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# Climate Resilient Practices for Augmenting Foxtail millet *Melia dubia* System Productivity and Carbon Sequestration

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***Abstract*:** Investigation to know the effect of climate resilient practices on carbon sequestration and productivity of foxtail millet-*Melia dubia* agroforestry was carried out during 2018-2019 to 2019-20 under UAS, Raichur, Karnataka. The foxtail millet was cultivated in five years old *Melia dubia* spaced at 9 m x 3 m. The experiment comprising of eleven treatments with three replications, laid out in randomized block design in agroforestry system involving various combination of FYM + poultry manure + panchagavya alternated with vermiwash imposed treatment showed its significant superiority in grain yield of foxtail millet (1487 kg $ha^{-1}$) over all other treatments. Significantly higher carbon stock in biomass was observed with the application of FYM + poultry manure **+** panchagavya (22.03 t $ha^{-1}$) followed by FYM + poultry manure + panchagavya + vermiwash spray (21.97 t $ha^{-1}$) while lower biomass was recorded with no organic manurial treatment (17.34 t $ha^{-1}$) in agroforestry system. Significantly higher carbon sequestration (80.87 t $ha^{-1}$) was observed with the application of FYM + poultry manure **+** panchagavya while lowest was with no organic manures treated plot (63.64 t $ha^{-1}$) with tree association. Significantly higher net returns of the system of Rs. 3,21,056 $ha^{-1}$ were obtained with FYM+ poultry manure + panchagavya + vermiwash spray except FYM + poultry manure + foliar spray of 3% panchagavya (Rs. 3,20,715 $ha^{-1}$) over all other treatments. No organic manurial treatment recorded significantly lower net returns from the system (Rs. 2, 40, 937 $ha^{-1}$). For higher and sustainable system productivity and income in agroforestry application of FYM (50 %) + poultry manure (50 %) equivalent to 100 % recommended 'N' along with foliar spray of 3% panchagavya at 30 and 45 DAS or foliar spray of 3% panchagavya at 30 DAS alternated with 5 % vermiwash at 45 DAS could be advised under organic production system.

***Keywords***: Agroforestry, Organics, Carbon, Sequestration, Productivity

Tree component in agroforestry systems is significant sink of atmospheric carbon (C) due to their fast growth and high productivity. By including trees in agricultural production systems, agroforestry can, arguably increase the amount of C stored in lands devoted to agriculture, while still allowing for the growing of food crops[2]. In agroforestry system, tree components are managed, often intensively by pruning of minimizing competition and maximize complementarity. The pruned materials are mostly non-timber products. Such materials are often returned to soil. Besides, the amount of biomass and therefore C that is harvested and exported from the system is relatively low in relation to the productivity of the tree. Therefore, unlike in tree plantations and other mono culture systems, agroforestry seems to have unique advantage in terms of C sequestration (Kulkarni 2017).

Recently *Melia dubia* tree species has been introduced in north eastern part of the state which is popularly known as Kalyana Karnataka region. Though it has multiuse, farmers are reluctant in adopting forestry system because of lack of knowledge on scientific cultivation. There is a need to take up studies on these research gaps for economic growth of *Melia* species under given agro-eco-system (Banyal et al 2018).

Millets are comparable to that of super cereals like rice and wheat due to their capacity to withstand drought, adaptable to poor environment and input management. They are suitable for inclusion in multiple/intercropping systems because of its short duration and adjustable to mid season correction. Thus, millets deserve a greater importance than the major cereal crops. Being eco-friendly, these crops are suitable for fragile and vulnerable eco-systems and regarded as preferred crop for sustainable and green agriculture. Hence promotion of millets can lead to efficient management of natural resources and holistic approach in sustaining precious agro-biodiversity. Among the eight millets, foxtail millet (*Setaria italica*) is extensively cultivated in Kalyana Karnataka region and it is an indigenous crop known for its rich nutritive value and fairly drought tolerant (Anon. 2018). In this context, either under sole cropping or with agroforestry system, it is worth to mention that nutrient management through organics plays a major role in exploiting the potential crop yields apart from maintaining soil health as a results of buildup of soil organic matter, beneficial microbes and enzymes thus improving soil physical and chemical properties under organic production system. In a farming system approach, the nutrient needs are met out through recycling process (Aarti et al 2023). Climate smart practices like use of organics, millet crop and tree plantation were tested for productivity and carbon sequestration potentiality in *Melia dubia* tree plantation.

