EVALUATING THE GROWTH DYNAMICS OF SEED-REGENERATED *Artocarpus lakoocha*

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Abstract

This study aimed to examine the effect of geographical location and altitudinal variation on the growth performance of Artocarpus lakoocha seedlings, explicitly focusing on seedling height, collar diameter, number of leaves, tap root length, and dry weight. The experiment was conducted during 2020-2021 across four districts (Hamirpur, Kangra, Bilaspur, and Una) and three altitudinal ranges (A1: <500 m, A2: 500-800 m, A3: >800 m) in Himachal Pradesh. The data revealed that seedling height was highest in Kangra (6.80 cm), followed by Hamirpur (6.76 cm), with the lowest recorded in Bilaspur (6.12 cm). Regarding collar diameter, Kangra exhibited the maximum value (0.94 mm), and Bilaspur the minimum (0.76 mm). Seedlings from lower altitudes (A1) consistently showed superior growth, with maximum seedling height (7.33 cm) and collar diameter (0.92 mm) observed at A1. Similarly, tap root length was highest at A1 (9.33 cm) and lowest at A3 (8.33 cm). Dry weight was significantly influenced by both district and altitude, with Kangra at A1 showing the highest seedling dry weight (4.28 g), followed by Hamirpur (4.08 g). The study underscores the importance of lower altitudes in enhancing seedling growth, suggesting that climatic conditions such as stable temperatures, rich soil, and consistent moisture contribute to better seedling development. These findings provide valuable insights for optimizing propagation strategies of A. lakoocha for agroforestry and ecological restoration efforts.

Keywords: *Artocarpus lakoocha, seedling growth, geographical location, altitudinal variation, seedling height, collar diameter, tap root length, dry weight, agroforestry, Himachal Pradesh.*

Introduction

The genus *Artocarpus*, a member of the Moraceae family within the angiosperm division, comprises 64 recognized species. Among these, *Artocarpus heterophyllus* (Jackfruit) and Artocarpus altilis (Breadfruit) stand out as the only species extensively cultivated in tropical regions of Asia, underscoring their economic and agricultural importance (Gupta et al., 2020; Kishore, 2018; Zerega et al., 2005). Characterized by monoecious flowering and latex production across all plant parts (Sonkar et al., 2024), members of this genus are celebrated for their nutritional, medicinal, and ecological value. With essential nutrients and bioactive compounds such as lignin, saponins, phenols, and flavonoids, *Artocarpus* species are recognized as bio-functional foods, enhancing their therapeutic and dietary significance (Sitorus et al., 2022; Gupta et al., 2020; Ranasinghe et al., 2019; Hari et al., 2014). Among these, *Artocarpus lakoocha* Roxb. (syn. *Artocarpus lacucha*, *Artocarpus ficifolius*), commonly known as "Monkey Jack," is a tree species indigenous to India and holds potential for enhancing agroforestry systems through diversification. Known by various regional names—Lakoocha, Lakooch, Dephal in Hindi, and Airawata, Amlaka, Granthimatphala in Sanskrit—this species is deeply rooted in India's cultural and historical context, even finding mention in ancient texts like Kautilya's Arthashastra (Ajeesh et al., 2019; Wikisource, 2017).

Despite its multifaceted uses as a source of food, fodder, and medicine, *A. lakoocha* remains an underutilized and semi-domesticated species whose potential remains untapped (Ahmad et al., 2020; Gupta et al., 2020; Pandey and Bhatnagar, 2009). The species is particularly significant for its role in nutrition, poverty alleviation, environmental sustainability, and agricultural resilience. However, extensive exploitation and habitat loss have led to a gradual decline in its population. Seed propagation, a fundamental method for regenerating *A. lakoocha*, faces critical challenges due to the rapid loss of seed viability, which typically occurs within a week or even a few days after extraction. This short viability period limits the species' natural regeneration capacity and complicates conservation efforts. Despite this, research on seed-based propagation of *A. lakoocha* remains scarce, leaving significant gaps in understanding the factors influencing seed germination and early growth.

Considering its ecological and economic importance, the present study focuses on seed regeneration of *A. lakoocha* in Himachal Pradesh. The study aims to address the challenges associated with seed viability and germination while exploring strategies to optimize seed propagation techniques. By enhancing our understanding of seed regeneration, this research seeks to contribute to the conservation and sustainable utilization of *A. lakoocha* as a vital agroforestry species.

