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Evaluation of Melia Dubia for its Biomass Production, Carbon Stock, Carbon Sequestration and Economic Returns in Agroforestry System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out to estimate biomass production, carbon stock, carbon sequestration and economic performance of Melia dubia under agri-silviculture system. This experiment was laid out in a Split design and replicated thrice, treatments comprised of two main plots (Clones) M I MTP-I M II MTP-II and seven subplots(Intercrops) T 1 Finger millet , T 2 Foxtail millet, T 3 Pearl millet, T 4 Greengram, T 5 Blackgram, T 6 Cowpea, T 7 Only trees. Sole crop without trees are maintained. Results showed that MTP-I clone recorded higher volume, biomass production, carbon stock, carbon dioxide sequestration in agri-silviculture system when compared to MTP-II and sole crop. In terms of income wise MTP-I recorded higher gross returns, net returns and B:C ratio than MTP-II. Incase of intercrops, blackgram registered higher net returns and B:C ratio than other intercrops.

Keywords: Agroforestry; tree parameters; carbon stock; carbon sequestration; economic returns.

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1. INTRODUCTION

Agroforestry is a land use option that increases livelihood security and reduces vulnerability to climate and environmental change. Agroforestry systems play a great role in the conservation of natural resources especially soil. The soils are protected from wind and water induced erosion. The adverse effects of temperature and wind on soil fertility, soil flora and fauna are ameliorated by agroforestry system [1]. An important environmental concern in the recent past is climate change that has attracted the world's attention towards the role of agroforestry in increasing the carbon sink and maintaining CO2 concentration in the atmosphere [2]. At present, agroforestry is a pertinent and efficient land-use system for dryland site improvement and also for optimization of productivity of agricultural crops as well as forest crops [3]. Here we study to what extent agroforestry mitigates and affects climate change. The primary greenhouse gases associated with agriculture are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N20). Although carbon dioxide is the most prevalent greenhouse gas in the atmosphere, nitrous oxide and methane have longer durations in the atmosphere and absorb more long-wave radiation. Hence the role of trees in carbon sequestration and climatic change mitigation is significant. The major consequences of agricultural intensification are a transfer of carbon (C) to the atmosphere in the form of carbon dioxide (CO2), thereby reducing ecosystem C pools. Agriculture contributes 10–12% of the total global anthropogenic greenhouse gas emissions. To meet the challenges of global climate change, greenhouse-gas emissions must be reduced. In the present scenario of enhanced atmospheric carbon dioxide coupled with rise in temperature, it is essential to have accurate and realistic estimates of carbon stocks in various agroforestry trees for determining their role in mitigating global warming and climate change.

Melia dubia, commonly called Malabar neem, belongs to the family Meliaceae. It is a fast growing short rotation multipurpose tree, fast-growing, deciduous tree with stout, straight, tall bole and wide-spreading branches, and suitable for agroforestry valued for its high-quality termite and fungus resistant timber. [4]. It can be used for in agricultural implements, house construction, pulp making and leaf used as a fodder [5].

Considering the above points, the present study was conducted with the primary objective of climate change mitigation and secondary benefits of increased farm income. The study estimates biomass production, carbon stock, CO2 sequestration and economics of agri-silviculture system.

2. MATERIALS AND METHODS

A field experiment entitled "Evaluation of Melia dubia for its Biomass production, carbon stock, carbon sequestration and economic returns in Agroforestry system was conducted during kharif season, 2018 at Agroforestry research block, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The experimental soil was sandy loam texture with pH(6.82), EC(0.153 dS m -1) and OC (0.41 %). The soil was medium in available nitrogen (287.2kg ha -1), high in phosphorus (37.5 kg ha -1) and medium in available potassium (252.7 kg ha -1). This experiment was laid out in a Split design and replicated thrice treatments comprised of two main plots (Clones) M I MTP-I M II MTP-II and seven subplots(Intercrops) T 1 Finger millet , T 2 Foxtail millet, T 3 Pearl millet, T 4 Greengram, T 5 Blackgram, T 6 Cowpea, T 7 Only trees. Sole crop without trees are maintained. M. dubia was planted at a spacing of 5 m × 5 m with 400 trees/ha. No special management practices were followed for M. dubia, except application of organic manure and fertilizers during the first year of plantation and pruning during later stages. The height of all the trees in each plot was measured using a measuring tape fixed on a straight wooden stick from the ground level to the tip of the main branch. Girth at breast height (GBH) was measured at 1.37 m from the ground level over the bark with the help of measuring tape [6]. Canopy spread was measured in East-West and North-South direction by placing four straight wooden poles at last shoot tip of the tree with measuring tape and the mean value was calculated [7].

