International Journal of Advanced Research in Botany (IJARB)
Volume 5, Issue 1, 2019, PP 25-33
ISSN No. (Online) 2455-4316
DOI: http://dx.doi.org/10.20431/2455-4316.0501004
www.arcjournals.org

Assessing Growth Performance of *Tectona Grandis in* Nepal

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Abstract: *The growth of any plant species is important characteristics which determine the yield of the plant. The growth performance of Tectona grandis was not so far assessed in Nepal. Therefore, this study was objectively carried out to assess the growth performance of T. grandis, show the relationship between the growth and soil nutrients and effect of spacing on the growth. Community and private plantations of this spp. in seven Tarai districts of Nepal were selected as study site. Altogether 215 samples were collected applying stratified random sampling. Particularly diameter and height of 8644 plants were measured and the spacing between plants was also recorded. The age of the plantation was noted from plantation report. Meanwhile, 102 soil samples were collected from 0-10, 10-20 and 20-30 cm depths. The increment of basal area, volume, biomass and carbon were analyzed and N, P, K, C, pH and bulk density were evaluated in the lab. The result showed that mean annual stem volume was the higher 171.46 m³/ha in community plantation while it was only 92.61 m³/ha in private plantation. The average soil organic carbon in community plantation was estimated to be 38.29±6.05 ton/ha whereas it was only 32.77±2.57 ton/ha in private plantation. Total nitrogen was only 0.07% while P and K were 21.23 and 166.04 kg/ha respectively in community plantation. Similarly, carbon and Nitrogen were 0.84 % and 0.06% respectively in private plantation. The P and K were 53.29 and 171.55 kg/ha simultaneously. The pH was 6.50 for community plantation and which was 6.46 in private plantation. The R value of MABAI of T. grandis and carbon was low 0.49 but it was significant (p value = 0.00). It was found that the highest MADI at >3 m spacing with 1.33±0.028 cm but it was the lowest at < 2 m spacing with 1.17±0.018 cm. This study will be useful to see the rotation and effect of spacing and soil fertility on growth performance.*

Keywords: *community, growth, plantation, private, spacing, Tectona grandis*

1. INTRODUCTION

Globally the forest area covers 3,999 million ha (30.6%) of land. About 299 million ha (7%) of this is planted forest which had been increased by 105 million ha since 1990 (FAO, 2016). *T. grandis* plantation forest constitutes about 4.346 million ha and represents 75% of high tropical hardwood plantation, 83% of which is in tropical Asia (IUFRO, 2018). Teak (*Tectona grandis* L.F., is a member of Verbenaceae family, one of the most important, widely planted, a valuable hardwoods spp. (Robertson and Reilly, 2006). The success of large scale plantation is mainly due to its relatively fast growth, fire resistance, non-browsability, high survivable rate (Robertson and Reilly, 2006). Besides, it is termite resistance and widely used for boat and ship, building construction, decorative veneer, furniture, handicraft, musical instruments and has been recognized for centuries as a king among timbers due to its durability, workability, attractiveness and strength (KFRI and ITTO, 2003; FAO, 2016, Thapa and Gautam, 2007).

For most of the countries like Nepal, *T. grandis* is an introduced species (Jackson, 1994), stands for a good opportunity to produce quality timber and is a major asset for the forest economy. In Nepal, *T. grandis* plantation had begun from 1960 in Chiliya, Rupendehi (Kayastha, 1974) followed by some block plantation in Sagarnath, Sarlahi and Ratuwamai by Forest Product Development Board. There was a serious problem of great decline suffering from die back in *Dalbergia sissoo* reported so *T. grandis* plantation came as alternative of *D. sissoo* (Paudel and Sah 2003).

T. grandis plantation has been prescribed for more than 60 years of rotation period for Nepal (Amatya and Shrestha, 2016). However, the growth performance is unknown. The growth is generally affected

due to fertility of the soil (Silva and Uchida, 2000, Laar and Akca, 2007). In addition, the growth is also affected by spacing between plant to plant and row to row. So, such type of study was not so far done in Nepal. Therefore, this research was objectively carried out to assess annual increment of *Tectona grandis* at community and private plantation, find the status of soil nutrients and explore the effect of plantation spacing regime on growth

2. MATERIALS AND METHODS

2.1. Study Site

This study was conducted in community and private plantation of seven low land (Tarai) districts representative to whole *T. grandis* plantation area of Nepal. These included the whole plantation area from East, Central and West part of Nepal lying between 26°20′–29°05′ N latitude and 80°30′–88°12′ E longitude. The mean annual temperature is higher than 16 °C and means annual rainfall is over 1500 mm. These areas represent almost 15% of households and 15% of population of Nepal (CBS, 2011). About 583,940 ha of forest and other wooded land of Tarai area has been included in these districts (Figur1, Table1).

