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Early Growth Performance of *Melia* species in Different Agro-Climatic Zones of Shivalik Region of Lower Himalayas

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Abstract: Short rotation fast growing tree species have gained attention among farming community and wood-based industries. Among them, *Melia* species (family- Meliaceae) are considered promising due to their fast growth, straight stem, clear bole, small leaves, and resistance to pests and insect attacks, making them highly suitable for farmers' plantations. In this experiment, saplings of three *Melia* species*, viz: Melia azedarach*, *M. composita* and *M. dubia* were planted in two agro-climatic zones during 2020. The first site was the experimental farm of Silviculture and Agroforestry, SKUAST-Jammu, located in the sub-tropical zone, while the second was a farmer's field at Dingi Simbli, Billawar, in Kathua district, representing the intermediate zone. After two years of growth (2021–22), *Melia composita* recorded the maximum plant height (3.03 m and 5.64 m), collar diameter (45.6 mm and 90.9 mm), leaf area index (1.20 and 1.78), and crown diameter (0.87 m and 1.85 m) under the sub-tropical zone, which were statistically higher than observed in the intermediate zone. The overall performance of the three *Melia* species with respect to growth parameters in the sub-tropical zone followed the order: *M. composita*>*M. dubia*> *M. azedarach* during both years of the study.

Keywords: *Melia azedarach, Melia composita, Melia dubia*, Crown diameter, Collar diameter, Leaf area index

Melia azedarach, belonging to Meliaceae family and known by its common name 'chinaberry' or 'Perisan lilac' is a moderate deciduous tree with a short bole and spreading crown, bi-pinnate and tri-pinnate leaves and a dark grey bark with shallow longitudinal furrows (Tiwari and Prajapati 2024). *M. azedarach* thrives in variety of soils, and the species is cold hardy and drought resistant. *M. azedarach* is now naturalized in most sub-tropical and tropical regions of the world (World Agroforestry Centre 2006) because of its fast-growing nature, stem straightness, fewer number of branches, less shade effect and being less susceptible to pest and insect attack (Srivastva et al., 2025, Parmar et al., 2019a,b). The multi-various uses like pulpwood, timber, fuel wood and ply wood can fit as a suitable species for farm forestry plantation programme and agroforestry.

For quick augmentation of domestic wood production and to fetch early income to the farmers, *M. dubia* and *M. composita* has been identified as one of the potential native species for plantation and agroforestry to supply industrial wood (Thakur et al., 2019, 2023, Jinger et al., 2024). Globally *M. dubia* is found in Sri Lanka, Malaysia, Indonesia, the Philippines and Australia. Fast growth, straight and round bole, self-pruning, good coppicing abilities, light demanding and adaptability to wide range of climatic and soil types have made a *Melia dubia* one of the most preferred tree species among planters (Sharma et al., 2017 and 2019; Prajapati et al., 2020, Thakur et al., 2021, Jinger et al., 2025). Despite its increasing importance, the interaction between fast-growing *Melia* species and environmental conditions remains poorly understood, particularly in the lower Himalayas, which represent a transitional region with distinct agro-climatic variability. Understanding these growth–environment interactions is critical for optimizing plantation success and enhancing agroforestry practices. It is hypothesized that the growth performance of different *Melia* species varies significantly across agro-climatic zones of the Shivalik region, with superior growth expected under the sub-tropical zone compared to the intermediate zone. In line with this hypothesis, the present study aimed to evaluate the comparative growth performance of *M. azedarach*, *M. composita*, and *M. dubia* under two contrasting agro-climatic conditions. The specific focus was to assess variations in plant height, collar diameter, crown diameter, and leaf area index, and to identify the most promising species that can be recommended for plantation and agroforestry interventions in the lower Himalayas.

