trees were randomly selected, and seeds were counted in November, just before maturation, following [24]. Seed production was estimated by recording the number of branches, average number of sub-branches, average number of sub-sub-branches, average number of inflorescences in sub-sub-branches, and average number of fruits per inflorescence and applying Formula 1. Additionally, for each tree, the mean number of inflorescences per sub-sub-branches (Figure 2(a)) was calculated from 10 randomly selected sub-sub-branches, and the mean number of fruits per inflorescence was obtained from 10 randomly chosen inflorescences. Conversely, the mean number of seeds per fruit was estimated from 15 randomly sampled pods (Figure 2(c)). In addition, a sample of 25 seeds (Figure 2(b)) was weighted to estimate the number of seeds per kilogram using Formula 2.

2.2.2. Seed Dispersal. Five individual fruiting trees of *A. chinensis* were selected and marked in the forest stand following [25]. The selected trees were at least 100 m apart, with no other conspecific adult trees were present between them. Using each tree as a center, concentric circles with 2.5-m radial increments were established beyond the ground crown radius, following [26]. The first circle had a radius of 5 m, and the maximum distance considered was 25 m. Seeds that fell directly beneath the crown were not considered dispersed. The sampling circles were monitored at 3-days intervals over a period of 8 weeks during seed-fall period, and seeds were collected and counted separately at each visit. The number of seeds dispersed at varying distance was converted to seeds square meter (m^2) using following Formula (3), and the proportion of seeds falling beneath the mother tree versus those dispersed away was calculated. Seeds damaged during seed fall were excluded from the analysis.

2.2.3. Fate of Seed Population in the Soil. To assess the fate of the seed population of *A. chinensis*, the number of seeds disappearing (fraction) during the seed-fall period was first

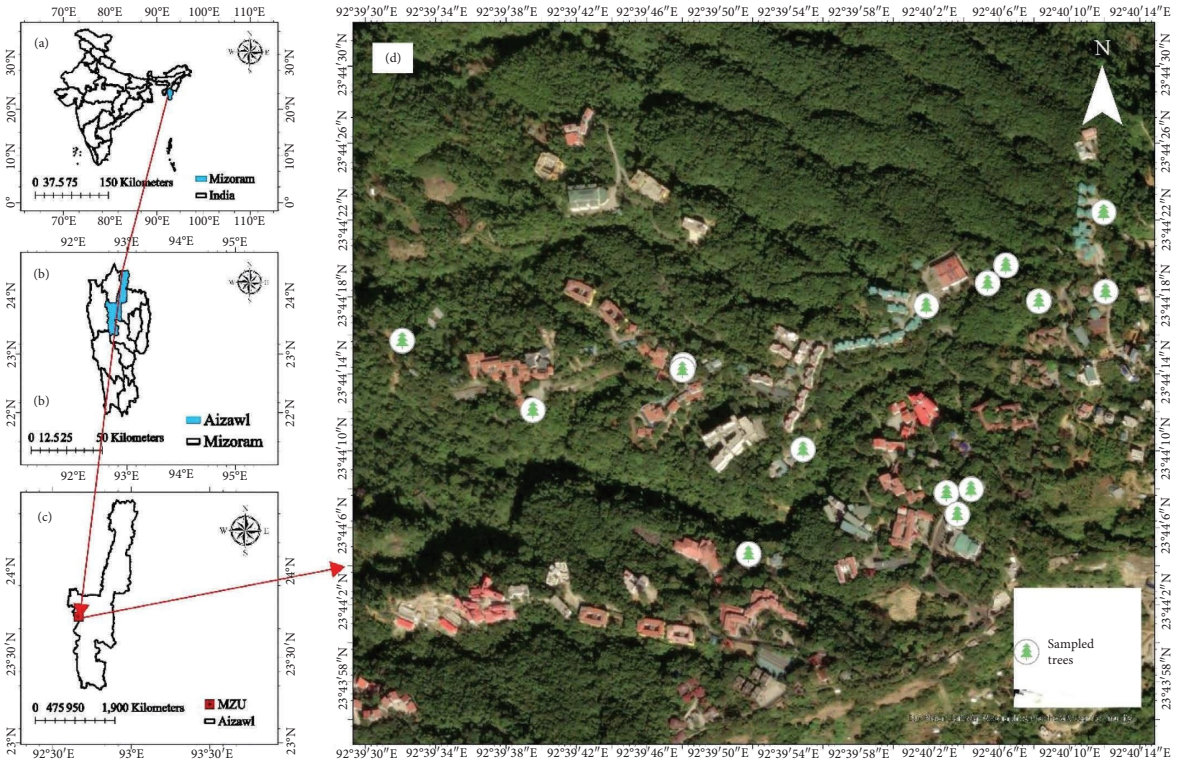


FIGURE 1: Map of the study site: (a) India, (b) Mizoram state, (c) Aizawl district and location of Mizoram University campus, and (d) sampled trees.