## MATERIAL AND METHODS

The experiment was conducted for two years (2018-19

and 2019-20) at Santhekallur under UAS, Raichur which represents Northern Dry Zone of Karnataka (Zone 3), situated between latitude of 15° 99N and longitude of 76° 66 E with a mean sea level of 499 m. There were eleven treatments with three replications, laid out in completely randomized block design. The treatments consisted of application of no organic manure (control), FYM equivalent to 100 per cent RDN, FYM (50%) + Vermicompost (50 %) and FYM (50 %) + Poultry manure (50 %) equivalent to 100 per cent RDN alone and in combination with foliar spray of 3.0 per cent panchagavya and 5.0 per cent vermiwash at 30 and 45 DAS and foliar spray of 3.0 per cent panchagavya at 30 DAS alternated with 5.0 per cent vermiwash at 45 DAS. Grain and straw yield of foxtail millet was recorded at physiological maturity and used for total biomass production from agroforestry system. Following observations were made for calculation of total biomass and carbon sequestration and stock.

**Tree Observations**

**Bole height (m):** It was measured using a measuring tape fixed on a straight wooden stick from the ground level to the crown point, which was expressed in metre (m).

**Diameter at breast height – DBH (cm):** It was measured with measuring tape at 1.37 m above the base of the plant and it was expressed in centimeter (cm).

**Total wood volume ($m^3$):** The standing volume of trees was calculated (Kulkarni 2017)

$$\text{Volume } (m^3) = \pi \times (D/2)^2 \times H$$

Where, D is the diameter at breast height (DBH in m) H is the bole height of the tree (m).

**Tree biomass (t $ha^{-1}$):** Biomass estimation was carried out using volume (tree bole height, DBH) and wood density. Wood density of 6 years old *Melia dubia* tree is 500.2 kg $m^{-3}$.

**Above ground biomass (AGB) (t $ha^{-1}$)**

Above ground biomass = Volume ($m^3$) X Wood density (kg $m^{-3}$).

Then biomass was converted into t $ha^{-1}$.

**Below ground biomass (BGB) (t $ha^{-1}$):** Below ground biomass of the tree was calculated using 0.26 factor of root: shoot ratio (Naguven 2012).

$$\text{BGB (kg tree}^{-1}) = \text{AGB (kg tree}^{-1}) \times 0.26$$

Then biomass was converted into t $ha^{-1}$.

**Total tree biomass (t $ha^{-1}$):** Sum of above ground and below ground biomass gave total biomass (TB) of the tree (Pandya et al 2014).

TB (kg $tree^{-1}$) = AGB (kg $tree^{-1}$) + BGB (kg $tree^{-1}$). Then biomass was converted into t $ha^{-1}$.

**Carbon Stocks and Sequestration**

**Carbon stocks (t $ha^{-1}$):** Both above and below ground biomass was converted into above and below ground carbon stocks was calculated (Naguven 2012).

Carbon stocks (t $ha^{-1}$) = 0.50 x TB (t $ha^{-1}$)

The total carbon storage was calculated by adding carbon stocks in above and below ground biomass.

**Carbon sequestration (t $ha^{-1}$):** The $CO_2$ equivalents (quantity of C x 44/12) were arrived from carbon stocks for calculating $CO_2$ sequestration (t $ha^{-1}$) by biomass of *Melia dubia* trees in agroforestry system (Naguven 2012).

