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Effect of weeding regimes on early growth of *Tectona grandis* Linn.f. in Ibadan, Nigeria

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ABSTRACT
The effects of weeding regimes on the early growth of Tectona grandis was investigated in this study. Seedlings of teak were raised from seeds collected from Onigambari Forest Reserve (Lat. 7^0 05′ N, Long. 3^0 50′ E) at the nursery of Heritage Resources Conservation Project, Ibadan, Nigeria. A total of 2,500 seedlings were planted out on a one hectare land at a spacing of 2m x 2m. The plantation was divided into two equal parts; one part was weeded four times in a year (FTPY) while the other part was weeded once in a year (OPY). A total of 50 trees each were randomly selected in the two plots and their height and diameter were measured at first and second year of establishment. The t – test analysis was used to compare the differences in growth variables under the two weeding regimes. The data were subjected to correlation and regression analyses. There was significant difference in height (t = 19.13) and diameter (t = 13.52) growth of juvenile teak trees under the two weeding regimes investigated. The maximum, minimum and mean heights of the FTPY weeding regime were 8.1m, 3.6m and 6.42m respectively. The mean height of 2.26m; minimum (0.4m) and maximum height (5.7m) were obtained for the OPY weeding regime. In the FTPY section, the mean, minimum and maximum diameter values were 30.78cm, 19.0cm and 44.0cm respectively. The minimum diameter value of 5.0cm, maximum of 28.0cm and a mean value of 16.26cm were obtained in the OPY section of the stand. There were significant positive correlations between height and diameter growth of teak in both the FTPY and OPY weeding regimes. The correlation coefficient values between plant height and diameter at the ground level in the second year assessment under FTPY and OPY weeding regimes are 0.59 and 0.87 respectively. This finding implies that height – diameter relationships even in young stands are dynamic.

Keywords: Weeding regimes, weeds, tree growth, plantation, teak.

INTRODUCTION
Forestry and its practice has been the exclusive reserve of the government and its agencies in Nigeria. The reason for this may not be unconnected with the cost of establishing and maintaining trees in plantations. The practice of taungya adopted in the past to reduce this heavy cost have since been abandoned because farmers complain of their inability to plant perennial crops such as cocoa, kola nut and palm trees on the land allocated to them under this scheme. However, rising human populations has placed serious pressures on the limited

available natural forests for its essential produce, hence, the need to embark on massive afforestation activities in plantations to meet up with the rising demand for forest produce. Evans (1992) reported an estimated increase in the area of forest plantation in Nigeria from 170,000ha in 1980 to 259,000ha in 1990. Nwoboshi (2000) opined that two reasons for increasing interest in plantations are their rapid growth and the ability to augment shortfalls in production from natural forest. Tropical plantations are known to greatly out yield natural forest (Evans, 1992).

Tectona grandis (teak) performs well in plantations (Centeno, 1997). Teak was first introduced outside Asia to Nigeria in 1902 (Horne, 1966). It ranks among the top five tropical hardwood species in terms of plantation area established worldwide (Krishnapillay, 2000). Teak is one of the world's premier hardwood timbers, rightly famous for its mellow colour, fine grain and durability. Its wood has dark golden yellow heartwood darkening with age (Keay, 1989). It grows best in localities with annual rainfall of 1,250 to 3,750mm, minimum temperature of 13^0 to 17^0 C and maximum temperature of 39^0 to 43^0C (Pandey and Brown, 2000). Teak accounted for 14.2% of species used in tropical forestry plantations in 1980 (Evans, 1992).

