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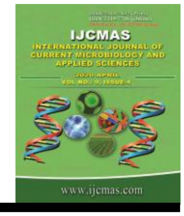

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Growth Performance of *Melia dubia* in Sole and *Melia dubia*-Sorghum Sudan Grass Silvi-Pasture Systems: Sorghum Sudan Grass Intercropping Implications

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A B S T R A C T

M. dubia growth and yield performance was evaluated using Randomized Block Design with 10 treatments. There was significant variation in tree height (m), girth at breast height (GBH) (cm), and standing volume (m^3/tree or /ha) and biomass (kg/tree or t/ha), at SSG intercropping (July, 2019) and final SSG forage harvest (November, 2019), among the silvi-pasture (T_1 to T_5) and sole plantation (T_6 to T_{10}) systems. The increment put up in growth and yield attributes over the SSG intercropping period also differed significantly. At the SSG planting period, the height (8.05 m) and GBH (33.85 cm) was higher under *M. dubia* (3 × 3 m)-SSG system and sole *M. dubia* plantation at 4×4 m, respectively. However, *M. dubia* (4 ×2 m)-SSG system was higher in height (9.99 m), GBH (44.18 cm) and increment in both i.e. height (2.94 m) and GBH (15.53 cm) at the SSG final harvest. At the time of SSG planting, volume (0.070 m^3/tree) and biomass (34.73 kg/tree) per tree were higher in trees from sole *M. dubia* plantation at 4 × 4 m spacing, however, at the final SSG harvest, *M. dubia* (4 ×2 m)-SSG system was higher in volume (0.156 m^3/tree), biomass (77.14 kg/tree) and increment in per tree volume (0.109 m^3/tree) and per tree biomass (53.72 kg/tree). The volume and biomass per hectare, at the time of SSG planting, was higher (84.69 m^3/ha and 41.92 t/ha, respectively) in sole *M. dubia* (3 × 2 m) plantation, whereas, same geometry in the *M. dubia*-SSG based silvi-pasture system produced highest volume (199.94 m^3/ha) and biomass (98.97 kg/ha). However, increment in volume and biomass per hectare were higher (128.83 m^3/ha and 63.77 kg/ha, respectively). The results showed that intercropping of SSG under *M. dubia* plantation has beneficial effect on growth and yield attributes of *M. dubia*.

Keywords

Melia dubia, Sorghum sudan grass, Silvi-pasture, Volume, Biomass

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Introduction

Melia dubia, belonging to the family meliaceae, found common in moist deciduous forests of the Indian states of Kerala, Karnataka (Nuthan *et al*., 2009), Tamilnadu (Parthiban *et al.*, 2009) Gujarat (Chauhan *et al*., 2018) etc. is one of the fast growing tree species (Parthiban *et al.*, 2009; 2018; Thakur *et al*., 2019b). It has emerged as an alternative raw material tree crop for the pulp and paper industries due to its increased pulp recovery and special strength of paper (Parthiban *et al.*, 2009). Besides an important industrial tree species, it has also ecological importance like soil enrichment, afforestation and phyto-remediation (Nuthan *et al*., 2009); medicinal uses (Malarvannan *et al.*, 2009; Yasodha *et al.*, 2011), fruit pulp as livestock feed (Sukhadiya *et al.*, 2019 &2020). It is also proven to be the most compatible agroforestry tree species amenable with different understorey crops (Jilariya *et al*., 2017; Thakur *et al*., 2018; Thakur *et al.*, 2019a; Mohanty *et al*., 2019) with transient or no allelopathic effect on intercrops (Kumar *et al*., 2017; Thakur *et al*., 2017a&b; Parmar *et al.*, 2019).

It has been reported that *M. dubia* based agroforestry systems are profitable than that of monocropping systems (Anusha, 2012, Jilariya *et al*., 2019; Mohanty *et al*., 2017). Even though it is being widely adopted as tree component in different types of agroforestry systems, the effect on *M. dubia* growth due to intercropping of understory crop is still need to be explored. Therefore, taking this into consideration, present study was carried out to estimate the growth and productivity of different spatial geometries of *M dubia*-sorghum sudan grass (SSG) based silvi-pasture systems and sole plantation systems as affected by intercropping of SSG.