MATERIAL AND METHODS

Study site characteristics: The study was conducted at Division of Silviculture and Agroforestry, Sher- e- Kashmir University of Agricultural Science and Technology Jammu (Zone 1) and at farmer field of Billawar, District Kathua (Zone 2). Jammu is located at an altitude of 332 m above MSL with 32º40ˊ N latitude and 74 º58ˊ E longitude which falls under sub-tropical agro-climatic zone. This agro-climatic zone (sub-tropical zone of Jammu) experiences hot dry summer, humid rainy season and cold dry winter months. The summer usually starts from April and last up to June. The maximum temperature rises up to 45ºC during May to June and minimum falls to 1ºC during winter months (December-January). The average annual rainfall ranges from 1000-1200 mm out of which 75-80 per cent is received during July to September and rest 20-25 per cent is received during winter months of December to February (Fig. 1). Soil samples were collected and analysis for the chemical properties at the beginning of the experiment. The soil texture in sub-tropical zone was sandy loam having pH of 7.78 and organic carbon of (0.56 %). The available N, P and K of the experimental site of sub-tropical zone were low to medium in range. The intermediate zone of Billawar region, district Kathua is a transition between sub-tropical-temperate zone of the mid and high altitude areas of lower Himalayas (Shivalik range). The Billawar region have an altitude of 844 m above mean sea level with 32º36˙598 N latitude and 75º30˙950 E longitudes. The zone is characterized by monsoon, concentration of precipitation, relatively wetter, cold winters and higher mean annual rainfall than sub-tropical zone. The soil texture of intermediate zone of Billawar region was observed to be clay loam and having a pH of 5.80 and organic carbon (0.36%). Soil available N, P and K of experimental site of intermediate zone was found to be low.

Experimental design: Uniform sized (approx 45 cm) sapling of *M. azedarach*, *M. composita* and *M. dubia* were transplanted (as main plot) for plantation in two agro-climatic zones (as sub-plot) *i.e.* sub-tropical and intermediate zone with a spacing of 3 m × 3 m. The experiment was laid out in factorial randomized block design and replicated three times at both the agro-climatic zones. The transplantation of saplings was done in the month of September, 2020 and the data was collected for consecutively two years for different growth parameters.

Field Preparation: The field was ploughed with one deep disc harrower by three round of rotavator to remove the unwanted debris of weed. Pits of 45 cm × 45 cm × 45 cm were dug up. Each pit was filled with 3-4 kg of FYM and supplement irrigation were given after the planting

Growth Parameters: Plant height was measured in meters from the ground level to the tip of the main shoot with the help of calibrated measuring rod. Collar diameter was measured using digital caliper from 2-5 cm above the ground level.

Lear area index and crown diameter: Ten leaves from selected trees were taken from each replication and their actual area was determined with the help of graphic method. Maximum length was measured from juncture to tip and maximum width was taken from center of the leaves. After calculating the leaf area, leaf area index was measured by using formula LAI= Leaf area (cm²)/Ground area (cm²). Cross sectional crown diameter was measured using meter tape and two poles holding straight touching to the outermost tip of the crown leaf in opposite side of the tree. The distance between these two poles were recorded. Similarly, it was repeated at perpendicular to measure the other direction and average crown diameter was computed out of the saplings.

Statistical analysis: Statistical analysis was conducted with the software package of OPSTAT, (Sheoran et al., 1998).

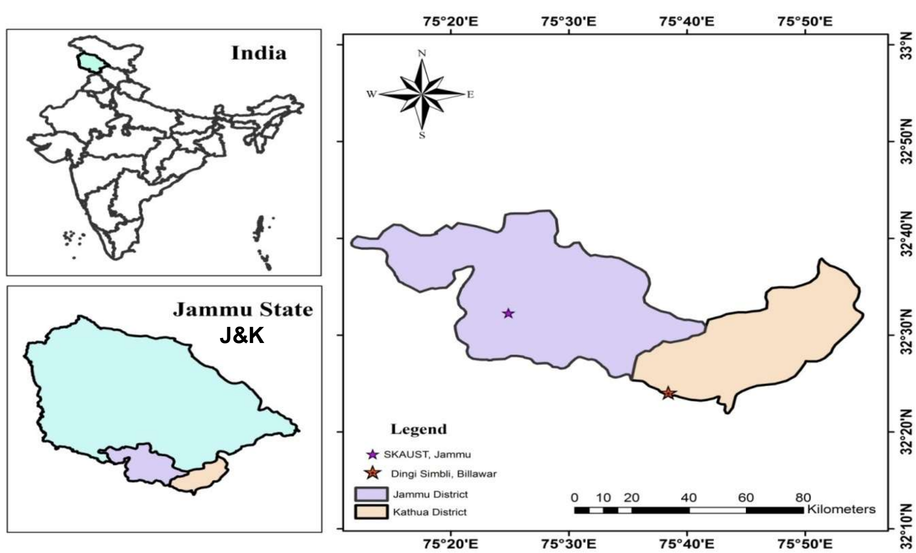

Fig. 1. Location map of two agro-climatic zone Jammu District (Sub-tropical zone) and Billawar (intermediate zone)