Success in the management of plantations of fast-growing tropical tree species can only be achieved by performing intensive and timely silvicultural interventions (Ola-Adams, 1990; Lowe, 1976; Larson and Zamman, 1985). Weed is a major problem to the luxuriant growth of seedlings in the early stages of plantation establishment. Weeds constitute both physical and mechanical hindrance to the survival and growth of plants. Although, competition for below ground resources is important and attributable to weeds (e.g. Ares and Brauer, 2005, Wagner, 2006 and Burgess *et al.* 2010), the above ground competition with plants for space and light is more critical. When compared to the temperate climates, the tropics enjoy luxuriant growth of weeds and have more plants per unit area; this seems to be ordained by nature to serve as a protective shield against the torrential rainfall common in tropical climates. Weeds and weeding practices contribute substantially to the cost of plantation establishment and maintenance. Weeding is a cultural operation that eliminates or suppresses undesirable vegetation, which, if no action is taken, could impair the growth of the plantation crops. Weeding increases the availability of all or the most critical of nutrient elements to the trees (FAO, 1989). *Tectona grandis* is a light demanding species. Its growth and development is reduced sharply under poor light conditions. Hence, intensive weeding is very necessary during early establishment of the plantation.

At the early stage of plantation establishment, when the transplanted seedling are yet to be firmly anchored to explore the new environment, weeds provide a severe competition, which may eventually determine the performance or the overall productivity of the stand. Therefore, at this early stage of establishment, there is a minimum regime of weeding per year that must be effected for optimum growth and productivity. Currently, there is dearth of studies on weeding regimes in Nigerian grown trees of *Tectona grandis*. This study was therefore conducted to provide baseline information on the growth performance of teak in order to enhance the appropriate silvicultural management for young teak plantations.

MATERIALS AND METHOD

Method of data collection

Mature and viable seeds of teak were collected in February 2002 from Onigambari Forest Reserve (Lat. 70 05′ N, Long. 30

50′E) in Oluyole Local Government Area of Oyo State, Nigeria. The seeds were pretreated to break dormancy by soaking them in bags inside running water for 2 days. Thereafter, the seeds were sown through broadcasting in seedbeds and covered lightly with soil materials. Nylon sheets were used to cover the seedbeds in the evening and removed in the morning during watering. This was done to ensure warm condition, consequently hastening the process of germination.

At the four – leaf stage, the seedlings were pricked out and transplanted into medium sized polythene bags measuring 16 x 14 x 12cm. The seedlings were left under the shade for 2 weeks to wean them; they were later transferred to the open nursery of Heritage Conservation Project, Ibadan, Nigeria. The seedlings were allowed to establish for 3 months in the nursery before they were transplanted to the field in a privately owned site located around Ibadan old toll gate along Lagos – Ibadan expressway.

The seedlings were planted out in the field in the last week of June 2002. One hectare (1ha) of land was demarcated and the seedlings were planted at 2m x 2m spacing. A total of two thousand, five hundred seedlings were planted in the hectare land. The 1 ha plantation was divided into two equal parts of one thousand two hundred and fifty plants each. One part was weeded four times per year (FTPY), in April, July, September and November while the other half hectare was weeded once per year (OPY) in September. Weeding was carried out manually using cutlass.

Fifty plants were selected randomly and assessed for total height and diameter at ground level in December 2003. Another assessment was carried out in December 2004. Furthermore, ecological survey involving enumeration of weeds was carried out by randomly laying three 1m x 1m quadrat each in the half hectare plots. All the weeds found in each quadrat were identified and collated.

Data analysis

The data collected were used to compute the volume index as follows:

$$VI = \pi D^2/4 * Ht \ldots\ldots\ldots eqn.1$$

Where, VI = Volume index (m^3), D= Diameter at ground level (m), Ht= Total seedling height.

The data obtained were subjected to Student t – test and correlation analysis using suitable statistical software. Furthermore, as a preliminary investigation of the height-diameter relationship, a simple linear regression model was fitted to the data. Samples of weeds in the regularly and the irregularly weeded plots were collected and taken to the herbarium for identification.

RESULTS

Height Growth

In the first year of assessment, the mean seedling height of teak in the section that was weeded four times per year(FTPY) was 2.8m, whereas, in the section that was weeded once per year (OPY) seedlings the mean height was 1.23m (Figure 1). In the second year assessment, the mean height of seedlings in the FTPY section was 6.42m, while in the OPY section, mean seedling height of 2.26m was obtained (Figure 1).

