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Exploring Carbon Sequestration Potential Across Various Clones in Teak Plantation

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Abstract

A study conducted during August, 2019- February, 2020 forty year old clonal teak plantation in Manchikere, Karnataka, showed substantial carbon sequestration potential across eight distinct clones, emphasizing the promising role of genetic diversity in enhancing carbon capture. The clone studied were MyHaD1, MyHaD4, MyHaV1, MyHaV3, MyHaK2, MySA1, MyHuT1 and MyMK3. The recognition and propagation of superior clones are crucial for enhancing carbon sequestration, aiding in the absorption and storage of atmospheric carbon dioxide. The diverse performance observed among the eight clones in the clonal teak plantation underscores the critical role of genetic diversity in shaping key parameters such as girth at breast height, volume, and biomass accumulation. Measurements of volume, aboveground biomass (AGB), belowground biomass (BGB), and soil carbon stock, along with nitrogen (N), phosphorus (P), and potassium (K) levels, were conducted. Carbon sequestration potential per tree varied, with all individuals contributing 395.56 t ha^{-1}. MySA1 showed the highest potential (3.85 t), followed by MyHaD4 (3.08 t), and MyHaV1 recorded the least (1.46 t). Soil analysis revealed available N, P and K concentrations, and the total carbon sequestration rate was 69.55 t ha^{-1}. The organic carbon (OC) content was 1.98% and 1.61%. This emphasizes the importance of factoring in both genetic diversity and soil nutrient dynamics to optimize carbon management in teak plantations effectively.

Keywords: Biomass, carbon sequestration, clones, soil organic carbon, tectonagrandis

1. Introduction

Concerns about global warming are escalating worldwide, primarily due to the surge in carbon dioxide (CO_2) emissions-a key driver of greenhouse gas (GHG) levels and a major contributor to global warming (Anwar et al., 2019). Due to rapid deforestation, industrialization, population outburst and increased transportation activities in developing nations, the concentration of air pollutants, especially CO_2 is increasing exceptionally (Mishra et al., 2014; Kumar et al., 2019). In the atmosphere carbon in the form of CO_2 constitutes about 0.041% out of which 32% of that amount is due to human activities. Intergovernmental Panel on Climate Change (2019) reported that anthropogenic activities like Agriculture, Forestry and Other Land Use (AFOLU) contributed around 23% of greenhouse gas emitted during 2007–2016 (Shukla et al., 2019). The important role in mitigating climate change is played by the forest by capturing carbon in the form of tree biomass from the atmosphere which is of major concern and is "biggest and cheapest tool" of carbon sequestration. Vegetation and soil recognized as a mechanism helps in mitigation of accumulated atmospheric carbon dioxide (Janzen, 2004). In comparison with vegetation or atmospheric carbon stocks, the forested land has three times greater potential to store carbon in soil (Schmidt et al., 2011), but atmospheric CO_2 concentrations can be altered even with the minor change in forest soil organic carbon (Cotrufo et al., 2015; Schmidt et al., 2011; Trumbore and Czimczik, 2008). Involving biomass, five terrestrial ecosystem carbon pools have been identified by the IPCC (2003), namely the aboveground biomass, below-ground biomass, litter, woody debris and soil organic matter. With 20.6% of the total geographical area, India has mainly tropical forest ecosystem (Anonymous, 2005), this area becomes important for analysis of forest carbon sequestration potential. The carbon sequestered in the world's forests is estimated to store 283 Gt of carbon in biomass alone and altogether in ecosystem, 638 Gt of carbon (soil depth up to 30 cm). Thus, biomass carbon storage of global terrestrial ecosystem accounts for 77% which is more carbon in forest than the entire atmosphere.

The potential to sequester carbon decreases from tropical to boreal, temperate and subtropical forest. Worldwide, in tropical forests the aboveground carbon stored is 50% and the minimum storage has been determined in the polar forest (Liu et al., 2012).