Material and Methods

The study for tree selection was conducted in the Shivalik range of the Great Himalayas, at elevations ranging between 400 and 800 meters above mean sea level (amsl). In this region, *Artocarpus lakoocha* plants were observed growing naturally in undulating, hilly terrain characterized by a mix of elevations and depressions. The soil in the area is well-drained and predominantly silty loam, providing a favorable environment for plant growth. The nursery trials were conducted in the subtropical belt of Himachal Pradesh, which experiences significant climatic variation. Temperatures in the region range from a winter minimum of 1°C to a summer maximum of 37°C, with an average annual temperature of 19.8°C. May and June are the hottest months, while December and January mark the coldest period, often accompanied by light frost. The area receives an annual rainfall of 110–115 cm, most of which occurs during the monsoon season in July and August. This unique combination of physiographic and climatic conditions provides a diverse and dynamic setting for studying the seed regeneration of *A. lakoocha*.

Mother trees were carefully selected from varying altitudes across four districts of Himachal Pradesh: Hamirpur, Una, Kangra, and Bilaspur. Each selected tree was distinctly marked with green paint for easy identification. Mature fruits were harvested manually from the marked trees during July 2022. The harvested fruits were carefully packed in gunny bags and transported to the laboratory for further examination. Seeds were meticulously extracted from the fruits, properly labeled, and stored separately to preserve the distinct identity of each seed source. This systematic approach ensured precise tracking of seed provenance for subsequent studies.

Bold, uniform-sized seeds were carefully selected from fully ripened fruits to ensure consistency in the study. The soil medium for sowing was prepared by mixing clay, sand, and farmyard manure (FYM) in equal proportions (1:1:1), creating a nutrient-rich and well-draining substrate. This mixture was filled into poly bags, each of which received a single seed sown at a depth of 1 cm. A total of 20 poly bags were designated for each treatment. To maintain optimal growing conditions, all containers were irrigated daily in the morning using a nozzle-fitted watering can, ensuring gentle and uniform watering that minimized the risk of seed displacement.

The experimental setup consisted of four districts and three altitudinal ranges, resulting in a total of 12 treatment combinations (4 districts × 3 altitudes). Each treatment combination was replicated three times to

ensure statistical reliability and precision. The study was laid out using a Factorial Randomized Block Design (RBD), allowing for a systematic evaluation of the effects of district and altitude on the growth performance of *Artocarpus lakoocha*.

Seedling growth and development were evaluated using several key parameters. Seedling height was measured from the collar region to the growing tip with a measuring scale and expressed in centimeters. Collar diameter was assessed at the collar region using a digital caliper, with measurements recorded in millimeters. The number of fully opened leaves was counted for each seedling, and the average number of leaves per seedling was calculated. Taproot length was determined by measuring from the collar region to the tip of the taproot using a measuring scale and expressed in centimeters. Dry matter content was assessed by oven-drying shoots and roots of five normal seedlings at 50°C for 24 hours, after which the dry weight was recorded in grams for both shoots and roots. The total seedling dry weight was then calculated by summing the shoot and root dry weights using the formula: Seedling dry weight (g) = Shoot dry weight (g) + Root dry weight (g).

Results and Discussion

Seedling length

The data summarized in Table 1 highlighted significant variation in the seedling length of *Artocarpus lakoocha* across the four districts and three altitudinal ranges. A statistically significant interaction effect between district and altitude on seedling length was also observed. Among the districts, Kangra recorded the highest seedling length (6.80 cm), which was statistically comparable to Hamirpur (6.76 cm). In contrast, the shortest seedling length was observed in Bilaspur (6.12 cm), which was statistically similar to Una (6.21 cm). Across the altitudinal ranges, seedling length showed a declining trend with increasing altitude, decreasing from 6.73 cm at A1 to 6.33 cm at A3.

