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Development of Suitable Melia dubia based Agroforestry Models for Higher Productivity

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Experiments were conducted to develop suitable *Melia dubia* based agroforestry models for higher productivity in Tamil Nadu. Greengram, blackgram, cowpea, bhendi, small onion, groundnut, sesame, brinjal and chillies were intercropped in 10 months old *Melia dubia*. Results revealed that the growth and yield of annual crops were found to be reduced under intercrop compared to pure crop, while the volume of trees improved when planted along with intercrops. Among the crops, blackgram (760 kg ha^{-1}) was the most affected and brinjal (8700 kg ha^{-1}) was the least affected. Growth of *M. dubia* was also found to be influenced due to intercropping; the lowest in seasame (11.56 m^3 ha^{-1}) and the highest in blackgram (19.63 m^3 ha^{-1}). However, the benefit: cost ratio was the highest for brinjal (4.30:1) and the lowest for small onion (2.10:1) due to the higher productivity in brinjal.

Key words: Agroforestry models, Intercropping, *Melia dubia*, Yield

In India, the current production of raw material for pulp and paper is 2.76 million tonnes, against the demand of 5.04 million tonnes with a shortfall of 45 % (Palsaniya *et al*., 2009). Inadequate raw materials and stringent forest policies have forced the wood based industries to become self-reliant in acquiring their own raw materials. Hence, the paper industries have established farm and agroforestry plantations through contract farming. *Eucalyptus* spp and *Casuarina* spp are the major tree species used as raw material for pulp and paper. However, poor productivity and increase of pests and diseases are the constrains in these two tree species (Parthiban *et al*., 2009). *Melia dubia* has emerged as an alternative raw material species for the pulp and paper industries due to its increased pulp recovery and exceptional paper strength.

In block plantations of Melia, intercrops can be raised successfully for the initial few years based on the canopy coverage and closure. Identification of suitable intercrops for such block plantations is an important need for popularizing Melia based agroforestry system. The viability of an agroforestry system would be validated only if both the tree and intercrop components are complementary with each other (Jose, 2011). As Melia has cylindrical and straight bole, there is a vast scope for vertical increase by introducing intercrops in the *M. dubia* plantations. Hence, an attempt has been made to explore the prospects of growing intercrops with *M. dubia* to boost farm income under long-term sustainable agroforestry system.

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Materials and Methods

The experiment was conducted during 2010-11 at Forest College and Research Institute, Mettupalayam, Tamilnadu, India (11° 19' and 11°20' N, 76°56' and 76°57' E). The mean annual rainfall at the site is 856 mm, received invariably during North East monsoon (October – November). The soil belongs to Inceptisol (*Typic Ustropept*), sandy loam in texture, non-calcareous, neutral in reaction, non-saline and low in organic carbon.

The treatments were fixed in 10 month old *M. dubia* plantation. Three pulse crops *viz.,* blackgram (*Vigna mungo;* var.CO5), greengram (*V. radiata*; var. CO6), cowpea (*V. unguiculata*; var. CO7); two oilseed crops *viz.,* groundnut (*Arachis hypogaea*; var. CO4), and sesame (*Sesamum indicum*; var. CO1) and four vegetable crops *viz.,* small onion (*Allium cepa*; local variety), bhendi (*Abelmoschus esculentus*; var. COBH1), brinjal (*Solanum melongena*; local variety), chillies (*Capsicum annuum*; local variety) were planted as inter crops in between rows of *M. dubia* planted at a spacing of 4x4m. The experiment was laid out in a randomized block design with four replications. Each of the intercrop and tree combinations were taken as different treatments. The agronomic practices like seed rate, spacing, fertilizer application and irrigation for the intercrops were followed as per crop production technique of horticultural crops recommendations of Tamil Nadu Agricultural University (2004). Blackgram, greengram, cowpea, groundnut, and sesame were grown at 30 x 15 cm spacing. Seedlings were used for planting in the case of bhendi, brinjal and chillies.

