



Diameter class-wise apportioned growth and productivity of *Melia dubia* under a silvi-horticulture system: A case study from South Gujarat

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ABSTRACT: The study was conducted in 2022, at Karadi Village, Navsari, Gujarat (20.923°N, 72.850°E and 9 m above mean sea level), near Arabian sea. Tree height averaged 11.03 to 16.02 m in DBH classes ranging from 6.50-9.00 to 24.00-26.50 cm, respectively. Mean tree volume varied from 0.038 to 0.410 m³ from 6.50-9.00 to 24.00-26.50 cm DBH class, respectively and it showed increasing trend as DBH increased. Whereas, tree volume (m³/tree) and fresh biomass (kg/tree) estimated using regression equation, indicated that the average DBH class wise volume ranged from 0.027 to 0.281 m³/tree under lowest (6.50-9.00 cm) and highest DBH class (24.00-26.50), respectively, whereas, the average fresh biomass varied between 30.87 to 283.47 kg/tree in 6.50-9.00 cm to 24.00-26.50 cm DBH class. At 5 years of age, DBH class productivity was 4.32 to 44.96 m³/ha/year for volume) and 4.94 to 45.36 tonne/ha/year for biomass with an overall mean of 22.69 tonne/ha/year. At the age of 5-year carbon stocks were 1.23-11.34 and carbon sequestration rate was 4.53-41.61 t/ha/year under 6.50-9.00 to 24.00-26.50 cm DBH class, with an overall average values of 5.67 and 20.82 t/ha/year. Economic analysis of *M. dubia* fresh biomass indicated returns of Rs. 0.98 lakh/ha for the 6.50-9.00 cm DBH class, rising to a maximum of Rs 1.11 lakh/ha for the 24.00-26.50 cm class, yielding a total of 5.42 lakhs/ha.

Research Article

ARTICLE INFO

Received: 02.09.2025

Accepted: 10.12.2025

Keywords:

Silvi-horticulture,
Melia dubia,
Biomass,
Volume,
Productivity,
Economics

1. INTRODUCTION

India is a net importer of timber and allied products. In 2015, India imported an estimated 18.01 million cum of timber, pulpwood and allied products worth US \$6,701.3 million, which included wood logs, panel and plywood, pulpwood, paper, furniture and other wooden products. Under all categories of timber, wood logs and paper constitute the major part of Indian wood imports (Chavan *et al.*, 2015; Ramanan *et al.*, 2022). Current forest resources are inadequate to meet the increasing demand for raw wood in various wood-based industries. Therefore, the plantation forestry sector holds significant potential to enhance wood production and bridge the widening gap between the demand and supply of pulpwood. In addition to exotic species, it is increasingly emphasized that suitable indigenous alternatives should be explored, evaluated, and adopted for sustainable production.

Melia dubia Cav. vernacularly known as Malabar neem is a member of Meliaceae family. It is a large deciduous perennial tree which can attain height up to 30 meters. The tree prefers deep red gravelly soil, high light intensity, 800-1000 mm rainfall, and an elevation

of 800-1000 meters. It has a clear cylindrical bole up to 15-20 feet and can grow up to 40 feet tall with large branches. The species originated from southern Asia (India-Pakistan-Iran). It has been introduced and widely grown in South Africa, the Middle East, America (Bermuda, Brazil, and Argentina), Australia, the SE Asia-Pacific islands, and southern Europe. It grows primarily in the arid eastern area of Indonesia. The species is found in very moist teak forests (3B/C1a), secondary moist deciduous forests (3C/2S1), and dry mixed moist deciduous forests (5B/C2) around the world (Parthiban *et al.*, 2019; Handa *et al.*, 2021). *M. dubia* is valued for its high-quality termite and fungus resistant timber (Suprapti *et al.*, 2004). Its branches are used as fuelwood, termite resistant poles and leaf as a fodder. The timber is mainly used for furniture, agricultural implements and house construction. *M. dubia* has decorative appearances, which is making it suitable for furniture making (Mandang and Artistien, 2003).

