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

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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 m^3 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 = Volume x Wood density (gcc^{-1} 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 x 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.

AGBC =AGB x 0.42
BGBC =BGBC x 0.42
TBC =AGBC + BGBC

Estimation of carbon (C) and carbon dioxide equivalent (CO_2e)

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

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

Where, t dm- tonne dry matter

Carbon dioxide equivalent (CO_2e) is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gases, CO_2e signifies the amount of CO_2 sequestered by trees in the form of biomass which would have the equivalent global warming impact.

Quantification of CO_2 = the quantum of carbon is converted into quantum of carbon dioxide by using the following equation (Ajay and Singh, 2003) [2].

$$\text{Quantum of } CO_2 = \frac{\text{Quantum of carbon} \times 44}{12}$$

Where, 44 is the molecular weight of CO_2
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} 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) [9] 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 (58.761 kg C tree$^{–1}$) and 12 months (62.942 kg C tree$^{–1}$) after start of the experiment as compared to rest of age gradation. 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 BGBC 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 (2.369 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 agrisilviculture 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) [11]; 1.45 t C ha$^{–1}$ yr$^{–1}$in Casuarina based systems (Vishwanath *et al*., 2004) [14]; 2.47 t C ha$^{–1}$ yr$^{–1}$in Gmelina based systems (Swamy and Puri, 2005) [12]; 3.5 t C ha$^{–1}$ year$^{–1}$in Albizia based system; 2.06 t C ha$^{–1}$ yr$^{–1}$ in Poplar based systems (Yadav, 2010) [13] and Amla based agrihorticulture system has been estimated to sequester 0.73 t C ha$^{–1}$ yr$^{–1}$ (Ajit *et al*., 2011) [3]. A study on *Pongamia pinnata* seedlings at different growth intervals noticed that, the biomass yield and carbon sequestration were 4.23, 2.11, 8.06 and 4.03, 12.40, 6.20 tonnes of carbon per ha at 8th, 16th and 24th months respectively (Shivanna *et al*., 2008) [7, 8].

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

Parameters/ Intervals / Treatments	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	128.021	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

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

Treatments \ Parameters/Intervals	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**
Soil type						
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	3.220
CD @ 5%	NS	NS	NS	NS	NS	NS
Age gradation (Years)						
2	7.816	15.548	2.110	4.198	9.927	19.745
4	25.390	40.328	6.855	10.889	32.245	51.217
6	69.117	89.833	18.662	24.255	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
Soil type ×Age gradation						
Black × 2	8.993	16.596	2.428	4.481	11.421	21.077
Black × 4	26.045	41.071	7.032	11.089	33.078	52.160
Black × 6	75.836	96.269	20.476	25.993	96.311	122.261
Black × 8	106.641	110.592	28.793	29.860	135.435	140.451
Red × 2	6.640	14.499	1.793	3.915	8.432	18.414
Red × 4	22.118	39.585	5.972	10.688	28.090	50.273
Red × 6	62.398	83.398	16.847	22.517	79.246	105.915
Red × 8	101.649	112.518	27.445	30.380	129.094	142.898
S.Em±	3.975	5.071	1.073	1.369	5.049	6.440
CD @ 5%	NS	NS	NS	NS	NS	NS

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

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

Treatments \ Parameters/Intervals	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**
Soil type						
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)						
2	4.410	8.772	1.191	2.369	5.601	11.141
4	14.326	22.754	3.868	6.144	18.194	28.898
6	38.998	50.686	10.529	13.685	49.527	64.372
8	58.761	62.942	15.866	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	1.250	1.594	5.879	7.499
Soil type ×Age gradation						
Black × 2	5.074	9.364	1.370	2.528	6.444	11.892
Black × 4	14.696	23.173	3.968	6.257	18.663	29.430
Black × 6	42.788	54.317	11.553	14.666	54.341	68.983
Black × 8	60.170	62.399	16.246	16.848	76.416	79.246
Red × 2	3.746	8.181	1.011	2.209	4.758	10.390
Red × 4	12.479	22.335	3.369	6.030	15.849	28.365
Red × 6	35.207	47.055	9.506	12.705	44.712	59.760
Red × 8	57.353	63.486	15.485	17.141	72.838	80.627
S.Em±	2.243	2.861	0.606	0.773	2.849	3.634
CD @ 5%	NS	NS	NS	NS	NS	NS

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

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

Treatments \ Parameters/Intervals	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**
Soil type						
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

Age gradation (Years)						
2	3.674	7.307	0.992	1.973	4.666	9.280
4	11.933	18.954	3.222	5.118	15.155	24.072
6	32.485	42.222	8.771	11.400	41.256	53.621
8	48.948	52.431	13.216	14.156	62.164	66.587
S.Em±	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						
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.Em±	1.868	2.383	0.504	0.643	2.373	3.027
CD @ 5%	NS	NS	NS	NS	NS	NS

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 to 8 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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