Carbon sequestration (t $ha^{-1}$) = C stock x 44/12

## RESULTS AND DISCUSSION

**Effect of climate smart practices on grain and stalk yield :** The foxtail millet cultivation with recommended organic nutrient practices without tree component recorded significantly higher grain yield (1656 kg $ha^{-1}$) when compared to all other organic manurial treatments with *Melia dubia* plantation system (801 to 1487 kg $ha^{-1}$) (Table 1). In agroforestry system, application of FYM + poultry manure + panchagavya alternated with vermiwash spray ($T_{10}$) resulted in significantly higher grain yield (1487 kg $ha^{-1}$) and it was found on par with FYM + vermicompost + panchagavya alternated with vermiwash spray- $T_9$ (1440 kg $ha^{-1}$), FYM + poultry manure + panchagavya (1412 kg $ha^{-1}$), FYM + vermicompost + panchagavya spray (1406 kg $ha^{-1}$) and FYM + poultry manure + vermiwash (1403 kg $ha^{-1}$) which were on par with each other. The $T_{10}$ recorded significantly higher straw yield (2611 kg $ha^{-1}$) over all other treatments except $T_6$, $T_9$, $T_8$, and $T_5$.

The mean grain yield of foxtail millet cultivated along with organic nutrient management schedule without tree component was 360 kg $ha^{-1}$ higher than in association with tree component, indicating 28 per cent reduction with agroforestry system. This might be due to better utilization of solar energy without any shade effect of trees in open condition. Yield reduction in foxtail millet when intercropped with *Melia dubia* compared to sole crop without trees as an intercrop was due to reduced photosynthetic active radiation on crop canopy. These results were in conformity with the findings of Ashalatha et al (2015)in blackgram, Bhusara et al (2018) in greengram and Chandana et al (2020) in pearl millet when these crops were grown with *Melia dubia* species in agroforestry system.

The negative effect of tree on crop growth and yield of foxtail millet was reduced by application of organic nutrient management practices over a long period of time. As clearly indicated in the investigation *i.e*., application of organic manures *i.e*., FYM with poultry manure/vermicompost along with foliar spray of panchagavya and vermiwash alone or in alternate application ($T_5$ to $T_{10}$) resulted significantly higher yield than with no organic manurial treatment. These results

were in line with findings of Bhat (2015) in *capsicum*, tomato, garden pea and cauliflower with *Melia composita* with application of vermicompost, Khan and Krishna (2016) in finger millet with *Melia azedaracha* by application of poultry manure, Pallavi et al (2016) in finger millet with *Melia* species with application of poultry manure. Use of balanced levels of nitrogen through organic sources has optimized the availability of nutrients and helped in inducing good vegetative growth. Increased grain yield might also be due to the increased photosynthetic activity which resulted in higher accumulation of photosynthates and translocation to sink due to better source and sink channel which resulted in higher grain yield. Similar results were also reported by Upendranaik et al (2018) and Krupashree (2019).

**Effect of Climate Smart Practices Properties**

**Tree growth:** At the end of second year of experimentation (2019) the highest bole height of *Melia dubia* was observed with treatment $T_6$ (10.45 m) followed by $T_{10}$ (10.42 m) while lower was recorded with no organic manurial treatment over all other treatments (Table 2, 3). The higher tree diameter at breast height (DBH) was with $T_7$ (66.8 cm) followed by $T_6$ .The lower DBH was registered with no organic manurial treatment (63.4 cm). *Melia dubia* tree wood volume was ranged from 49.99 (no organic manurial treatment) to 61.48 t $ha^{-1}$ in $T_6$. Total biomass production was calculated by adding biomass production in below and above grounds, which was ranged from 6.23 to 44.07 t $ha^{-1}$. Treatment $T_6$ showed its significant superiority in total biomass production (44.07 t $ha^{-1}$) over $T_2$, $T_1$, $T_3$, $T_{11}$ (6.23 t $ha^{-1}$) .

**Total carbon stock in biomass (t $ha^{-1}$):** Total carbon stock ranged from 3.11 to 22.03 t $ha^{-1}$. In agroforestry system, significantly higher carbon stock was observed in treatment as compared with $T_1$ (17.34 t $ha^{-1}$).

**Carbon sequestration (t $ha^{-1}$) (Fig. 1):** Total carbon sequestration in biomass was the sum total of carbon sequestration in above and below ground in both agroforestry and non-agroforestry system which ranged from 11.42 to 80.87 t $ha^{-1}$. Significantly higher carbon sequestration was observed with tree association than the without tree. Among the organic manurial treatments with *Melia dubia*, significantly higher carbon sequestration was observed with $T_6$ (80.87 t $ha^{-1}$) when compared with $T_1$, FYM and FYM + vermicompost. Next best treatment was $T_{10}$ (80.64 t $ha^{-1}$), which in turn showed its significant superiority over rest of other treatments. Other treatments were intermediary in their effect. The significantly lower total carbon sequestration was observed with sole foxtail millet with recommended organic nutrient practices without tree component (11.42 t $ha^{-1}$).