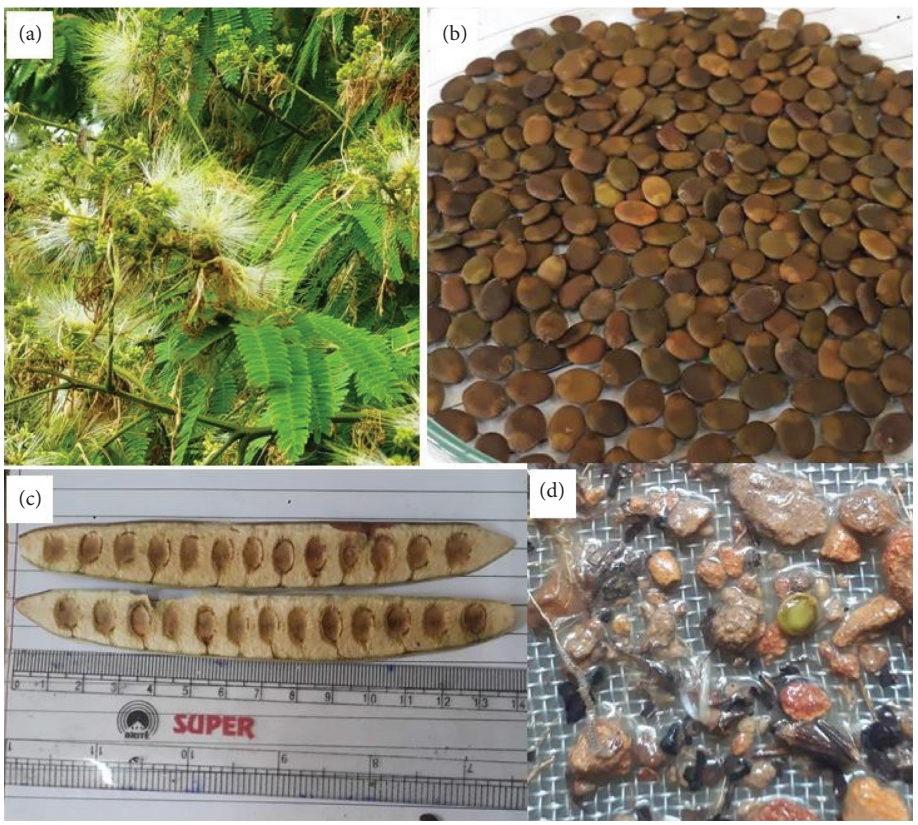


FIGURE 2: *A. chinensis* seeds at different stages from seed formation to soil seed bank formation: (a) infructescence, (b) mature seeds, (c) fruit pod, and (d) excavation of buried seeds using wet sieving technique.



Figure 3: Fate of seed population of *A. chinensis*: (a) laying seed trap to collect the dispersed seeds and (b) monitoring the fate of undamaged seed population (toward germination, disappearance, and rotted seeds) from plots beneath the mother tree and at varying distance from the mother tree.

estimated. Seed traps (Figure 3(a)) were used following [26–28]. Five traps (1×1 m and 30 cm deep) were placed randomly beneath the crown of the mother tree at the beginning of seed fall. The traps were visited for 5-days intervals until seed shedding was complete. At each visit, all seeds were counted, and insect- or rodent-damaged seeds were separated from undamaged ones. The difference between total seed production and the number of undamaged seeds that fell beneath the crown represented the fraction of the seed population lost during the seed-fall period [26].

The fate of undamaged seeds after fall was studied by sowing 20 seeds in each of the five 1×1 m plots beneath sample mother trees (Figure 3(b)). These plots were monitored at 7-day intervals up to 3 months, recording germination, disappearance, and rotted. To assess distance effect, three additional 1×1 m plots were established at 5, 15, 25, and 35 m from the fruiting tree base. In each sample plot, 20 seeds were marked with waterproof paint and placed on the soil surface. This procedure simulated conditions of seed dropped or transported by dispersal agents during and after seed fall. The plots were monitored at 7-day intervals for 3 months to record seed losses due to predation, transport, disappearance, or germination.

2.2.4. Soil Seed Bank. To assess the soil seed bank, soil sample was collected at the end of rainy season following the method described by the authors [29–33]. Four sites were selected using stratified sampling, and within each sample, 5 soil samples were collected from an area of 5-cm^2 and 5-cm depth. To estimate seed soil bank, 100 g were weighted from each sample and washed using water (Figure 2(d)) as studied by Padonou et al. [30]. The number of seeds found was computed as number of seeds in m^2.