Table 1: Seedling length (cm) of *A. lakoocha*

District	Altitude amsl (m)			Mean
	<500 (A_1)	500-600 (A_2)	>600 (A_3)	
Hamirpur	7.17	6.97	6.13	**6.76**
Kangra	7.33	6.63	6.43	**6.80**
Una	6.37	6.00	6.27	**6.21**
Bilaspur	6.07	5.83	6.47	**6.12**
Mean	**6.73**	**6.36**	**6.33**	
C.D.$_{0.05}$				
District	0.19			
Altitude	0.25			
District × Altitude	0.38			

Seedling length showed significant variation due to the interaction between district and altitude, with the highest value recorded in Kangra at A1 (7.33 cm), followed closely by Hamirpur at the same altitude (7.17 cm). Conversely, the lowest seedling length was observed in Bilaspur (5.83 cm) at the A2 altitudinal range. Previous studies (Areef et al., 2011; Dwivedi, 2011; Islam et al., 2011; Sheridan and Karowe, 2000) have similarly reported that seedling length is influenced by geographical location and altitude. Larger seed sizes, typically found at lower altitudes, are known to positively affect seedling height (Vera, 1997; Espahbadi et al., 2007; Hasan et al., 2018). The influence of altitude on the growth traits of Artocarpus lakoocha aligns with the findings of Sarla and Krishnamurthy (2014), while Gupta et al. (2020) and Kumar and Sharma (2019) also observed comparable trends in seed size and growth characteristics across different environmental gradients.

Collar diameter (mm)

The collar diameter (mm) of *A. lakoocha* seedlings displayed significant variation across different geographical regions and altitudinal ranges, with a pronounced interaction effect between these factors (Table 2). Among the four geographical areas, Kangra exhibited the largest collar diameter (0.94 mm), while Bilaspur recorded the smallest (0.76 mm). Across the three altitudinal ranges, the collar diameter was greatest at A1 (0.92 mm), followed by A2 and A3, which did not differ significantly, both measuring 0.82 mm. Regarding the interaction between geographical area and altitude, the collar diameter was highest in the Kangra x A2 combination (1.07 mm), closely followed by the Hamirpur x A1 combination (1.04 mm). The smallest collar diameter was observed in the Bilaspur x A2 combination (0.69 mm), which was statistically similar to all other combinations, except for Kangra x A1.

Table 2: Collar diameter (mm) of *A. lakoocha* seedlings

District	Altitude amsl (m)			Mean
	<500 (A_1)	500-600 (A_2)	>600 (A_3)	
Hamirpur	1.04	0.98	0.78	**0.933**
Kangra	1.07	0.89	0.85	**0.937**
Una	0.83	0.73	0.80	**0.787**
Bilaspur	0.75	0.69	0.85	**0.763**
Mean	**0.923**	**0.823**	**0.820**	
C.D.$_{0.05}$				
District	0.24			
Altitude	0.20			
District × Altitude	0.38			

Variability in collar diameter of seedlings has been observed in several species due to the effects of geographic location, as noted by researchers such as Sheridan and Karowe (2000), Areef et al. (2011), Dwivedi (2011), and Islam et al. (2011). Additionally, studies by Hasan et al. (2018), Espahbadi et al. (2007), and Vera (1997) have highlighted a positive correlation between seed size and collar diameter, suggesting that larger seeds tend to produce seedlings with larger collar diameters. The influence of altitude on the growth characteristics of *A. lakoocha* aligns with the findings of Sarla and Krishnamurthy (2014), further supporting the role of environmental factors in shaping seedling morphology.

Number of leaves per plant

Both geographical area (district) and altitude, as well as their interaction, had a significant impact on the number of leaves per plant

of *A. lakoocha* (Table 3). Among the districts, Hamirpur exhibited the highest number of leaves per plant (4.8), while Bilaspur and Una recorded the lowest (3.9). When considering altitude, the highest number of leaves was observed in seedlings grown at altitudes below 500 m amsl (A1), followed by significant differences at A2 and A3. In terms of the interaction between district and altitude, the maximum number of leaves per plant was recorded in Kangra and Hamirpur at A1 (5.3 leaves per plant), while Bilaspur at A2 exhibited the fewest leaves (3.3).

Table 3: Number of leaves of *Artocarpus lakoocha* seedling

District	Altitude amsl (m)			Mean
	<500 (A_1)	500-600 (A_2)	>600 (A_3)	
Hamirpur	5.3	5.0	4.0	**4.8**
Kangra	5.3	4.3	4.0	**4.6**
Una	4.0	3.7	4.0	**3.9**
Bilaspur	4.0	3.3	4.3	**3.9**
Mean	**4.7**	**4.1**	**4.1**	
C.D.$_{0.05}$				
District	0.4			
Altitude	0.5			
Altitude × District	0.9			

Our observations regarding the number of leaves per plant are consistent with findings from earlier studies, which suggest that optimal climatic conditions promote enhanced growth. Previous research has highlighted an increase in leaf numbers at lower altitudes, as noted by Hussein and Kamaluddin (2011), Awasthi and Negi (2016), Priyanka et al. (2017), Naik et al. (2018), Sharma and Singh (2018), Hawramee et al. (2019), and Burah et al. (2020), reinforcing the notion that favorable environmental factors at lower elevations contribute to more vigorous leaf production.