The present study highlights that *Melia dubia* + foxtail millet agroforestry system is a better option than the sole agricultural cropping in respect of climate mitigation and sustainable productivity and doubling farmer's income. 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. Higher carbon sequestration with various agroforestry systems was also reported by Rahul Arya et al (2021).

**System Economic analysis**

**Gross returns (Rs. $ha^{-1}$):** At the end of sixth yea plantation (2019) significant variation in gross returns was observed between cultivation of foxtail millet with and without tree

**Table 1.** Grain yield and straw of foxtail millet as influenced by organic nutrient management practices in *Melia dubia* based agroforestry system (Pooled data)

| Treatments | Grain yield (Kg $ha^{-1}$) | Straw yield (Kg $ha^{-1}$) |
|---|---|---|
| $T_1$ : No organic manure | 801 | 1637 |
| $T_2$: FYM equivalent to 100 % RDN | 1104 | 2072 |
| $T_3$ : FYM (50%) + Vermicompost (50%) equivalent to 100 % RDN | 1227 | 2198 |
| $T_4$: FYM (50%) + Poultry manure (50%) equivalent to 100 % RDN | 1291 | 2270 |
| $T_5$ : $T_3$ + Foliar spray of Panchagavya @ 3 % at 30 and 45 DAS | 1406 | 2461 |
| $T_6$: $T_4$ + Foliar spray of Panchagavya @ 3 % at 30 and 45 DAS | 1412 | 2545 |
| $T_7$ : $T_3$ + Foliar spray of Vermiwash @ 5 % at 30 and 45 DAS | 1389 | 2402 |
| $T_8$: $T_4$ + Foliar spray of Vermiwash @ 5 % at 30 and 45 DAS | 1403 | 2484 |
| $T_9$ : $T_3$ + Foliar spray of Panchagavya @ 3 % at 30 DAS and Vermiwash @ 5 % at 45 DAS | 1440 | 2511 |
| $T_{10}$: $T_4$ + Foliar spray of Panchagavya @ 3 % at 30 DAS and Vermiwash @ 5 % at 45 DAS | 1487 | 2611 |
| $T_{11}$: Sole foxtail millet without tree component | 1656 | 3127 |
| CD at 5% | 90 | 188 |

**NS:** Not significant

components. Significantly lower gross returns were observed in sole foxtail millet with recommended organic nutrient practice without tree component (Rs 59,813 $ha^{-1}$). The significantly higher gross returns were with $T_6$ (Rs. 4, 05, 577 $ha^{-1}$) and $T_{10}$(Rs. 4, 05, 368 $ha^{-1}$), which were significantly superior over all other treatments. No organic manurial treatment recorded significantly lower gross returns (Rs. 3, 17, 189 $ha^{-1}$) in agroforestry system.

**Net returns (Rs. $ha^{-1}$):** At the end of sixth year of plantation (2019), net returns were significantly influenced by cultivation of foxtail millet with and without tree component. Significantly higher system net returns were obtained in all organic manurial treatments with agroforestry system from Rs. 2,40,937 to 3,21,056 $ha^{-1}$ with an average of Rs. 289920 $ha^{-1}$ over the treatment foxtail millet cultivation with recommended organic nutrient schedule in non agroforestry system (Rs. 37,111 $ha^{-1}$). In agroforestry system, significantly higher net returns of the system of Rs. 3 ,21, 056 $ha^{-1}$ were obtained with $T_{10}$.

**Benefit cost ratio:** The significantly higher benefit cost ratio from the whole system was realized with application of $T_{10}$ (4.81) followed by application of $T_6$ and $T_7$ which were significantly superior over all other treatments. Treatment $T_1$ recorded significantly lower benefit cost ratio in agroforestry system (4.16) compared to all the treatments. Foxtail millet cultivated organically with nutrient management schedule without tree component recorded significantly lower benefit cost ratio (2.63) over all other treatments.