2.2.5. Seedling Growth Performance in Natural Conditions and Its Relation to Microclimatic Variables. Seedling growth performance under natural forest conditions and its relation to microclimate variables were assessed using 10 quadrats (1×1 m each), laid randomly in the forest stand where the mother of *A. chinensis* tree was located. All seedlings of *A. chinensis* within the quadrats were recorded and monitored for 14 months. Seedlings' height and diameter were measured at 2-week intervals. Height was measured using a 30-cm scale, and stem diameter was measured with a digital Vernier caliper (150 mm). Conversely, monthly increment in height and diameter, as well as their relative growth rates, were then calculated. During the same period, soil temperature, soil moisture, and humidity were recorded using a stainless-steel dial thermometer, a digital soil moisture meter, and a hygrometer, respectively.

2.2.6. A. chinensis Population Flux Cycle. The life cycle of *A. chinensis* was derived from the data on seed production, seed dispersal, seed fate during and after seed-fall period, and 1 year seedling survival and mortality monitoring. Average seed production from 15 trees was calculated, along with estimates of seed dispersal and seed damage. The percentage of disappeared seeds was computed from the fate of undamaged seed at varying distances from the mother trees, which also included records of germinated and contributions to the soil seed bank. Additionally, seedling survival and mortality were monitored over 1 year to determine overall survival rates.

2.3. Data Analysis. All data collected from seed production, seeds dispersal, and seed fate population were compiled and organized into tables for analysis. Data were summarized and expressed as mean and standard deviation (SD). The percentage of seeds falling under the mother tree (UMT) and those dispersed at varying distance were calculated using formulas (4 and 5), while germination and disappearance rates were determined using Formulas 6 and 7, respectively. However, seedlings' height and stem diameter were averaged monthly, and their increment and relative growth rates were calculated. Correlation analyses were conducted to examine the effect of tree characteristics on total seed production and the influence of microclimatic variables on seedling growth (height and stem diameter increment). In addition, linear regression models and one-way ANOVA post hoc Tukey test ($p < 0.05$) were used to assess the variation in seed

production and seed dispersal among individual trees. All statistical analyses were performed using Statistical Package for Social Sciences (SPSS, Version 22.0), Jamovi (Version 2.5.6) [34], OriginPro 2024b, and Microsoft Excel (Version 365).

2.4. Formula and Equations

$$\begin{aligned}\text{A. Total seed production} = {} & \text{total number of branches} \times \text{mean number of} \\ & \text{sub-branches in the main branch} \times \text{mean number of sub-sub-branches in} \\ & \text{sub-branch} \times \text{mean number of inflorescences per sub-sub-branches} \\ & \times \text{mean number of fruits per inflorescence} \times \text{mean number of seeds per fruit},\end{aligned} \tag{1}$$

$$\text{B. Number of seeds in kg} = \frac{1000}{\text{Mean seeds weight}}, \tag{2}$$

$$\text{C. Seed density}\left(\text{seeds/m}^2\right) = \frac{\text{Number of seed per sample plot (raduis 2.5m)}}{\text{Area of sample plot}}, \tag{3}$$

$$\begin{aligned}&\text{D. Percentage of seeds fall beneath the mother tree or dispersed with distance} \\ &= \frac{\text{Number of seeds in m}^2 \text{ beneath the mother tree or dispersed with distance}}{\text{Total number of seeds fall beneath the mother tree and dispersed with distance in m}^2} \times 100,\end{aligned} \tag{4}$$

$$\begin{aligned}&\text{E. Total seeds fall beneath the mother tree or dispersed with distance from the mother tree} \\ &= \frac{\text{Percentage of seeds fall beneath the tree or dispersed with distance}}{100} \\ &\times \text{Mean No. of seeds produced},\end{aligned} \tag{5}$$

$$\text{F. Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{total number of seeds sown or placed}} \times 100, \tag{6}$$

$$\text{G. Disappeared or rotted seeds (\%)} = \frac{\text{Number of seeds disappeared}}{\text{total number of seeds sown or placed}} \times 100. \tag{7}$$

3. Results

3.1. Seed Production, Soil Seed Bank, and Seed Dispersal. The mean seed production of *A. chinensis* per individual was 179,977 in 2022, while no seed production was observed in 2023 among the sampled trees (Table 1 and Figures 4 and 5). Seed production differed significantly among the individual trees ($p < 0.001$) (Table 1). Additionally, the mean seed weight was 0.028 g, corresponding to an estimated 35,511 seeds per kilogram, while the estimated seed soil bank density was 140 seeds per m^2 (Table 1). A strong positive correlation was observed between total seed production and several tree characteristics, including number of branches, mean number of inflorescences per sub-sub-branches and mean number of fruits in inflorescences, crown height, and crown diameter (Table 2).

Seed dispersal declined with increasing distance from the mother tree in forest floor (Figure 6). Significant variation was also observed among individual trees ($p < 0.001$; Table 3). Dispersal distance extended up to a maximum distance of 20 m from the mother tree, with a strong negative correlation between seed density and dispersal distance ($r = -0.92$; Figure 6). Overall, 76.29% of seeds fell directly beneath the mother tree, while the remaining seeds were dispersed at varying distances up to 20 m (Figure 7).