India has undertaken a commitment to reduce its projected carbon emissions by as much as 1 billion tons by the year 2030, along with adopting other ambitious climate change targets agreed upon during the recent COP26 summit held in Glasgow (Prabha et al., 2023). The best management practices for CO_2 mitigation are reforestation, agroforestry and natural reforestation (Chaudhari et al., 2014; Kumar et al., 2018) and promoting plantations has emerged as a viable strategy (Kongmeesup and Boonyanuphap, 2019). Given the continued decline in natural forest timber resources, forest plantations are probably going to play a major part in the future wood supply as the growth and output of forest plantations are significantly greater than those of wild forests (McEwan et al., 2020). Plantation is very important land use not only to increase soil carbon store but also for carbon sink expansion (Gupta and Pandey, 2008). This approach involves not only natural forest growth but also considers the potential of clones-genetically identical individuals derived from a single parent plant. Clones, offer advantages such as uniform growth patterns and enhanced adaptability. Globally, rapidly increasing plantations, constituting 5% of the total forest cover, efficiently sequester carbon and have the potential to mitigate the projected rise in atmospheric CO_2 levels and address future climate change (Zhang et al., 2012). Forest plantations have a major influence on the global carbon sink, according to research findings and tree species capacity to store carbon is mostly determined by its rotation age of its plantations (Vijaykumar et al., 2011; Behera and Mohapatra, 2015) and clone type determining biomass production (Rae et al., 2004). Diverse genotypes within genomic groups maximize growth and adaptability across varied environments, optimizing biomass yields for various uses (Madiwalar et al., 2023). As Teak has the highest capacity for carbon sequestration among trees in India, makes it an excellent choice for plantation efforts aimed at mitigating climate change (Pichhode and Nikhil, 2017). The aim of the study is recognition and propagation of superior clones crucial for enhancing carbon sequestration, aiding in the absorption and storage of atmospheric carbon dioxide, contributing to mitigating climate change and supporting sustainable forestry practices aligned with global carbon reduction goal.

2. Materials and Methods

During August, 2019–February, 2020, an extensive study was carried out inforty year old clonal teak plantation in Manchikere, at latitude 13.32° N and longitude 74.79° E, in Uttara Kannada district under the Coastal Zone-10 with loamy soil of Karnataka. Eight clones were randomly selected to study their Carbon sequestration potential (Biomass+soil) where each clone was considered as a treatment and potential was compared among ramets of the clones.

Total 24 numbers of ramet (three clone^{-1}) were surveyed for the study and three replications were done in each treatment. The clone studied were MyHaD1 (Haliyala), MyHaD4 ((Haliyala), MyHaV1 (Haliyala), MyHaV3 (Haliyala), MyHaK2 (Mysore), MySA1 (Shimoga), MyHuT1 (Virajpet) and MyMK3 (Mysore).Nondestructive method was used to calculate the volume, biomass and CSE potential of the tree (Table 1).

Table 1: Formula for determining carbon content in a standing tree

Parameters studied	Formula
Basal area	g 4 π^{-1}
Volume (m)	Basal area (m)×Height (m)
AGB (ton)	Volume of biomass (cm)×wood density (g cm^{-1})
BGB (ton)	0.26×Above ground biomass (ton)
Total biomass (TB)	Above Ground Biomass (AGB)+Below Ground Biomass (BGB)
Carbon Storage	Biomass(ton)×50% or Biomass/2
Soil organic carbon (SOC)	((B-S)×N of $(NH_4)_2$ Fe $(SO_4)_2.6H_20$×0.003/ Weight of soil)×100
Total carbon stock (Mg ha^{-1})	SOC (%)×Bulk density×depth (cm)

B: Volume of 0.5 N $(NH_4)_2$ Fe $(SO_4)_2.6H_20$ used for blank (ml); S: Volume of 0.5 N $(NH_4)_2$ Fe $(SO_4)_2.6H_20$ used for soil sample (ml)

The available N in the soil was determined by alkaline permanganate method (Subbaiah and Asija, 1956). The available K in the soil was determined by neutral normal ammonium acetate method using Flame photometer (Jackson, 1973). The available P in the soil was determined by sodium bicarbonate method (Olsen et al., 1954) as described by Jackson (1973).

3. Results and Discussion

3.1. Biomass of the selected clones

The diverse performance observed among the eight clones in the clonal teak plantation underscores the critical role of genetic diversity in shaping key parameters such as girth at breast height, volume, and biomass accumulation. The current study revealed notable distinctions in specific growth attributes among different clones (Table 2). The study revealed varying values for the clones characteristics, notably the greatest girth at breast height (GBH) being observed in MySA1 (147 cm), succeeded by MyHaD4 (144 cm), MyMK3 (134 cm), MyHuT1 (133 cm), MyHaK2 (123 cm), MyHaD1 (122 cm), MyHaV3 (121 cm), and MyHaV1 (103 cm). In terms of volume,

Table 2: Mean annual biomass and carbon sequestration rate in different clones of Teak