**Table 2.** *Melia dubia* tree growth properties under organic nutrient management practices with foxtail millet inter cropping system

| Treatments | Bole height (m) | | | | DBH (cm) | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | 2018 | 2019 | Increment (%) | Initial | 2018 | 2019 | Increment (%) |
| $T_1$ | 10.00 | 10.10 | 10.20 | 1.99 | 62.1 | 63.2 | 63.4 | 2.09 |
| $T_2$ | 9.85 | 10.05 | 10.21 | 3.62 | 61.8 | 62.3 | 64.1 | 3.70 |
| $T_3$ | 9.82 | 10.05 | 10.23 | 4.13 | 62.2 | 63.2 | 64.6 | 3.82 |
| $T_4$ | 9.78 | 10.02 | 10.35 | 5.75 | 63.1 | 64.10 | 65.6 | 3.92 |
| $T_5$ | 9.65 | 09.88 | 10.18 | 5.42 | 63.4 | 64.8 | | 4.14 |
| $T_6$ | 9.85 | 10.25 | 10.45 | 6.01 | 63.1 | 64.1 | 66.5 | 5.33 |
| $T_7$ | 9.62 | 09.98 | 10.25 | 6.45 | 64.2 | 65.3 | 66.8 | 4.01 |
| $T_8$ | 9.65 | 09.89 | 10.28 | 6.43 | 59.4 | 60.8 | 65.5 | 5.07 |
| $T_9$ | 9.85 | 10.20 | 10.45 | 6.00 | 62.3 | 63.8 | 65.8 | 5.54 |
| $T_{10}$ | 9.7 | 10.15 | 10.42 | 7.30 | 62.0 | 63.8 | 65.9 | 6.04 |
| $T_{11}$ | - | - | - | - | - | - | - | - |

See Table 1 for treatment details

**Table 3.** *Melia dubia* tree properties and carbon sequestration under nutrient management practices

| Treatments | Wood volume (t $ha^{-1}$) | Total biomass (t $ha^{-1}$) | C stock above ground (t $ha^{-1}$) | C stock below ground (t $ha^{-1}$) | Total C stock (t $ha^{-1}$) | C sequestration above ground (t $ha^{-1}$) | C sequestration below ground (t $ha^{-1}$) | Total C sequestration (t $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| $T_1$ | 49.99 | 34.68 | 13.76 | 3.58 | 17.34 | 50.50 | 13.13 | 63.64 |
| $T_2$ | 54.13 | 38.29 | 15.19 | 3.95 | 19.14 | 55.76 | 14.50 | 70.26 |
| $T_3$ | 55.45 | 39.53 | 15.69 | 4.08 | 19.77 | 57.57 | 14.97 | 72.54 |
| $T_4$ | 58.46 | 41.59 | 16.50 | 4.29 | 20.79 | 60.57 | 15.75 | 76.31 |
| $T_5$ | 55.67 | 40.28 | 15.98 | 4.16 | 20.14 | 58.66 | 15.25 | 73.91 |
| $T_6$ | 61.48 | 44.07 | 17.49 | 4.55 | 22.03 | 64.18 | 16.69 | 80.87 |
| $T_7$ | 60.44 | 43.15 | 17.12 | 4.45 | 21.58 | 62.85 | 16.34 | 79.19 |
| $T_8$ | 54.55 | 38.25 | 15.18 | 3.95 | 20.13 | 57.71 | 15.49 | 74.20 |
| $T_9$ | 57.04 | 41.17 | 16.34 | 4.25 | 20.59 | 59.96 | 15.59 | 75.55 |
| $T_{10}$ | 61.04 | 43.95 | 17.44 | 4.53 | 21.97 | 64.00 | 16.64 | 80.64 |
| $T_{11}$ | - | 6.23 | 2.47 | 0.64 | 3.11 | 9.07 | 2.36 | 11.42 |
| CD at 5% | - | 4.05 | 1.61 | 0.42 | 2.02 | 5.89 | 1.53 | 7.42 |

It is evident that the intercropping of foxtail millet with *Melia dubia* showed maximum gross and net monetary returns when compared to sole cropping without tree component. Improved monetary returns from the system (tree + crop) are mainly due to higher biomass production from the tree in the form of timber with better performance of foxtail millet under organic nutrient management practices. This clearly shows that arable crops like foxtail millet when grown as an intercrop with the trees exhibit compatibility with the trees in mutual sharing of the natural resources available. Agroforestry practices fetched higher returns when compared to sole crop. These results are in accordance with results obtained by Chandana et al (2020) in pearl millet with *Melia dubia* based agroforestry systems.