Height distribution of sampled seedlings (Table 1) in the 2 years old plantation revealed that there were no plant representatives in the lower height classes of 0 – 3m in the FTPY section. Plants in the OPY section had no representative in the upper height classes of 6 – 9m. Among seedlings under FTPY weeding regime, 44% of the sampled plants occurred in the 6 – 7m height class, 4% were found in the low height class of 3 – 4m, while 4% occurred in the highest class of 8 – 9m. In the OPY weeding regime, 34% of the sampled

juvenile teak trees were found in the 2 – 3m height class, 12% occurred in the lowest class of 0 – 1m while 2% occurred in the 5 – 6m height class. The result of the t – test showed that there was a significant difference in height growth between the two weeding regimes in terms of height growth as shown in Table 2 (t = 19.13, df = 98).

Table 1: Height distribution in a 2 year – old teak stand under two weeding regimes

	Regular Weeding (RW or FTPY)		Irregular weeding (IW or OPY)	
Height Class (m)	**Frequency**	**% Value**	**Frequency**	**%Value**
0 – 1	-	-	6	12
1 – 2	-	-	15	30
2 – 3	-	-	17	34
3 – 4	2	4	9	18
4 – 5	2	4	2	4
5 – 6	10	20	1	2
6 – 7	22	44	-	-
7 – 8	12	24	-	-
8 – 9	2	4	-	-
9 – 10	-	-	-	-
Total	**50**	**100**	**50**	**100**

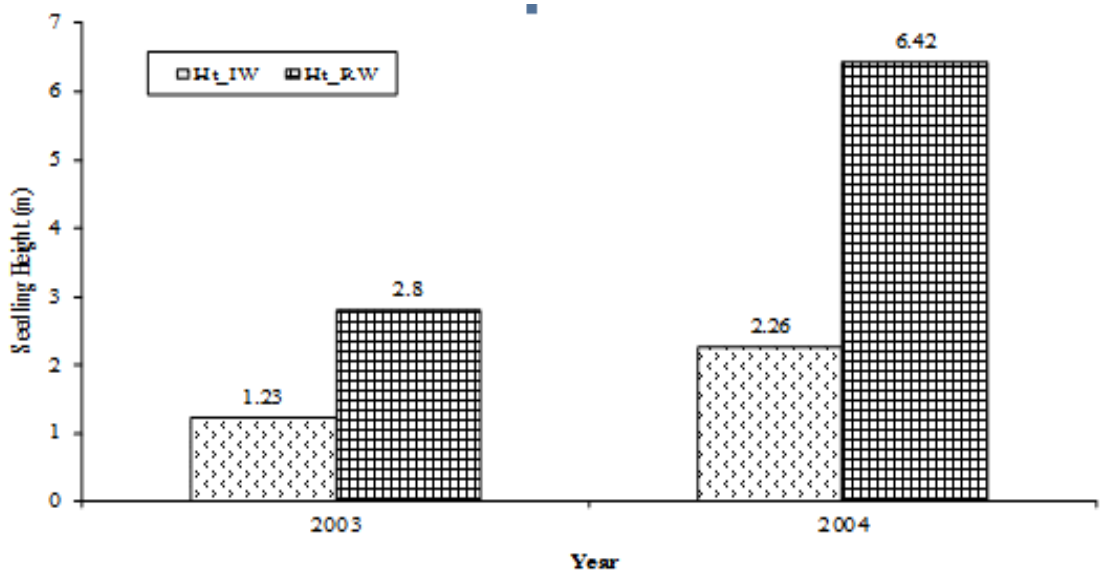

Figure 1: Height growth of planted *Tectona grandis* seedlings under irregular weeding (IW) and regular weeding (RW) between 2003 and 2004.

