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Influence of *Melia dubia* on Growth and Biomass of Fodder Grasses

M. B. Praveen Kumar[1], Rinku Verma[2], D. C. Hanumanthappa[3], M. Mahadeva Murthy[4], Savitha Madappa[5], G. Gangadhar Eshwar Rao[6] and T. C. Yogesh[7]

[1&5]Department of Forestry and Environmental Science, [5]Department of Crop Physiology, College of Agriculture, UAS, GKVK, Bengaluru - 560 065

[3]AICRP on Agroforestry, [6]Distance Education Unit (FTI), UAS, GKVK, Bengaluru - 560 065

[7]Agricultural Research Station, Madenur, Hassan - 573 225

e-Mail : praveenkumarmb777@gmail.com

Authors Contribution

M. B. Praveen Kumar : Conceptulization, investigation data curation and preparation of manuscript

Rinku Verma & D. C. Hanumanthappa : Editing, experimental deisgn, critical feedback and supervision

M. Mahadeva Murthy ; Savitha Madappa ; G. Gangadhar Eshwar Rao & T. C. Yogesh : Critical feedback and guidance

Corresponding Author :

M. B. Praveen Kumar

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Abstract

The present research was carried out in Agroforestry field unit, UAS, GKVK, Bengaluru. Experiment was conducted in *Melia dubia* plantation of 12 years-old, which has six planting densities *viz.*, 24 m x 5 m, 20 m x 5 m, 16 m x 5 m, 12 m x 5 m, 10 m x 5 m and 8 m x 5 m. The study aimed to know the influence of different planting densities of *Melia dubia* on four fodder grasses *viz*. Rhodes grass, Panicum grass, Guinea grass and Super Napier. Percentage light reduction was recorded highest in 8 m x 5 m (72.9%) and lowest in 24 m x 5 m (35.6%). Because of less competition for light, nutrients and other resources in wider tree spacing, fodders growth parameters like plant height, number of tillers and leaves per clump, leaf area values showed higher under 24 m x 5 m over other spacings. Green forage and dry forage yield of fodder grasses were highest under 24 m x 5 m (42.93 t ha^{-1} and 9.94 t ha^{-1}, respectively) and least in 8 m x 5 m (16.22 t ha^{-1} and 3.95 t ha^{-1}, respectively). Among fodder grasses, Super Napier performed better with respect to growth and biomass production, followed by Guinea grass and least in Panicum grass. Super Napier under Melia tree spacing of 24 m x 5 m was found to be the best treatment combination.

Keywords : Agroforestry, Biomass, Grasses, *Melia dubia*, Planting densities, Fodder

Every country has to maintain 33 per cent of its total geographical area under forest cover to maintain ecological balance, but currently India is having only 21.71 per cent, where still there is shortage of 11.29 per cent of area under forest cover (ISFR, 2021). In present scenario, it is very difficult to increase the area under forest cover due to urbanization, industrialization, encroachment of forest land, clearing of forest for various developmental activities and conversion of forest land into agricultural land to feed growing population. Even after implementation of various measures like afforestation, reforestation and planting in waste lands, India is still facing shortage of forest cover to maintain ecological balance. Hence, this problem can be effectively addressed by the practice of agroforestry, where trees are grown in agricultural fields along with livestock component simultaneously on same piece of land. Agroforestry is an effective tool to increase forest cover along with maintaining food security to growing human population.

On the other hand, providing green and nutritious fodder is crucial for effective dairy management and enhancing long-term milk productivity, which serves as a primary nutritional source for much of the global population. However, inadequate and seasonal fodder production leads to severe shortages in livestock feeds, creating a significant gap between demand and supply, which is a major challenge in ensuring both the quality and quantity of available fodders (Ranjan *et al*., 2016). Currently, availability of green fodder and dry fodder in India is 734.2 million tons and 326.4 million tons respectively (Roy *et al*., 2019). Still there is deficit of 93 million tons of green fodder and 99.7 million tons of dry fodder, which signifies that fodder production has to be enhanced to meet the demand.

Silvi-pastoral systems have emerged as an important aspect of climate-smart agriculture, offering a variety of goods and services. Integrating fodder crops under trees in these systems is a promising strategy to enhance and stabilize productivity, reduce grazing pressure, preserve tree health and improve self-sufficiency in fodder production (Ranjan *et al.,* 2016). *Melia dubia* is highly regarded for its termite and fungus-resistant timber, which is of excellent quality (Suprapti *et al.,* 2004). The branches serve as fuel wood and termite-resistant poles, while the leaves are utilized as fodder. The timber is primarily used in furniture making, agricultural tools and house construction due to its decorative appearance (Mandang and Artistien, 2003). Growing *Melia dubia* in agroforestry system increases the total tree cover of the country. Usually, agricultural crops can be grown as inter crop profitably under *Melia dubia* up to 4-5 years. But, later due to shading effect of Melia, field crops failed to produce profitable yield. Hence, there is a need to identify suitable shade tolerant crops under Melia. This requirement can befulfilled by fodder grasses, which are efficient to grow in more unlikely conditions and simultaneously produces green fodder for livestock to maintain food security. By considering all these in view, the present research was planned to assess the performance of different fodder grasses *viz*., Rhodes grass (*Chloris guyana*), Panicum grass (*Panicum virgatum*), Guinea grass (*Megathyrsus maximus*) and Super Napier (*Pennisetum purpureum*) under Melia based silvi-pasture system.

