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Biomass Accumulation and Carbon Stocks in 13 Different Clones of Teak (*Tectona grandis* Linn. F.) in Odisha, India

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ABSTRACT

The rate of biomass accumulation and carbon stocks of 13 different clones of Teak in Odisha were studied to identify the promising genotypes suitable for massive clonal plantations in Odisha. ORANP2 produced highest biomass among the 13 clones of teak i.e. 223.72m^3/ha, while ORANP1 registered lowest value of 64.05m^3/ha in regards to biomass accumulation. The total carbon stock values were found in the range of 32.02-111.86t/ha for 13 different clones of teak. The Mean Annual Increment (MAI) value for total tree biomass lies between 1.91t/ha to 4.76t/ha in different clones of teak studied. Similarly the total CO_2 content was evinced to be varied from 128.77 to 440.21t/ha among the clones studied. The Current Annual Increment (CAI) values for total carbon stock and carbon content varied from 0.95-2.38t/ha and 3.50-8.73t/ha with the net annual carbon storage was found to be within 2.91-8.16t/ha. ORANP2 was found to be superior one in terms of net biomass and carbon content. It was ascertained that selection of suitable teak clone is highly required to meet both economic and environmental obligations.

Key words: Biomass, Carbon stock, Teak, MAI, CAI

INTRODUCTION

Anthropogenic greenhouse gas emissions have been increasing alarmingly since the pre-industrial era and is mostly driven by population growth and industrialization. Today, the world is confronted with the challenges or concerns of anthropogenic induced climate change which is adversely affecting economic and social progress across continents. In its fifth assessment report, Intergovernmental Panel on climate Change (IPCC) has highlighted the need of additional mitigation efforts beyond those in place today. Mitigation involves some level of co-benefits and of risks due to adverse side effects, but these risks do not involve the same possibility of severe, widespread and irreversible impacts as risks from climate change, increasing the benefits from near-term mitigation efforts (IPCC, 2015). Kyoto Protocol is the international legal instrument which formulates rules for putting in an integrated approach by the member countries to address climate change concerns with legally binding protocol for developed countries to reduce their Green House Gas (GHG) emissions by an average of 5.2% relative to 1990 levels. Given that the Kyoto Protocol recognizes forest as one of the important carbon sinks, and research evidences suggest that trees and stands of trees sequester carbon within their main stem wood, bark, branches, foliage and roots for decades, research on different tree species to assess their carbon sequestration potential could help in prioritizing the best land use practices to ensure sustainability and benefit sharing among countries (Kyoto, 1997; Nizami, 2012: Adnan and Nizmai ,2014). Further, Certified Emission Reductions (CERs) commonly known as carbon credits, where each unit is equivalent to the reduction of one metric tonne of CO_2e helped in quantifying the role of carbon sinks such as forests or plantations. The carbon sequestration potential of tree species vary with species, climate, soil and management. Research evidences also suggest that forest plantations have significant impact as a global carbon sink. The rotation of tree species and age of plantations mostly govern the carbon storage potential of different tree species. Long rotation species such as teak (*Tectona grandis Linn.f.*) has long carbon locking period compared to short duration species and has the added advantage that most of the teak wood is used indoors extending the locking period further (Sreejesh *et al.,* 2013). It may be perhaps the reason behind wide popularity of teak plantations in south-east Asia and in Africa, South and Central America. This teak based global sink would certainly increase because during the past 20 years most supplies of teak wood from natural forests have dwindled and increased interest has developed in the establishment of teak forest plantations.

In India, teak has a discontinuous distribution from its western limit in the western Aravallies at 24°42'N Latitude, northern most limit to Jhansi (25° 33') from where it extends to Mahanadi river in the east (Brandis, 1906). The Nilambur man made teak forests are known to the foresters throughout the world. In Odisha, teak has been introduced or planted in most of the districts across different agro climatic zones. However, Barbara Teak forests which were planted by the British in 1910 find a special place in the research and development of Teak in the state. Considering the fact that clonal plantations play a vital role in increasing productivity of forest species so also enhance the carbon storage potential, the present study was conducted in a 33 year Clonal Seed Orchard (CSO) of Teak. The study was aimed to find out the accumulation of biomass and carbon stocks in 13 different clones of Teak. The objective of the study was to capture the variation in regard to carbon storage potential among different clones of Teak. This would help a researcher to recommend the best clone for plantations or integrated land use practices with teak as a major component.