Table 2: Results of t-test for height of teak under the two weeding regimes

Group 1 vs Group 2	df	t-cal	P-level
Ht_OPY_{03} vs Ht_FTPY_{03}	98	8.44	0.0216
Ht_FTPY_{03} vs Ht_FTPY_{04}	98	16.33	0.0342
Ht_OPY_{04} vs Ht_OPY_{03}	98	5.65	0.0350
Ht_OPY_{04} vs Ht_FTPY_{04}	98	19.13	0.0486

Diameter Growth

In the first year of sampling, the mean diameter of the plants in the regularly weeded (i.e. RW, same as FTPY) plot was 6.63cm, while the mean diameter of 4.06cm was obtained for plants in the irregularly weeded (i.e. IW, same as OPY) plot (Figure 2). Table 3 shows the diameter distribution of plantation grown teak under the different weeding regimes. The plants weeded regularly had no representative in the lower diameter class of 0 – 15cm while trees in the irregularly weeded plot had no representative in the upper diameter class of 30 – 45cm. In the regularly weeded plot, trees occurred mostly in the 30 – 35cm diameter class (i.e. 30%), 2% of the sampled trees occurred in the 15 – 20cm diameter class while 12% of the trees occurred in the highest diameter class of 40 – 45cm. Among the teak plants subjected to irregular weeding regime, 46% of the population sampled occurred in the 15 – 20cm diameter class, 8% were found in the 5 – 10cm class, while 2% of the sampled plants occurred in the 25 – 30cm diameter class. In the regularly weeded plot the mean diameter value of 30.78cm was observed, while the mean diameter value of 16.26cm was observed for the juvenile trees in the irregularly weeded plot (Figure 2). The result of the t – test (Table 4) to compare the mean diameter values of the trees in the two different weeding regimes showed significant differences (t = 13.52, df = 98).

Table 3: Diameter distribution in a 2 year-old plantation grown teak under two weeding regimes.

	Regular Weeding (i.e. FTPY)		**Irregular Weeding (i.e. OPY)**	
Diameter Class	**Frequency**	**% Representative**	**Frequency**	**% Representative**
0 – 5	-	-	-	-
5 – 10	-	-	4	8
10 – 15	-	-	11	22
15 – 20	1	2	23	46
20 – 25	7	14	11	22
25 – 30	14	28	1	2
30 – 35	15	30	-	-
35 – 40	7	14	-	-
40 – 45	6	12	-	-
45 – 50	-	-	-	-
Total	**50**	**100**	**50**	**100**

Table 4: Results of t-test for diameter at ground level of teak under different weeding regimes

Group 1 vs Group 2	**df**	**t-cal**	**P – level**
D_OPY_{03} vs D_FTPY_{03}	98	7.51	0.008
D_FTPY_{03} vs D_FTPY_{04}	98	27.34	0.000
D_OPY_{04} vs D_OPY_{03}	98	22.19	0.000
D_OPY_{04} vs D_FTPY_{04}	98	13.52	0.005