Plantation area	*Tectona grandis* clones	Average gbh (cm)	Average height (m)	Basal area (m^2)	Total Volume (m^3)	AGB (t)	BGB (t)	Total biomass (t)	Carbon Sequestration (t)
Manchikere (Yellapura)	MyHaD1	122	14.00	0.13	5.35	1.09	0.28	4.13	2.06
	MyHaD4	144	15.00	0.18	7.98	1.63	0.42	6.16	3.08
	MyHaV1	103	14.00	0.09	3.79	0.78	0.20	2.93	1.46
	MyHaV3	121	17.30	0.13	6.53	1.33	0.35	5.04	2.52
	MyHaK2	123	19.60	0.13	7.58	1.55	0.40	5.85	2.92
	MySA1	147	18.00	0.19	9.97	2.04	0.53	7.70	3.85
	MyHuT1	133	16.3	0.15	7.43	1.52	0.39	5.73	2.86
	MyMK3	134	15.60	0.16	7.19	1.47	0.38	5.55	2.77
	SEm±	0.04	0.53	0.01	0.49	0.30	0.07	0.37	0.19
	CD(p=0.05*)	0.09	1.13	0.04	1.05	0.64	0.16	0.81	0.40
	C V	4.16	4.01	16.23	25.84	25.80	25.92	25.82	25.82

MySA1 exhibited the highest volume (9.97 m^3), followed by MyHaD4 (7.98 m^3), MyHaK2 (7.58 m^3), MyHuT1 (7.43 m^3), MyMK3 (7.19 m^3), MyHaV3 (6.53 m^3), MyHaD1 (5.35 m^3), and MyHaV1 (3.79 m^3). The cumulative standing biomass for surveyed tree individuals ranked highest in MySA1, followed by MyHaD4, MyHaK2, MyHuT1, MyMK3, MyHaV3, MyHaD1, and MyHaV1. The total volume for surveyed ramets (3 trees for each clone) was maximum at 9.97 m^3 in MySA1, followed by MyHaD4 (7.98 m^3), MyHaK2 (7.58 m^3), MyHuT1 (7.43 m^3), and a minimum of 3.79 m^3 in MyHaV1. The mean stem biomass for surveyed clones was highest in MySA1 (2.04 t), MyHaD4 (1.63 t), and MyHaK2 (1.55 t), while MyHaV1 exhibited the minimum (0.78 t). The overall biomass accumulation by the clones in the area reached 1543.56 t ha^{-1}. The mean below-ground biomass (BGB) was greatest in MySA1 (0.53 t), followed by MyHaK2 (0.40 t), MyHaD4 (0.42 t), and least in MyHaV1 (0.20 t). The total BGB for the seed orchard amounted to 621.78 t ha^{-1}. The maximum total biomass per tree for CSO was recorded in MySA1 (7.71 t), succeeded by MyHaD4 (6.163 t), MyHaK2 (5.85 t), and the lowest in MyHaV1 (2.93 t). The total biomass for the surveyed area reached 589.09 t ha^{-1}. The exemplary performance of MySA1 not only highlights its potential for biomass production but also emphasizes the significance of selecting clones with superior growth traits.

3.2. Carbon sequestration potential of clones

Carbon sequestration potential of the surveyed tree individuals (24 trees) demonstrated varying capacities, with MySA1 (3.85 t), MyHaD4 (3.08 t), MyHaK2 (2.92 t), MyHuT1 (2.86 t), MyMK3 (2.77 t), MyHaV3 (2.52 t), MyHaD1 (2.06 t), and the least in MyHaV1 (1.46 t) (Table 2). The confirmation of substantial variances in growth and yield attributes affirms the existence of inter-clonal variation among the studied clones. Behera and Mohopatra (2015) also reported similar findings carried out in Orissa where among 13 clones of teak, ORANP2 demonstrated the highest biomass accumulation at 223.72 m^3 ha^{-1}, whereas ORANP1 recorded the lowest value of 64.05 m^3 ha^{-1}.

3.3. Soil parameters of the clonal plantation

The integration of soil nutrient dynamics into the analysis provides valuable insights into carbon management strategies in plantations. Soil analysis at two depths (0–15 cm) and (15–30 cm) showed nitrogen levels of 220 kg ha^{-1} and 236 kg ha^{-1}, which is a vital growth stimulant, that increases biomass production, directly influencing carbon sequestration. Phosphorus content of 38.10 kg ha^{-1} and 30.00 kg ha^{-1}, essential for robust root development, enhances nutrient uptake, and potassium levels of 359.29 kg ha^{-1} and 381.01 kg ha^{-1} crucial for photosynthesis and carbohydrate synthesis. Total carbon sequestration, comprising biomass and soil, measured 69.55 t ha^{-1}, with 5.66 t attributed to biomass and 63.89 t to soil. The overall carbon sequestration per hectare per tree was 69.55 t.

4. Conclusion

We conclude that, recognizing the interplay between genetic factors and soil nutrient availability is crucial for optimizing carbon sequestration. Ongoing research in this direction will contribute to screening and prioritizing tree species in planting for each land use with potentially high C sequestration capacity, for achieving optimal carbon outcomes in the context of clonal plantations.

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