Material and Methods

The experiment was carried out at 'M' block, All India Coordinated Research Project (AICRP) on Agroforestry Unit, Zonal Agricultural Research Station (ZARS), Gandhi Krishi Vigyana Kendra (GKVK), University of Agricultural Sciences, Bangalore, Karnataka. It is located in the Northern part of Bengaluru between 13^0 04' North latitude and 77^0 34' East longitude at analtitude of 930m above mean sea level (MSL). There were 24 treatment combinations comprising S_1: 24 m × 5 m (83 trees ha^{-1}), S_2: 20 m × 5 m (100 trees ha^{-1}), S_3: 16 m × 5 m (125 trees ha^{-1}), S_4: 12 m × 5 m (166 trees ha^{-1}), S_5: 10 m × 5 m (200 trees ha^{-1}), S_6: 8 m × 5 m (250 trees ha^{-1}) in main plots and F_1: Rhodes grass, F_2:Panicum grass, Guinea grass and F_4: Super Napier as intercrops in sub-plots with F_5:Sole Rhodes grass, F_6:Sole Panicum grass, F_7: Sole Guinea grass and F_8:Sole Super Napier, replicated three times under strip plot design. *Melia dubia* was 12 years old maintained by AICRP on Agroforestry, Bengaluru center. Further, the study was carried out from April 2023 to July 2024. Fodder grasses were planted with spacing of 90 cm x 60 cm and provided with recommended dosages of fertilizers *i.e.,* Rhodes grass (50 N: 30 $P_2O_{5:}$ 20 K_2O), Panicum grass (50 N:50 P_2O_5:40 K_2O), Guinea grass (50 N:50 P_2O_5:40 K_2O) and Super Napier (60 N:50 P_2O_5:40 K_2O).

Soil and its Characteristics

The soil of the experimental site was red sandy loam in texture, classified under the order *Alfisols*. The soil samples were collected at 0-30 cm depth with the specified technique (Table 1) and the values obtained are furnished in Table 2 for the physical and chemical properties of the soil. Bulk density, Particle density and Porosity of soil decreased with increasing planting density of Melia (Pradeep and Krishnamurthy, 2023). pH decreased with increasing Melia planting density. EC and OC increased with increasing planting density (Ananthkumar, 2011). With increasing soil organic carbon, all the major nutrients *viz.*, Available nitrogen, phosphorus and potassium as well as secondary nutrients *viz.*, Exchangeable calcium, magnesium and sulphur were increased with increasing planting density.

Studies on Growth and Yield Attributes of Fodder Grasses

The plant height in cm was recorded from the base of the culm to the tip of the top most-leaf at different

TABLE 1
Methodologies used for soil analysis

Parameters	Methods	References
Bulk density Particle density Porosity	Keen Raczkowaski brass cup method	Piper, 1966
pH of soil	Glass electrode pH meter	Jackson, 1973
Electrical conductivity	EC bridge	
Soil organic carbon	Walkley-Black chromic acid wet oxidation method	Walkley and Black, 1938
Available Nitrogen	Alkaline potassium permanganate method	Subbiah and Asija, 1956
Available Phosphorus	Olsen's or Bray's method	Jackson, 1973
Available Potassium	Flame photometer method	Jackson, 2005
Available Sulphur	Turbidometry method	Jackson, 1973
Exchangeable Calcium	Versenate titration method	
Exchangeable Magnesium		

TABLE 2
Initial status of soil physico-chemical properties as influenced by planting density of Melia in Melia based agroforestry system

Spacing	BD	PD	Porosity	pH	EC	OC	N	P_2O_5	K_2O	S	Ca	Mg
	g/cc		%		dS m^{-1}	%	kg ha^{-1}				cmol (p+) kg^{-1}	
24m x 5m	1.37	2.62	43.05	5.52	0.05	0.65	208.54	46.13	194.00	15.46	2.09	0.60
20m x 5m	1.35	2.55	43.12	5.39	0.05	0.64	212.32	46.89	196.38	16.88	2.10	0.70
16m x 5m	1.34	2.57	43.22	5.37	0.06	0.67	213.83	50.40	202.22	18.50	2.10	0.70
12m x 5m	1.33	2.52	43.25	5.35	0.06	0.67	226.49	57.95	222.57	19.34	2.20	0.70
10m x 5m	1.33	2.53	43.54	5.30	0.06	0.67	232.31	60.46	227.13	20.00	2.30	0.80
8m x 5m	1.31	2.53	43.72	5.29	0.07	0.68	243.83	64.17	229.65	21.87	3.10	1.10
Open	1.38	2.6	41.94	5.58	0.05	0.48	206.51	45.62	192.64	14.52	1.60	0.50

BD-Bulk density; PD-Particle density; EC-Electrical conductivity; OC-Organic carbon; N-Available nitrogen; P_2O_5-Available phosphorus; K_2O-Available potassium; S-Available sulphur; Ca and Mg- Exchangeable calcium and magnesium

growth stages by randomly selecting five plants at each cut and the means were worked out. Number of tillers and leaves per clump was counted from five randomly selected plants in each interaction at each cutting and the means were worked out. Leaf area was measure dusing a leaf area meter.

The SPAD chlorophyll readings were recorded from the third fully opened leaf of five randomly selected plants with different growth stages at 15, 30 and 45 days after third cut (DATC) and the means were worked out. Solar radiation interception (%) under a canopy of trees in the silvi-pastoral system (X100, LUX 2,00,000) was recorded by a digital lux meter and expressed as a percentage of open field conditions during different growth stages. The crops were harvested for the green fodder yield. The green fodder yield was recorded at 90 days after planting (DAP) at first cut and there after yield of fodders was recorded at 60 DAC (Days After Cutting). The harvested green fodder yield was weighed by using a hanging electrical scale balance and was converted into t ha^{-1}.