Bhendi and chillies were planted at 60 x 30 cm spacing, while brinjal at 60 x 60 cm and small onion at 30 x 10 cm. Control plots with trees alone and crops alone were maintained for comparison. The growth and yield parameters in intercrops *viz.,* plant height (cm), collar diameter (cm) and number of branches were measured at 30, 60 DAS, and at the time of harvest. Number of pods / capsules / fruits per plant and yield in kg ha^{-1} during harvest were also recorded. The following growth parameters of trees *viz.,* tree height (m), basal diameter (cm), diameter at breast height (DBH) (cm), and volume (m^3) were estimated before sowing and after harvest of inter crops. The data were statistically analyzed for comparison (Panse and Sukhatme, 1967).

Gross income (Rs.), net income (Rs.) and benefit:cost ratio were also recorded for each treatment. Gross return was calculated by multiplying the yield of crops with the cost of produce and expressed as Rs. ha^{-1}. Net return was calculated by deducting the cost of cultivation from the gross return and expressed as Rs. ha^{-1}. Benefit:cost ratio was worked out by using the formula:

$$\text{B: C ratio} = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

Results and Discussion

Growth and productivity of intercrops

The results revealed that among the intercrops tried, the highest reduction in plant height at all stages *viz.,* 30, 60 DAS and at harvest were observed in sesame with the reduction of 8.0, 8.0 and 9.0 %, respectively. The lowest reduction in plant height was recorded in cowpea, groundnut and chilli (5 %) on 30 DAS and cowpea and groundnut (4.0 %) in 60 DAS. However, blackgram, cowpea and groundnut also showed a reduction of 4.0 % in plant height during harvesting stage when compared to control. The reduction in plant height of intercrop in agroforestry system when compared to that of sole crop was observed in wheat, when it was planted in the open compared to shade condition in kapok based agri-silviculture system (Puri *et al.,* 2001). This reduction in the plant height of intercrop might be due to the competition with the trees for the resources *viz.,* light, moisture and nutrients (Mohanraj, 2004).

The highest reduction in collar diameter during 30, 60 DAS and at harvest was observed in sesame with a reduction of 8.0, 9.0 and 8.0 %, respectively (Table 1); and the minimum reduction was observed in groundnut on 30, 60 DAS and at harvest (4.0, 4.0 and 3.0 %, respectively). This also might be due to the competition of intercrops with trees for resources. Similar reduction in collar diameter of intercrops was observed pertaining to intercrops, mainly, due to competition for resources (Divya *et al*., 2005).

Since Melia trees were only 10 month old at the start of experiment, the canopy was very less and there was no shade. Hence, at 30 DAS same numbers of branches were observed in all the intercrops when compared to the respective sole cropping. The highest per cent reduction in the number of branches at 60 DAS and harvest was observed in blackgram with a percentage reduction of 17 and 13, respectively. The reduction in number of branches when grown as intercrop compared to sole crop was also observed in redgram planted in between rubber trees (Brahmam *et al*., 1997). Compared to open field, the yield and yield

Table 1. Growth and yield attributes of intercrops under *Melia dubia* based agroforestry system