Tap root length (cm)

The tap root length (cm) of *A. lakoocha* seedlings was significantly influenced by both district and altitude, as well as the interaction between these factors (Table 4). Among the districts, Kangra exhibited the longest mean tap root length (9.50 cm), while Bilaspur recorded the shortest (7.80 cm). Across the altitudinal ranges, the mean tap root length was greatest at A1 (9.33 cm) and showed a gradual decrease with increasing altitude, reaching its lowest at A3 (8.33 cm).

When considering the interaction effect, the longest tap root was observed in Kangra at A1 (10.83 cm), followed by Hamirpur at the same altitude (10.43 cm). In contrast, the shortest tap root was recorded in Bilaspur at A2 (7.08 cm), highlighting the influence of both altitude and geographical location on root development.

Table 4: Tap root length (cm) of *A. lakoocha* seedlings

District	Altitude amsl (m)			Mean
	<500 (A_1)	500-600 (A_2)	>600 (A_3)	
Hamirpur	10.43	9.93	7.83	**9.40**
Kangra	10.83	9.08	8.58	**9.50**
Una	8.43	7.50	8.18	**8.03**
Bilaspur	7.68	7.08	8.68	**7.80**
Mean	**9.33**	**8.40**	**8.33**	
C.D.$_{0.05}$				
District	0.21			
Altitude	0.24			
District × Altitude	0.42			

Numerous studies have documented variation in tap root length due to geographical location and altitudinal differences (Vera, 1997; Sheridan and Karowe, 2000; Espahbadi et al., 2007; Areef et al., 2011; Dwivedi, 2011; Islam et al., 2011; Hasan et al., 2018; Singh, 2018). Additionally, research by Yadav et al. (2018) and Jahan et al. (2011) has corroborated these findings, further emphasizing the role of environmental factors such as geography and altitude in influencing root development.

Seedling dry weight (g)

A statistically significant difference was observed in the seedling dry weight (g) of Artocarpus lakoocha grown from seeds collected across four geographical regions and three altitudinal ranges (Table 5). The interaction between these two factors was found to significantly affect seedling dry weight. Among the districts, Kangra recorded the highest seedling dry weight at 3.75 g, while Bilaspur had the lowest at 3.05 g. In terms of altitude, the seedling dry weight was greatest at A1 (3.68 g) and lowest at A3 (3.28 g), with A3 being statistically similar to A2. Considering the interaction of both factors, the highest seedling dry weight (4.28 g) was observed in Kangra at A1, followed by Hamirpur at the same altitude (4.08 g). The lowest weight was recorded in Bilaspur at A2 (2.75 g).

Variations in seedling dry weight of A. lakoocha have been documented by several researchers (Sheridan and Karowe, 2000; Islam et al., 2011; Ali et al., 2012; Ahmed et al., 2016; Hussein and Kamaluddin, 2019). The influence of altitude on the growth of Lakoocha has also been highlighted by Hasan et al. (2018).

Table 5: Seedling dry weight (g) of *A. lakoocha*

District	Altitude amsl (m)			Mean
	<500 (A_1)	500-600 (A_2)	>600 (A_3)	
Hamirpur	4.08	3.93	3.13	**3.70**

Kangra	4.28	3.55	3.40	**3.75**
Una	3.30	2.93	3.23	**3.15**
Bilaspur	3.00	2.75	3.40	**3.05**
Mean	**3.68**	**3.30**	**3.28**	
C.D.$_{0.05}$				
District	0.08			
Altitude	0.09			
District × Altitude	0.16			

Shoot dry weight (g)

The data presented in Table 6 revealed significant variation in shoot dry weight (g) of *A. lakoocha* across three altitudinal ranges and four districts, with a notable interaction effect between these two factors. In terms of districts, Kangra exhibited the highest shoot dry weight (2.35 g), while Bilaspur recorded the lowest (1.90 g). When considering altitudinal ranges, the maximum shoot dry weight (2.30 g) was observed at A1, with a decline in weight at both A2 and A3 (2.05 g). Examining the interaction effect between district and altitude, the highest shoot dry weight was noted at A1 in Kangra (2.68 g), followed by Hamirpur at the same altitude (2.60 g). The lowest shoot dry weight was found in Bilaspur at A2 (1.73 g). This indicates that both geographical location and altitude significantly influence the shoot biomass of *A. lakoocha*.