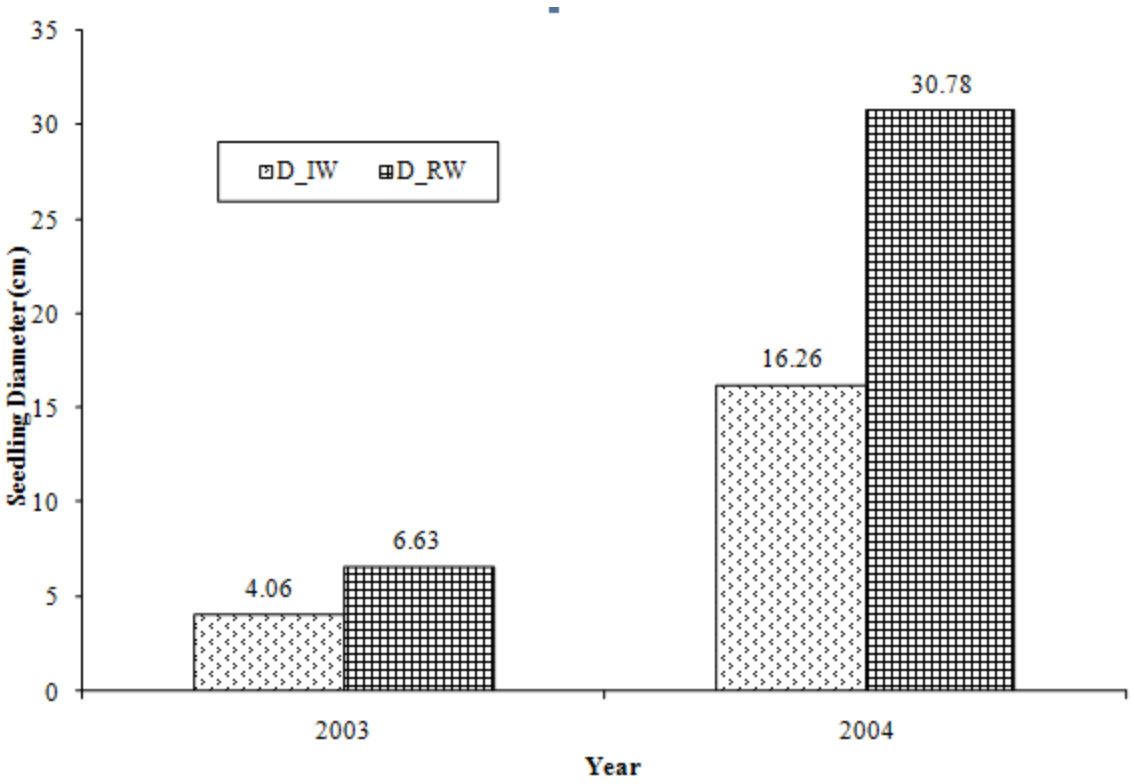

Figure 2: Diameter growth planted *Tectona grandis* seedlings under irregular weeding (IW) and regular weeding (RW) between 2003 and 2004.

Volume Index

The mean volume index of the juvenile teak in the first year of establishment was 0.9598m^3 in the regularly weeded plot while it was 0.1585m^3 in the irregularly weeded plot. In the second year of assessment, the mean volume index was 4.8247m^3 in the regularly weeded plot while 0.4743m^3 was recorded in the irregularly weeded plot.

Correlation Analysis

In the first year of sampling, diameter and height were significantly and positively correlated in both the FTPY (r = 0.94) and OPY (r = 0.92) weeding regimes. There were high positive correlations between height and diameter growth of teak in the FTPY (r = 0.59) and the OPY (r = 0.87) weeding regimes in the second year of assessment. However, there was a negative correlation (r = -0.29) between height in the first year and diameter in the second year of sampling in the OPY weeing regime (Table 5). The squared correlation coefficient (R^2) expressed as a percentage revealed that 76% of the variations in height was accounted for by the variations in diameter observation in the OPY weeding regime in the second year assessment, while only 35% of the variations in height was accounted for by the variations in diameter in regularly weeded plot in the second year of assessment.

Table 5: Results of correlation analysis (rectangular matrix) of growth parameters in a 2 year – old plantation grown teak under two weeding regimes.

Variable	D_OPY_04	D_OPY_03	D_FTPY_04	D_FTPY_03
Ht_OPY_04	0.87*	-0.26	-0.24	-0.05
Ht_OPY_03	-0.29*	0.92*	0.14	-0.04
Ht_FTPY_04	-0.22	-0.03	0.59*	-0.08
Ht_FTPY_03	-0.11	0.03	0.04	0.94*

Note: *= Significant at 5% probability, Ht= Height, D = Diameter, OPY = Once per year weeding regime, FTPY = Four times per year weeding regime, 03 = First year of sampling, 04 = Second year of sampling.

