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Effects of light intensity on seed germination and early growth seedlings of *Spondias mombin* in Bangladesh

NIAMJIT DAS
Department of Forestry and Environmental Science, School of Agriculture and Mineral Science, Shahjalal University of Science and Technology. Kumargaon, Sylhet-3114, Bangladesh. Tel.: +880-1705-545048, email: niamjit.forestry@gmail.com

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Abstract. *Das N. 2023. Effects of light intensity on seed germination and early growth seedlings of* Spondias mombin *in Bangladesh. Cell Biol Dev 7: 82-88.* The experiment was conducted to determine the effects of light intensity on the seed germination and early growth of *Spondias mombin* L. under four light-intensity treatments (40%, 60%, 100%, and under a closed natural forest canopy) in polybags containing a mixture of topsoil and cow dung in a 3:1 ratio. The results showed that the closed natural forest canopy and 100% light intensity treatments resulted in unsatisfactory germination of *S. mombin* seeds. The 40% light intensity treatment (medium shading) significantly increased seed germination, with the highest cumulative seed germination at 40% light intensity (71.61%) and the lowest at 100% light intensity (26.58%). Intense light delayed germination. Light intensity significantly ($P \leq 0.05$) affected most of the morphological and physiological parameters of the seedling early growth. The early growth phase of seedlings did not perform well under heavy shade, indicating that *S. mombin* requires shading during early growth. Seedlings under 100% light intensity died shortly after emergence. The findings demonstrated that the best growth and most stable seedlings were obtained under 60% light intensity. Therefore, adequate exposure to light at the nursery stage is necessary for the optimum growth performance of *S. mombin* seedlings for agroforestry and afforestation purposes in Bangladesh.

Keywords: Germination, light intensity, seedling growth, *Spondias mombin*

INTRODUCTION

Seed germination and seedling establishment are fundamental factors in plant growth and development. Light availability is a major ecological factor influencing seed germination, seedling survival, and establishment (Guenni et al. 2008). Germination of many species requires specific light requirements, with species responding to slight variations in the light spectra associated with the season or shaded habitat, triggering or inhibiting germination (Fenner and Thompson 2005). Knowledge of the effect of light on germination is essential in the propagation of plant species for restoration purposes (Khurana and Singh 2001) and for a better understanding of germination ecology (Baskin and Baskin 2014). Although soil moisture content strongly affects light penetration into the soil, it generally appears to be physiologically and ecologically significant amounts of light (Tester and Morris 1987). Thus, the germination response to light may vary between habitats. For example, in shaded environments such as forests, intense light can be associated with a canopy gap that increases the probability of seedling's establishment (Khurana and Singh 2001).

Light is essential for photosynthesis and influences various physiological processes, such as stomatal function, electrolyte absorption, and transportation (Muhammad et al. 2021). There is a direct relationship between light intensities and plant growth rate, as plant growth increases as light intensity gradually increases to a certain extent (Wang et al. 2021). Plants growing at high light intensities allocate more biomass to the underground part for root growth, facilitating water and nutrient absorption and reducing leaf temperature to meet plant growth needs (Balliu et al. 2021). Plants grown in full sunlight have thicker stems, well-developed, shorter internodes, and better development of palisade tissues in leaves (Rina et al. 2019). However, plants grown in a poor-light environment allocate more biomass to the aboveground part for leaf growth to fully absorb limited light energy and meet the photosynthetic needs of plants (Pearcy 1999). Increasing light intensity positively impacts plant growth; the stem grows faster in the dark than in light conditions (Jeong et al. 2013). Light directly affects the vegetative and flowering phases of plants.

Spondias mombin L. belongs to the family Anacardiaceae and is endemic to tropical regions in Asia, America, and Africa (Mitchell and Daly 2015). The *Spondias* spp. (Anacardaceae) also found in the biodiversity-rich primary forest of Bangladesh (Sarker et al. 2015). The *S. mombin* is a hermaphrodite tree with a trunk diameter range of 20-40 cm and a height range of 8-25 m (Mitchell and Daly 2015). The fruit is oval-shaped, 5-10 cm long, with a thin and hard shell, and an average weight of 150-240 g, and its fruit has been used as an antipyretic and diuretic (Mohammed et al. 2011). The shape of the seed looks like a virus due to the various fibers on it, with an oil content of 31.5% (Oyelade et al. 2005). The plant has been traditionally known for its medicinal and food source (Okwu 2001). The fruits, leaves, bark, seeds, and roots treat various diseases. Young leaves are cooked as a vegetable, but excessive consumption of the fruit can cause dysentery (Ayoka et al. 2008). Urugulaga and Laghton (2000) reported that this plant has broad-spectrum antibacterial and antifungal properties. Furthermore, collecting, processing, and marketing *S. mombin* products help reduce poverty by providing employment and strengthening the rural economy (Leakey et al. 2005; Das 2014d).

