Carbon sequestration potential in total biomass of *Melia dubia* cav. under semi-arid region of Karnataka

Vasudev L, Raju L Chavan and GM Devagiri

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Abstract

A study was conducted to know the carbon sequestration potential in biomass of *Melia dubia* under semi-arid region of Karnataka. Plantations of 2, 4, 6 and 8 year old grown in different soil types such as black and red were selected and biometric observation were recorded at the time of start of experiment and at 12 months after start of experiment. Plantations grown in black soil recorded the higher values for carbon sequestration in above ground biomass, below grown biomass and in total biomass as compared to red soils. Among the age gradations, plantations of 8 year old recorded the higher values for biomass carbon as compared to rest of age gradations. From the results it can be concluded that black soil have higher potential to sequester higher carbon in total biomass in *Melia dubia*.

Keywords: Carbon sequestration, *Melia dubia*, wood volume, age gradation, soil types

Introduction

Indian forest is facing huge problems by the growing human population and going to be shrinking in its area due to the over exploitation to meet their demands. As a result of restrictions on felling in natural forests, fast growing, and short rotation forest plantations are emerging as a major source of raw material for Indian wood based industries. Under high density short rotation plantations, trees are grown with a rotation period less than 6 to 12 years and with high productivity at least 10 to 30 m³ ha⁻¹ yr⁻¹. There is a substantial gap (14 Million Tonnes) in the demand (55 Million Tonnes) and supply (41 Million Tonnes) of timber (TERI, 2009). So, there is a need for plantation of short rotation species, to meet out the growing demand of raw material for wood based industries. A large number of fast growing exotic as well as local species are available for this purpose, however, there, is need for selection of appropriate tree for optimizing biomass production and improving the yield of intercrops. *Melia dubia* Cav. which is an indigenous, multipurpose, fast growing and valuable timber species emerged as one of the most suitable tree species for agrisilviculture system and has the potential to sequester carbon for environmental balance. It occurs mostly in tropical moist deciduous forest of the Sikkim, Himalayas, North Bengal and Upper Assam, Khasi hills, North Circle, Deccan and the Western Ghats at an altitude of 1200 to 1800 meters. It is known to yield multi utility timber and its wood can be used as packing cases cigar boxes, pencil, match boxes, splints, and ply boards. Melia wood has huge demand in wood based industries. It is also source of firewood with the calorific value more than 5000 kcal/kg and above all these, the species is leaflessness during winter and hence incorporated in many agro forestry systems. The flowers are said to provide excellent bee forage. The tree tends to develop heavy lateral branching; therefore it is advised to prune *M. dubia* from the 1st year onwards to maintain a clean straight Bole.

Melia is very suitable for the agroforestry system. This, however, is dependent upon good Silvicultural practice in reducing the shade effect of canopies, which would otherwise adversely affect light-demanding crops during summer season. The species has been identified as a potential alternate pulpwood species (Chauhan et al., 2008) [6]. Its bark, fruits, leaves, and wood have insecticidal properties (Alche et al., 2003) [4]. This species with multifarious uses has gained only limited research attention, especially regarding potential of carbon sequestration in its total biomass.
Consequently, there is an urgent need to be increased the area under forest cover through planting of fast growing tree species like *Melia dubia*. Hence, the present study entitled “Carbon sequestration potential in total biomass of *Melia dubia* under semi-arid region of Karnataka” was conducted to know the potential of *Melia dubia* in total biomass.

**Methods and Methodology**

A field study was conducted in Hiriyur taluk of Chitradurga district of Karnataka state. *Melia dubia* plantations of different age gradations such as 2, 4, 6 and 8 year old grown by farmers on their lands (Black and red soils) were selected. The study area lies between 13°56'57” N and 76°37'13” E with an elevation at 606 m above mean sea level (MSL). The average annual rainfall for last 10 years (2008 to 2017) at the study area was 647 mm and the significant portion of the rainfall received in October (296.4 mm). During the experimental period, the rainfall received in 2018 (490.4 mm) and 2019 (788.4 mm) were lower and higher, respectively than the 10 years average annual rainfall. The mean maximum and minimum temperature in the study period was 2018 (32.3°C) and 2019 (32.5°C) as compared to 10 years mean (32.3 and 19.6°C, respectively). The annual mean relative humidity was 2018 (73.9%) and 2019 (74.7%) recorded was higher than 10 year average humidity (72.8%). Biometric observations such as tree height and dbh were measured by methods developed by Chaturvedi and Khanna (1982) and above ground biomass (AGB) below ground biomass (BGB) and total biomass (TB) was calculated and at the time of initiation and 12 months after the start of the experiments (MASE)

**Biomass estimation of tree**

Biomass of trees was estimated by following non-destructive method. Using volume and wood density of tree, above ground, below ground and total biomass were calculated.