It is both industrially and economically important fast growing multipurpose tree species, which can be harvested in short rotation, used for afforestation and land rehabilitation. It is amenable for the pulp and paper industry due to superior pulp yield as well as quality (Sinha *et al.*, 2019). *M. dubia* also has medicinal properties and the extract from different part of the plant has antiviral, bacteriostatic and fungistatic and antifeedant activity (Ramanan *et al.*,

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2024). Recently its fruit pulp and leaf fodder has been reported as energy rich feed source and its feeding to small ruminants has been found as good as other feed stuffs which can reduce the cost of feeding as well (Sukhadiya *et al.*, 2021& 2022; Malek *et al.*, 2024). The species is thriving well in south Gujarat condition and is adopted as an agroforestry component for its multiple utility without any allelopathic propensity on under storey crops (Parmar *et al.*, 2019). In recent times many *M. dubia* based agroforestry systems involving have been investigated for its bio-physical and economic feasibility with pulse, vegetable crops and medicinal and aromatic plants (Thakur *et al.*, 2018; Mohanty *et al.*, 2019; Jilariya *et al.*, 2019; Thakur *et al.*, 2020) in the south Gujarat region. In addition to the simpler agroforestry systems currently established or under development in Gujarat, farmers have also started integrating this valuable species with fruit trees. However, the performance of *M. dubia*, in particular and components of such systems namely silviculture has not been attempted so far. Therefore, the study assess the diameter class wise growth and productivity of 5 years old *M. dubia* under silviculture system in Navsari, Gujarat has been estimated.

2. MATERIALS AND METHOD

The present study was carried out in the year 2022-23, at Karadi Village, Navsari, Gujarat situated at 20.923°N latitude, 72.850°E longitude and at an altitude of 9 m above mean sea level near Arabian sea. The silvi-horticulture system comprised of *Melia dubia* + Mango + Lemon as main components (Fig. 1). *M. dubia* trees were 5 years of age planted at 3.5 × 3.5 m. Between two *M. dubia* trees either lemon or mango tree was incorporated alternatively.

Growth measurements Tree height and diameter at breast height (DBH, 1.37 m from ground level) was measured as per standard methods.

Volume (m³/tree) and fresh biomass

Tree volume and fresh biomass was calculated using regression equations

$$\text{Volume} = 0.00003 * (h * D^2) + 0.0038,$$

where, h = height of tree in m and D = DBH of the tree in cm, and, where, h = height of tree in m, D = DBH of the tree in cm developed by Thakur *et al.* (2021).

Carbon stock and carbon sequestration

Estimated fresh biomass was converted to dry mass *i.e.* 50 per cent of the fresh biomass (Laxmai *et al.*, 2021). Then biomass was converted to total carbon stock by multiplying factor of 0.51 (Dury *et al.*, 2002) and carbon sequestration by multiplying the carbon stock by factor of 3.67 (Van Kooten, 1999).

Economics

The gross and net realization from fresh wood biomass production (per hectare under each diameter class up to the age of 5 years) was worked out on the basis of prevailing market rates (Rs. 5000/tonne) *M. dubia* wood and cost of cultivation following Thakur *et al.* (2023a).

3. RESULTS AND DISCUSSION

Tree height

Among eight diameter classes (Table 1), the height ranged from 7.60 to 23.70 m. The lowest diameter class (D1: 6.50-9.00 cm) represented the shortest tree height (11.03 m), whereas tallest tree highest (23.70 m) was recorded in 19.00-21.50 cm diameter class (D6). The mean overall height data showed that average height increased with increase in diameter. The average height ranged from 11.03 to 16.02 m from DBH class D1 to D7, respectively.

Tree volume (m³/tree)

Volume estimated (Table 1) as per volumetric equation ranged from 0.019 to 0.036 m³/tree in lowest DBH class (6.50-9.00) and it was between 0.230 to 0.303 m³/tree 24.00-26.50 cm diameter classes. The average DBH class wise volume ranged from 0.027 to 0.281 m³/tree under lowest (6.50-9.00 cm) and highest DBH class (24.00-26.50), respectively. Further, data indicated that as the diameter class increases mean per tree volume estimated increased gradually.

Fresh biomass (kg/tree)

Fresh biomass, estimated using regression equation, under different diameter classes expressed that it ranged from 22.98 to 39.99 kg/tree in lowest DBH class (6.50-9.00 cm) and 233.37 to 305.68 kg/tree in maximum DBH class *i.e.* 24.00-26.50 cm (Table 1). The average fresh biomass varied between 30.87 to 283.47 kg/tree in 6.50-9.00 to 24.00-26.50 cm DBH class.