Materials and Methods

The current study was carried out at the College of Forestry, ACHF, NAU, Navsari, Gujarat, during 2019-20. The experiment was conducted following randomized block design with 10 treatments*viz.*T_1 [*M. dubia* (2 × 2 m) + SSG], T_2 [*M. dubia* (3 × 3 m) + SSG], T_3 [*M. dubia* (3 × 2 m) + SSG], T_4 [*M. dubia* (4 × 4 m) + SSG], T_5 [*M. dubia* (4 × 2 m) + SSG] and $T_6$to T_{10}sole *M. dubia* at 2 × 2, 3 × 3, 3 × 2, 4 × 4 and 4 × 2 m, respectively, with 4 replications. The *M. dubia* trees were of 5 years of age. Height and girth at breast height (GBH) were measured both at sowing (July, 2019) and final harvest of SSG forage (October, 2019). Volume and biomass were extrapolated to per hectare basis considering 5% mortality in each spatial geometry. The standing tree volume was calculated using standard formulae [Volume (m^3/tree) = $g^2 \times h/4\pi$ where, g = Girth at Breast Height (cm), h = height of tree (m)] then the volume was multiplied with specific gravity of the wood to get total biomass of the tree.

The statistical analysis of the data was done using randomized block design and ANOVA was prepared following Sheoran *et al.*, (1998).

Results and Discussion

The data presented in the table 1, 2 and 3 revealed that, growth *i.e.* height (m) and GBH (cm) and yield attributes *i.e.* volume (m^3/tree or m^3/ha) and biomass (kg/tree or t/ha) expressed significant differences ($P<0.05$) among *M. dubia*-SSG silvi-pasture systems (T_1 to T_5) formed due to spatial configurations *viz*., 2 x 2, 3 x 2, 3 x 3, 4 x 2 and 4 x 4 m of *M. dubia* and subsequent intercropping of SSG, and *M. dubia* sole plantations (T_6 to T_{10}) at same spatial magnitude. The increment put-on by trees in silvi-pasture systems and sole plantations, during one year of growth period also varied significantly.

Height growth and increment (m)

The results on height growth (Table 1) revealed that, initially (at sowing of SSG) tallest trees (8.05 m) were under *M. dubia* (3 x 3 m)-SSG system, which was at par with those of *M. dubia* (3 x 2 m)-SSG, *M. dubia* (4 x 4 m)-SSG systems, sole *M. dubia* planted at 3 x 2 m, 3 x 3 m and 4 x 4 m. Minimum tree height (5.30 m) was of trees under sole *M. dubia* (2 x 2 m) plantation *i.e.* treatment T_6.

However, at the end of intercropping period, significantly maximum height (9.99 m) and increment (2.94 m) put up by trees was in *M. dubia* (4 x 2 m)-SSG (T_4) system. Minimum tree height (6.88 m) and increment (1.00 m) was recorded under sole plantation of *M. dubia* at 2 x 2 m and 4 x 2 m, respectively.

Girth at breast height (GBH) and increment (cm)

The data presented in the table 1 revealed that significantly maximum GBH (33.85 cm) of *M. dubia* at SSG planting was of trees under sole plantation having 4 x 4 m spatial geometry and the trees from sole plantation at 2 x 2 m were recorded with lowest GBH of 20.10 cm. At the end of SSG intercropping, GBH of trees under *M. dubia* (4 x 2 m)-SSG system was maximum (44.18 cm) and the minimum (29.28 cm) was of trees in *M. dubia* (2 x 2 m) sole plantation.

Further, GBH increment (difference in GBH at final SSG harvest and at sowing of SSG) was put up maximum (15.53 cm) by the trees under *M. dubia* (4 x 2 m)-SSG (T_4) silvi-pasture system and minimum GBH increment (8.20 cm) was put up by the trees under *M. dubia* (4 x 2 m) sole plantation.

Volume and increment (m^3/tree)

The results indicated that significantly maximum per tree volume (at SSG sowing) to the tune of 0.070 m^3/tree was of trees under sole *M. dubia* planted at 4 x 4 m and minimum (0.017 m^3/tree) was under *M. dubia* (2 x 2 m) sole plantation (Table 2). However, at SSG final harvest, significantly maximum volume (0.156 m^3/tree) was of trees in *M. dubia* (4 x 2 m)-SSG system and the minimum per tree volume (0.047 m^3/tree) was recorded under sole plantation of *M. dubia* planted at 2 x 2 m geometry. The increment in volume per tree was put up maximum (0.109 m^3/tree) by the trees under *M. dubia* (4 x 2 m)-SSG (T_4) system and the lowest volume increment i.e. 0.030 m^3/tree was put up by the trees from *M. dubia* 2 x 2 m (T_6) sole plantation (Table 2).

Biomass and increment (kg /tree)

The data in the table 2 evinced that per tree standing biomass was significantly maximum (34.73 kg/tree) under sole *M. dubia* spaced at 4 x 4 m, whereas, minimum (8.51 kg/tree) was recorded under *M. dubia* sole plantation with 2 x 2 m spacing. However, at the final SSG forage harvest, biomass and its increment were maximum (77.14 and 53.72 kg/tree, respectively) of trees in *M. dubia* (4 x 2 m)-SSG system. The minimum per tree biomass (23.31 kg) and its increment (14.81 kg/tree) were recorded for the trees under sole plantation of *M. dubia* at 2 x 2 m spacing.