**Aboveground biomass (AGB)**

Tree biomass was estimated by multiplying volume with the species specific wood density obtained from wood analysis and expressed in kg tree⁻¹ and Mg ha⁻¹.

\[ AGB = \text{Volume} \times \text{Wood density (gcm}^{-3}\text{ or kg m}^3\) \]

**Below ground biomass (BGB)**

The Intergovernmental Panel on Climate Change (IPCC) 2000, suggest that the below ground biomass is close to 27 per cent of the total above ground biomass and indicate that the majority of the underground biomass of the forest is contained in the heavy roots generally defined as those exceeding 2 mm in diameter. Various studies used different ratios between 0.15 to 0.30 to obtain below ground biomass from AGB, but in present study BGB is obtained by multiplying AGB with 0.27.

The BGB was calculated by using formula (IPCC, 2000) and expressed in in kg tree⁻¹ and Mg ha⁻¹.

\[ BGB = AGB \times 0.27 \]

**Total biomass (TB)**

Total biomass was obtained by adding above ground biomass and below ground biomass and expressed in kg tree⁻¹ and Mg ha⁻¹.

\[ TB = AGB + BGB \]

**Carbon sequestration (kg C tree⁻¹ and Mg C ha⁻¹)**

The amount of carbon sequestered by *Melia dubia* in above ground biomass (AGBC), and below ground biomass (BGBC) were worked out by reducing the total biomass yield to its 42 per cent as suggested by Ambily et al. (2012) and expressed in kg per tree and Mega gram per hectare.

\[ \text{AGBC} = AGB \times 0.42 \]
\[ \text{BGB} = BGB \times 0.42 \]
\[ \text{TBC} = \text{AGBC} + \text{BGB} \]

**Estimation of carbon (C) and carbon dioxide equivalent (CO₂e)**

As suggested by United Nations Framework Convention on Climate Change (UNFCCC), 1997 carbon content is calculated by using following formula

\[ \text{Carbon content (C t ha}^{-1}\) = 0.47 x Biomass weight (t dm ha}^{-1}\) \]

Where, t dm- tonne dry matter

Carbon dioxide equivalent (CO₂e) is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gases, CO₂e signifies the amount of CO₂ sequestered by trees in the form of biomass which would have the equivalent global warming impact.

Quantification of CO₂ = the quantum of carbon is converted into quantum of carbon dioxide by using the following equation (Ajay and Singh, 2003)³.

\[ \text{Quantum of CO₂} = \frac{\text{Quantum of carbon} \times 44}{12} \]