3.2. Fate of Seed Population in the Soil. During the seed-fall period, 97.30% of *A. chinensis* seeds that fall beneath the mother crown were undamaged, while 2.70% were damaged by insect or rodents (Table 4). After seed fall, 70% of seeds disappeared, whereas only 26.2% germinated, indicting high postdispersal losses (Table 4).

3.3. Seed Disappearance and Germination in Relation to Distance From the Mother Tree. Seed predation and disappearance were most severe near to the mother trees and reduced with increasing distance. About 86% of sown seeds

Table 1: Interannual variations in seed production and soil seed bank formation by *A. chinensis*

Variables	(Mean ± SD)	Sig.
Mean no. of inflorescence/sub-branch	6.77 ± 1.90	0.00
Mean no. of fruit/inflorescences	9.69 ± 2.98	0.00
Mean no. of seeds/fruits	12.1 ± 1.67	0.00
Mean seed production/plant	179,977 ± 15380.60	0.00
Mean soil seed bank (number/m^2)	140 ± 0.67	0.00
Mean seed number/kg	35,511 ± 4570.81	0.00

Abbreviation: SD, standard deviation.

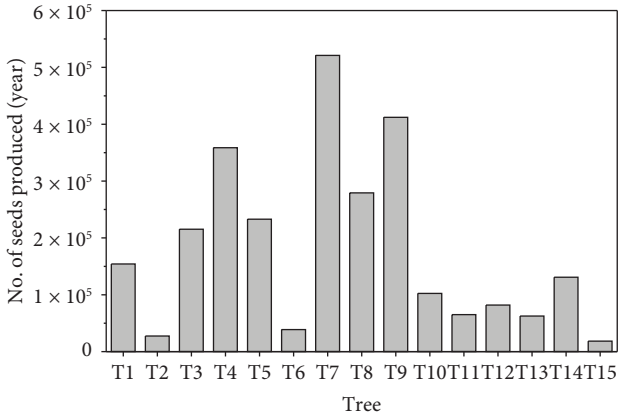


Figure 4: *A. chinensis* seed production per year (where T1 to T15 are sampled trees).

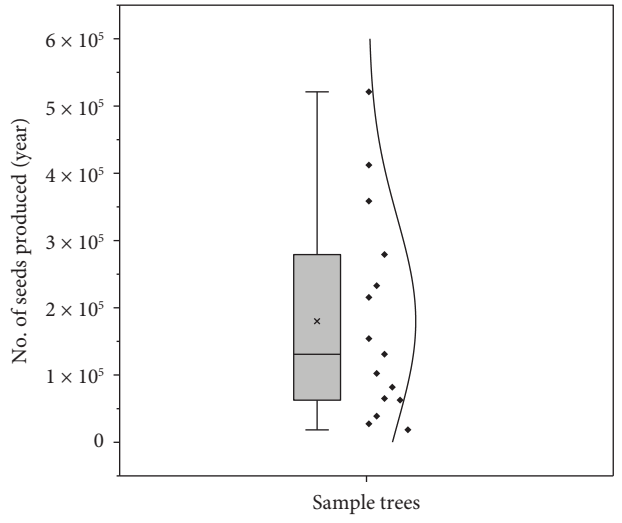


Figure 5: Normal box plot of *A. chinensis* seed production.

disappeared within 5 m of the tree, compared to 71.33% at 35 m, the farthest distance tested. In contrast, germination of sown seeds increased with distance, with 14% and 28.67% of seed germinated at 5 m and 35 m, respectively (Figure 8).

3.4. Seedling Growth and Its Relation to Microclimate. Seedling growth performance of *A. chinensis* over 14 months in the natural forest conditions reached a maximum height of 23.13 cm and diameter of 3.25 mm (Figure 9). During the study period, the highest soil temperature was recorded in July (24.63°C), coinciding peak soil moisture in July (68.75%) (Figure 10). Relative seedling height growth was strongly correlated with soil temperature ($r = 0.60$), soil moisture ($r = 0.95$), and humidity ($r = 0.78$), while relative seedling stem diameter showed similarly positive correlations (Table 5). Significant difference in relative growth in both height and stem diameter was observed across the months during the study period ($p < 0.05$).

3.5. A. chinensis Population Flux. The life cycle of *A. chinensis* integrates seed production, seed dispersal, and seedling recruitment. Based on 15-sampled trees, mean annual seed production was 179,977 seeds per tree in 2022. Of these seeds, 97.31% fell beneath the mother tree and dispersed at varying distance. Conversely, fate of seed during postfall revealed that 79.66% disappeared, 18.67% germinated, and only 1.67% contributed to the soil seed bank. Among the germinated seeds, only 48.89% developed into seedlings that survived for 1 year, while 51.11% died due to intense biotic and abiotic stresses beneath and around the mother tree in the forest (Figure 11).