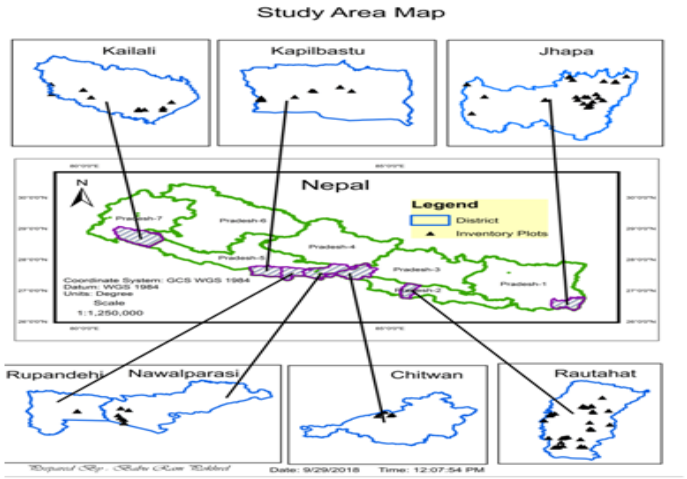

Figure1. *Map of Study Area*

Table1. *Information about Study Area*

District	Latitude N	Longitude E	Elevation Range (m)	Forest area (ha)	Other wooded land (ha)	Total Area (ha)	Mean Annual Temperature ^{0}C	Annual Rainfall (mm)
Jhapa	26°20′–26° 50′	87° 39′–88° 12′	58-500	17,349	358	160,369	24.5	2,346.60
Rautahat	26°44′–27° 14′	85° 14′–85° 30′	76-872	25,874	414	103,816	16.1	1,537.80
Chitwan	27°22′–27°53′	83° 55′–84° 48′	244-1945	141,668	5,821	223,970	23.5	1,783.70
Nawalparasi	27°21′–27° 47′	83° 36′–84° 35′	91-1936	103,593	1,813	215,255	23.6	1,952.80
Rupandehi	27°20′–27° 47′	83°12′–83° 38′	100-1229	25,105	403	130522	24.8	1502.7
Kapilbastu	27°25′–27° 48′	82° 42′–83° 14′	93-1491	59,025	1,944	165,136	24.2	1,532.00
Kailali	28°22′–29° 05′	80° 30′–81° 18′	109-1950	198,239	2,334	328,716	20.7	1,719.00
Total				570,853	13087	1,197,262		

Source: *DOHM, 2017; DFRS, 2016*

3. SAMPLING METHOD

The area of community plantation was 4.81 ha and that of private plantation was 5.57 ha. Both primary and secondary data were collected to meet the objectives (DoF, 2004). Total 215 sample plots were established having 20 m * 25 m in the field. So, diameter and height of 8644 plants were measured from the seven districts. Specifically, 97 and 118 samples were gathered from community and private plantations respectively. The diameter and height of trees were measured by and spacing between plants was also measured. The stratified random sampling was applied based on private and community plantation. A total of 102 soil samples from 0-10, 10-20 and 20-30 cm were collected. Collected data were analyzed.

Mean of growth of diameter, height, basal area, volume, biomass and carbon using following formulae:

Mean Volume in m³ (MV) = Sum of total volume /total number of measured tree

Mean Annual Volume Increment (MAVI) = MV/Age of tree

Mean Biomass in kg (MB) = Sum of total biomass /total number of measured tree

Mean Annual Biomass Increment (MABI) = MB/Age of tree

Mean Carbon in kg **(**MC) = Sum of total Carbon /total number of measured tree

Mean Annual Carbon Increment (MACI) = MC/Age of tree

Total Quantity /ha= Sum of Total Quantity/Actual Area of total sample plot sampled in ha

In addition, for Carbon content in the soil was analyzed by using dry combustion method (Walkley & Black, 1958) Nitrogen was analyzed using Kjeldahl Method (Kjeldahl, 1883), Potassium, Ammonium Acetate Method for K Determination (Hanway and Heidel, 1952). In addition, Olsen's Method (Olsen et al., 1954) was applied for Phosphorus analysis and pH meter for pH analysis (Bates, 1954).