Regression Analysis

There were linear regression relationships between height and diameter in both the regularly weeded and the irregularly weeded plots in each year of sampling. The result of the regression equations are presented as follows:

$$Ht\_OPY_{03} = -0.5138 + 0.4288 D\_OPY_{03} \; .eqn.2$$

$$\boldsymbol{R^2 = 0.83, SE = 0.4237}$$

$$Ht\_FTPY_{03} = -0.2020 + 0.7271 D\_FTPY_{03} . eqn.3$$

$$\boldsymbol{R^2 = 0.89, SE = 0.3991}$$

$$Ht\_OPY_{04} = -1.2545 + 0.2164 D\_OPY_{04} \; .eqn.4$$

$$R^2 = 0.76, SE = 0.5686$$

$$Ht\_FTPY_{04} = 3..3245 + 0.1006 D\_FTPY_{04} . eqn.5$$

$$R^2 = 0.35, SE = 0.8404$$

Generally, the values of coefficient of determination (R^2) were higher and the standard error (SE) values were smaller in the first year of assessment compared to the second year of assessment (*eqn. 2-5).*

Weed Samples in the Plots

The composition of weeds in the FTPY weeding regime was quite different from those in the OPY weeding regime section. Herbaceous weeds like *Tridax procumbens, Aspillia africana* (Pers.) C.D and *Ageratum conyzoides* L. were predominant in the FTPY section while woody weed plants such as *Chromolaena odorata* (Linn.) King and Robinson, *Cida acuta* and sapling of non-economic trees like *Trema orientalis* (L.) Blume and *Newbouldia laevis* (P. Beauv) Seeman ex Bureau; and climbers like *Momodica charantia* (L) and *Mucuna slonaei* Fawcett & Rendle were prevalent in the OPY section. Table 6 shows the different species of weeds observed in the two plots.

Table 6: Weed undergrowth in plots of teak subjected to different weeding regimes

Regular Weeding Plot (FTPY)	*Irregular Weeding Plot (OPY)*
Tridax procumbens	*Ficus exasperate* Vahl
Aspillia africana (Pers.) C. D.	*Morinda lucida* (Benth)
Talinum triangulare (Jacq.) Wild	*Glyphaea brevis* (Spreng)
Acalypha fimbriata Schum & Thonn Forsk	*Chromolaena odorata* (Linn.) King & Robinson
Ageratum conyzoide L.	*Momordica charantia* L.
Phyllanthus amarus Schaum et Thonn.	*Luffa cylindrical (*Linn) M. J. Roem
Chromolaena odorata (Linn.) King & Robinson	*Newbouldia laevis* (P. Beauv) Seeman ex Bureau
	Senna occidentalis (Linn.) Link
	Trema orientalis (L.) Blume
	Mucuna sloanei Fawcett & Rendle
	Lonchocarpus cyanescens (Schum. & Thonn.) Benth

DISCUSSION

Weeds have been reported to offer both mechanical and structural resistance to plants (e.g. Cogliastro *et al* 1990 and Fournier *et al* 2007). Most weeds in plantations are perennial which confer on them undue advantage in competing for space, nutrients and light. These weeds already have their roots in the soil before the transplanted seedlings can adjust and establish itself in its new environment. Weeding however, serves to increase plantation crop uniformity, speedup the process of establishment and growth; reduce mortality and maintain an adequate stocking of trees. Nwoboshi (2000) reported that the presence of weeds and the weeding operations have some influence on the ecosystem nutrient cycling.

In this study, FTPY weeding regime resulted in significant height and diameter increase of the trees. This assertion confirms the findings of other studies (e.g. Willoughby, 1999 and Fournier *et al.* 2007). It has also been pointed out that lack of appropriate silvicultural management could negatively affect the expected productivity of teak (e.g. Torres *et al.* 1995, Castro and Raigosa 2001 and De camino *et al.* 2002).