4. Discussion

4.1. Seed Production, Dispersal, Soil Seed Bank, and Fate of Seed Population in the Soil. *A. chinensis* showed a significant difference in seed production among individual trees and produced no seeds in 2023. The absence of seed production in 2023 may be attributed to masting behavior, climatic stress, or resources limitation, phenomena commonly observed in tropical tree species. Similar interannual variability has been reported for other Fabaceae species [10, 35]. Forest tree seed production can be highly variable, ranging from no seeds in some seasons to extremely high seed production [10]. However, several authors [9, 10, 35, 36] have reported that the number of seeds produced varies within tree species. Moreover, our result confirms that with increased number of branches, sub-branches, and inflorescences in a given individual tree, the total seed production increases and these variations could be attributed to both biotic and abiotic factors. According to Iralu et al. [12], the annual rainfall acts as a limited factor for seed production. However, the Sahoo and Lalfakawma [26] argued that seed production of a species is influenced by a variety of factors, for example, resources availability, plant age, pollination failure, predation on flower, fruit, and climatic condition. In general, tall and dominant trees with large crowns, which receive a lot of light, produce a maximum number of seeds [25].

We found that *A. chinensis* seed dispersal reached a maximum distance of 20 m from the mother tree, and this distance is very short compared to other tree species which are dispersed by large animal and other dispersal agents. The short distance recorded by seed dispersal in this species is a result of self-dispersal or explosion of seeds or flinging seeds far away from the mother tree when dry pod burst open. Additionally, a strong negative correlation was observed between seed density and dispersal distance from the

Table 2: Correlation between *A. chinensis* characteristics and seed production.

Variable	DBH	NB	MSB	MSSB	MI/SSB	MF/I	CH	CD	TSP
DBH	1								
NB	0.57*	1							
MSB	0.42	0.19	1						
MSSB	0.15	0.061	0.23	1					
MI/SSB	0.26	0.61*	0.14	0.46	1				
MF/I	0.031	0.36	0.08	0.35	0.92**	1			
CH	0.39	0.68**	0.33	0.37	0.78**	0.67**	1		
CD	0.51	0.53*	0.49	0.37	0.67**	0.62*	0.89**	1	
TSP	0.35	0.64**	0.47	0.61*	0.85**	0.72**	0.83**	0.764**	1

Note: MSB: mean number of sub-branches, MSSB: mean number of sub-sub-branches, MI/SSB: mean number of inflorescences per sub-sub-branches, and MF/I: mean number of fruits per inflorescences.
Abbreviations: CD, crown diameter; CH, crown height; DBH, diameter at breast height; NB, number of branches; TSP, total seed produced.
*,**Correlation is significant at the 0.05 and 0.01 level, respectively.

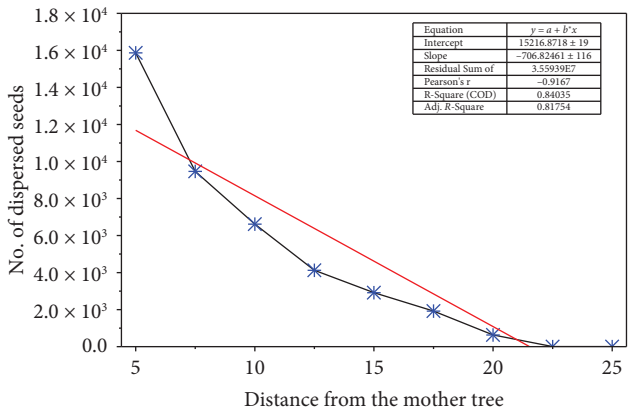


Figure 6: Seed dispersal at varying distance from the mother tree and linear model.

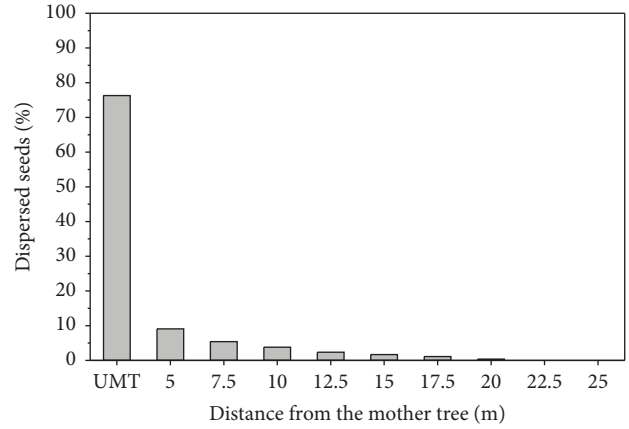


Figure 7: Percentage of seeds fall under the mother tree (UMT) and dispersed at varying distance from the mother tree.