The seeds of different tree species are fundamental in silviculture for natural and artificial regeneration, as these are essential, flourishing, high-quality trees. However, dormancy is a significant constraint in working with seeds, even when all other conditions are constant. Previous research on seed germination and seedling establishment has mainly focused on the influence of external environmental factors on storage method and duration (Wawrzyniak et al. 2020), temperature and water (Das 2014a, 2015a; Khaeim et al. 2022), and dormancy-breaking technology (Babaei-Ghaghelestany et al. 2020). Seeds placed across the entire light energy spectrum significantly affected germination and growth, with maximum light effectiveness suitable for promoting seed germination and seedling growth. Seeds from some plant species require heavy shade to keep the soil moist and fresh before germination, while others do not require shade to germinate without shade. The study on light requirements for seed germination and early growth seedlings of *S. mombin* species is still very limited. Therefore, this study aimed to determine the effect of different light intensities in nurseries and closed natural forest canopy on *S. mombin* seed germination and early growth characteristics.

MATERIALS AND METHODS

Study area and seed collection

The experiment was conducted in the nursery of Bangladesh Agricultural University, Bangladesh (24° 44' N and 90° 24' E) in February-July 2021. The air temperature ranged between 24° and 33°C, with a relative humidity of 66-78% during the experiment. The seeds were collected from 9- to 15-year-old and healthy trees. All seeds were dried under the sunlight and stored in airtight polybags until applied to treatments. The collected seeds were sorted to discard the damaged and discolored seeds, and only healthy dried seeds were used for the experiment.

Experimental design and early growth seedling

The germination test was carried out in a medium of topsoil and cow dung in a ratio of 3:1 by sowing the seeds in 4 × 6 cm polybags. During the experiment, the potting media was used for filling the polybags, followed by (i) A mixture on top and floor forest soil (up to 5 cm depth), (ii) Polybags, (iii) Decomposed cow dung, and (iv) Compost. Then, the beds were laid systematically and slightly higher than the surrounding areas so that water did not remain long. The polybags were filled with soil and fertilizer, and the seed was sown in each polybag. One seed was planted in each polybag at a depth of 0.5-1.5 cm. Watering was carried out manually once a day during the experiment. Afterward, the seed germination and seedlings were exposed to four light intensities: direct light (100% light intensity), 60%, and 40% light intensity, and under a closed natural forest canopy. Direct sunlight was obtained by arranging the seedlings under total exposure (100%). 60% light intensity was achieved by placing seedlings under growing media covered with a single layer of synthetic green (1 mm) fine mesh net, and 40% light intensity was achieved by placing seedlings covered with double layers of 1mm mesh net of synthetic green. The amount of Photosynthetic Active Radiation (400 to 700 nm waveband) was measured using LI-COR 190 Quantum Sensor. The close natural forest canopy implies trees that grow densely where the leaves and branches at the top form a canopy or ceiling, which inhibits light penetration to the forest floor (Ita et al. 2022). Weeding in the pot was carried out to eliminate competition with weeds.

Cumulative germination was monitored daily for 60 days until no further germination. The parameters observed were seedling height (cm), collar diameter (mm), number of leaves, total leaf area (cm^2), Root Dry Weight (RDW) (g), and total biomass (g) at six months old. The seedling height (cm) was determined using a calibrated ruler. Collar diameter assessment used Vernier Caliper (Das et al. 2018). Visual count determined the number of leaves, while the leaf area (Sarker et al. 2013; Das 2014b, c) was assessed by the graphical method (Oni and Bada 1992). Biomass increment was estimated monthly (Das 2015b; Das and Sarker 2015). A total of 20 seedlings were randomly selected and carefully uprooted. The seedlings were separated for biomass determination, and then the dry weights of these components were determined after oven drying at 80°C for 24 hours. The dry weight of leaves, stems, and roots were measured. The total biomass of the seedlings was calculated as follows: Total biomass = leaf biomass + stem biomass + root biomass.