## CONCLUSION

By practicing climate smart practices in *Melia dubia* based agroforestry system, foxtail millet could able to show their potential yield even under shade stress condition which is mainly attributed to the application of organic manures like FYM, poultry manure and vermicompost in combination with foliar spray of panchagavya and vermicompost. The present study highlights, *Melia dubia* + foxtail millet agroforestry system as a better option than sole agricultural cropping. The combination of crop with tree in the study led to higher

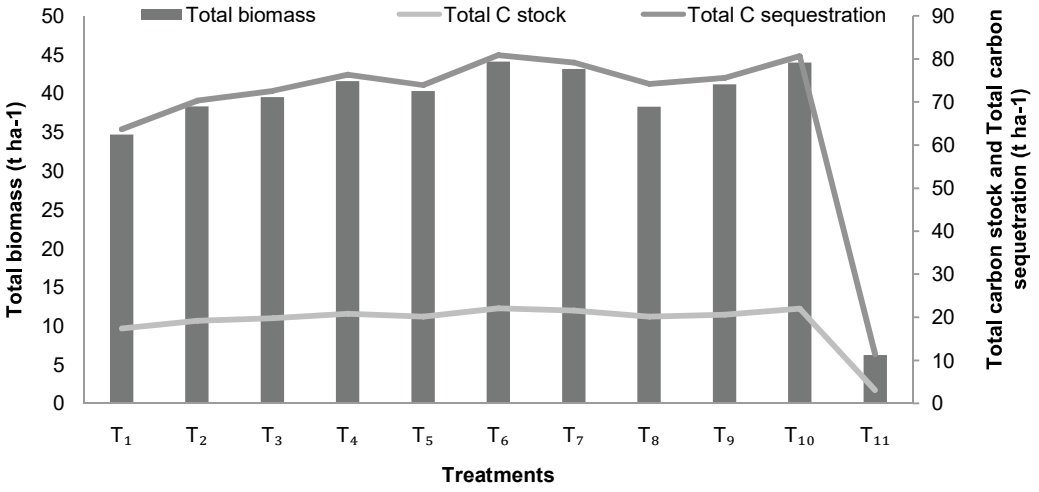


**Fig. 1.** *Melia dubia* tree total biomass, total c stock and total C sequestration under organic nutrient management practices foxtail millet- *Melia dubia* agroforestry system

**Table 4.** System economic analysis

| Treatments | Agroforestry system (Crop + *Melia dubia*) at the end of 6th year of plantation (2019) | | | |
|---|---|---|---|---|
| | Gross returns (Rs. ha$^{-1}$) | Cost of cultivation (Rs. ha$^{-1}$) | Net returns (Rs. ha$^{-1}$) | B : C ratio |
| $T_1$ | 317189 | 76252 | 240937 | 4.16 |
| $T_2$ | 352032 | 83952 | 268080 | 4.19 |
| $T_3$ | 364226 | 83857 | 280369 | 4.34 |
| $T_4$ | 384215 | 83062 | 301153 | 4.63 |
| $T_5$ | 371593 | 85657 | 285937 | 4.34 |
| $T_6$ | 405577 | 84862 | 320715 | 4.78 |
| $T_7$ | 399735 | 84557 | 315179 | 4.73 |
| $T_8$ | 353976 | 83762 | 270214 | 4.23 |
| $T_9$ | 380662 | 85107 | 295555 | 4.47 |
| $T_{10}$ | 405368 | 84312 | 321056 | 4.81 |
| $T_{11}$ | 59813 | 22702 | 37111 | 2.63 |
| CD at 5% | 3833 | - | 3833 | 0.09 |

biomass and carbon sequestration which is of positive benefit in mitigating climate change and maintaining ecological balance.

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