Table 3: Mean number of seed per m^2 under the mother tree (UMT) and at varying distance from the mother tree.

Seed under and at varying distance from the mother tree	No. of seed (mean ± SD)
Under the mother tree	185.80 ± 51.15
5.00	22.06 ± 6.20
7.50	13.16 ± 5.18
10.00	9.20 ± 5.19
12.50	5.73 ± 3.80
15.00	4.05 ± 2.90
17.50	2.67 ± 2.81
20.00	0.88 ± 1.69

Abbreviation: SD, standard deviation.

Table 4: Fate of seed population during seed-fall period and post seed-fall period, expressed as fractions (%) of the total seed trapped.

Seeds conditions		Seed (%)
Seed fall period	Undamaged	97.30
	Insect-damaged	2.70
Post–seed fall period	Disappeared	70
	Rotten	3.8
	Germinated	26.2

mother tree. These findings indicate that, with increasing the distance from the mother tree, the seeds density per unit area decreases. Also, similar findings have been reported in other tree species [26, 37, 38]. Moreover, long-dispersal of seeds is more commonly observed in open terrestrial landscapes and usually driven by migratory animals [39] while Chen et al. [9] highlighted that, with the increased distance from the parent tree, the number of seeds spread per unit area in the forest floor dropped. Furthermore, the present findings revealed that about 75% of seeds produced fell beneath the mother tree while the remaining seeds dispersed at varying distance from the mother tree. Since a majority of seeds fell beneath the mother trees, a considerable proportion of the seeds were dispersed away from the mother trees by various external agents [40]. In tree species, while seed dispersal occurs through gravity, seeds are mostly aggregated around the mother tree [9]. Besides, in *A. chinensis*, wind also played a significant role in seed dispersal, higher wind intensity during the seed fall period resulted in greater seed release compared to low wind conditions.

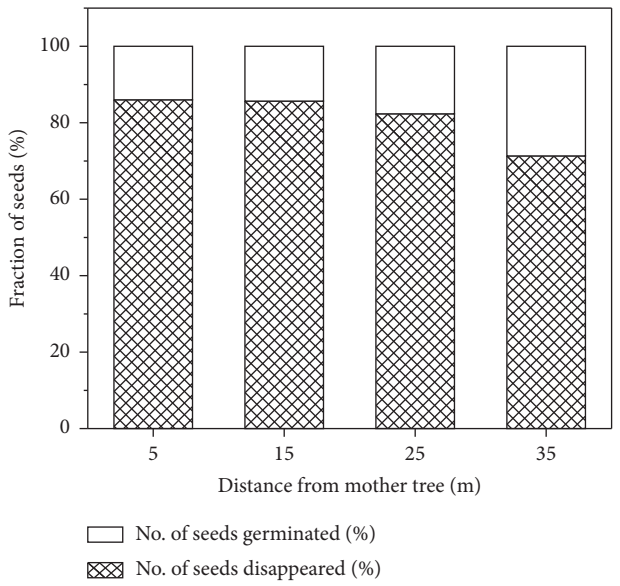


Figure 8: *A. chinensis* seed germination and disappearance at varying distance from the mother tree.

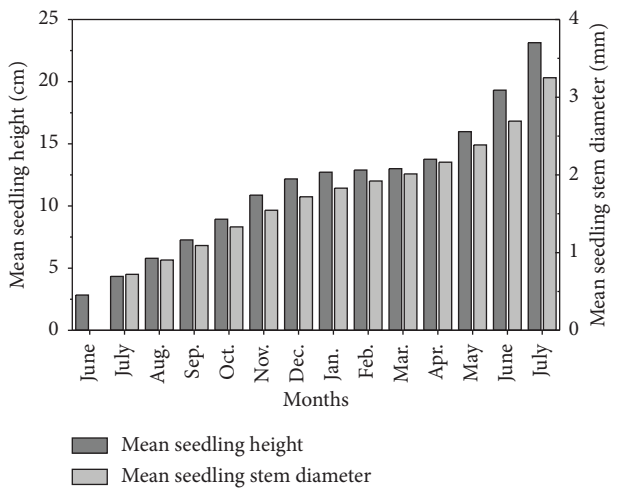


Figure 9: *A. chinensis* seedling growth: mean seedling height and mean seedling stem diameter.