The following formula was used for calculating the standing volume of trees [8]

Volume (m3) = π (D/2)2 × H,

where π = 3.14,

D is the diameter at breast height (DBH; m), i.e. one-third of GBH, and H is the height of the tree (m).

Non-destructive method of biomass estimation was carried out using volume (tree height, DBH) and wood density. Wood density of 2-yr-old M. dubia trees is 450.70 kg m–3 [9].

Above-ground biomass (AGB; kg tree–1) = Volume (m3) × wood density (kg m–3).

Below-ground biomass (BGB) of the tree includes live root biomass, excluding fine roots and was calculated using 0.26 factor of root: shoot ratio BGB (kg tree–1) = AGB (kg tree–1) × 0.26. Sum of AGB and BGB gives total biomass (TB) of the tree [10-11] TB (kg tree–1) = AGB (kg tree–1) + BGB (kg tree–1).

A literature search revealed that carbon concentration in stem wood of M. dubia was 50% of the standing biomass [12-13]. Therefore, carbon storage in stem wood of M. dubia was computed by fraction of biomass.

C (t ha–1) = 0.50 × TB (t ha–1),

where C is the carbon stock and TB is the total dry biomass. The CO2 equivalents (quantity of C × 44/12) were arrived from carbon stocks for calculating CO2 sequestration (t ha–1) by biomass of M. dubia trees in agri silviculture system.

3. RESULTS AND DISCUSSION

Table 1 lists height of the tree, DBH, canopy spread. The results indicate that significant difference was observed in tree height of Melia dubia clones. Between the two clones, MTP-I has recorded significantly higher initial (7.71m) and final (7.91m) tree height compared to MTP-II. This might be due to the better growth habit of MTP-I when compared to MTP-II. In case of intercropping system, tree height of Melia clones was found non significant when compared to only trees. This shows that tree height was not significantly influenced by various intercrops. There was significant difference in DBH was observed between the clones. Higher DBH was recorded with MTP-I (7.4 , 8.5 cm) compared to MTP-II (6.9,7.4 cm) initial and final readings. This might be due to the fast growth habit of the MTP-I as compared to MTP-II. Significant difference was not observed in DBH before and harvest of intercrops. This might be due to the intercrops taken were short duration crops. Results revealed that higher DBH was with sole tree at harvest of intercrops. It might be due to the less competition for resources. Similar results were obtained by Pradeep et al. [14].

There was no significant difference was observed in canopy spread between two clones. However, MTP-I has recorded slightly higher initial and final canopy spread in N-S(3.08, 3.50) and E-W(3.12, 3.49) direction than the MTP-II. The canopy spread is more towards the E-W direction compared to the N-S direction both at initial and final stages. No significant difference was observed among the intercrops in relation to canopy spread of tree. Interaction effect on tree height, DBH, canopy spread was found non significant.

Table 2 shows the volume, AGB, BGB, TB. Results revealed that Volume of the tree at harvest of intercrop was found significant. Higher volume is recorded with MTP-I (0.045 m3) followed by MTP-II (0.032 m3). Higher tree height, DBH of the tree and better translocation of photosynthates to cambium region attributed to the increased volume of tree at harvest. Significant difference was not observed among the tree in intercrops. However higher volume is recorded with the only trees (0.042 m3) followed by the greengram (0.041 m3) as an intercrop. Interaction effect was found non significant. Biomass of the tree varied significantly between the clones. The higher biomass was recorded with the MTP-I (25.55 t ha-1) than MTP-II (18.17 t ha-1). Higher volume and higher DBH of the clone I attributed to the increased biomass of the tree. AGB, BGB were also higher for MTP- I clone compared to MTP-II. There was no significant difference was observed among the intercrops, but slightly higher biomass was recorded with only trees. Interaction effect was found non significant.

The variation in the productivity of trees is mainly depends on the genotype of the species. In addition, the species grows in different climatic conditions which ultimately reflect on species performance, hence, environment also has significant influence on the productivity. In the present study also there is variation in the girth, height and volume of the species which could be due to the competition for limiting factors such as moisture, light and nutrients [15].