RESULTS AND DISCUSSION

Plant height: The agro-climatic zones had significant effect on plant height during both the year of study irrespective of species (Table 1). The average plant height was significantly higher (2.53 and 2.05 fold) in sub-tropical zone as compare to intermediate zone during both the years of study. The order of plant height under sub-tropical zone among *Melia* species was *M. composita* > *M. dubia* > *M. azedarach* during both the years. In intermediate zone, the performance of species with respect to plant height was different. In first year, *M. composita* attained significantly higher (1.20 m) in intermediate zone while in the second year *M. dubia* recorded the maximum height (3.12 m) as compared to *M. composita* and *M. azedarach*. Among species, the performance of *M. composita* observed to be significantly higher as compared to *M. azedarach* and *M. dubia* regardless of agro-climatic zones. The average maximum plant height of 2.31 m and 4.58 m was during August 2021 and 2022, respectively in *M. composita*. However, during second year, plant height of *M. composita* was statistically at par with *M. dubia* in intermediate zone. The interaction of agro-climatic zone and species was significant. The interaction effect of (sub-tropical zone × *M. composita*) resulted in maximum plant height of 3.43 m and 6.39 m which was statistically superior from the remaining interactions during both the study years. Tree height may have served as an important trait in determine the growth of the species under given site qualities and climate. The significantly higher plant height in sub-tropical zone during both the year as compared to that in intermediate zone indicates better environmental and site quality conditions for plant growth. This could be ascribed to available soil moisture during dry season which favour the nutrient absorption in plants which resulted in higher plant height in *M. dubia* (Niveditha and Shirhatti 2017). Trees height growth are often largely controlled by climate and specifically by water availability, while factors such as soil fertility are secondary (Wagner et al., 2014, Guan et al., 2015).

Higher precipitation and shorter and less intense dry period are associated with significantly higher plant growth rates (Toledo et al., 2011, Meason and Meason 2014). The soil texture of sub-tropical zone was found to be sandy loam. Sandy soils with high drainage, accompanied by well-developed root system prevent saturation of soil during the growing season. This emphasizes the importance of ground water for plants which can reach at least the capillary fringe during dry periods (Tuzinsky 2006). The response of intermediate zone with respect to plant height reflected a significant variation among climatic and site qualities characteristics. The intermediate zone had mid-altitudinal zone which had a profound effect on temperature. Growth may decline with altitude because of reduce air soil

Table 1. Plant height (m) and collar diameter (mm) of *Melia* spp. under different agro-climatic zones after 12 months (August 2021) and 24 months (August 2022)

Species/Location	August 2021				August 2022			
	M. azedarach	*M. composita*	*M. dubia*	Mean	*M. azedarach*	*M. composita*	*M. dubia*	Mean
Plant height (m)								
Sub-tropical zone	2.70	3.43	2.94	3.03	5.04	6.39	5.50	5.64
Intermediate zone	1.12	1.20	1.16	1.16	2.36	2.78	3.12	2.75
Mean	1.91	2.31	2.05		3.70	4.58	4.31	
CD (p=0.05)								
AZ	0.20				0.35			
Species	0.24				0.42			
AZ x Species	0.34				0.60			
Collar diameter (mm)								
Sub-tropical zone	40.9	51.4	44.5	45.6	83.8	99.3	89.5	90.9
Intermediate zone	17.5	20.7	24.7	21.0	31.5	40.0	45.8	39.1
Mean	29.2	36.1	34.6		57.7	69.6	67.6	
CD (p=0.05)								
AZ	3.05				5.60			
Species	3.74				6.86			
AZ x Species	5.29		`		NS			

AZ=Agro-climatic zone

temperature, shorter growing season and reduced supply of nutrients (Coomes and Allen 2007). Decrease in plant height with increase in altitude was also reported by Ndema and Missanjo (2015) in *Pinus oocarpa*. Colder regions may lead to reduced photosynthetic activity and chilling injury of tropical trees (Feng and Cao 2005). *Melia*, being a species of tropical to sub-tropical zone strive hard to acclimatize in adverse climatic and soil conditions during first year of plantation.