Soil seed bank includes all viable seeds and fruit found in soil [12, 41]. The density of seeds in soil per unit area may either increase or decrease depending on seed production and germination of a given tree species in a year. The fluctuation in temperature can influence germination time, while low temperature enhances soil seed bank by limiting germination [42]. In contrast, seed predation can reduce soil seed bank in the forest floor, it may also affect its persistence or longer survival [12]. Following any forest disturbance, seed source from the soil seed bank can play an important role in reforestation or regeneration of given plant species [14]. The size and longevity of the seed soil bank is also depended on vegetation history and past tree species composition influenced by seed production and dispersal [30, 43]. Thus, the soil seed bank is said to play a vital role in plant population dynamics [41, 44]. During the seed fall

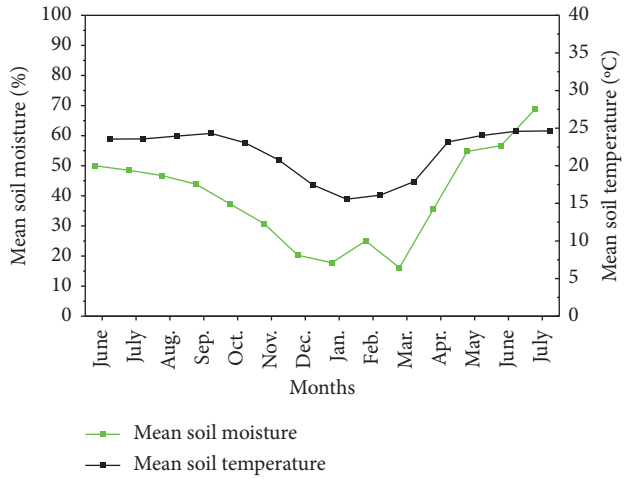


Figure 10: Mean soil temperature and mean soil moisture across study months.

period, majority of the seeds were undamaged, but most of seeds disappeared from the forest floor after seed fall. This explains that the seed predation or seed loss is far more after seed fall period. The higher seed loss after seed fall was mostly due to predation and intraspecific competition.

The observed mean seed disappearance rate of 79.66% from the mother tree highlights the substantial postdispersal seed loss in *A. chinensis*. This loss is likely driven by multiple interacting factors. First, seed predation by rodents, insects, and other forest floor fauna is a major contributor, particularly for seeds that fall directly beneath or close to the mother tree where predation risk is typically highest. Second, microbial decay and fungal attack in the moist, shaded understory may further reduce seed viability. However, environmental stresses such as high humidity, fluctuating soil temperatures, or waterlogging can also accelerate seed decomposition. Moreover, high seed density near the parent tree may promote density-dependent mortality through intensified competition or predator aggregation. These findings are consistent with several studies [12, 40, 45], which emphasize the critical role of biotic pressures and microsite conditions in shaping seed fate in tropical forests. Understanding these loss mechanisms is vital for interpreting regeneration patterns and managing seed banks in such ecosystems.

4.2. Seed Disappearance and Germination in Relation to Distance From the Mother Tree. Disappearance of seed from forest floor after fall has been reported by various authors [24, 26]. Our study found that by increasing the distance from the mother tree, the number of disappeared seeds decreases, and at the same time, the number of seeds germinated increases with increasing the distance from the mother tree. Although, seed predation is higher near to the crown of the mother tree and decreases with distance. Chesson and Warner [46] highlighted that, the seed germination probability increases if the seed moves far from the mother trees, escaping higher chance of predation around and beneath mother tree and Souza et al. [47] reported that,

Table 5: Correlation between seedling parameters and microclimate variables.

Variables	ST	SM	pH	H	RHG	RDG
Soil temperature (ST)	1.00					
Soil moisture (SM)	0.88**	1.00				
pH	0.19	0.33	1.00			
Humidity (H)	0.52	0.59*	0.31	1.00		
Relative height growth (RHG)	0.71**	0.86***	0.14	0.67**	1.00	
Relative diameter growth (RDG)	0.59*	0.79**	0.22	0.56*	0.92***	1.00

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{***}p < 0.001$, one-tailed.