Table 3 provides results on carbon stock, carbon sequestration potential of 2-year old Melia dubia tree under agri silvisystem. Above ground carbon recorded higher in MTP-I 10.14 than MTP-II 7.21. total carbon was also higher in MTP-I 12.77, MTP-II 9.08. The total carbon sequestered by agri-silviculture system under rainfed conditions ranged from 46.85, 33.31 t ha–1. Higher amount

Table 1. Tree parameters as influenced by the *Melia dubia* based Agri-silvi system

	Tree height(m)		DBH (cm)		Canopy spread(m)			
	Initial	Final	Initial	Final	Initial		Final	
Main plots(clones)					N.S	E.W	N.S	E.W
MTP1	7.71	7.60	7.41	8.5	3.08	3.12	3.50	3.49
MTP2	6.62	7.15	6.9	7.4	**2.27**	2.99	3.06	3.46
SEd	0.14	0.17	0.012	0.22	0.19	0.21	0.17	0.15
CD(5%)	0.29	0.35	0.08	1.06	NS	NS	NS	NS
Sub plots (Intercrops)								
T1-Finger millet	7.10	7.55	6.6	7.8	2.80	2.75	3.08	3.03
T2-Foxtail millet	6.94	7.36	6.7	7.8	2.86	3.18	3.18	3.53
T3-Pearl millet	6.33	6.83	6.8	7.7	2.88	3.00	3.33	3.41
T4-Greengram	7.25	7.65	7.8	8.0	3.36	3.25	3.63	3.86
T5-Blackgram	7.00	7.61	7.4	8.0	2.91	3.08	3.38	3.55
T6- Cowpea	6.76	7.36	7.1	8.1	2.46	3.00	2.91	3.43
T7 – Only trees	6.76	7.25	7.7	8.4	3.00	3.11	3.41	3.50
SEd	0.44	0.46	0.2	0.22	0.40	0.43	0.40	0.41
CD(5%)	NS	NS	NS	NS	NS	NS	NS	NS
Interaction effect								
SEd MxS	0.62	0.65	0.32	0.34	0.57	0.61	0.57	0.59
CD(5%)	NS	NS	NS	NS	NS	NS	NS	NS
SEd SxM	0.58	0.64	0.33	0.39	0.56	0.61	0.55	0.57
CD(5%)	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Volume(m^3) and biomass of the tree at harvest of intercrops influenced by the Agri-silvi system

	Volume (m^3)	AGM (t/ha)	BGM (t/ha)	TB (t/ha)
Main plots (clones)				
MTP I	0.045	20.29	5.27	25.55
MTP II	0.032	14.42	3.74	18.17
SEd	0.002	2.32	0.2	2.62
CD(5%)	0.01	5.06	NS	5.28
Sub plots (Intercrops)				
T1-Finger millet	0.037	16.68	4.33	21.01
T2-Foxtail millet	0.036	16.22	4.21	20.43
T3-Pearl millet	0.034	15.32	3.98	19.30
T4-Greengram	0.041	18.47	4.80	23.28
T5-Blackgram	0.039	17.57	4.57	22.14
T6- Cowpea	0.039	17.78	4.57	22.14
T7 – Only trees	0.042	18.92	4.92	23.85
SEd	0.003	2.02	0.93	2.67
CD(5%)	NS	NS	NS	NS
Interaction effect				
SEd MxS	0.005	2.76	0.71	1.23
CD(5%)	NS	NS	NS	NS
SEd SxM	0.005	2.24	0.92	1.21
CD(5%)	NS	NS	NS	NS

Table 3. Carbon stock and carbon sequestration of M. dubia in agri-silviculture system

Treatments	Carbon stock (t/ha)			Carbon sequestration (t/ha)		
	Above ground	Below ground	Total	Above ground	Below ground	Total
Main plots (clones)						
MTP I	10.14	2.63	12.77	37.18	9.66	46.85
MTP II	7.21	1.87	9.08	26.44	6.87	33.31
Sub plots (Intercrops)						
T1-Finger millet	8.33	2.16	10.50	30.57	7.94	38.52
T2-Foxtail millet	8.11	2.10	10.22	29.74	7.73	37.48
T3-Pearl millet	7.66	1.99	9.65	28.09	7.30	35.39
T4-Greengram	9.23	2.40	11.64	33.87	8.80	42.68
T5-Blackgram	8.78	2.28	11.07	32.22	8.37	40.60
T6- Cowpea	8.78	2.28	11.07	32.22	8.37	40.60
T7 – Only trees	9.46	2.46	11.92	34.70	9.02	43.72