Determination of seed germination

The number of seeds germinated in each treatment was recorded. The 1st and last day of seed germination were recorded periodically. At the end of the germination period, the rate of germination and the germination percentage (Maguire 1962) were calculated using the following equations:

$$G_p = \frac{N_g}{N_t} \times 100$$

i.e.,

$$G_r = \sum \frac{N_g}{days\ of\ count}$$

$$G_r = \sum \frac{N_g}{days\ to\ first\ count} + \cdots + \frac{N_g}{days\ to\ final\ count}$$

Where:
G_p: Germination percentage
N_t: Total number of seeds planted
N_g: Number of germinated seeds
G_r: Germination rate

Data analysis

Data on seed germination were statistically analyzed to determine treatment variations using R statistical software version 4.1.2 (R Development Core Team 2021). The Duncan Multiple Range Test (DMRT) (Duncan 1955) and Analysis of Variance (ANOVA) were carried out to analyze the data. One-way ANOVA was used to compare seed germination and early growth characteristics of seedlings in various treatments. DMRT was conducted to compare mean germination percentages, end date of germination, and germination periods. The significance among treatment means was analyzed using DMRT.

RESULTS AND DISCUSSION

Effects of light intensity on the seed germination of *Spondias mombin*

Seed germination of *S. mombin* was started and concluded on the 7th and 43rd Days After Sowing (DAS), with the highest germination rate within the first three weeks. Germination percentages at 21st DAS ranged from 13.1-33.7%. The highest germination was obtained at the treatment of 40% light intensity, which is significantly different ($P \leq 0.05$) from other treatments (Figure 1). The highest cumulative germination was obtained at the treatment of 40% light intensity (71.61%), while the least was at the treatment of 100% light intensity (26.58%) (Table 1).

Light intensity significantly affected the germination of *S. mombin* seeds. The 40% light intensity treatment had a significantly higher germination rate than other treatments. The germination rate for *S. mombin* seeds sown at 40% and 60% light intensity was not significantly different. Three treatments of 40%, 60% light intensity, and under closed natural forest canopy) had higher germination than 100% light intensities (Table 1). There was no significant difference in germination starting dates among the treatments; however, there were significant differences ($P \leq 0.05$) in germination end dates, germination periods, germination percentages, and rates of germination (Table 1).

Table 1. Effects of light intensity on seed germination of *Spondias mombin* at nursery stage

Treatment	Germination Starting Date (d)	Germination End Date (d)	Germination Period (d)	Germination Percentage (%)	Rate of Germination
Under forest canopy	8.35±0.43	42.11±0.32b	33.76±0.36b	46.67±3.43a	1.41±0.11b
40% light intensity	7.16±0.25	40.01±0.23a	32.95±0.27b	71.61±2.38b	1.59±0.06a
60% light intensity	7.58±0.16	41.02±0.24a	33.34±0.22b	54.93±2.64a	1.53±0.07a
100% light intensity	8.93±0.23	43.06±0.46b	34.93±0.34a	26.58±3.51c	1.22±0.10c

Note: The same letter(s) in the column indicates no significant difference. Data are mean ± SD at $P \leq 0.05$