Dry matter content was recorded at each cut. The fresh weight of the samples was weighed and then the samples were sun dried. The sun-dried samples were placed in hot air oven at 70 ± 2 °C until a constant weight was observed. Dried samples were weighed and dry matter content was recorded.

Statistical Analysis

The experimental data obtained during the course of investigation were subjected to statistical analysis by applying the technique of analysis of variance (ANOVA) appropriate to the design to test the significance of the overall differences among treatments by the 'F' test. The data were analysed statistically for different soil attributes by factorial design using Microsoft Excel 2019. When the 'F-Value' was found to be significant, means for different planting densities and fodder grasses were compared by using Tukey HSD procedure (Steel and Torrie, 1960). Differences in mean were considered to be statistically significant at (P= 0.05) level of significance.

Results and Discussion

Growth Parameters of Fodder Grasses as Influenced by Planting Densities of Melia in Agroforestry System

The data pertaining to plant height of fodder grasses at different growth stages are presented in the Table 3. The results of plant height of fodder grasses reveals that significantly higher plant height was recorded in wider Melia tree spacing of 24 m x 5 m (51.55 cm at 15 DATC, 103.50 cm at 30 DATC and 194.37 cm at fourth cut) in all the growth stages, followed by 20 m x 5 m (47.53 cm at 15 DATC, 96.13 cm at 30 DATC and 180.39 cm at fourth cut) and lowest was recorded under narrow Melia spacing of 8 m x 5 m (31.60 cm at 15 DATC, 68.80 cm at 30 DATC and 131.56 cm at fourth cut). Among fodder grasses, significantly higher plant height was recorded in sole Super Napier (97.20 cm at 15 DATC, 137.60 cm at 30 DATC and 252.70 cm at fourth cut) in all growth stages followed by sole Guinea grass (60.70 cm at 15 DATC, 121.50 cm at 30 DATC and 217.34

Table 3

Plant height (cm) of fodder grasses at different growth stages after 3rd cut as influenced by density of Melia in *Melia dubia* based agroforestry system

Treatments	15 DATC	30 DATC	Fourth cut
Main plots (Melia planting density)			
S_1: 24 m x 5 m (83 trees/ha)	51.55	103.50	194.37
S_2: 20 m x 5 m (100 trees/ha)	47.53	96.13	180.39
S_3: 16 m x 5 m (125 trees/ha)	44.28	90.93	169.43
S_4: 12 m x 5 m (166 trees/ha)	40.38	85.16	159.83
S_5: 10 m x 5 m (200 trees/ha)	37.10	77.88	147.06
S_6: 8 m x 5 m (250 trees/ha)	31.60	68.80	131.56
S.Em±	0.39	0.80	2.02
CD (p=0.05)	1.09	2.24	5.68
Sub Plots (Fodder crops)			
F_1: Rhodes grass	41.39	84.67	158.76
F_2: Panicum grass	28.28	56.02	109.36
F_3: Guinea grass	43.17	89.73	221.67
F_4: Super Napier	55.45	117.84	165.29
S.Em±	0.32	0.65	1.65
CD (p=0.05)	0.89	1.83	4.64
F_5: Sole Rhodes grass	56.10	114.70	214.72
F_6: Sole Panicum grass	40.60	72.40	130.34
F_7: Sole Guinea grass	60.70	121.50	217.34
F_8: Sole Super Napier	67.20	137.60	252.70
Interactions (SXF)			
S_1F_1: 24m x 5m + Rhodes grass	51.02	105.90	202.14
S_1F_2: 24m x 5m + Panicum grass	36.40	67.20	123.02
S_1F_3: 24m x 5m + Guinea grass	55.60	110.60	210.48
S_1F_4: 24m x 5m + Super Napier	63.18	130.30	241.84
S_2F_1: 20m x 5m + Rhodes grass	48.30	97.20	181.84
S_2F_2: 20m x 5m + Panicum grass	31.80	62.40	116.06
S_2F_3: 20m x 5m + Guinea grass	48.48	100.20	187.30
S_2F_4: 20m x 5m + Super Napier	61.52	124.72	236.34
S_3F_1: 16m x 5m + Rhodes grass	44.50	90.40	168.30
S_3F_2: 16m x 5m + Panicum grass	29.50	57.90	111.32
S_3F_3: 16m x 5m + Guinea grass	45.20	95.40	172.70
S_3F_4: 16m x 5m + Super Napier	57.90	120.00	225.40
S_4F_1: 12m x 5m + Rhodes grass	40.90	81.42	150.08
S_4F_2: 12m x 5m + Panicum grass	26.10	53.10	109.02
S_4F_3: 12m x 5m + Guinea grass	41.12	89.30	163.84
S_4F_4: 12m x 5m + Super Napier	53.40	116.80	216.36
S_5F_1: 10m x 5m + Rhodes grass	35.40	72.30	133.24
S_5F_2: 10m x 5m + Panicum grass	24.00	49.60	103.52
S_5F_3: 10m x 5m + Guinea grass	37.60	78.70	136.96
S_5F_4: 10m x 5m + Super Napier	51.40	110.90	214.50

Continued....

TABLE 3 Continued....