Volume and increment (m^3/ha)

The data illustrated in the table 3 indicated that, at SSG intercropping, the maximum wood volume production (84.69 m^3/ha) was under sole *M. dubia* plantation spaced at 3 x 2 m and minimum (37.27 m^3/ha) was recorded under *M. dubia* sole plantation at 2 x 2 m spacing. However, at final SSG forage harvest, highest wood volume (199.94 m^3/ha) from *M. dubia* (3 x 2 m)-SSG system, whereas, lowest (76.12 m^3/ha) was recorded in *M. dubia* (4 x 4 m)-SSG system. Further, the increment in wood volume was put-up maximum (128.83 m^3/ha) by trees under *M. dubia* (4 x 2 m)-SSG silvi-pasture system and minimum (38.85 m^3/ha) was of those under *M. dubia* (4 x 4 m)-SSG silvi-pasture system (Table 3).

Biomass and increment (t/ha)

The data pertaining to biomass at SSG planting (Table 3) revealed that *M. dubia* sole plantation with spatial configuration 3 x 2 m recorded with highest biomass (41.92 t/ha) and lowest (18.45 t/ha) was under *M. dubia* (4 x 4 m)-SSG system. However, at SSG final harvest, maximum wood biomass to the tune of 98.97 t/ha was gained by the trees under *M. dubia* (3 x 2 m)-SSG silvi-pasture system and minimum *M. dubia* wood biomass (37.68 t/ha) was recorded under *M. dubia* at (4 x 4 m)-SSG silvi-pasture system.

Further, maximum wood biomass increment (63.77 t/ha) was acquired under *M. dubia* (4 x 2 m)-SSG system, whereas, *M. dubia* (4 x 4 m)-SSG (T_5) system exhibited minimum biomass increment i.e. 19.23 t/ha (Table 3). Overall, the present investigation pointed out that there were significant differences observed in growth and yield attributes of *M. dubia* either in silvi-pasture or sole plantation systems. Both, the growth and yield parameters including increments in them were higher under silvi-pasture system compared to sole plantation systems, which confirm the beneficial effect of conflating *M. dubia* with SSG as intercrop.

Similar findings were put forth by Khan and Chaudhary (2007) in *Populus deltoids*, Thakur *et al.,* (2019b) and Jilariya *et al.*, (2017) in *M. dubia*. The overall divergence in the volume and biomass were due to the tree numbers in lesser spacings which directly affected total yield in both terms. This reveals that growth is the cumulative result of age, spacing and site quality (Nissen *et al.*, 2001). In the wider spacings, more availability of light, water and nutrients resulting in increase in crown size, leaf area and synthesis of carbohydrates and hormonal growth regulators may have improved the height and GBH growth (Baldwin *et al*., 2000; Nissen *et al*., 2001; Zang *et al*., 2013; Thakur *et al*., 2019b).

Table.1 Comparative growth attributes of *M. dubia* under *M. dubia*-SSG silvi-pasture systems and sole *M. dubia* plantations

Land use systems	Height (m)		GBH (cm)		Increment	
	At SSG planting	At SSG final harvest	At SSG planting	At SSG final harvest	Height (m/tree)	GBH (cm/tree)
T_1	5.73	7.30	21.75	31.18	1.58	9.43
T_2	7.55	9.23	29.13	41.03	1.68	11.90
T_3	8.05	9.90	28.10	39.13	1.85	11.03
T_4	7.05	9.99	28.65	44.18	2.94	15.53
T_5	7.33	8.73	32.80	43.00	1.40	10.20
T_6	5.30	6.88	20.10	29.28	1.58	9.18
T_7	7.48	8.78	30.00	39.33	1.30	9.33
T_8	7.78	9.60	31.88	43.58	1.83	11.70
T_9	6.90	7.90	31.05	39.25	1.00	8.20
T_{10}	7.68	9.03	33.85	44.08	1.35	10.23
SEm (±)	0.28	0.27	1.71	1.84	0.24	1.34
$CD_{(0.05)}$	0.82	0.80	4.98	5.37	0.69	3.92
CV (%)	7.96	6.28	11.89	9.34	28.49	25.18

Note: T_1 = *M. dubia* (2 x 2 m)-SSG, T_2 = *M. dubia* (3 x 2 m)-SSG, T_3 = *M. dubia* (3 x 3 m)-SSG, T_4 = *M. dubia* (4 x 2 m)-SSG, T_5 = *M. dubia* (4 x 4 m)-SSG, T_6 = *M. dubia* (2 m X 2 m), T_7 = *M. dubia* (3 x 2 m), T_8 = *M. dubia* (3 x 3 m), T_9 = *M. dubia* (4 x 2 m), T_{10} = *M. dubia* (4 x 4 m)