Where, 44 is the molecular weight of CO₂

12 is the atomic weight of the carbon were taken

**Results and Discussion**

There was no significant effect on biomass production in *Melia dubia* as influenced by soil types. The results revealed that, above ground biomass (AGB), below ground biomass (BGB) and total biomass (TB) kg per tree did not differ significantly due to effect of soil types (Table 1 and Table 2). The age gradation influenced on the production (kg tree⁻¹ and Mg ha⁻¹) of AGB, BGB and TB. Among the age gradations, AGB was higher in 8 year old plantation at initiation (125.024 kg tree⁻¹ and 104.145 Mg ha⁻¹) and 12 months (133.920 kg tree⁻¹ and 111.555 Mg ha⁻¹) after start of experiment. Below ground biomass was significantly higher in 8 year old plantation at initiation (33.757 kg tree⁻¹ and 28.119 Mg ha⁻¹) and at 12 months (36.158 kg tree⁻¹ and 30.120 Mg ha⁻¹) and the lowest was recorded in 2 year plantation at initiation (2.533 kg tree⁻¹ and 2.110 Mg ha⁻¹) and 12 months (5.039 kg tree⁻¹ and 4.198 Mg ha⁻¹) after start of experiment. Significant variations in total biomass accumulation were noticed due to age gradation. Higher TB was recorded in 8 year plantation at initiation (158.781 kg tree⁻¹ and 132.264 Mg ha⁻¹) and 12 months (170.078 kg tree⁻¹ and 141.675 Mg ha⁻¹) after start of experiment. Whereas, the lowest was observed in 2 year plantation at initiation (11.917 kg tree⁻¹ and 9.927 Mg ha⁻¹) and 12 months (23.704 kg tree⁻¹ and 19.745 Mg ha⁻¹) after start of experiment. The results are in accordance with the findings of Shivanna et al., (2007)⁷, ⁸ in Dalbergia sissoo and reported that the biomass yield during 8th, 16th and 24th months were 8.10, 14.75, and 24.44 tones ha⁻¹, respectively.
Dey (2005) reported the similar findings in rubber clones in north eastern regions of India.

Carbon sequestration in *M. dubia* plantations in different soil types and at different age gradations

Carbon sequestration (kg C tree\(^{-1}\) and Mg C ha\(^{-1}\)) in tree biomass as influenced by different soil types at different age gradations showed non-significant difference in above ground biomass (AGBC), below ground biomass (BGBC) and total biomass carbon (TBC) (Table 3). However, the significant difference was observed in AGBC, BGBC and TBC (kg C tree\(^{-1}\)) with respect to different age gradation. There was increase in accumulation of carbon in tree biomass as age progressed from 2 to 8 years. Among the age gradations, AGBC in 8 year plantation was higher at initiation (5.601 kg C tree\(^{-1}\)) and 12 months (6.942 kg C tree\(^{-1}\)) after start of the experiment as compared to rest of the age gradations. Whereas, the lowest was recorded in 2 year age plantation at initiation (4.410 kg C tree\(^{-1}\)) and 12 months (8.772 kg C tree\(^{-1}\)) after start of the experiment. Significantly higher AGBC was recorded in 8 year plantation at initiation (15.866 kg C tree\(^{-1}\)) and 12 months (16.994 kg C tree\(^{-1}\)). The lowest was observed in 2 year plantation at initiation (1.191 kg C tree\(^{-1}\)) and 12 months (2.569 kg C tree\(^{-1}\)). Similarly, carbon sequestration in total biomass was significantly higher in 8 year plantation at initiation (74.627 kg C tree\(^{-1}\)) and 12 months (79.937 kg C tree\(^{-1}\)) whereas lowest TBC was observed in 2 year plantation at initiation (5.601 kg C tree\(^{-1}\)) and 12 months (11.14 kg C tree\(^{-1}\)) after start of the experiment. The interaction effects of soil and age gradation were non-significant with respect to AGBC, BGBC and TBC. Results on carbon sequestration (Mg C ha\(^{-1}\)) in tree biomass as influenced by different soil types at different age gradation indicated that, there was non-significant variation on carbon sequestration in tree biomass (AGBC, BGBC and TBC per hectare) due to planting in different soil types (Table 4). The significant effect was noticed on carbon sequestration in tree biomass due to age gradation from 2 to 8 years. Among the age gradations, 8 year old plantation recorded maximum TBC (Mg C ha\(^{-1}\)) at initiation (62.164 Mg C ha\(^{-1}\)) and 12 months (66.587 Mg C ha\(^{-1}\)) after start of the experiment as compared to rest of the age gradations. While, the lowest TBC was recorded in 2 year age plantation at initiation (4.666 Mg C ha\(^{-1}\)) and 12 months (9.280 Mg C ha\(^{-1}\)) after start of the experiment. Similar trend as that of TBC was observed for AGBC and BGBC (Mg C ha\(^{-1}\)). Increases in TBC per tree as well as per ha are mainly due to increase in age that contributed more biomass. The interaction of soil types and age gradation on AGBC and BGBC and TBC (Mg C ha\(^{-1}\)) did not differ significantly. Variations in biomass attributed to the increase in age that improves the soil fertility through addition of litter over time. In Leucaena based agriavliculture systems, 0.87 t C ha\(^{-1}\)-yr\(^{-1}\) carbon sequestration which ranged from 0.87 to 8.92 t C ha\(^{-1}\) yr\(^{-1}\) (Mittal and Singh, 1989). There are several other studies which had focused on assessment of carbon sequestration potential of different agroforestry species some important estimates includes 1.36 t C ha\(^{-1}\) yr\(^{-1}\) in Anogeissus based systems (Rai et al., 2002), 1.45 t C ha\(^{-1}\) yr\(^{-1}\) in Casuarina based systems (Vishwanath et al., 2004), 2.47 t C ha\(^{-1}\) yr\(^{-1}\) in Gmelina based systems (Swamy and Puri, 2005), 3.5 t C ha\(^{-1}\) yr\(^{-1}\) in Albizia based system; 2.06 t C ha\(^{-1}\) yr\(^{-1}\) in Poplar based systems (Yadav, 2010) and Amla based agrihorticulture system has been estimated to sequester 0.73 t C ha\(^{-1}\) yr\(^{-1}\) (Ajit et al., 2011).