Table 4. Cost of cultivation (₹ha^{-1}), gross returns (₹ha^{-1}), net returns (₹ ha^{-1}) of tree and intercrops as influenced by the *Melia* based Agri-silvi system

	Tree			INTERCROP		
	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})
Main plots						
MTP-I	16000	24091	8091	6486	11549	5990
MTP-II	16000	17461	1461	6486	13270	7711
Sub plots						
T1-Finger millet	16000	20155	4155	6960	16065	9105
T2-Foxtail millet	16000	19355	3355	5349	13109	7760
T3-Pearl millet	16000	18350	2350	6873	11997	5124
T4-Greengram	16000	22250	6250	6764	15400	8636
T5-Blackgram	16000	21200	5200	6764	18764	11999
T6- Cowpea	16000	21080	5080	6204	11536	5332
T7 – Only trees	16000	23045	7045	0	0	0

Table 5. Cost of cultivation(₹ ha^{-1}), gross returns(₹ ha^{-1}), net returns(₹ ha^{-1}), B:C ratio of Tree+ intercrops as influenced by *Melia dubia* based Agroforestry system

	Cost of cultivation (₹ ha^{-1})	Gross returns(₹ ha^{-1})	Net returns(₹ ha^{-1})	BC ratio
Main plots				
MTP-I	21559	35641	14081	1.6
MTP-II	21559	30732	9172	1.4
Sub plots				
T1-Finger millet	22960	36220	13260	1.6
T2-Foxtail millet	21349	32464	11114	1.5
T3-Pearl millet	22873	30347	7473	1.3
T4-Greengram	22764	37650	14886	1.6
T5-Blackgram	22764	39960	17199	1.7
T6- Cowpea	22204	32616	10412	1.5
T7 – Only trees	16000	23045	7045	1.4

of carbon stock and carbon sequestration in the MTP-I clone is might be due to the higher biomass production in the MTP-I than MTP-II. The plantations of fast growing, short rotation woody crops like Melia dubia gained more importance in Carbon sequestration besides providing income from wood products.

Data pertaining to economics of intercrops as influenced by the Agri-silvi system is presented in the Table 4 and 5. Growing of intercrops under the Melia dubia clones progressively increased the gross returns and net returns and B:C ratio of Agri- silvi system. Higher gross returns were recorded with MTP-I (35641 Rs ha-1) followed by the MTP-II (30732 Rs ha-1). Higher tree parameters like height and DBH in the MTP-I, which resulted in the higher monetary returns and B:C ratio, when compared to MTP-II. Among the intercrops, higher gross returns were obtained with blackgram (39960 Rs ha-1) followed by the greengram (37650 Rs ha-1) , finger millet, (36220 Rs ha-1). The higher net returns and BC ratio were obtained with the MTP-I(14081 Rs ha1 ,1.6) followed by MTP-II (9172 Rs ha-1, 1.4). Among the intercrops, higher net returns and B:C ratio were observed with blackgram (17199 Rs ha-1 ,1.7) followed by greengram (14886 Rs ha-1 , 1.6), finger millet (13260 Rs ha-1 1.6). The higher net returns in blackgram and greengram was due to higher market price when compared to millets.

4. CONCLUSION

Improved monetary returns from the system (tree + crop) are mainly due to additional advantage of value-added products from the tree in the form of timber, plywood and fodder coupled with better performance of pulses and millets . This clearly shows that arable crops like pulses and millets when grown as an intercrops with the trees exhibit compatibility with the trees in mutual sharing of the natural resources available. Agroforestry practices may fetch higher returns when compared to sole crops [16]. Agroforestry mitigates climate change through carbon sequestration. Growing of trees only for carbon is not a feasible choice for farmers in the irrigated agroecosystem, but the carbon market is gearing up in the present and demand is yet to increase in the near future, creating additional revenue in terms of carbon trading. The present study highlights, Melia dubia agri-silvi system as a better option than the sole agricultural cropping, not only for climate mitigation but also for sustainable productivity. Hence, it is required to proceed with the system; otherwise the profit gained in-terms of carbon sequestration in the system would revert to the original state

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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