Journal of Science and Technology, Vol. 31, No. 3 (2011), pp 30-41 30

http://dx.doi.org/10.4314/just.v31i3.4

RESEARCH PAPER

EFFECT OF TAP ROOT SIZE, PERCENTAGE ROOTLETS RETENTION AND PLANTING DEPTH ON BIOMASS PRODUCTION OF TEAK (*TECTONA GRANDIS* Linn. F.) STUMPS

K. A. Nkyi
Department of Silviculture and Forest Management
Faculty of Renewable Natural Resources, KNUST
Kumasi, Ghana

ABSTRACT:
Teak (Tectona grandis Linn. F.) is a highly preferred plantation species in Ghana. Stumps are usually used to establish teak plantation. There has been persistent problem of low survival rate of planted teak stumps in large-scale plantation establishment in the country. A 4x3x3 factorial experiment in randomized complete design in two blocks was undertaken to evaluate the dependence of length of tape root bellow root collar, percentage of retention of rootlets and depth of planting of stumps on the biomass of planted teak (Tectona grandis Linn. F) stumps. The main aim was to develop suitable method of converting teak seedlings into stumps and appropriate planting practice to improve the survival and growth of teak stumps. The quadratic reciprocal with an optimal level model ($79 \leq R^2 \leq 95$ %) appears to be precise modeling the trends in the number of shoots production on sprouted teak stumps over time for length of tap root and depth of planting of stumps. Length of tape root below, percentage of retention of rootlets and depth of planting of stumps significantly affected the growth of tree height, tree collar diameter, stem dry weight, root dry weight, leaf dry weight and total tree dry weight. The two-factor interaction of length of tap root and percentage of retention of rootlets also had a significant influence on tree growth, except leaf dry weight. The best biomass production was observed for non-treated stump tap root and rootlets and planting at 9 cm soil depth ensuring a gain of about 486 % of tree dry weight over the traditional method of stump preparation and planting.

Keywords: *Tap root, Rootlets retention, Planting depth*

INTRODUCTION

Wood products from teak plantations provide high quality timber and generates substantial amount of foreign exchange for Ghana. The establishment of teak plantations in Ghana is dependent mostly on planting of teak stumps. The leaves, upper stem portion and roots of bare-rooted teak seedlings raised on seed beds are trimmed into stumps as done with many species prior to planting. For example, Shiver *et al.* (1990) report that tape roots and lateral roots of seedlings of some species such as *Pinus elliottii* and *Pinus taeda* are pruned before planting. These stumps are examples of hardwood stem and root cutting planting materials. Hardwood stem and root cuttings are some of the cheap means of large-scale plant propagation (Erez and Yablowitz, 1981).

Stumps are not difficult to prepare, not easily perishable and can be transported over long distances without much difficulties (Hartmann *et al*., 1997).

Many reports have indicated that the sprouting and rooting of stem cuttings are influenced by large number of interacting factors forming complex relationships. These include treatments of cutting, propagation environment, planting methods, source and size of stock plants, management of stock plants, species and genotypes, and propagating medium (Hartmann *et al*., 1997). Propagation environment for instance is influenced by ambient environment consisting of some climatic factors such as sunlight, temperature, rainfall, soil type and depth of planting. The source and size of planting materials consist of some factors such as age, length, diameter and root mass.

The poor rooting of stem cuttings of some species are due to limited supply of hormones and carbohydrates reserves and growth rooting cofactors and also high concentrations of nitrogenous substances and growth inhibitors (Hartmann *et al*., 1983). Other workers such as Hambrick *et al*., (1991) and Henry *et al*., (1992) have indicated that the nutrition of the cuttings has strong influence on the development of roots and shoots from cuttings. The effect may relate to a specific physiological state of the tissues of the cuttings and also carbon and nitrogen relationships. While carbohydrate content and rooting of cuttings are positively correlated, cuttings with high carbohydrate reserve and low to moderate nitrogen is optimal for rooting of hardwood cuttings (Hartmann *et al*., 1997).

The depth at which stumps are planted has great influence on biomass production since soil depth determines the amount of mineral water and nutrients the roots of the stumps can access and also the degree at which the roots are prone to desiccation. Smith (1986) observed that seedlings should be planted at the same depth they occupied in the nursery with roots spread out in a manner as natural as possible to ensure effective absorption of water and nutrients.