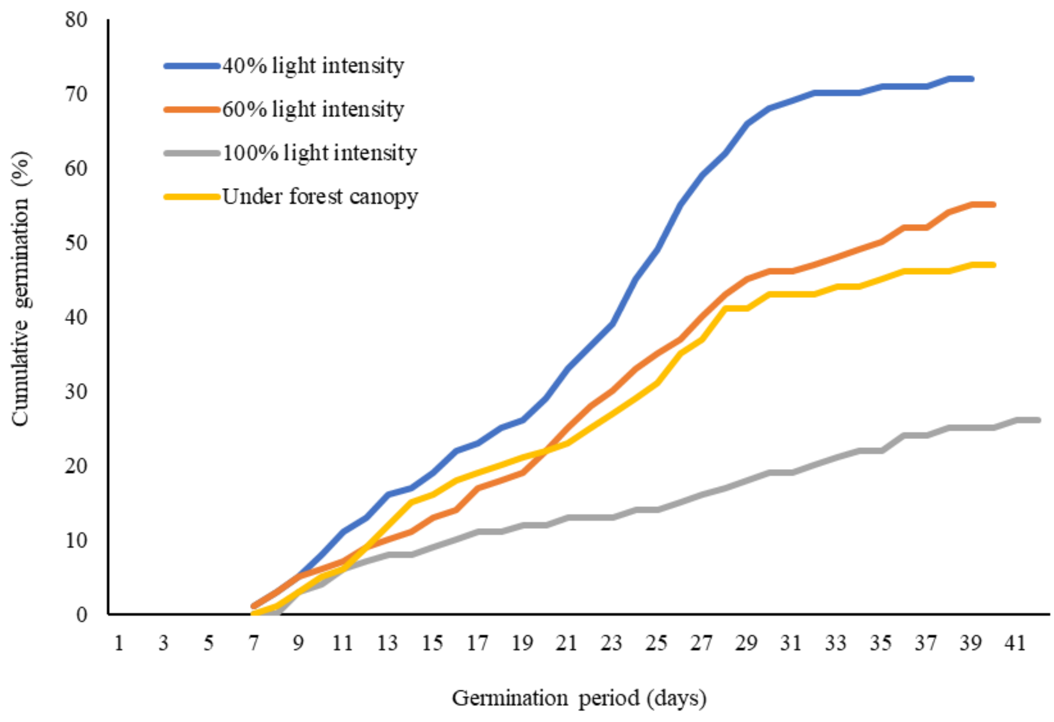

Figure 1. Cumulative germination (%) throughout the germination period of *Spondias mombin* with different light-intensity treatments

Table 2. Growth parameters of *Spondias mombin* seedlings affected by light intensities.

Treatment	Total Height (cm)	Collar Diameter (mm)	Height/ Diameter Ratio (%)	Number of Leaves	Total Leaf Area (cm^2)	Number of Branches	RDW (g)	Total Biomass (g)
Under forest canopy	9.5±0.28b	0.45±0.03b	59.8±2.47b	11.7±0.58b	13.6±0.75c	0.9±0.01	1.4±0.02	4.1±0.11c
40% light intensity	11.3±0.31b	0.53±0.06b	56.2±1.86b	12.6±0.51b	15.4±0.89c	0.9±0.02	1.5±0.02	5.2±0.18b
60% light intensity	13.9±0.29a	0.68±0.04a	41.3±2.01a	14.8±0.32a	19.6±0.81a	1.0±0.01	1.5±0.02	6.9±0.21a
100% light intensity	10.8±0.36b	0.69±0.07a	43.7±2.94a	12.1±0.67b	17.5±0.62b	0.9±0.01	1.6±0.03	5.8±0.19b

Note: The same letter(s) in the column indicates no significant difference. Data are mean ± SD at $P \leq 0.05$