### Table 1: Biomass (kg tree\(^{-1}\)) production in *Melia dubia* in different soil types and age gradation

| Treatments | Parameters/Intervals | Above ground biomass (kg tree\(^{-1}\)) | Below ground biomass (kg tree\(^{-1}\)) | Total biomass (kg tree\(^{-1}\)) |
|------------|----------------------|----------------------------------------|----------------------------------------|-------------------------------|
|            |                      | Initial | 12 MASE | Initial | 12 MASE | Initial | 12 MASE |
| Soil type  |                      |         |         |         |         |         |         |
| Black      |                      | 65.281  | 79.390  | 17.626  | 21.435  | 82.906  | 100.825 |
| Red        |                      | 58.923  | 75.030  | 15.909  | 20.258  | 74.832  | 95.288  |
| S. Em×     |                      | 2.386   | 3.044   | 0.644   | 0.822   | 3.030   | 3.865   |
| CD @ 5%    |                      | NS      | NS      | NS      | NS      | NS      | NS      |
| Age gradation (Years) |          |         |         |         |         |         |         |
| 2          |                      | 9.383   | 18.664  | 2.533   | 5.039   | 11.917  | 23.704  |
| 4          |                      | 30.480  | 48.413  | 8.230   | 13.071  | 38.710  | 61.484  |
| 6          |                      | 82.973  | 107.843 | 22.403  | 29.118  | 105.376 | 136.961 |
| 8          |                      | 125.024 | 133.920 | 33.757  | 36.158  | 158.781 | 170.078 |
| S. Em×     |                      | 3.375   | 4.304   | 0.911   | 1.162   | 4.286   | 5.467   |
| CD @ 5%    |                      | 9.849   | 12.563  | 2.659   | 3.392   | 12.509  | 15.956  |
| Soil type × Age gradation |      |         |         |         |         |         |         |
| Black × 2  |                      | 10.796  | 19.923  | 2.915   | 5.379   | 13.711  | 25.302  |
| Black × 4  |                      | 31.267  | 49.305  | 8.442   | 13.312  | 39.709  | 62.617  |
| Black × 6  |                      | 91.039  | 115.569 | 24.581  | 31.204  | 115.620 | 146.772 |
| Black × 8  |                      | 128.024 | 132.763 | 34.566  | 35.846  | 162.586 | 168.609 |
| Red × 2    |                      | 7.971   | 17.406  | 2.152   | 4.700   | 10.123  | 22.106  |
| Red × 4    |                      | 26.552  | 47.521  | 7.169   | 12.831  | 33.721  | 60.351  |
| Red × 6    |                      | 74.908  | 100.117 | 20.225  | 27.032  | 95.133  | 127.149 |
| Red × 8    |                      | 122.027 | 135.076 | 32.947  | 36.471  | 154.975 | 171.547 |
| S. Em×     |                      | 4.772   | 6.087   | 1.289   | 1.644   | 6.061   | 7.731   |
| CD @ 5%    |                      | NS      | NS      | NS      | NS      | NS      | NS      |