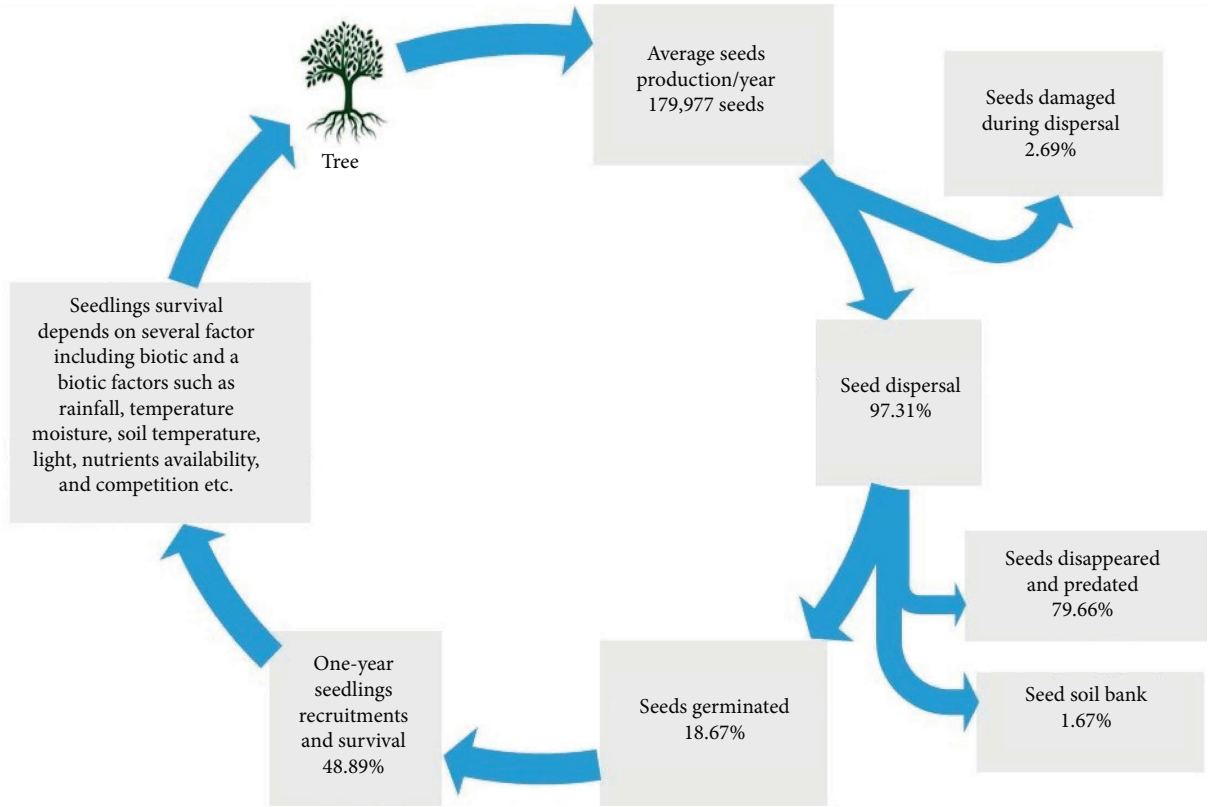


Figure 11: *A. chinensis* population flux.

seed germination percentage increased when the seed dispersed away from the parent tree. Therefore, the number of seeds germinated far from the mother tree can survive from the competition between their parents and siblings and contribute to the tree population dynamic.

4.3. Seedling Growth Performance in Natural Forest Conditions and Its Relation to Microclimatic Variables. Microclimate conditions vary from forest to another and depend on forest canopy [48]. However, the difference in microclimate influences the tree species' composition and regeneration gaps. In this study, a strong correlation was observed between soil temperature, moisture, and humidity with relative seedling growth metrics (seedling height and stem diameter) provides insights into the factors that drive seedling establishment and success in the natural environment of humid subtropics. Particularly, moisture and soil temperature seem to be key determinants of early seedling growth vigor. Seedling (Figure 12(a)) survival is influenced by moisture and other nutrients in the soil. Although, this underscores the importance of water availability and microclimate conditions for the natural recruitment of *A. chinensis*. In line with the studies by others [48, 49], temperature and soil temperature are important factors for establishment of small seedlings. Meanwhile, seedling growth tends to reduce or stop shoot increment during winter months (Figure 12(b)), which demonstrates that with declined soil temperature, the seedling growth decreases too. Furthermore, many authors [50, 51] highlighted that, soil temperature is also influenced by availability of nutrient; therefore, warmer soil could lead to increased growth. The relationship between seedling growth and soil temperature as well as seedling establishment seems complex and warming in both cases have positive and negative implications; hence, the increase of temperature may negatively



Figure 12: Growth performance of the seedling of *A. chinensis* in natural conditions: (a) one year seedling, (b) response of the seedling to dry winter season, and (c) seedling growth at the onset of rainy season.

impact seed germination in some cold adapted species [52]. In this study, we observed that seedlings started to continue the shoot growth pre- or at the beginning of rainy season (Figure 12(c)). Similarly, observation is also reported by Musa and Sahoo [17].

5. Conclusion

In conclusion, the seed production of *A. chinensis* showed positive correlation with tree characteristics. Besides, there was a strong negative correlation between the number of seeds dispersed per unit area and dispersal distance from the mother tree. However, the majority of produced seeds fell UMT, while the seeds disappearance decreased with the increased distance from the mother tree. Furthermore, the seedling growth of the species was significantly ($p < 0.05$) influenced by its microclimatic variables (soil temperature, moisture, and humidity).

Data Availability Statement

All data used/analyzed in this paper are available from corresponding author upon request.

Ethics Statement

The authors hereby declare that the paper is the authors' own original work, which has neither been previously published nor has been submitted for publication elsewhere. Besides, the paper properly credits than meaningful contribution of the co-authors, and all sources used in the paper are properly disclosed, and all authors have been personally and actively involved in the substantial work leading to the paper and take public responsibility for its content.

Conflicts of Interest

The authors declare no conflicts of interest.

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