MATERIAL AND METHODS

The experiment was carried out in a 32 year old clonal teak plantation located at Silvicultural Research Station, Angul, Odisha, India. The experimental site is located between 21° 01' 17.8"N longitude and 84° 55'19.6"E latitude and an altitude of 440m above mean sea level. It was laid out in Latin Square Design (LSD) with thirteen replications. The experimental material comprised of thirteen clones of Teak (*Tectona grandis* L.) as treatments. The clones were planted at a spacing of 4m× 4m in 1981. The clones were collected from thirteen plus trees of Purunakote and Raigoda provenances of Odisha. In total, the experiment was comprised of 169 trees belong to 13 different clones i.e. ORANP1, ORANP2, ORANP3, ORANP4, ORANP5, ORANP6, ORANP7, ORANR1, ORANR2, ORANR3, ORANR4, ORANR5 and ORANR6. (ORAN)P1-P7 are clones from Purunakote provenance and (ORAN)R1-R6 represents clones from Raigoda provenance.

Stem Volume

Field observations on important growth parameters such as DBH and height of individual trees were recorded by following the standard procedures. Diameter at breast height (DBH) was measured with the help of caliper in two directions following the established guidelines and the average was computed and expressed in cm. The height of trees was measured from ground level to the top of the main shoot with the help of altimeter and expressed in meter. Then, the volume of stem per tree was calculated by the formula given by Forest Survey of India (FSI, 1996) for Odisha i.e.

$$VUB\ (m^3) = -0.0645 + 0.2322D^2H$$

Where, VUB = Volume under bark
D= DBH over bark
H= Height of the tree

The volume of stem per hectare was calculated by multiplying the average volume of stem per tree with plant population per ha. It was expressed in m^3/ha. The observations have been noted down in two consecutive years to assess annual increment and accumulation.

Wood Biomass

The stem volume obtained for different clones was multiplied with wood density (Bohre *et al.,* 2013, Reyes *et al.,* 1992; Pearson and Brown, 1932) to obtain stem wood biomass. Here, in absence of information about actual wood density, reference have been made to World Agroforestry Centre species data base i.e. 610-750Kg/m^3. After getting values of stem volume for both inputs, average of the obtained values for stem volume has been taken. Total tree biomass was calculated using below formula.

Total tree biomass (t ha-1) = Stem biomass (t ha-1) × Biomass expansion factor (BEF).

Here 1.5 was used as the biomass expansion factor (Brown and Luge, 1992).

Carbon stock

The total carbon stock was calculated by using conversion factor of 0.5. This conversion factor was multiplied with total biomass (t ha-1) and total carbon stocks (t ha-1) were estimated (Roy et al., 2001; Brown and Lugo, 1982; Malhi et al., 2004 and Nizami, 2012; Adnan et al., 2014).

Total carbon stock (t ha-1) = Total biomass (t ha-1) × Conversion factor (CF).

Carbon content was then multiplied by 44/12 to estimate CO_2 (Amir *et al.,* 2015)

RESULTS AND DISCUSSION

In the present study, the stem and tree biomass were estimated from the calculated value of stem volume for different clones (Table-1). The values for total stem and tree biomass varied significantly among the clones of teak studied. Clone ORANP2 exhibited highest quantity of stem volume of 219.33m^3/ha at the age of 32 years, whereas, the stem volume production in clones such as ORANP2, ORANP3, ORANP6, ORANP7 and ORANR3 was at par with each other. On the other hand, ORANP1 manifested least quantity of stem volume (62.79m^3/ha). The variation in stem volume production is attributed to the differences in Individual's genetic make-up. As the clones were obtained from two different provenances of the same district namely Purunakot and Raigoda of Angul district, environmental parameters have little impact on growth and development of individual clones. Phenotype is a product of genotype and environment (Zobel and Talbert, 1984). Here, the variation among genotypes is quite relevant and useful for obtaining next generation orchards. Palanisamy (2009), Saxena *et al.* (1971) and Kharche (1974) have also reported variations among different clones of teak in the same provenances.