Intercrops	Plant height (cm)						Collar diameter (cm)						Number of branches						No of pods / capsules /		Yield per kg	
	30 DAS		60 DAS		At harvest		30 DAS		60 DAS		At harvest		30 DAS		60 DAS		At harvest		fruits per plant		ha^{-1}	
	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S	I	S
Greengram	14.5	15.6	39.4	42.4	46.5	49.4	3.2	3.4	5.5	5.8	6.1	6.4	3	3	6	7	8	9	58	59	780	805
	(7%)		(7%)		(6 %)		(6%)		(5%)		(5%)		(0 %)		(14%)		(11%)		(2%)		(3%)	
Blackgram	16.4	17.5	36.5	38.6	42.8	44.6	4.5	4.8	6.1	6.5	7.2	7.6	3	3	5	6	7	8	55	57	760	810
	(6%)		(5%)		(4%)		(6%)		(6%)		(5%)		(0 %)		(17%)		(13%)		(4%)		(6%)	
Cowpea	12.1	12.7	32.6	33.8	39.1	40.8	3.9	4.1	7.1	7.5	8.2	8.6	3	3	9	10	11	12	57	58	830	855
	(5%)		(4%)		(4%)		(5%)		(5%)		(5%)		(0 %)		(10%)		(8%)		(2%)		(2%)	
Bhendi	19.2	20.6	32.1	33.8	40.4	42.4	5.8	6.2	6.7	7.1	7.5	8.2	4	4	8	9	11	12	25	27	3172	3210
	(7%)		(5%)		(5%)		(7%)		(6%)		(7%)		(0 %)		(11%)		(8%)		(7%)		(1%)	
Small onion	22.0	23.6	30.1	32.2	34.0	36.2	-	-	-	-	-	-	-	-	-	-	-	-	7	9	2100	2250
	(7%)		(7%)		(6%)														(22%)		(3%)	
Groundnut	19.3	20.3	32.7	34.2	39.4	41.2	4.6	4.8	7.1	7.4	7.8	8.0	2	2	6	7	8	8	20	22	3145	3240
	(5%)		(4%)		(4%)		(4%)		(4%)		(3%)		(0 %)		(14%)		(0%)		(9%)		(3%)	
Sesame	27.7	30.1	102.3	110.6	112.0	122.6	5.4	5.9	8.2	9.0	9.5	10.3	4	4	6	7	8	9	70	75	1120	1250
	(8%)		(8%)		(9%)		(8%)		(9%)		(8%)		(0 %)		(14%)		(11%)		(7%)		(7%)	
Brinjal	19.1		48.7		51.0		6.3		8.56		10.3		4		7		10		24		8700	8950
	(7%)	20.5	(7%)	52.2	(6%)	54.2	(6%)	6.7	(7%)	9.2	(6%)	10.9	(0 %)	4	(0%)	7	(9%)	11	(29%)	34	(3%)	
Chillies	20.6	21.6	45.3	48.0	51.3	54.5	10.4	11.1	17.3	18.7	18.4	19.8	2	2	6	6	11	11	50	52	4200	4380
	(5%)		(6%)		(6%)		(6%)		(7%)		(7%)		(0 %)		(0%)		(0%)		(4%)		(4%)	
SEd	1.38		6.22		6.25		0.20		0.25		0.15		0.29		0.33		0.39		1.35		10.79	
CD (0.05)	2.81		12.68		12.74		0.40		0.55		0.31		0.61		0.68		0.80		2.8		21.17	

I – Intercropping S – Sole cropping; Figures in parenthesis indicates the per cent reduction over the sole crop

attributing characters of intercrops were found to be reduced under *M. dubia.* The highest reduction in number of pods was observed in blackgram (4 %) when compared to the control. Green gram and blackgram also showed a reduction of 2 % each. Among the two oil seeds, the highest reduction in the number of capsules was observed in ground nut (9 %) followed by a reduction of 7 % in sesame. Among the four vegetables, the highest reduction was observed in brinjal (29 %) while, the least reduction was observed in chillies (4 %). The reduction in the number of pods of intercrops under agroforestry practice when compared to mono cropping was earlier reported by Naugraiya and Jhapat Singh (2004).

Table 2. Effect of intercrops on growth and development of *Melia dubia*

Intercrop	Height(m)			Basal diameter (mm)			DBH (cm)	Volume (m^3 ha^{-1})
	Before sowing intercrops	After harvesting intercrops	Increment	Before sowing intercrops	After harvesting intercrops	Increment		
Greengram	2.45	5.20	2.75	46.75	107.70	60.95	7.99	16.13
			(43%)			(42%)	(5%)	(39%)
Blackgram	2.48	5.50	3.03	45.83	108.20	62.38	8.51	19.63
			(48%)			(43%)	(10%)	(50%)
Cowpea	1.88	4.40	2.53	36.40	70.60	34.20	8.19	15.00
			(36%)			(-4%)	(7%)	(34%)
Bhendi	2.13	4.60	2.48	38.53	95.60	57.08	8.19	15.50
			(36%)			(38%)	(7%)	(36%)
Small onion	2.33	4.70	2.38	42.10	111.80	69.70	8.07	13.94
			(34%)			(49%)	(6%)	(29%)
Groundnut	2.08	4.70	2.63	42.73	95.40	52.68	7.83	14.00
			(40%)			(33%)	(3%)	(29%)
Seasame	2.00	4.00	2.00	45.80	101.90	56.10	7.83	11.56
			(21%)			(37%)	(3%)	(15%)
Brinjal	2.45	4.60	2.15	44.98	94.40	49.43	7.55	12.75
			(27%)			(28%)	(-1%)	(23%)
Chillies	1.93	4.60	2.67	36.90	95.20	58.30	7.55	13.00
			(41%)			(39%)	(-1%)	(24%)
Tree alone	1.93	3.50	1.58	42.25	77.80	35.55	7.63	9.88
SEd			0.54			22.80	0.17	2.32
CD (0.05)			1.10			NS	0.35	5.35