Treatments	15 DATC	30 DATC	Fourth cut
S_6F_1: 8m x 5m + Rhodes grass	28.20	60.80	116.94
S_6F_2: 8m x 5m + Panicum grass	21.90	45.90	93.22
S_6F_3: 8m x 5m + Guinea grass	31.00	64.20	120.46
S_6F_4: 8m x 5m + Super Napier	45.30	104.30	195.60
S.Em±	0.77	1.59	4.04
CD (p=0.05)	2.18	4.48	11.37

DATC- Days after third cut

cm at fourth cut) and least was recorded in Panicum grass as intercrop fodder grass (28.28 cm at 15 DATC, 56.02 cm at 30 DATC and 109.36 cm at fourth cut). Interactions showed significant variations, wherein the highest plant height was recorded by Super Napier under Melia tree spacing of 24 m x 5 m (63.18 cm at 15 DATC, 130.30 cm at 30 DATC and 241.84 cm at fourth cut) and least in Panicum grass under Melia spacing of 8 m x 5 m (21.90 cm at 15 DATC, 45.90 cm at 30 DATC and 93.22 cm at fourth cut).

The variation in plant height of fodder grasses under different spacings of Melia might be due to variation in light penetration through Melia tree canopy, as tree spacing decreases the total tree canopy coverage increases, which affects the penetration of light and in turn affects the growth and development of intercrop fodder grasses. In closer spacing of trees increases the competition for different requirements of plants like soil nutrients, light and soil moisture, which affects the growth of intercrop fodder grasses Chauhan *et al*. (2013), whereas the higher plant height in a sole crop is ascribed to optimum light penetration, air circulation, comparatively higher nutritional area accessible to sole crop and less competition.

These findings coincided with the results of Chandana *et al.* (2018) and Pallavi (2014). The interaction effect of different variables was shown highest in Super Napier when grown under Melia tree spacing of 24 m x 5 m due to higher accessibility of fodder grasses to soil nutrients, light and soil moisture in wider tree spacing of Melia. It is in line with the findings of Sushma *et al*. (2021). Variation of plant height among different fodder grasses might be due to the genetical variation, adaptability of fodder grasses to local environmental conditions and their innate tolerance to environmental stress.

Number of tillers per clump of fodder grasses (Table 4) were recorded significantly higher under wider Melia tree spacing of 24 m x 5 m (64.8) followed by 20 m x 5 m (57.1) and least was found under Melia tree spacing of 8 m x 5 m (29.3). Among fodder grasses, significantly higher number of tillersper clump was recorded in sole Panicum grass (92.2). Consequently, among fodder grasses, which were grown as intercrops Panicum grass found have significantly higher number of tillers per clump (65.2) followed by Rhodes grass (56.0) and least was observed in Super Napier (20.0). Among the interactions, significantly higher number of tillers per clump was found in Panicum grass under Melia tree spacing of 24 m x 5 m (91.2) and least was found in Super Napier under Melia tree planting density of 8 m x 5 m (12.2). More tillers per clump recorded in Panicum grass might be due to their varietal characters Gupta *et al*. (2012). It is suspected that lower number of tillers per clump in intercrops due to tree-crop competition for resources like water, soil nutrients and light for their growth (Devkota, 2000). Low light intensity showed negative effect on number of tillers, which is because of emergence and development of tillers in fodder grasses requires sufficient light and nutrients. These results coincide with the findings of Chandana *et al*. (2018).

Number of leaves per clump of fodder grasses at fourth cut (Table 4) was found significantly higher under wider Melia tree spacing of 24 m x 5 m (696.60) followed by 20 m x 5 m (545.05) and least was found under Melia tree spacing of 8 m x 5 m (173.95). Among fodder grasses, significantly higher number of leaves per clump was found in sole Panicum grass (1346.00). Consequently, among fodder grasses, which were grown as intercrops under Melia trees, Panicum grass recorded significantly higher number of leaves per clump (685.37) followed by Rhodes grass (359.97) and least was observed in Super Napier (276.70). Among the interactions significantly higher number of leaves per clump was found in Panicum

TABLE 4

Number of tillers and leaves per clump of fodder grasses at fourth cut as influenced by density of Melia in *Melia dubia* based agroforestry system

Treatments	Number of tillers per clump	Number of leaves per clump
Main plot (Melia planting density)		
S_1: 24 m x 5 m (83 trees/ha)	64.8	696.6
S_2: 20 m x 5 m (100 trees/ha)	57.1	545.1
S_3: 16 m x 5 m (125 trees/ha)	49.8	430.6
S_4: 12 m x 5 m (166 trees/ha)	44.0	332.3
S_5: 10 m x 5 m (200 trees/ha)	36.3	240.7
S_6: 8 m x 5 m (250 trees/ha)	29.3	174.0
S.Em±	0.6	10.0
CD (p=0.05)	1.6	28.0
Sub Plots (Fodder grasses)		
F_1: Rhodes grass	56.0	360.0
F_2: Panicum grass	65.2	685.4
F_3: Guinea grass	46.2	290.8
F_4: Super Napier	20.0	276.7
S.Em±	0.5	8.1
CD (p=0.05)	1.3	22.9
F_5: Sole Rhodes grass	81.2	730.8
F_6: Sole Panicum grass	92.2	1346.0
F_7: Sole Guinea grass	67.2	564.8
F_8: Sole Super Napier	35.0	679.2
Interactions (S x F)		
S_1F_1: 24m x 5m + Rhodes grass	76.2	580.4
S_1F_2: 24m x 5m + Panicum grass	91.2	1204.4
S_1F_3: 24m x 5m + Guinea grass	63.0	529.4
S_1F_4: 24m x 5m + Super Napier	28.8	472.2
S_2F_1: 20m x 5m + Rhodes grass	66.6	480.0
S_2F_2: 20m x 5m + Panicum grass	82.0	935.0
S_2F_3: 20m x 5m + Guinea grass	55.2	386.2
S_2F_4: 20m x 5m + Super Napier	24.6	379.0
S_3F_1: 16m x 5m + Rhodes grass	59.6	382.0
S_3F_2: 16m x 5m + Panicum grass	67.8	734.4
S_3F_3: 16m x 5m + Guinea grass	50.0	300.8
S_3F_4: 16m x 5m + Super Napier	21.8	305.2

Continued....