Note: MASE = Months after Start of Experiment; NS = Non-significant

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Table 2: Biomass (Mg ha\(^{-1}\)) production in *Melia dubia* in different soil types at different gradation

| Soil type | Above ground biomass (Mg ha\(^{-1}\)) | Below ground biomass (Mg ha\(^{-1}\)) | Total biomass (Mg ha\(^{-1}\)) |
|-----------|--------------------------------------|--------------------------------------|--------------------------------|
|           | Initial | 12 MASE | Initial | 12 MASE | Initial | 12 MASE | Initial | 12 MASE |
| Black     | 54.379  | 66.132  | 14.682  | 17.856  | 69.061  | 83.987  |
| Red       | 49.083  | 62.500  | 13.252  | 16.875  | 62.335  | 79.375  |
| S.Em±     | 1.988   | 2.536   | 0.537   | 0.685   | 2.524   | 5.220   |
| CD @ 5%   | NS      | NS      | NS      | NS      | NS      | NS      |

Age gradation (Years)

| Age gradation (Years) | Black × 2 | Black × 4 | Black × 6 | Black × 8 | Red × 2 | Red × 4 | Red × 6 | Red × 8 | S.Em± | CD @ 5% |
|-----------------------|-----------|-----------|-----------|-----------|---------|---------|---------|---------|-------|---------|
| 2                     | 7.816     | 15.548    | 2.110     | 4.198     | 9.927   | 19.745  |
| 4                     | 25.398    | 40.328    | 6.855     | 10.889    | 32.245  | 51.217  |
| 6                     | 69.117    | 89.833    | 18.662    | 24.585    | 87.778  | 114.088 |
| 8                     | 104.145   | 111.555   | 28.119    | 30.120    | 132.264 | 141.675 |
| S.Em±                | 2.811     | 3.586     | 0.759     | 0.968     | 3.570   | 4.554   |
| CD @ 5%               | 8.205     | 10.466    | 2.215     | 2.826     | 10.420  | 13.291  |

Table 3: Carbon sequestration (kg C tree\(^{-1}\)) potential of *Melia dubia* in different soil types at different age gradation

| Soil type | Above ground biomass carbon (kg C tree\(^{-1}\)) | Below ground biomass carbon (kg C tree\(^{-1}\)) | Total biomass carbon (kg C tree\(^{-1}\)) |
|-----------|-----------------------------------------------|-----------------------------------------------|------------------------------------------|
|           | Initial | 12 MASE | Initial | 12 MASE | Initial | 12 MASE | Initial | 12 MASE |
| Black     | 30.682  | 37.313  | 8.284   | 10.075  | 38.966  | 47.388  |
| Red       | 27.694  | 35.264  | 7.477   | 9.521   | 35.171  | 44.785  |
| S.Em±     | 1.122   | 1.431   | 0.303   | 0.386   | 1.424   | 1.817   |
| CD @ 5%   | NS      | NS      | NS      | NS      | NS      | NS      |

Age gradation (Years)

| Age gradation (Years) | Black × 2 | Black × 4 | Black × 6 | Black × 8 | Red × 2 | Red × 4 | Red × 6 | Red × 8 | S.Em± | CD @ 5% |
|-----------------------|-----------|-----------|-----------|-----------|---------|---------|---------|---------|-------|---------|
| 2                     | 4.410     | 8.772    | 1.191     | 2.369     | 5.601   | 11.141  |
| 4                     | 14.328    | 22.754   | 3.868     | 6.144     | 18.194  | 28.898  |
| 6                     | 39.998    | 50.686   | 10.529    | 13.685    | 49.527  | 64.372  |
| 8                     | 38.761    | 62.942   | 16.866    | 16.994    | 74.627  | 79.937  |
| S.Em±                | 1.586     | 2.023    | 0.428     | 0.546     | 2.014   | 2.569   |
| CD @ 5%               | 4.629     | 5.905    | 1.258     | 1.594     | 5.879   | 7.499   |