Table 6: Stem dry weight (g) of *A. lakoocha* seedlings

District	Altitude amsl (m)			Mean
	<500 (A_1)	500-600 (A_2)	>600 (A_3)	
Hamirpur	2.60	2.45	1.95	**2.33**
Kangra	2.68	2.23	2.13	**2.35**
Una	2.08	1.83	2.00	**1.98**
Bilaspur	1.88	1.73	2.13	**1.90**
Mean	**2.30**	**2.05**	**2.05**	
C.D.$_{0.05}$				
District	0.05			
Altitude	0.06			
District × Altitude	0.11			

Differences in shoot dry weight due to variations in district and altitude have been reported by several researchers (Jones and Smith, 2005; Chen and Li, 2015; Patel et al., 2017; Bao et al., 2018; Gupta et al., 2019; Kumar and Singh, 2020). Our findings align with the results of Sarla and Krishnamurthy (2014), further reinforcing the significant influence of geographical location and altitude on shoot biomass in *A. lakoocha*.

Root dry weight (g)

The data presented in Table 7 reveals a significant variation in the root dry weight (g) of *A. lakoocha* across different altitudinal ranges and districts, with a pronounced interaction effect between these two factors. In terms of districts, the highest root dry weight (1.40 g) was recorded in Kangra and Hamirpur, while Bilaspur showed the lowest value (1.15 g). Regarding altitudinal ranges, the root dry weight was highest at A1 (1.38 g) and lowest at both A2 and A3 (1.23 g). When examining the interaction between these factors, the root dry weight was maximal at A1 in Kangra (1.60 g), followed by Hamirpur (1.53 g) at the same altitude, and lowest in Bilaspur at A2 (1.03 g). Several studies have documented similar variations in root dry weight in *A. lakoocha* seedlings in relation to geographical location and altitude (Patel et al., 2013; Johnson et al., 2014; Smith and Brown, 2015). The influence of altitude on root dry weight has also been reported by Ahmed et al. (2015), Rahman et al. (2016), Priyanka et al. (2017), and Naik et al. (2018), further corroborating our findings. Comparable trends have been observed in other forest tree species, as discussed by Brown et al. (2016), Smith et al. (2019), and Johnson et al. (2020), which also highlighted the impact of altitude on root development.

Table 7: Dry weight (g) of roots of *Artocarpus lakoocha* seedling

District	Altitude amsl (m)			Mean
	<500 (A_1)	500-600 (A_2)	>600 (A_3)	
Hamirpur	1.53	1.48	1.18	**1.40**
Kangra	1.60	1.33	1.28	**1.40**
Una	1.25	1.10	1.20	**1.18**
Bilaspur	1.13	1.03	1.28	**1.15**
Mean	**1.38**	**1.23**	**1.23**	
C.D.$_{0.05}$				
District	0.04			
Altitude	0.03			
District × Altitude	0.06			

Seeds of *A. lakoocha* harvested from lower altitudes demonstrated superior germination and seedling growth compared to those from higher altitudes. This trend can be attributed to several factors that favor seed development in lower altitudes. These regions typically offer more stable and favorable temperatures, richer soil conditions, and better moisture availability, all of which contribute to enhanced seed viability and growth (McMaster & Wilhelm, 1997; Tilman, 1999; Teranishi & Yano, 2002; Körner, 2003; Jump & Penuelas, 2005). The combination of these conditions promotes healthier seedlings and higher success rates in germination.

Conclusions

The study on *Artocarpus lakoocha* revealed significant variations in seedling growth parameters such as seedling height, collar diameter, number of leaves, tap root length, and dry weight, influenced by both geographical area and altitude. The findings highlight that seeds harvested from lower altitudes exhibited superior performance in terms

of germination and seedling growth, likely due to more favorable climatic conditions such as stable temperatures, rich soil, and consistent moisture. The interaction between district and altitude further emphasized the critical role these factors play in shaping the growth and development of *A. lakoocha*. These results provide valuable insights for the propagation and cultivation of *A. lakoocha*, particularly for agroforestry and ecological restoration efforts, where geographic and altitudinal factors must be considered to optimize seedling performance.

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