TABLE 4 Continued....

Treatments	Number of tillers per clump	Number of leaves per clu0mp
S_4F_1: 12m x 5m + Rhodes grass	54.0	324.2
S_4F_2: 12m x 5m + Panicum grass	59.0	531.0
S_4F_3: 12m x 5m + Guinea grass	45.8	247.0
S_4F_4: 12m x 5m + Super Napier	17.2	227.0
S_5F_1: 10m x 5m + Rhodes grass	43.2	224.4
S_5F_2: 10m x 5m + Panicum grass	50.4	403.6
S_5F_3: 10m x 5m + Guinea grass	36.0	172.4
S_5F_4: 10m x 5m + Super Napier	15.6	162.4
S_6F_1: 8m x 5m + Rhodes grass	36.6	168.8
S_6F_2: 8m x 5m + Panicum grass	41.0	303.8
S_6F_3: 8m x 5m + Guinea grass	27.2	108.8
S_6F_4: 8m x 5m + Super Napier	12.2	114.4
S.Em±	1.1	19.9
CD (p=0.05)	3.1	56.0

grass under Melia tree spacing of 24 m x 5 m (1204.40) and least was found in Guinea grass under Melia tree planting density of 8 m x 5 m (108.8). More leaves per clump recorded in Panicum grass might be due to their varietal characters Gupta *et al*. (2012). It is suspected that lower number of leaves per clump in intercrops due to tree-crop competition for resources like water, soil nutrients and light for their growth (Devkota, 2000). These results coincide with the findings of Sushma *et al*. (2021). Wider spacing allows more light penetration through tree canopy and offers less competition for soil nutrients and moisture among tree-crop interactions, hence fodder grasses under Melia tree spacing of 24 m x 5 m had highest plant height, number of tillers and number of leaves per clump.

Leaf area per clump of fodder grasses were found significantly higher under wider Melia tree spacing of 24 m x 5 m (15 DATC: 19065 cm^2 per clump, 30 DATC: 46520 cm^2 per clump and at fourth cut: 73070 cm^2 per clump) in all the growth stages (Table 5) and least was found under Melia tree spacing of 8 m x 5 m (15 DATC: 3807 cm^2 per clump, 30 DATC: 7247

cm^2 per clump and at fourth cut:12446 cm^2 per clump). Among fodder grasses, significantly higher leaf area per clump was found in sole Super Napier (15 DATC: 24856 cm^2 per clump, 30 DATC: 59324 cm^2 per clump and at fourth cut: 91645 cm^2 per clump).

Consequently, among fodder grasses, which were grown as intercrops under Melia trees, Super Napier found have significantly higher leaf area per clump (15 DATC: 14115 cm^2 per clump, 30 DATC: 34015 cm^2 per clump and at fourth cut: 52224 cm^2 per clump) followed by Rhodes grass (15 DATC: 12154 cm^2 per clump, 30 DATC: 29834 cm^2 per clump and at fourth cut:47924 cm^2 per clump) and least was observed in Panicum grass (15 DATC: 7798 cm^2 per clump, 30 DATC: 16445 cm^2 per clump and at fourth cut: 26659 cm^2 per clump).

Among the interactions significantly higher leaf area per clump was found in Super Napier under Melia tree spacing of 24 m x 5 m (15 DATC: 21564 cm^2 per clump, 30 DATC: 54266 cm^2 per clump and at fourth cut: 82640 cm^2 per clump) and least was recorded in Panicum grass under Melia tree planting density of 8 m x 5 m (15 DATC: 2156 cm^2 per clump, 30 DATC: 3264 cm^2 per clump and at fourth cut: 7218 cm^2 per clump). The reduction in leaf area in intercrops might be due to tree-crop competition for growth resources *viz.,* light, nutrients and moisture (Sneh *et al*., 2019). More leaf area of Super Napier may due to genotypic characters and better usage of growth resource for photosynthetic activity (Sushma *et al*., 2021).

TABLE 5

Leaf area (cm^2 $clump^{-1}$) of fodder grasses at different growth stages as influenced by density of Melia in *Melia dubia* based agroforestry system

Treatments	15 DATC	30 DATC	Fourth cut
Main plots (Melia planting density)			
S_1: 24 m X 5 m (83 trees/ha)	19065	46520	73070
S_2: 20 m X 5 m (100 trees/ha)	15799	38739	60089
S_3: 16 m X 5 m (125 trees/ha)	11700	29263	45011
S_4: 12 m X 5 m (166 trees/ha)	8949	20607	32696

Continued....

TABLE 5 Continued....