Volume (m³/ha/year) and biomass (tonne/ha/year) productivity

The data (Table 1) revealed that DBH class wise volume productivity (m³/ha/year) of *M. dubia* ranged from 4.32 to 44.96 m³/ha/year in DBH class of 6.50-9.00 cm to 24.00-26.50 cm DBH class, respectively. Similarly, and fresh biomass productivity (tonne/ha/year) ranged from 4.94 to 45.36 tonne/ha/year under 6.50-9.00 and 24.00-26.50 DBH class, respectively. The overall volume and fresh biomass productivity to the tune of 22.18 m³/ha/year and 22.69 tonne/ha/year from *M. dubia* trees from the system at the age of age of 5 years.

Table 1. Diameter class wise apportioned height, volume and fresh biomass productivity of *M. dubia* under silvi- horticulture agroforestry system in South Gujarat

DBH class (cm)	Height (m)	Volume (m ³ /tree)	Fresh Biomass (kg/tree)	Volume (m ³ /ha)	Fresh biomass (tonne/ha)	Volume productivity (m ³ /ha/year)	Fresh biomass productivity (tonne/ha/year)
D1	11.03	0.027	30.87	21.60	24.70	4.32	4.94
D2	12.63	0.045	48.18	36.00	38.54	7.20	7.71
D3	14.01	0.074	76.95	59.20	61.56	11.84	12.31
D4	14.60	0.106	109.17	84.80	87.34	16.96	17.47
D5	15.00	0.142	145.62	113.60	116.50	22.72	23.30
D6	15.43	0.190	193.53	152.00	154.82	30.40	30.96
D7	16.02	0.244	246.59	195.20	197.27	39.04	39.45
D8	15.62	0.281	283.47	224.80	226.78	44.96	45.36
Mean	14.29	0.140	141.80	110.90	113.44	22.18	22.69
SD	1.59	0.090	86.66	74.37	69.33	13.91	13.87

D1: 6.50-9.00; D2: 9.00-11.50; D3: 11.50-14.00; D4: 14.00-16.50; D5: 16.50-19.00; D6: 19.00-21.50; D7: 21.50-24.00; D8: 24.00-26.50

Table 2. Diameter class wise apportioned carbon stocks and carbon sequestration of *M. dubia* under silvi- horticulture agroforestry system in South Gujarat

DBH class (cm)	Carbon stocks kg/tree	Carbon sequestration kg/tree	Carbon stocks t/ha	Carbon sequestration t/ha	Carbon stocks t/ha/year	Carbon sequestration t/ha/year
D1	7.72	28.32	6.17	22.66	1.23	4.53
D2	12.05	44.21	9.64	35.37	1.93	7.07
D3	19.24	70.60	15.39	56.48	3.08	11.30
D4	27.29	100.16	21.83	80.13	4.37	16.03
D5	36.40	133.60	29.12	106.88	5.82	21.38
D6	48.38	177.56	38.71	142.05	7.74	28.41
D7	61.65	226.25	49.32	181.00	9.86	36.20
D8	70.87	260.09	56.69	208.07	11.34	41.61
Mean	35.45	130.10	28.36	104.08	5.67	20.82
SD	23.16	85.00	18.53	68.00	3.71	13.60

D1: 6.50-9.00; D2: 9.00-11.50; D3: 11.50-14.00; D4: 14.00-16.50; D5: 16.50-19.00; D6: 19.00-21.50; D7: 21.50-24.00; D8: 24.00-26.50

Carbon stocks and carbon sequestration

The per tree carbon stock and carbon sequestration (Table 2) ranged from 7.72-70.87 and 28.32-260.09 kg, respectively from 6.50-9.00 to 24.00-26.50 cm DBH class with an average of 35.45 to 130.10 kg, respectively. On hectare basis, it was 6.17-56.69 (mean of 28.36) and 22.66-208.07 average of 104.08) t/ha carbon stock and carbon sequestration, respectively under 6.50-9.00 to 24.00-26.50 cm DBH class. Yearly (at the age of 5 years) carbon stocks amounted 1.23-11.34 and carbon sequestration rate was 4.53-41.61 t/ha/year under 6.50-9.00 to 24.00-26.50 cm DBH class, with an overall average respective values of 5.67 and 20.82 t/ha/year (Table 2).