The evaluation of the extent of influence of some factors, especially the root biomass of stumps after pruning of the roots and the depth of planting of cuttings, is important for the success of the plantation program in Ghana. Information about the level at which the tap roots and lateral roots or rootlets of teak stumps should be pruned and the depth at which these stumps should be planted on the field to achieve high survival rate of sprouted stumps and biomass production is scanty. The main goal of this study is to develop suitable methods concerning the treatment of roots of teak seedlings into stumps and best planting depth to maximise biomass production. The objectives of the study were to investigate the effect of root trimming of tap root and rootlets of stumps and also the depth at which the stumps are planted on shoot biomass, tree height and collar diameter and also leafy, stem and roots biomass production of the sprouted teak stumps.

MATERIALS AND METHODS

The study was carried out at the demonstration farm of the Faculty of Renewable Natural Resources of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The area is located within the Moist Semi-deciduous forest South-east Subtype (Hall and Swaine, 1981).The farm lies on longitude 06º 43’ N and latitude 01º 36’ W. The mean annual rainfall ranges between 1300 mm and 1600 mm while the mean daily temperature ranges between 22.0º C and 31.1º C (Hall and Swaine, 1981). The soils belong to the Asuasi series, classified as forest *Ochrosols* (Sarkodie-Addo *et al*., 2006)

The experiment was started in 2009. Four hundred and thirty two six-month old teak seedlings with root collar diameters ranging between 1.5 cm and 2.5 cm were obtained from a heavily watered seed bed of a nursery at the farm. The seedlings were carefully uprooted and then cut at heights of 10 cm above root collar using a sharp medium-sized cutlass and a one-meter ruler. The roots were cut according to the specifications of a treatment combination.

A factorial experiment in a randomised complete block design (RCBD) was used. The factors were depth of planting of stumps below root collar (D), length of tap root below root collar (L) and percentage of retention of rootlets (R). The depth of planting of seedling stumps below root collar were 1 cm (D_1), 5 cm (D_2) and 10 cm (D_3). The length of tap root below root collar were 1 cm (L_1), 5 cm (L_2), 10 cm (L_3) and no cutting of tape root (L_4). The percentage of retention of rootlets were 0 % (R_1), 50 % (R_2) and 100 % (R_3).Two rectangu lar blocks were used. The depth of planting of a seedling stump was total stump height from the base of the stump to the tip before planting minus stump height above soil level after planting. On each plot 6 teak stumps were transplanted at a spacing of 30 x 30 cm. During the twelfth week of the experiment the number of shoots per plot was recorded. Also after one year, stem height (measured to the nearest cm using a meter-rule), collar diameter (measured to the nearest 0.1 mm using a veneer calliper) and tree components of dry weight (measured to the nearest milligram) were recorded. Dry weight measurements were undertaken using the standard method of oven-dry weight determination method.

RESULTS

Effect of length of tap root, percentage of retention of rootlets and depth of planting on the number of shoots

The F-ratio values for length of tap root below root collar of 8.12 and percentage of retention of rootlets of 4.9 were significant (Table1). The F-ratio for depth of planting of stumps below root collar of 1.0 was not significant, even though over the 12-week period the F-ratio for

Table 1: Analysis of variance of mean number of teak shoots per plot

Sources of variation	Sum of squares	Degrees of freedom	Mean sum of squares	F-ratio
Blocks (B)	48.17	1	48.17	0.74^{ns}
Length of tap root above root collar (L)	1578.40	3	526.13	8.12^{***}
Percentage of retention of rootlets (R)	635.29	2	317.65	4.90^{*}
Depth of planting (D)	129.72	2	64.86	1.00^{ns}
LR	365.32	6	60.89	0.94^{ns}
LD	344.72	6	57.45	0.87^{ns}
RD	125.25	4	31.31	0.48^{ns}
LRD	361.17	12	30.10	0.46^{ns}
Error (a)	2269.00	35	64.83	
Whole plots	5857.04	71		
T (time)	1451.95	11	132.00	56.46^{***}
LT	117.19	33	3.55	1.52^{*}
RT	69.12	22	3.14	1.34^{ns}
DT	81.03	22	3.68	1.58^{*}
LRT	160.93	66	2.44	1.04^{ns}
LDT	174.53	66	2.64	1.13^{ns}
RDT	63.34	44	1.44	0.62^{ns}
LRDT	271.25	132	2.06	0.88^{ns}
Error (b)	925.83	396	2.34	
Subplots	9172.20	863		

*Legend: *significant at 5 %; ** significant at 1 % ***; significant at 0.5 %; ns non-significant* depth of planting of seedling stumps below root collar and time interaction was significant.