4. Result and Discussion

4.1. Growth Performance of Tectona Grandis in Community and Private Plantation

The age range of T. grandis was 3 to 50 years and 3 to 30 years in community and private plantation respectively. The mean volume and mean annual volume increment (MAVI) in community plantation were 171.46±11.6 m³ /ha and 8.8 m³ /ha whereas these values were 91.61±4.59 m³ /ha and 10.2 m³/ha respectively in private plantation. Similarly the basal area (BA) was 17.85±1.00 m²/ha and 14.13±0.49 m²/ha with the mean above ground tree carbon (MAGTC) of 124.56±5.08 ton and 40.2±2.0 ton /ha and the average density of 604 and 1031 stem /ha in community and private plantation respectively (Table 3). The reason of higher growth in community plantation was due to low stem density per ha than private plantation, it was nearly 1.9 times more (1031 stem/ha). The higher the stem density the lower diameter increment (Thapa, and Gautam, 2007, FRA/DFRS, 2014). According to them, MDBH and MH in Shankharapur, Rupandehi, Nepal of 7.5 years of plantation before thinning were 11.7 cm and 12.4 m which was comparable with the 7 years MDBH and MH growth in this research.

According to Evans and Turnbull, (2004), the MAI in tropical forest plantation is 15- 40 m³/ha/yr and 1-7 m³/ha/yr in natural tropical forest. The mean total yield from *T. grandis* plantations in Nilambar of India was 151.257 m³/ha and the MAI during the rotation of 53 years was 2.854 m³/ha /yr. The mean total yield and MAI for Kerala were 144.833 m³/ha and 2.287 m³/ha/yr respectively in a mean rotation of 58 year (Chundamanni, 1997). Author Keogh (1996) stated that the aim of at least 8 m³/ha/yr MAI is feasible for *T. grandis* plantation. Comparing with these results, the MAI in plantation of both community and private were greater > 8 m³/ha/yr, so the growth was found feasible for Nepal although this was much less than that of Keogh, 1996.

Table2. *Mean Statistics For T. Grandis Plantation Forest Of Nepal*

Forest type	Age (Yr)	Vol (m³/ha)±SE	MAVI (m³/ha)	BA (m²/ha)±SE	MAGTC (ton/ha)±SE	Density/ha
Community	3-50	171.46±11.6	8.8	17.85±1.00	124.56±5.08	604
Private	3-32	91.61±4.59	*10.2*	14.13±0.49	40.2±2.0	1031

4.2. Soil Organic Carbon in Community and Private Plantation

The average soil organic carbon from the surface of 0-30 cm layer of soil in community plantation of *T. grandis* was estimated to be 38.29±6.05 ton/ha whereas in private plantation it was found to be 32.77±2.57 ton/ha. The first 0-10 cm layer of soil had maximum soil carbon. However, there was no significant difference in SOC available amount in each layer of 1-10, 10-20 and 20-30 cm when compared at 5% level of significance. In the community and private plantation of *T. grandis,* SOC was not significantly difference (Table 4). However, the district wise data showed that the availability in different district with community and private plantation land is different (Table 5). Soil carbon variation depends up on the microbial activities. The average SOC in Tarai forest of Nepal was 33.66 ton/ha (FRA/DFRS, 2014). In private *T. grandis* plantation, the average SOC was very near to Forest Research Assessment result of 32.77 ton /ha (FRA/DFRS, 2014).