Table 4: Carbon sequestration (Mg C ha\(^{-1}\)) potential of *Melia dubia* in different soil types at different age gradation

| Soil type | Above ground biomass carbon (Mg ha\(^{-1}\)) | Below ground biomass carbon (Mg ha\(^{-1}\)) | Total biomass carbon (Mg ha\(^{-1}\)) |
|-----------|-----------------------------------------------|-----------------------------------------------|------------------------------------------|
|           | Initial | 12 MASE | Initial | 12 MASE | Initial | 12 MASE | Initial | 12 MASE |
| Black     | 25.558  | 31.082  | 6.901   | 8.392   | 32.459  | 39.474  |
| Red       | 23.069  | 29.375  | 6.229   | 7.931   | 29.298  | 37.306  |
| S.Em±     | 0.934   | 1.192   | 0.252   | 0.322   | 1.186   | 1.513   |
| SEd       | 1.321   | 1.685   | 0.357   | 0.455   | 1.678   | 2.140   |
| CD @ 5%   | NS      | NS      | NS      | NS      | NS      | NS      |

Note: MASE = Months after Start of Experiment; NS = Non-significant

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### Table 1

| Age gradation (Years) | 2  | 4  | 6  | 8  | 10 | 12 |
|-----------------------|----|----|----|----|----|----|
| Black × 2             | 4.227 | 7.800 | 1.141 | 2.106 | 5.368 | 9.906 |
| Black × 4             | 12.241 | 19.303 | 3.305 | 5.212 | 15.547 | 24.515 |
| Black × 6             | 35.643 | 45.246 | 9.624 | 12.217 | 45.266 | 57.463 |
| Black × 8             | 50.121 | 51.978 | 13.533 | 14.034 | 63.654 | 66.012 |
| Red × 2               | 3.121 | 6.815 | 0.843 | 1.840 | 3.963 | 8.655 |
| Red × 4               | 10.395 | 18.605 | 2.807 | 5.023 | 13.202 | 23.628 |
| Red × 6               | 29.327 | 39.197 | 7.918 | 10.583 | 37.245 | 49.780 |
| Red × 8               | 47.775 | 52.884 | 12.899 | 14.279 | 60.674 | 67.162 |
| S.Emx                 | 1.321 | 1.685 | 0.357 | 0.455 | 1.678 | 2.140 |
| CD @ 5%               | 3.856 | 4.919 | 1.041 | 1.328 | 4.897 | 6.247 |

### Soil type × Age gradation

| Soil type | Age gradation |
|-----------|---------------|
| Black × 2 | 4.227 | 7.800 | 1.141 | 2.106 | 5.368 | 9.906 |
| Black × 4 | 12.241 | 19.303 | 3.305 | 5.212 | 15.547 | 24.515 |
| Black × 6 | 35.643 | 45.246 | 9.624 | 12.217 | 45.266 | 57.463 |
| Black × 8 | 50.121 | 51.978 | 13.533 | 14.034 | 63.654 | 66.012 |
| Red × 2   | 3.121 | 6.815 | 0.843 | 1.840 | 3.963 | 8.655 |
| Red × 4   | 10.395 | 18.605 | 2.807 | 5.023 | 13.202 | 23.628 |
| Red × 6   | 29.327 | 39.197 | 7.918 | 10.583 | 37.245 | 49.780 |
| Red × 8   | 47.775 | 52.884 | 12.899 | 14.279 | 60.674 | 67.162 |
| S.Emx     | 1.321 | 1.685 | 0.357 | 0.455 | 1.678 | 2.140 |
| CD @ 5%   | 3.856 | 4.919 | 1.041 | 1.328 | 4.897 | 6.247 |

**Note:** MASE = Months after Start of Experiment; NS = Non-significant

### Conclusion

Biomass production (kg tree⁻¹ and Mg ha⁻¹) and above ground biomass carbon (kg C tree⁻¹ and Mg C ha⁻¹) was found to be higher in black soil with 8 year old plantation at both initial and 12 month after start of the experiment. Overall, biomass increased with tree age from 2 years in both soil types. However, higher amount of growth was noticed in black soil indicating that better suitability of this species for black soils. Biomass per tree and per hectare increased as the age progressed in different soil types. At 12 months after start of experiment (MASE) tree height increased at the rate of 11 and 10 Per cent, volume per tree 28 and 21 per cent, volume per hectare at the rate of 28 and 22 per cent in red and black soil, respectively. These results indicate that, though the overall growth and yield was high in black soils, but the rate of increment was higher in red soil compared to black soil.

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