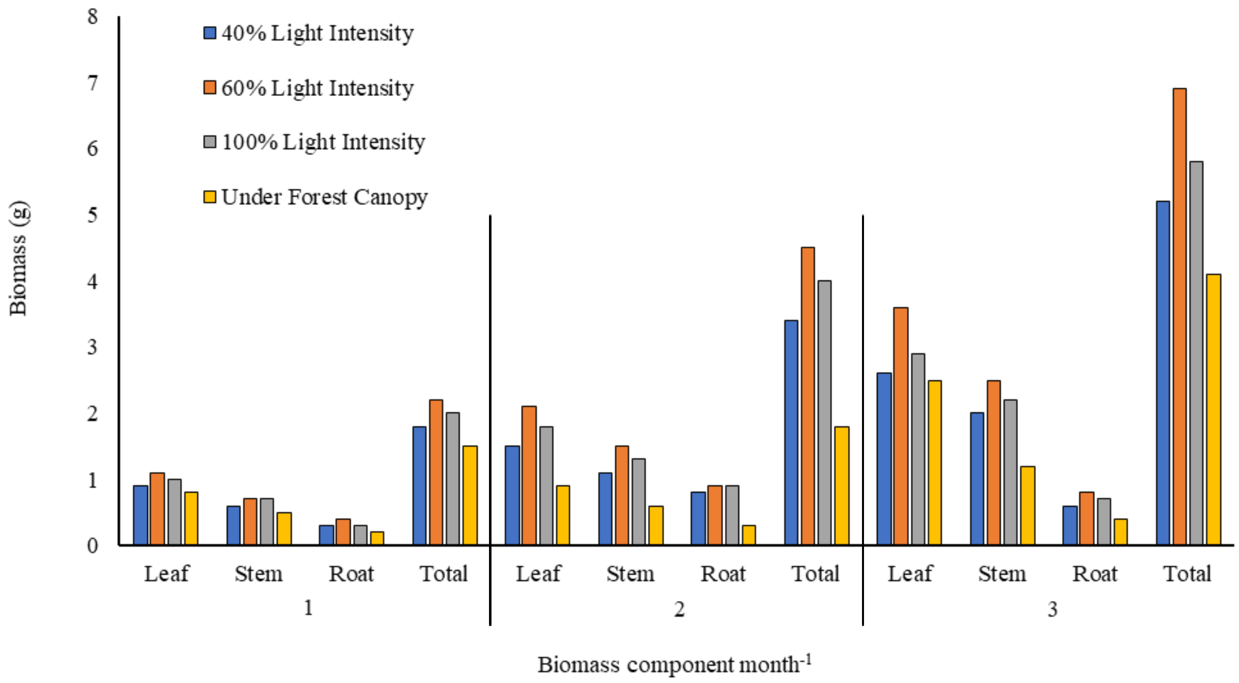

Figure 2. Effect of light intensity on biomass accumulation of *Spondias mombin* seedlings

Effects of light intensity on the growth of the seedlings of *Spondias mombin*

At the end of 12 weeks, the mean height of *S. mombin* seedlings ranged from 9.5-13.9 cm. The highest was obtained at 60% light intensity, while the lowest was at the closed natural forest canopy treatment. There was no significant difference in the heights of seedlings at the treatments of 40% and 100% light intensities (Table 2). At 12 and 21 weeks of growth, the collar diameter of seedlings ranged from 0.45-0.68 mm. The mean collar diameter at 60% light intensity was significantly higher than those at 40% and forest canopy. The effect of light intensity on collar diameter differed significantly ($P \leq 0.05$) (Table 2). The Height/Diameter (H/D) ratio of the seedlings was initially increased at the 8th and 14th weeks and then gradually decreased with the increase of age. At the end of the 15th week, the H/D ratio under closed natural forest canopy and 40% light intensity did not differ. The H/D ratio of closed natural forest canopy and 40% light intensity were significantly higher than those at 60% and 100% (Table 2).

The mean number of leaves of *S. mombin* seedlings varied from 11.7 to 14.8. The number of leaves produced at the treatments of 40%, 100% light intensities, and closed natural forest canopy were not significantly different. The 60% light intensity treatment had significantly higher numbers of leaves than other treatments (Table 2). Light intensities had a significant ($P \leq 0.05$) effect on the seedling's total leaf area. Seedlings exposed to 60% light intensity had the largest leaf area (19.6 cm^2). The smallest leaf area was obtained at a closed forest canopy, with a mean value of 13.6 cm^2. However, the treatments did not affect the number of branches (Table 2). Light-intensity treatments did not affect Root Dry Weight (RDW) (Table 2).

After three months of growth, the mean accumulation of total biomass of *S. mombin* seedlings ranged from 4.1-6.9 g. In the first month of growth, biomass accumulation did not differ in all treatments. In the second month, biomass accumulation was higher at 60% light intensity than at 40%, 100% light intensity, and forest canopy (Figure 2). In the third month, biomass accumulation was higher at 60% and 100% light intensities than at 40% light intensity and closed natural forest canopy.

Discussion

The best treatment for germination of *S. mombin* was at 40% light intensity, considering the germination period, percentage, and germination rate. The successful germination at 40% light intensity due to *S. mombin* seeds require a low light to germinate. The S. *mombin* seeds had some form of dormancy since their ungerminated seeds were viable at the end of the experiments. A higher germination rate of *Chrysophyllum albidum* G.Don seeds was also obtained at 40% light intensity than that of 60% and 100% light intensities (Onyekwelu et al. 2012). The result of *S. mombin* seed germination may help cultivate large quantities of *S. mombin* outside their habitats, promoting ex-situ conservation.

The results also showed that light intensity significantly ($P \leq 0.05$) affected most of the morphological and physiological parameters of the seedlings. The results showed that *S. mombin* seedlings had a moderate annual growth rate of 25-41 cm and a yearly diameter growth rate of 0.56-1.08 cm. However, this annual growth rate depends on the light intensity. Ekeke et al. (2006) reported a mean height growth of between 24.7 and 32.9 cm for *Dacryodes edulis* after 12 weeks, which is higher than the height of *S. mombin* in this study. In silviculture, the H/D ratio is used as an indicator of stability, growth vigor, and the ability of trees to resist wind damage (Wang et al. 1998). A low H/D ratio indicates stable and robust growth, while a high ratio indicates the opposite growth. The *S. mombin* seedlings treated with 60% light intensity were more stable than those treated with under-forest canopy and 40% light intensity. *S. mombin* seedlings in the closed natural forest canopy treatment and treatment of 40% light intensity had a higher H/D ratio, so they may not be suitable as planting stock.