The total tree biomass accumulation in 13 different clones in a 32 year old plantation of teak showed an interesting trend (Table-1). ORANP2 produced highest biomass among the 13 clones of teak i.e. 223.72m^3/ha, while ORANP1 registered lowest value of 64.05m^3/ha for biomass accumulation. The results are in line with the findings of Buvaneswaran *et al.* (2006) and Bohre *et al.* (2013). This implies that ORANP2 has higher genetic worth value than others. The data pertaining to total carbon stock and CO_2 content in different clones of teak also varied significantly in line with the trend observed in total tree biomass of different clones. The total carbon stock values were found in the range of 32.02-111.86t/ha for 13 different clones of teak. Similarly the total CO_2 content was evinced to be varied from 128.77 to 440.21t/ha among the clones studied. The findings are very similar with the findings of Kraenzal *et al.* (2003) and Bohre *et al.* (2013).

The values of Mean Annual Increment (MAI) in different clones of Teak as well as stem biomass, total tree biomass, total carbon stock and carbon content are presented in Table-2. On examining the data, it was found that the mean annual contributions from the above computed parameters are significant and varies among clones. The total tree biomass was in between 1.91t/ha to 4.76t/ha in different clones of teak studied. ORANR3 showed maximum value of mean annual biomass increment at this age, while like previous results ORANP1 again fall behind other clones in regards growth or performance. Similar trend was noticed in total carbon stock and carbon content values for different clones.

The range of values for total carbon stock and carbon content varied from 0.95-2.38t/ha and 3.50-8.73t/ha, respectively. Bohre *et al.* (2013) also reported closely similar results in this regard. This changing trend indicates that biomass and carbon stock potential get varied among clones of same species. The selection of suitable clone requires due attention before going for large scale planting programmes.

The annual biomass accumulation in different clones of Teak was found in the range of 5.82-16.98t/ha (Table-3). Maximum biomass accumulation in a year was observed in clone

ORANR3 followed by ORANR5, ORANP7 and ORANP3. This indicates a different growth trend when it comes about annual biomass accumulation rate. A study by Kaul *et al.* (2010) has reported annual biomass accumulation of 4.4t/ha in Teak at the age of 30 years in Indian condition. The present study findings indicate that teak continues to accumulate significant amount of biomass even after attaining 30 years of age. However, inter clonal variation in biomass accumulation is mostly because of the high influence of genotypes.

Knowledge on annual carbon storage potential and its trend over years is of vital need for foresters or ecologists for a myriad of reasons. This helps in the designing and execution of tree and plantation management approaches. In case of teak, which is considered as a moderate growing plant species with high commercial value, information about annual carbon storage potential and its inter and intra clonal variation as well as trend of carbon storage over years make it easier to take a right decision in popularizing suitable plantations through

Table 1: Biomass production and carbon storage potential of different clones of Teak (*Tectona grandis* Linn.f.)

Clone	Stem Volume (m)	Stem Biomass (t/ha)	Total Tree Biomass (t/ha)	Total Carbon Stock (t/ha)	CO_2 content (t/ha)
ORANP1	62.79	42.70(±4.82)	64.05(±7.23)	32.02(±3.62)	128.77(±13.26)
ORANP2	219.33	149.15(±16.48)	223.72(±24.72)	111.86(±12.36)	440.21(±45.32)
ORANP3	145.40	98.87(±11.37)	148.30(±17.06)	74.15(±8.53)	303.74(±31.27)
ORANP4	105.10	71.47(±8.13)	107.20(±12.19)	53.60(±6.10)	217.10(±22.35)
ORANP5	101.21	68.83(±7.84)	103.24(±11.76)	51.62(±5.88)	209.49(±21.57)
ORANP6	127.02	86.37(±9.61)	129.56(±14.42)	64.78(±7.21)	256.85(±26.44)
ORANP7	131.60	89.49(±0.46)	134.23(±15.68)	67.11(±7.84)	279.30(±28.75)
ORANR1	119.78	81.45(±9.00)	122.18(±13.50)	61.09(±6.75)	240.46(±24.75)
ORANR2	87.37	59.41(±7.01)	89.12(±10.52)	44.56(±5.26)	187.29(±19.28)
ORANR3	153.40	104.31(±12.02)	156.47(±18.03)	78.23(±9.01)	321.05(±33.05)
ORANR4	119.77	81.45(±9.30)	122.17(±13.95)	61.09(±6.97)	248.44(±25.57)
ORANR5	122.97	83.62(±9.87)	125.43(±14.80)	62.72(±7.40)	263.59(±27.13)
ORANR6	148.08	100.70(±11.46)	151.05(±17.19)	75.52(±8.59)	306.09(±31.51)