Treatments	15 DATC	30 DATC	Fourth cut
S_5: 10 m X 5 m (200 trees/ha)	6058	12556	20573
S_6: 8 m X 5 m (250 trees/ha)	3807	7247	12446
S.Em±	121	297	447
CD (p=0.05)	339	837	1258
Sub Plots (Fodder crops)			
F_1: Rhodes grass	12154	29834	47924
F_2: Panicum grass	7798	16445	26659
F_3: Guinea grass	9519	22995	35783
F_4: Super Napier	14115	34015	52224
S.Em±	98	243	365
CD (p=0.05)	277	683	1028
F_5: Sole Rhodes grass	22086	54258	84284
F_6: Sole Panicum grass	19556	46349	72723
F_7: Sole Guinea grass	20648	48366	75792
F_8: Sole Super Napier	24856	59324	91645
Interactions (SxF)			
S_1F_1: 24m X 5m + Rhodes grass	19586	48564	78271
S_1F_2: 24m X 5m + Panicum grass	16854	36985	58945
S_1F_3: 24m X 5m + Guinea grass	18256	46264	72423
S_1F_4: 24m X 5m + Super Napier	21564	54266	82640
S_2F_1: 20m X 5m + Rhodes grass	17571	43440	70522
S_2F_2: 20m X 5m + Panicum grass	11491	25617	39908
S_2F_3: 20m X 5m + Guinea grass	14254	35512	53425
S_2F_4: 20m X 5m + Super Napier	19880	50389	76501
S_3F_1: 16m X 5m + Rhodes grass	13897	35974	55460
S_3F_2: 16m X 5m + Panicum grass	7236	15476	25062
S_3F_3: 16m X 5m + Guinea grass	9986	24851	37908
S_3F_4: 16m X 5m + Super Napier	15682	40751	61615
S_4F_1: 12m X 5m + Rhodes grass	11256	27178	43618
S_4F_2: 12m X 5m + Panicum grass	5165	10843	16975
S_4F_3: 12m X 5m + Guinea grass	7845	16543	26944
S_4F_4: 12m X 5m + Super Napier	11530	27865	43247
S_5F_1: 10m X 5m + Rhodes grass	6760	15952	24907
S_5F_2: 10m X 5m + Panicum grass	3886	6486	11846
S_5F_3: 10m X 5m + Guinea grass	4096	9236	15771
S_5F_4: 10m X 5m + Super Napier	9489	18550	29767
S_6F_1: 8m X 5m + Rhodes grass	3854	7896	14764
S_6F_2: 8m X 5m + Panicum grass	2156	3264	7218
S_6F_3: 8m X 5m + Guinea grass	2675	5561	8230
S_6F_4: 8m X 5m + Super Napier	6543	12268	19571
S.Em±	241	595	895
CD (p=0.05)	678	1673	2517

DATC- Days after third cut

Highest canopy cover (Fig. 1) was observed in Melia tree spacing of 24 m x 5 m (N:S-18.15 m and E: W-11.7 m) followed by 20 m x 5 m (N:S-16.85 m and E: W-11.6 m) and least canopy cover was found in 8 m x 5 m (N:S-10.55 m and E: W-9.1 m). Canopy cover increased with increasing spacing, which might be due to higher availability of space and light for extension of tree branches, where as it is limited in closer spacing and ultimately affected the canopy of individual trees. Whereas, because of higher planting density at closer spacing increases the overall canopy coverage of the area, which affects the penetration of light and affects the growth of intercrops (Luedeling *et al*., 2016).

The higher lux meter readings (Fig. 2) were observed in open field (morning: 452.0, afternoon: 649.3 and evening: 378.5). Simultaneously, in silvi-pastoral system higher lux readings were found under Melia tree spacing of 24m x 5 m (morning: 218.3, afternoon:

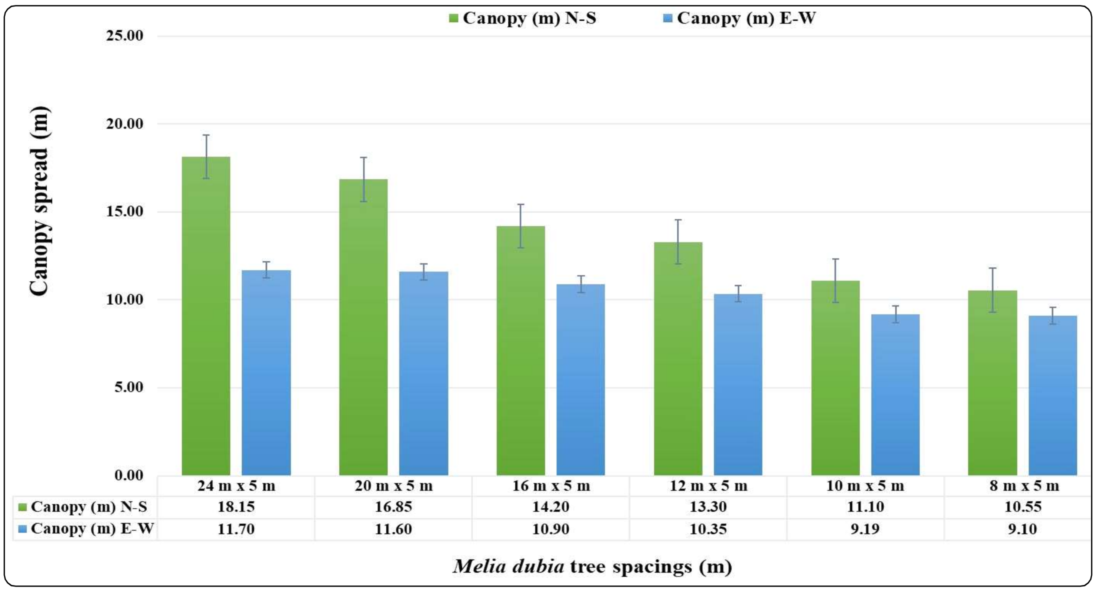

Fig. 1 : Canopy cover of Melia trees in Melia based silvi-pasture system

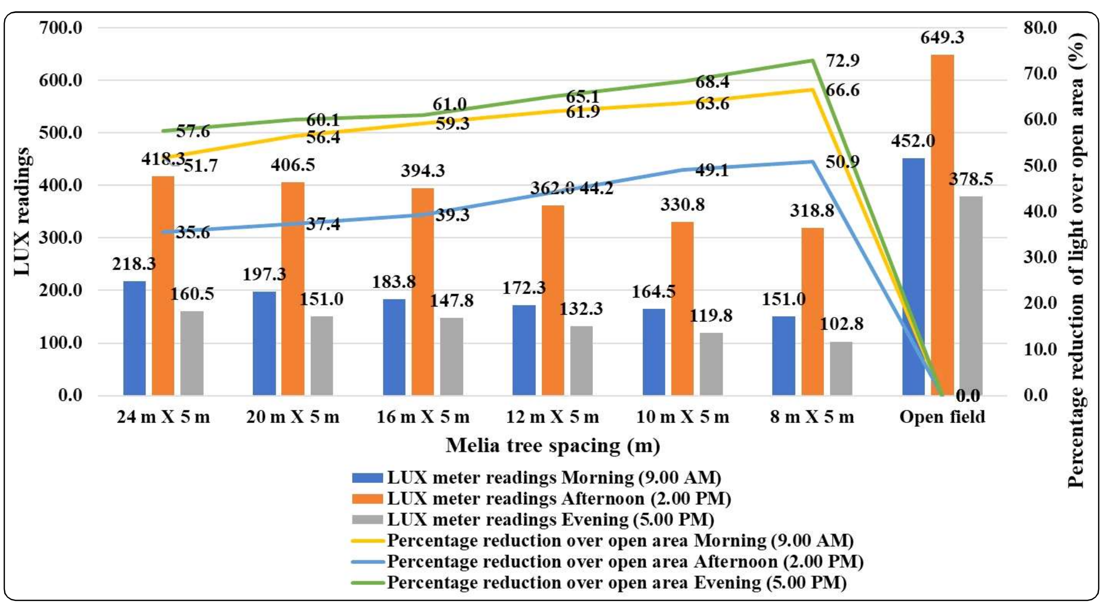

Fig. 2 : LUX readings and percentage reduction of LUX readings as influenced by Melia planting density over open area

418.3 and evening: 160.5) and lowest lux readings were recorded under Melia tree spacing of 8m x 5m (morning: 151.0, afternoon:318.8 and evening:102.8). More per cent lux reduction in silvi-pasture system over open area was noticed under narrow Melia spacing of 8 m x 5 m (morning: 66.6%, afternoon: 50.9% and evening: 72.9%).

Considerably, increasing trend of lux data has been observed from narrow Melia tree spacing to wider tree spacing. Wider spacing allows more light to penetrate when compared to narrow spacings in silvi-pasture system. The limit in light intensity to intercrops may vary depending on tree age, crown spread and planting density. More light penetration has been seen in wider spacing. These results follow the earlier findings of Luedeling *et al*. (2016) and Pallavi (2014).

Higher SPAD chlorophyll reading (Fig. 3) was observed in wider Melia spacing of 24 m x 5 m (46.3) and lowest was recorded in narrow tree spacing of 8 m x 5 m (34.5). SPAD chlorophyll readings decreased with decreasing Melia tree spacing, which indicates chlorophyll content decreased with increase in Melia planting density. Wider tree spacing allows more light to penetrate into tree inter spaces, because of which higher growth parameters were observed in fodder grasses whereas, in closer tree spacing due to less light, very poor growth was observed and similar findings were also reported earlier by Sandip (2017) and Chandana *et al*. (2018).

Total Biomass of Fodder Grasses as Influenced by Planting Densities of Melia in Agroforestry System

After the fourth cut, green forage yield and dry forage yield of fodder grasses (Table 6) was recorded significantly higher under wider Melia tree spacing of 24 m x 5 m (42.93 t ha^{-1} and 9.94 t ha^{-1}, respectively) followed by 20 m x 5 m (36.05 t ha^{-1} and 8.18 t ha^{-1}, respectively) and least was found under Melia tree spacing of 8 m x 5 m (16.22 t ha^{-1} and 3.95 t ha^{-1}, respectively). Among fodder grasses, significantly higher green forage yield and dry forage yield was obtained in sole Super Napier (64.84 t ha^{-1} and 13.72 t ha^{-1}, respectively). Under Melia trees, Super Napier produced significantly higher green forage and dry forage (40.98 t ha^{-1} and 8.99 t ha^{-1}, respectively) followed by Guinea grass (26.83 t ha^{-1} and 6.27 t ha^{-1}, respectively) and least was observed in Panicum grass (22.29 t ha^{-1} and 5.42 t ha^{-1}, respectively). Among the interactions significantly higher green forage yield and dry forage yield was recorded by Super Napier under