Table3. *Soil Organic Carbon on T. grandis Plantation Forest*

Plantation	Soil depth (cm)	Soil Organic Carbon in Districts (ton/ha)							Total (ton/ha±SE)
		Jhapa	Rautahat	Chitwan	Nawalparasi	Rupandehi	Kapilbastu	Kailali	
Community	0-10	14.53	22.46	9.88	5.50	15.65	12.85	18.08	14.51±1.87
	10-20	12.21	17.27	7.85	3.72	9.48	8.15	16.19	11.70±2.04
	20-30	5.65	24.94	1.93	4.46	6.73	19.51	15.33	12.07±2.72
Total	0-30	32.38	64.67	19.67	13.67	31.86	40.51	49.59	38.29±6.05
Private	0-10	12.68	14.54	14.59	6.26	-	14.57	17.24	12.80±1.06
	10-20	12.37	11.85	8.41	5.50	-	11.30	15.05	9.96±1.22
	20-30	8.22	10.88	18.10	7.75	-	7.87	10.57	10.29±1.20
Total	0-30	33.26	37.28	41.10	19.51	-	33.74	42.85	32.77±2.57

4.3. Soil N, P, K, Ph, BD and Texture in Private and Community Plantations

The nutrients contents were varied in private and community plantation. Total nitrogen 0.07%, phosphorus 21.23 Kg/ha and potassium 166.04 kg/ ha. Similarly, in private plantation, carbon 0.84 %, total nitrogen 0.06%, phosphorus 53.29 Kg/ha and potassium 171.55 kg/ha was estimated. The pH value of soil from the first 30 cm layer was 6.50 for community plantation and 6.46 for private plantation. Bulk density (BD) for community and private plantation land soil were 1.44 and 1.40 gm per cm^3 respectively. Both of the forest land had moderately acidic soil of pH 6.50 (community plantation) and 6.46 (private plantation). The texture of the soil was loam (L) to sandy loam (SL) in both plantation regimes (Table 6). Independent Sample mean t-test was applied to compare the soil nutrients. There was a significant difference in P in private and community plantation at 5% level of significance. However, there was no significance difference in other nutrient contents.

Liu, et al (2014), justified that SOC increased with the succession in 0-10 cm soil layer. The succession in community plantation is more when compared to private land. So, this argument may also be matched with the result. The sandy loam soil texture was recorded in *T.grandis* plantation forest in Uttarakhanda, India (Salim, et al., 2018) which is quite similar results with this study. Adkulne, (2011) found that pH of soil 5.77-8.33 in *T.grandis* plantation in Nigeria, This range was also similar in Nepal. According to Vitousek, et al (2010), six mechanisms can cause P limitation to terrestrial ecosystem: P depletion, soil barriers, transactional, low parent material, P sinks and anthropogenic forcing. According to Chamshama, et al., (2000). Jordon (1985) suggested that when the natural forest is cut and burnt, there is quick scarcity of P in tropical soils due to destruction of mechanism of P mobilization. In community plantation, there was natural forest before plantation. Also the fire risk was found higher in community plantation than private plantation. So, the available P in community plantation can be lower.

Table4. *Soil Parameters Status in Community and Private Plantation of T. Grandis*

SN	District	Plantation	N%	P kg/ha	K kg/ha	pH	BD gm/cc	Tex.
1	Jhapa	Community	0.07	33.55	208.00	6.24	1.12	SL
		Private	0.06	78.26	403.47	7.13	1.02	L
2	Rautahat	Community	0.11	36.89	179.20	6.06	1.07	SL
		Private	0.06	27.70	198.60	5.72	1.12	Sl
3	Chitwan	Community	0.08	9.97	160.00	7.26	1.34	L
		Private	0.05	78.57	80.80	5.76	1.42	SL
4	Nawalparasi	Community	0.05	8.70	103.60	6.49	1.51	L
		Private	0.05	79.25	163.20	6.62	1.45	L
5	Kapilbastu	Community	0.06	12.04	124.80	7.23	1.68	L
		Private	0.06	13.15	83.60	6.91	1.63	SL
6	Kailali	Community	0.08	30.32	197.87	6.77	1.63	SL
		Private	0.06	42.80	99.60	6.65	1.75	SL
7	Rupandehi	Community	0.05	17.10	188.80	5.42	1.72	L

4.4. Correlation among Soil Parameters and Growth of T. Grandis

The Pearson Correlation was applied to find the correlation with Nutrients level with growth performance of *T. grandis.* These correlations were also examined using ANOVA. The result showed that there was a positive correlation between nutrients parameters and growth performance. Specifically, R value of MABAI of *T. grandis* and carbon was low 0.49 was but its significant relation

(p value = 0.00). According to Salim et al. (2018), high BD means low organic matter (low soil nutrients) and vice-versa. The negative correlation between soil nutrients and BD may match with their findings. Adekunle, et al. (2011) reported that very high correlation (+0.96) was found between P and growth variables in *T. grandis* plantation, Nigeria because of the importance of P in tree growth and development. Aydin et al.(2005) also reported that N and P will increase plant yield dry matter and nutrients. Similarly, soil P also showed a high positive correlation with growth variable except mean height. In this study, significant correlation of soil P with MADI (r = +0.455), MAHI (r = +0.497) and density/ha (r = 0.388) was recorded.