Collar diameter: There was significant variation in root collar diameter among the different *Melia* species grown in sub-tropical zone The maximum collar diameter was of *M. composita* (51.4 mm) followed by *M. dubia* and *M. azedarach* after 12 months of study (Table 1). Collar diameter growth was *M. composita>M. dubia>M. azedarach*. Response function of the *Melia* species showed significant relation with collar diameter under sub-tropical zone might be due to appropriate availability of moisture, light and nutrients and also morphology of the species (Song et al., 2020). Furthermore, favorable climatic conditions such as increase in temperature after bud burst in February promote cell production and precipitation during the monsoon period which enhanced the growth in *M. composita*. Climatic factors mainly light intensity and rainfall may have a strong effect on collar diameter (Toledo 2011 and Janson 2013). Temperature rise in general, may increase stem diameter as well as plant height (Way and Oren 2010). Soil texture of the site which was sandy loam might have improved the soil moisture content by permitting water to infiltrate into the horizons which directly increased the water level in the soil (Nanda et al., 2021). Role of soil nutrients and moisture in improving collar diameter in *M. composita* under sub-tropical conditions are well reported by Sharma et al., (2017 and 2019).

In intermediate zone, significant effect on collar diameter among the different *Melia* species was observed. However, as compared to sub-tropical zone it was comparatively on lower during both the years of study. The order of increase in collar diameter was as *M. dubia>M. composita>M. azedarach*. Growth of *Melia* species reduced significantly with different soil moisture conditions prevailed under different agro-climatic zones. This indicated that growth is specifically driven by moisture availability in case of fast growing species (Zobel et al., 1987). Despite of soil moisture conditions, altitudinal changes might be another reason for lower growth in intermediate zone. The changes in altitude attributed to difference in supply of soil nutrients which may contribute to slow growth at higher altitude (Ndema and Missanjo 2015). The soil texture in intermediate zone was clay loam which due to high run off resulted in less recharge of the soil profile, having higher micro-porosity, bind water molecule more tightly and hence lesser availability to plants. Flooded soil due to heavy precipitation during monsoon period (ending June onward) reduced growth potential rates as well, due to their anaerobic conditions and to the phytotoxins which are by product of the reductive processes (Pezeshki and De 2012). Despite, the climatic variability and poor soil fertility, the performance of *M. dubia* was observed better in intermediate zone during course of study. This is because of the trait that enables *M. dubia* to perform well under moisture limited conditions (Tolia et al., 2019, Parthibhan et al., 2009, Warrier 2011).

Leaf area index : The overall better performance was observed in sub-tropical zone among the different *Melia* species during two-year (Table 2). Increasing order in leaf area index was *M. composita>M. dubia>M. azedarach* after 24 months of study. Leaves exhibit a remarkable ability to acclimatize in variable environment conditions by acquiring plasticity in morphological, anatomical and physiological traits (Valladares et al., 2007). The leaf attributes in the present study were significantly influenced by season, site and their interactions. Craven et al. (2011) stated that species vary in their photosynthetic rate seasonally and demonstrated adaptive capacity to regulate leaf photosynthesis between wet and dry season. This is in agreement with findings where *Melia* species showed greater variation in leaf area. Abundant light availability could enhance the growth rate of leaf area and also improve the site qualities by shedding leaves during winter period by adding more nutrients to the soil (Nanda et al., 2021). *M. composita* being a highly light demanding species suppressed under shade (Laxmi et al., 2021) and tendency to gain more height is depicted under plant height parameter. The significant variation was observed in leaf area index in intermediate zone among different *Melia* species . The leaf area index decelerates significantly in intermediate zone as compared to sub-tropical zone during both the years of study. The order of increase in leaf area index among the different *Melia* species was *M. dubia>M. composita>M. azedarach* after 12 and 24 months of plantation.

The varied results with respect to agro-climatic zone can easily be distinguished. The possible reason for minimum leaf area index as compared to sub-tropical may be due to altitudinal variation (Coomes and Allen 2007), temperature effect (Castro et al., 2017), light variation (Park et al., 2022) and soil properties (Meijer et al., 2011). Among these species, *M. dubia* was better in terms of leaf area index in intermediate zone due to the adaptabilities and tolerance under intermittent moisture variant conditions. These results under limited moisture stress condition in *Melia* species are coinciding with Loushambam (2017), Loushambam (2021) and Dias et al. (2014).