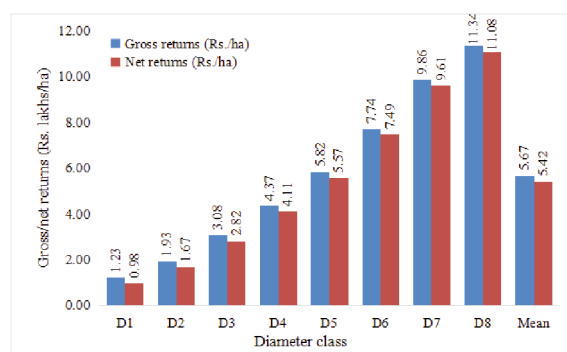


Fig. 2. Diameter class wise apportioned gross and net returns accrued on account *M. dubia* fresh biomass production under silvi- horticulture system in south Gujarat at 5-year rotation

Gross and net returns (Rs/ha)

The DBH class wise gross returns (Fig. 2) on account of *M. dubia* of fresh biomass indicated that gross

returns ranges from Rs. 1.23 lakhs/ha to Rs. 11.34 lakhs/ha from lowest DBH class D1 (6.50-9.00 cm) to maximum at D8 (24.00-26.50 cm). The DBH class wise net economic returns (Fig. 2) on account *M. dubia* of fresh biomass indicated that Rs. 0.98 lakhs/ha could be accrued from DBH class ranging from 6.50-9.00 cm and it could be maximum to the tune of Rs. 11.08 lakhs/ha from the trees having DBH range of 24.00-26.50 cm with overall return of Rs. 5.42 lakhs/ha based on 5-year rotation age. In states of Punjab, Haryana and Uttarakhand, at 3x3 m spacing (at the age of 7 years) tree height 9.67 to 16.19 m, and DBH 17.20 to 25.73 cm individual tree stem under bark volume 0.104 to 0.255 m³ and productivity 23.19 to 55.83 m³ha⁻¹year⁻¹ have been reported by Kumar *et al.* (2017). Similar, growth and productivity have also been reported by Prajapati *et al.* (2020) and Thakur *et al.* (2021, 2023b) in south Gujarat. The parameters of present study for height, DBH, volume (over bark) and productivity under 3x3 m spacing, at the age of 5 years is in full agreement of results reported in these studies. However, growth performance in present study is much superior to that reported by Chandana *et al.* (2020) for *M. dubia* planted with 5x4 m spacing. The variation in growth and productivity of tree species varies from location to location due to edapho-climatic attributes and genetic worth of material (Luna *et al.*, 2009 & 2011). Laxmi *et al.* (2021) have reported about 10 t/ha and 47 t/ha carbon stock and carbon sequestration, respectively from *M. dubia* planted at 5 × 5 m in Telangana State. The carbon sequestration rate of *M. dubia* at the age of 5 years in the present study is in agreement with the earlier findings of Kumar *et al.* (2024) and Jinger *et al.* (2025) from Karnataka and Gujarat.

4. CONCLUSION

The present study revealed that, at the age of 5 years, the average height, volume of *M. dubia* increased with increase in diameter. Individual tree produced fresh biomass ranging from 30.87 to 283.47 kg/tree in 6.50-9.00 to 24.00-26.50 cm DBH class. The volume (m³/ha/year) and fresh biomass productivity of *M. dubia* ranged from 4.32 to 44.96 m³/ha/year and 4.94 to 45.36 tonne/ha/year under 6.50-9.00 and 24.00-26.50 DBH class, respectively. The overall per hectare combined volume and biomass productivity was 22.18 m³/ha/year and 22.69 tonne/ha/year. Economic analysis indicated returns of Rs. 0.98 lakhs/ha for the 6.50–9.00 cm DBH class, increasing to Rs. 1.11 lakhs/ha for the 24.00–26.50 cm class, with an overall return of Rs. 5.42 lakhs/ha based on 5-year rotation age.

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