Yield per ha was also found to be significantly reduced under *M. dubia* based agroforestry system. Among the pulses, the maximum reduction in yield per ha was noticed in blackgram (6 %), while the minimum reduction was recorded in cowpea (2 %). Among the oil seeds, the maximum reduction in yield per ha was recored in sesame (7 %) and the minimum was observed in ground nut (3 %). Among the vegetable crops, the maximum reduction in yield per ha was recorded in chillies (4 %) and the lowest reduction in yield was recorded in bhendi (1%). Similar reduction in yield and yield attributes of intercrops under trees was observed in *Ailanthus excelsa* based agro forestry system (Ravi, 2005). The reduction in yield of intercrops under tree canopy might be due to shade effect and competition for other resources (Bennett *et al*., 1997).

Effect of intercrops on tree growth

The height increment in trees due to intercropping was significant (Table 2). The results revealed that the tree height varied between 1.88 and 2.48 m before sowing and from 3.5 to 5.5m after harvesting the intercrops. The maximum height increment in tree was recorded when blackgram was sown as intercrop (3.03 m), with an increase of 48 % while, the lowest increment was observed in plots intercropped with sesame (2.00 m), with an increase of 21 %. Similar findings were observed in babul (*Acacia nilotica*) planted with intercrops (Gill, 2005) and in *Gmelina arborea* (Vanlalngurzauva *et al*., 2010). The increment of diameter in trees due to intercropping was not significant. The basal diameter of the tree varied from 36.4 to 46.75 mm and 94.4 to 111.80 mm, before sowing and after harvesting of the intercrops, respectively. Among the intercrops the maximum increment in the basal diameter of the tree was recorded with small onion (69.70 mm) with an increase of 49 % and the minimum was recorded while intercropped with cowpea (34.2 mm) (Table 2). The diameter at breast height (DBH) of the trees varied from 7.55 to 8.51 cm. The highest per cent increase in the DBH of the tree was observed when intercropped with blackgram (10%) and there

Table 3. Economics of intercrops under *Melia dubia*

Intercrop	Gross Income (Rs)	Net income (Rs)	BC ratio
Greengram	31,200	21,200	3.10
Blackgram	38,000	26,000	3.16
Cowpea	24,900	14,800	2.46
Bhendi	38,064	23,064	2.53
Small onion	31,500	16,500	2.10
Groundnut	31,450	19,450	2.62
Sesame	33,600	21,600	2.80
Brinjal	87,000	67,000	4.30
Chillies	50,400	30,400	2.50

existed a percentage reduction in the DBH of the tree when brinjal and chillies were inter cultivated (1% each). The volume (m^3 ha^{-1}) of the trees varied from 19.63 to 11.56 m^3 ha^{-1}. The highest per cent increase in the tree volume was observed with blackgram inter cropping (50 %) and the lowest was observed when sesame was inter cropped (15 %). Similar findings were observed in wild cherry and hybrid walnut trees planted with intercrops (Chifflot *et al*., 2010) and also in eucalyptus tree grown with blackgram as intercrop (Pal *et al*., 2000).

Economics of Melia dubia based agroforestry system

The maximum gross income (Rs 87,000 ha^{-1}) and net return (Rs.67,000 ha^{-1}) was registered in brinjal + *M. dubia* combination. The minimum gross income (Rs. 24,900 ha^{-1}) and net return (Rs. 14,800 ha^{-1}) was observed in cowpea + *M. dubia* combination. The highest benefit cost ratio of 4.30 was recorded in brinjal + *M. dubia* and the lowest of 2.10 in small onion + *M. dubia* (Table 3). The performance of brinjal under *M. dubia* might be due to higher productivity and better return when compared to pure crops. Similar results of the highest benefit cost ratio was obtained from brinjal intercropped with *Bambusa vulgaris* (Nithya kalyani, 2010). Agroforestry practices may fetch higher returns when compared to sole crops (Dey *et al*., 2007).

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