Table.2 Volume (m^3/tree) and biomass (kg/tree) of *M. dubia* under *M. dubia*-SSG silvi-pasture systems and sole *M. dubia* plantations

Land use systems	Volume (m^3/tree)		Biomass (kg/tree)		Increment	
	At SSG planting	At SSG final harvest	At SSG planting	At SSG final harvest	Volume (m^3/tree)	Biomass (kg/tree)
T_1	0.022	0.057	10.79	28.36	0.036	17.57
T_2	0.052	0.126	25.58	62.52	0.075	36.94
T_3	0.053	0.123	26.44	60.82	0.069	34.38
T_4	0.047	0.156	23.42	77.14	0.109	53.72
T_5	0.063	0.128	31.11	63.54	0.066	32.43
T_6	0.017	0.047	8.51	23.31	0.030	14.81
T_7	0.054	0.108	26.48	53.38	0.054	26.90
T_8	0.065	0.147	32.21	72.98	0.082	40.77
T_9	0.053	0.097	26.31	47.90	0.044	21.59
T_{10}	0.070	0.140	34.73	69.26	0.070	34.52
SEm (±)	0.008	0.013	3.75	6.21	0.010	4.87
$CD_{(0.05)}$	0.022	0.037	10.94	18.13	0.029	14.22
CV (%)	30.527	22.228	30.55	22.23	31.079	31.08

Note: T_1 = *M. dubia* (2 x 2 m)-SSG, T_2 = *M. dubia* (3 x 2 m)-SSG, T_3 = *M. dubia* (3 x 3 m)-SSG, T_4 = *M. dubia* (4 x 2 m)-SSG, T_5 = *M. dubia* (4 x 4 m)-SSG, T_6 = *M. dubia* (2 m X 2 m), T_7 = *M. dubia* (3 x 2 m), T_8 = *M. dubia* (3 x 3 m), T_9 = *M. dubia* (4 x 2 m), T_{10} = *M. dubia* (4 x 4 m)

Table.3 Volume (m^3/ha) and biomass (t/ha) of *M. dubia* under *M. dubia*-SSG silvi-pasture systems

Land use systems	Volume (m^3/ha)		Biomass (t/ha)		Increment	
	At SSG planting	At SSG final harvest	At SSG planting	At SSG final harvest	Volume (m^3/ha)	Biomass (t/ha)
T_1	51.78	136.06	25.63	67.35	84.28	41.72
T_2	81.80	199.94	40.49	98.97	118.14	58.48
T_3	56.35	129.62	27.90	64.16	73.27	36.26
T_4	56.16	184.99	27.80	91.57	128.83	63.77
T_5	37.27	76.12	18.45	37.68	38.85	19.23
T_6	40.81	111.85	20.20	55.36	71.04	35.17
T_7	84.69	170.71	41.92	84.50	86.02	42.58
T_8	68.65	155.54	33.98	76.99	86.89	43.02
T_9	63.09	114.87	31.23	56.86	51.78	25.63
T_{10}	41.61	82.96	20.60	41.07	41.36	20.47
SEm (±)	8.75	16.53	4.33	8.18	13.45	6.66
$CD_{(0.05)}$	25.52	48.22	12.63	23.87	39.23	19.42
CV (%)	30.05	24.26	30.05	24.26	34.46	34.46

Note: T_1 = *M. dubia* (2 x 2 m)-SSG, T_2 = *M. dubia* (3 x 2 m)-SSG, T_3 = *M. dubia* (3 x 3 m)-SSG, T_4 = *M. dubia* (4 x 2 m)-SSG, T_5 = *M. dubia* (4 x 4 m)-SSG, T_6 = *M. dubia* (2 m x 2 m), T_7 = *M. dubia* (3 x 2 m), T_8 = *M. dubia* (3 x 3 m), T_9 = *M. dubia* (4 x 2 m), T_{10} = *M. dubia* (4 x 4 m)

The growth and yield parameters of *M. dubia* planted at various spatial configurations, either in silvi-pasture systems or sole plantations, differed significantly due to intercropping of SSG. The findings suggested that maximum wood biomass, which is the ultimate salable product from the tree, can be obtained from the *M. dubia* planted at 3 × 2 m and 4 × 2 spatial arrangements in silvi-pasture systems.

The maximum increment in wood biomass was also higher in the above mentioned two spatial configurations under silvi-pasture. Therefore, it can be substantiated from this study that silvi-pasture has positive effect on the *M. dubia* growth and yield performance and are considered best suited spatial arrangements for getting higher wood biomass.

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