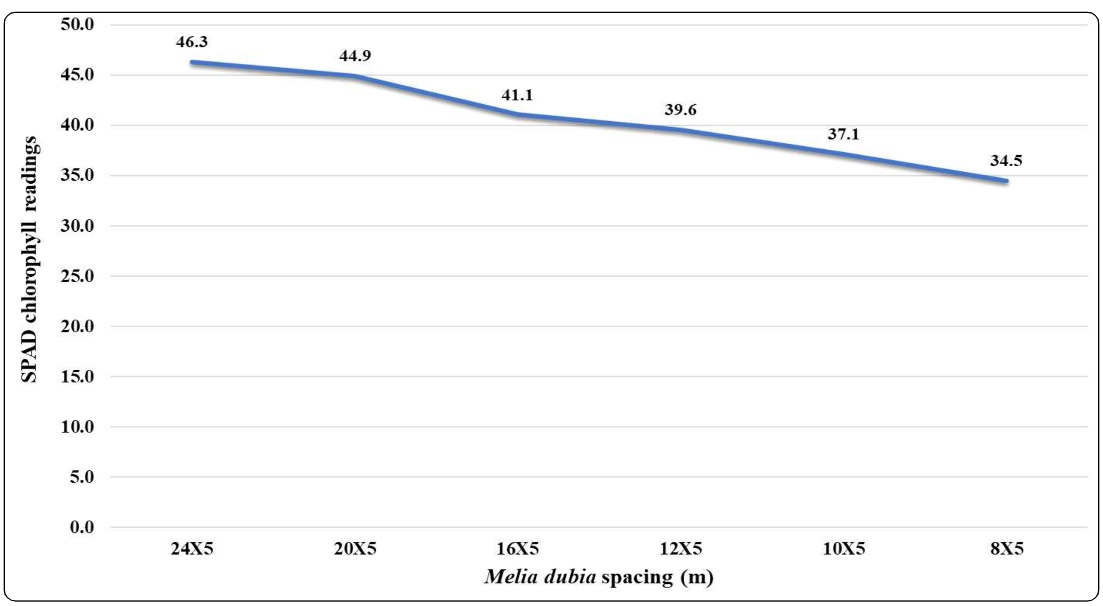

Fig. 3 : SPAD chlorophyll readings of fodder grasses as influenced by planting densities of Melia in Melia based silvi-pasture system

TABLE 6

Green forage yield and dry forage yield (t ha[-1]) of fodder grasses at fourth cut as influenced by density of Melia in *Melia dubia* based agroforestry system

Treatments	Green forage yield (t ha-1)	Dry forage yield (t ha-1)
Main plot (Melia planting density)		
S_1: 24 m X 5 m (83 trees/ha)	42.93	9.94
S_2: 20 m X 5 m (100 trees/ha)	36.05	8.18
S_3: 16 m X 5 m (125 trees/ha)	30.72	7.15
S_4: 12 m X 5 m (166 trees/ha)	26.81	5.98
S_5: 10 m X 5 m (200 trees/ha)	18.04	4.41
S_6: 8 m X 5 m (250 trees/ha)	16.22	3.95
S. Em±	0.28	0.07
CD (p=0.05)	0.80	0.18
Sub Plots (Fodder grasses)		
F_1: Rhodes grass	23.75	5.71
F_2: Panicum grass	22.29	5.42
F_3: Guinea grass	26.83	6.27
F_4: Super Napier	40.98	8.99
S. Em±	48.88	10.40
CD (p=0.05)	42.96	9.70
F_5: Sole Rhodes grass	57.84	12.78
F_6: Sole Panicum grass	64.84	13.72
F_7: Sole Guinea grass	0.23	0.05
F_8: Sole Super Napier	0.65	0.15
Interactions (S X F)		
S_1F_1: 24m X 5m + Rhodes grass	39.82	9.14
S_1F_2: 24m X 5m + Panicum grass	35.25	8.48
S_1F_3: 24m X 5m + Guinea grass	42.62	10.14
S_1F_4: 24m X 5m + Super Napier	54.01	11.98
S_2F_1: 20m X 5m + Rhodes grass	32.78	7.59
S_2F_2: 20m X 5m + Panicum grass	31.75	7.15
S_2F_3: 20m X 5m + Guinea grass	34.70	8.25
S_2F_4: 20m X 5m + Super Napier	44.98	9.72
S_3F_1: 16m X 5m + Rhodes grass	26.19	6.55
S_3F_2: 16m X 5m + Panicum grass	25.60	6.07
S_3F_3: 16m X 5m + Guinea grass	29.50	6.95
S_3F_4: 16m X 5m + Super Napier	41.57	9.01
S_4F_1: 12m X 5m + Rhodes grass	21.40	5.07
S_4F_2: 12m X 5m + Panicum grass	20.59	4.85
S_4F_3: 12m X 5m + Guinea grass	25.62	5.58
S_4F_4: 12m X 5m + Super Napier	39.64	8.44
S_5F_1: 10m X 5m + Rhodes grass	11.72	3.19
S_5F_2: 10m X 5m + Panicum grass	10.99	3.15
S_5F_3: 10m X 5m + Guinea grass	15.75	3.59
S_5F_4: 10m X 5m + Super Napier	33.71	7.69
S_6F_1: 8m X 5m + Rhodes grass	10.56	2.74
S_6F_2: 8m X 5m + Panicum grass	9.57	2.85
S_6F_3: 8m X 5m + Guinea grass	12.79	3.11
S_6F_4: 8m X 5m + Super Napier	31.97	7.09
S. Em±	0.57	0.13
CD (p=0.05)	1.60	0.37

Continued....

TABLE 6 Continued....

Melia tree spacing of 24 m x 5 m (54.01 t ha^{-1} and 11.98 t ha^{-1}, respectively).

Super Napier found to produce highest amount of green and dry forage yield, which might be due phenotypictraits, genetical superiority and better utilization of growth resource for photosynthetic activity (Sushma *et al*., 2021). The lower availability of solar radiation and more competition for water and nutrients in higher Melia planting density (8 m x 5 m) might be responsible for lower biomass production by intercrop fodder grasses. Similar findings were also recorded by Bhati *et al*. (2004), Ranjan *et al*. (2016), Ratan *et al*. (2015) and Sneh, (2019).

After 12 years of Melia planting, cultivating forage grasses *viz.,* Super Napier and Guinea grass under Melia tree spacing of 24 m x 5 m found to be best in producing higher forage yield and economics.

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