Table 2. Leaf area index and crown diameter (m) of *Melia spp* under different agro-climatic zone after 12 months (August 2021) and 24 months (August 2022)

Species/Location	August 2021				August 2022			
	M. azedarach	*M. composita*	*M. dubia*	Mean	*M. azedarach*	*M. composita*	*M. dubia*	Mean
Plant height (m)								
Sub-tropical zone	1.10	1.34	1.16	1.20	1.65	1.98	1.72	1.78
Intermediate zone	0.83	0.91	0.94	0.89	1.25	1.38	1.45	1.36
Mean	0.96	1.13	1.05		1.45	1.68	1.59	
CD (p=0.05)								
AZ	0.06				0.06			
Species	0.07				0.08			
AZ x Species	0.10				0.11			
Collar diameter (mm)								
Sub-tropical zone	0.84	1.00	0.77	0.87	1.71	2.02	1.81	1.85
Intermediate zone	0.58	0.61	0.64	0.60	1.14	1.30	1.47	1.31
Mean	0.70	0.80	0.71		1.43	1.66	1.64	
CD (p=0.05)								
AZ	0.04				0.09			
Species	0.04				0.11			
AZ x Species	0.06		`		0.16			

AZ=Agro-climatic zone

Crown diameter: The crown diameter presented wide variation in maximum crown diameter with respect to sub-tropical zone was observed after 12 and 24 months of study period (Table 2). The maximum of 2.02 m was in *M. composita* followed by *M. dubia* and *M. azedarach* during second year. The better performance of *M. composita* in sub-tropical zone attributed to well distributed light which is a determining factor in seasonal tropical forest, as spatial and temporal dynamics of light and moisture availability inflict major constraints on leaf phenology and canopy occupancy of the plants between wet and dry season (Jinger et al., 2024). For growth to take place, the formation of substrate in the form of sugar is the basic requirement. Therefore, carbon assimilation by the leaves through the efficient interception of light is the driving force of the growth (Niinemetes 2007). The orientation of branches and leaves usually shape the geometry of the crown, and is related to its adaptive strategy for light interception. Increase of day length after the bud burst in February and higher precipitation during monsoon period resulted in increased growth rate of crown diameter. Higher temperature is also associated with N uptake and the production of leaves, increasing the total leaf area per plant (Castro et al., 2017).

However, the crown diameter among the different *Melia* species under intermediate zone reflected a reducing trend as compared to sub-tropical zone. The order of increase in crown diameter was *M. dubia*>*M. composita*>*M. azedarach* after 24 month of study. The intermediate zone having higher elevation, temperature and light variation resulted in stunted growth in all the three *Melia* species. The available soil moisture required for growth in fast growing species was comparatively low in intermediate zone. Plant genotype responds to variability of environmental condition (light, soil moisture and soil nutrient availability) by producing differences in phenotype.

CONCLUSIONS

The present study demonstrated that agro-climatic zones (sub-tropical and intermediate) exerted a significant influence on the growth performance of *Melia* species. These species exhibited better growth under the sub-tropical zone, with *M. composita* emerging as the most promising species due to its superior growth characteristics. The future prospects of *M. dubia* in the *Shivalik* region of lower Himalayas appear highly promising owing to its fast growth, adaptability to diverse conditions, and suitability for multiple end-uses such as timber, pulpwood, veneer and fuelwood. However, successful large-scale adoption will depend on careful site selection to avoid frost-prone areas, provision of adequate soil moisture through conservation or irrigation, and the availability of quality planting material. Integration into agroforestry systems, combined with market linkages to plywood, pulp and emerging carbon markets, can offer farmers attractive income opportunities while contributing to ecological restoration. Thus, with scientific management, farmer awareness and institutional support, *M. dubia* can emerge as a viable short-rotation forestry species for livelihood enhancement and environmental sustainability in this region. These findings suggest that while *M. composita* is highly recommended for large-scale plantations in sub-tropical regions, *M. dubia* holds potential for introduction and expansion in the intermediate zone of the Jammu division, making it a valuable species for agroforestry interventions.

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