The *S. mombin* seedlings treated under a closed natural forest canopy produced fewer leaves and a lower total leaf area than the other treatments. The low number of leaves and total leaf area might have led to low photosynthetic activity and low biomass production (Egharevba and Osunde 2001). In the present study, biomass accumulation was higher in the seedlings under 60% than for those under 40%, 100% light intensity, and closed natural forest canopy. Chen et al. (2023) showed that the growth characteristics of *Liquidambar formosana* Hance seedlings were significantly better under sunlight than under shade, and the root, leaf, stem, and total biomasses were significantly higher under sunlight compared to heavy shade conditions. Furthermore, more biomass was allocated to the leaves to ensure photosynthesis in an adequate light environment; consequently, more matter and energy accumulated. The stress tolerance of *S. mombin* may affect its biomass distribution pattern in a low-light environment. It suggests that shade-tolerant plants invest more biomass in the stem and propel the stems and roots to store more material to improve their low-light environment tolerance. The lack of light inhibits photosynthesis under heavy shade conditions, affecting the transport of photosynthetic products to the root system and inhibiting root growth (Li et al. 2017). In this study, the decrease in light intensity significantly decreased the seedling height, total biomass, and stem diameter of *S. mombin* seedlings. The seedling growth in a closed natural forest canopy was poor, indicating that it may not perform well under heavy shade.

Light directly affects the developmental processes and growth of the above-ground plant parts and indirectly affects the underground roots (Li et al. 2017). Intense light benefited the basal stem diameter and the root system growth of the seedlings, but they had minimum height. Therefore, plants usually develop and elongate to improve light interception in a closed forest environment, resulting in increased stem diameter, seedling height, and decreased root length (Mediavilla and Escudero 2010). The death of young *S. mombin* seedlings at intense light, especially at 100% light intensity, suggested that *S. mombin* may not tolerate full sunlight. The seedling growth under 100% light intensity died shortly after emergence, implying the species needs shading during early growth. Therefore, *S. mombin* seedlings need shade for the establishment and early growth, evidenced by their survival and growth under moderate shade environments (i.e., 60% light intensities). Therefore, the best growth and most stable seedlings were obtained under 60% light intensity. A study by Wardiana and Herman (2011) showed a better collar diameter, a higher number of leaves, and biomass production for *Reutealis trisperma* (Blanco) Airy Shaw seedlings under a reduced light environment (65% light intensity) than full light (100% light intensity). To improve light interception in a closed forest environment, plants usually invest more resources in the growth and elongation of seedlings and thickening of the stem diameter, resulting in increased seedling height, stem diameter, number of leaves, total leaf area, and biomass production. Veenendaal et al. (1996) obtained similar results for *Terminalia superba* Engl. & Diels and *Entandrophragma utile* (Dawe & Sprague) Sprague, while Osunkoya et al. (1994) reported on twelve forest tree species that showed reduced growth with decreasing light intensity.

Previous studies revealed that enhanced light within a specific range promotes seedling growth (Xia et al. 2020; Chen et al. 2020). The study results were similar to the morphological characteristics observed in the seedlings of *Pinus massoniana* Lamb. (Pinaceae) and *Quercus mongolica* Fisch. Ex Ledeb. (Fagaceae) under different light intensities (Li et al. 2017). Under heavy shade conditions, the lack of light inhibits photosynthesis in the aboveground parts, which affects the transport of photosynthetic products to the root system, and, therefore, root growth is inhibited (Li et al. 2017). Insufficient energy is invested in the root length, seedling height, and stem diameter, inhibiting plant growth.

In conclusion, light is one of the factors affecting *S. mombin* germination and seedling early growth, as demonstrated by 40% and 60% light intensities. Seedlings under closed natural forest canopy had poor performance by decreasing survival percentage on heavy shading, corresponding to a low H/D ratio essential for growth and development. To enhance the natural regeneration of *S. mombin*, silvicultural measures such as thinning or gap openings are suggested for increasing light irradiance in the forest understory. Therefore, the *S. mombin* tree species distributed throughout the country constitute potential stocks for agroforestry, afforestation, reforestation, and breeding programs.

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