The importance of height growth in plantation species cannot be overemphasized as it determines to a large extent the number of sawlogs that can be obtained from a tree stand. Invariably, trees that produce as many saw logs as possible will yield a higher return on investment. Furthermore, a good height growth of plantation species for pole production ensures that pole size attained within a few years. Nwoboshi (1982) reported that *Tectona grandis* might grow in height at rates up to 3 – 5m per year during their first 5 to 10 years of age, this is only true for a regularly weeded teak plantation. The result of this study revealed that OPY weeding regime could be introduce a serious setback for height growth of teak in plantations. In the same vein, Nwoboshi (1978) reported that the rapid growth stage in juvenile teak ends by the production of terminal inflorescence at 4 – 5 years of age. Chacko (1995) reported first flowering occurs in teak as early as 3 – 4 years. The result of this studies equally revealed that some of the juvenile teak plants in the FTPY weeding regime produced terminal inflorescence in 2004, two years after establishment. This shows that seed production challenges of teak may be addressed through regular and timely weeding regime in young teak plantations. However, judging from the promising results of weeding regimes examined in this study, further research will be necessary in this direction to determine optimum weeding regime.

Volume growth is perhaps the most important measure of increment as it gives a direct measure of the amount of wood available for sale at harvest. Toumey and Korstain (1959) observed that the object of most height and diameter growth studies is for the determination of volume. Therefore, a good height and diameter growth of teak under regular weeding presupposes a good harvest at the end of rotation year.

Already, forestry suffers from the distinctive disadvantage of long gestation period for its products especially timber. Adopting technical and scientific rationalization to circumvent this problem remains the only panacea for forestry to favourably compete with other land uses. It seems proper weeding regime in the early stage of plantation establishment can offer some hope on this issue. The possibility of having two-year old teak plants within diameter class bracket of 40 – 45 cm gives room for a faster return on investment. Nwoboshi (1982) reported that photosynthetic efficiency is low in young stands in which canopies have not closed because of inefficiency in light interception.

Nevertheless, teak is a light demanding species and its growth and development is reduced sharply under poor light conditions encouraged by weeds (Kaosaard, 1995).

The prevalence of *Chromolaena* odorata observed in the OPY weeding regime confirms the findings of other studies. For example, Norbu (2004) reported that *Chromolaena odorota* is a perennial weed which invades young plantations. However, if weeds are effectively controlled, the plants can grow unhindered to ensure canopy closure with attendant increases in the photosynthetic efficiency of the stand and concomitant decrease in the cost of plantation maintenance. The high values of coefficient of determination and small values of standard error of estimate indicated that the regression models fit well to the sample data; Adesoye (2004) affirmed this observation. On the other hand, a comparative lower coefficient of determination in the FTPY weeding regime in the second year of assessment revealed the negative correlation relationship in trees after a stage of development when height and diameter increment proceed at different rates.

One incentive for regular weeding of young tree plantation is the planting of agronomic crops in between the tree stands in agroforestry practice. In trying to control weeds to enhance the performance of the agronomic crops, which has less competitive ability with weeds, the trees benefit indirectly. This underscores the importance of agroforestry practice in plantation establishment (Ford – Robertson, 1971). It also reduces the cost of maintenance of such plantations since the yield from these agronomic crops inter-planted with the trees can be sold to offset some of the cost of hiring labour.

In this preliminary study, herbaceous and succulent weeds were observed in the FTPY weeding regime section while woody weed plants and climbers were found in the OPY weeding regime section. These woody weed plants in conjunction with the climbers were strong enough to strangle the struggling seedlings within its branches with resultant reduction in the growth rates of such plants and eventual death in some.

CONCLUSION AND RECOMMENDATION

In conclusion, the need for timely and regular weeding of young plantations is based on the good form, early canopy closure to check weeds and the early returns on investment from early maturity of desired produce. Transplanted seedlings and/or sprouted stumps in plantations compete with weeds for survival in the early days of establishment; the severity of this competition determines their performance. Timely and proper weeding regime in the first two years of the young trees on the site would guarantee a good growth that will ensure permanent victory in the struggle for survival against weeds.

It is therefore recommended that a minimum of four weeding per year should be given to teak in the first two years of establishment in plantation to enhance their growth and consequently faster returns on investment. Further research in this direction will enhance the development of efficient protocols of weeding regime for young stands of *Tectona grandis.*

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