Table5. *Correlation Test between Soil Parameters and Growth Parameters*

		MADI	MAHI	MABAI	MAVI	Density/ha
C	Pearson Correlation	0.01	0.14	-0.490**	-0.462**	0.347*
	Sig. (2-tailed)	0.95	0.42	0.00	0.01	0.04
	N	34	34	34	34	34
N	Pearson Correlation	-0.231	-0.139	-0.400*	-0.221	0.099
	Sig. (2-tailed)	0.189	0.433	0.019	0.209	0.578
	N	34	34	34	34	34
P	Pearson Correlation	0.455**	0.497**	0.088	-0.167	0.388*
	Sig. (2-tailed)	0.007	0.003	0.621	0.346	0.024
	N	34	34	34	34	34
K	Pearson Correlation	-0.035	0.080	-0.199	-0.143	0.100
	Sig. (2-tailed)	0.846	0.653	0.260	0.418	0.574
	N	34	34	34	34	34
pH	Pearson Correlation	-0.25	-0.14	-0.27	-0.11	0.14
	Sig. (2-tailed)	0.16	0.42	0.12	0.52	0.44
	N	34	34	34	34	34
BD	Pearson Correlation	-0.097	-0.125	0.120	0.196	-0.230
	Sig. (2-tailed)	0.59	0.48	0.50	0.27	0.19
	N	34	34	34	34	34

4.5. Effect of Plantation Spacing Regime on Growth

The results showed the variation in growth according to spacing between the plants. It was found that the highest MADI at >3 m spacing with 1.33±0.028 cm but it was the lowest at < 2 m spacing with 1.17±0.018 cm (Table 10).

Table6. *Mean Growth Parameters in Four Different Spacing of T. grandis Plantation*

Spacing	MADI(cm)±SE	MAHI (m)±SE	MABAI(m^2)±SE	MAVI (m^3)±SE
1 (<2m)	1.17±0.018	0.923±0.009	0.00161±4.863E-05	0.01101±0.0004
2 (2-2.49 m)	1.28±0.058	0.863±0.029	0.00184±1.507E-04	0.01128±0.001
3 (2.5-3m)	1.30±0.029	0.983±0.013	0.00180±7.714E-04	0.01181±0.001
4 (4 m)	1.33±0.028	1.105±0.015	0.00185±4.201E-04	0.01356±0.001

One wasy ANOVA was applied to compare the effect of spacing between plant to plant. It showed that there were significant difference between the MADI (p value = 0.002) and MAHI (p value = 0.000) of the < 2m, 2.50 to 3 m and 4 m spacing at 5% level of significant. The Tukey's multiple comparisons showed difference in MADI and MAHI. Generally wider spacing indicates the good growth of *T. grandis*. It found that proper thinning and wide spacing produces large diameter trees (Ramnarine, et al. 2003, Kanninen et al., 2004, Zahabu et al. 2015). The result from Haninec, et al. (2016), showed that spacing 1*1m created trees with lower growth parameters.

5. Conclusion and Recommendations

The growth performance of *T. grandis* community plantation was better than private plantation in Nepal. Soil nutrients like C and N were found to be poor in both community and private plantation. However, availability of K was satisfactory. Soil nutrient P, was showing significant correlation with diameter and height growth of tree in private plantation but poor in community plantation. This study showed that wider spacing of more than 2.5 m was found suitable for better growth in diameter and height of T. grandis in Nepal.

The study will be useful to find the appropriate rotation showing the highest increment. There should be an immediate application of thinning operation in the community and private T. grandis plantation forest to make sufficient spacing for better growth of individual trees.

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Citation: *B.R. Pokhrel, R.A. Mandal" Assessing Growth Performance of Tectona Grandis in Nepal" International Journal of Advanced Research in Botany (IJARB), vol. 5,no.1, pp.25-33, 2019. http://dx.doi.org/10.20431/2455-4316.0501004*