Table 2: Meant annual biomass and carbon accumulation rate in different clones of Teak

Clone	MAI (m3/ha)	Stem Biomass (t/ha)	Total Tree Biomass (t/ha)	Total Carbon Stock (t/ha)	Carbon content (t/ha)
ORANP1	2.09	1.27	1.91	0.95	3.50
ORANP2	7.13	4.35	6.53	3.26	11.97
ORANP3	4.92	3.00	4.50	2.25	8.26
ORANP4	3.52	2.15	3.22	1.61	5.90
ORANP5	3.40	2.07	3.11	1.55	5.70
ORANP6	4.16	2.54	3.81	1.90	6.98
ORANP7	4.53	2.76	4.14	2.07	7.59
ORANR1	3.90	2.38	3.57	1.78	6.54
ORANR2	3.04	1.85	2.78	1.39	5.09
ORANR3	5.20	3.17	4.76	2.38	8.73
ORANR4	4.03	2.46	3.68	1.84	6.75
ORANR5	4.27	2.61	3.91	1.95	7.16
ORANR6	4.96	3.03	4.54	2.27	8.32

Table 3: Current annual biomass and carbon accumulation rate in different clones of Teak

Clone	CAI (m3/ha)	Stem Biomass (t/ha)	Total Tree Biomass (t/ha)	Total Carbon Stock (t/ha)	Carbon content (t/ha)
ORANP1	6.36	3.88	5.82	2.91	10.67
ORANP2	16.03	9.78	14.67	7.33	26.89
ORANP3	16.81	10.25	15.38	7.69	28.19
ORANP4	11.10	6.77	10.15	5.08	18.61
ORANP5	10.77	6.57	9.85	4.93	18.07
ORANP6	10.48	6.39	9.59	4.79	17.57
ORANP7	17.48	10.66	16.00	8.00	29.33
ORANR1	8.59	5.24	7.86	3.93	14.40
ORANR2	12.65	7.72	11.58	5.79	21.22
ORANR3	18.56	11.32	16.98	8.49	31.13
ORANR4	12.85	7.84	11.76	5.88	21.56
ORANR5	17.83	10.88	16.32	8.16	29.91
ORANR6	15.56	9.49	14.24	7.12	26.10

proven research findings. In case of the present investigation, the net annual carbon storage was found to be within 2.91-8.16t/ha. Similarly, the total carbon content per year was estimated to be in the range of 10.67 to 31.13t/ha. Kaul *et al*. (2010) also reported similar findings in their research works carried out in India. From the research findings, it is well ascertained for now that selection of suitable clone is very important in the present situation in order to fulfill both commercial and ecological obligations. The clones with higher carbon content potential shall be given preference for large scale planting.

CONCLUSION

The present study concludes that teak plantations have high biomass accumulation and carbon storage potential. This has further improved with the introduction of potential clones in view of increased use and demand of teak wood in the national and international market. Inter-clonal variation is very useful and desired for furthering research and development works on clonal materials. The mean and current annual accumulation in 32 year old teak plantation is quite appreciable. It tells us how teak plantation contributes to carbon sequestration. Though ORANP2 was found to be superior one in terms of net biomass and carbon content, other clones such as ORANR3, ORANR5, ORANP7 and ORANP3 have immense role in the annual contribution. Clones vary from each other in one or more ways. Therefore, the selection of superior clone is important to meet both ecological and commercial obligations.

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