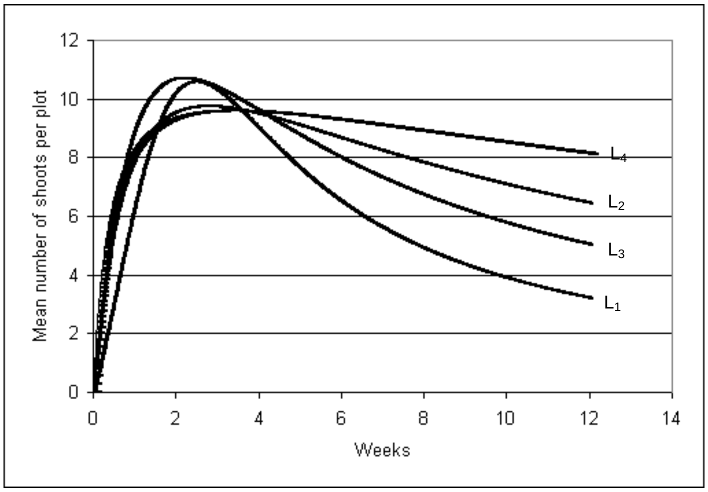

Fig. 1: Trends in the mean number of shoots per plot on stumps as affected by length of tap root below root collar; L is length of tap root below root collar (L_1 = 1 cm, L_2 = 5 cm, L_3 = 10 cm and L_4 = no cutting of tap root)

[y= $\frac{x}{ax^2+bx+c}$; 81.67 % $\leq$ R^2 $\leq$ 94.58 %]

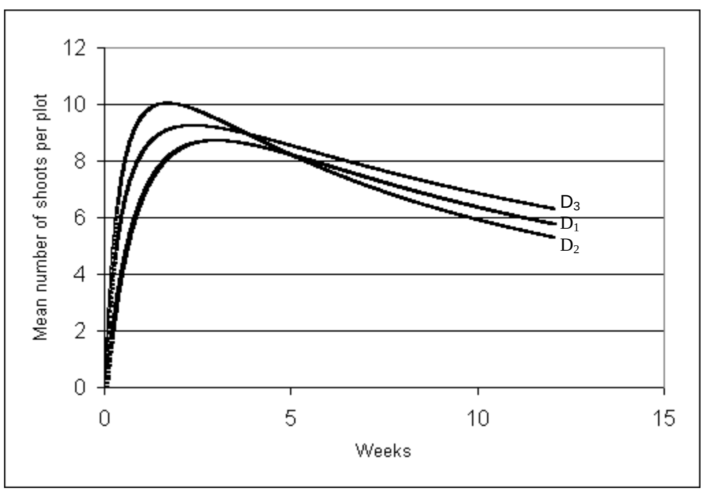

Fig. 2: Trends in the mean number of shoots per plot on teak stumps as affected by depth of planting of stumps below root collar; D is depth of planting (D_1 = 1 cm, D_2= 5 cm and D_3= 10 cm)

[y= $\frac{x}{ax^2+bx+c}$; 79.51 % $\leq$ R^2 $\leq$ 82.98 %]

Figure 1 shows the trends in the number of shoots on sprouted stumps per plot for various lengths of tap root below root collar. The trends followed the quadratic reciprocal model of the

Form y = $\dfrac{x}{ax^2 + bx + c}$ with coefficient of

determination (R^2) lying between 82 and 95 %

In the model a, b and c are constants.

The number of shoots per plot increased sharply initially and reached a maximum value of about 10 per plot for periods between 2 and 3 weeks and gradually decreased for all treatments of length of tap root below root collar diameter. At the end of the 12th week the mean number of shoots per plot was highest with a value of 8.1 for untrimmed tape root, followed by respective mean values of 6.4, 5.1 and 3.2 for tape root length below root collar of 10 cm, 5 cm and 1 cm.

Figure 2 also shows the trends in the number of shoots on sprouted stumps per plot for various depths of planting of stumps below root collar. The trends also followed the quadratic reciprocal model of the form

y = $\dfrac{x}{ax^2 + bx + c}$ with coefficient of determination (R^2) lying between 79 and 83 %.

The number of shoots per plot increased sharply initially and reached a maximum value of about 9.5 per plot for periods between 2 and 3 weeks and gradually decreased for all depths of planting. At the end of the 12th week the respective number of shoots per plot for depth of planting of stumps below root collar of 1 cm, 5 cm and 10 cm were 5.7, 5.3 and 6.3.

Interdependence of number of stems per plot on length of tap root, percentage of retention of rootlets and depth of planting of teak stumps. Table 2 shows the F-ratios for the number of stems and dry weight of teak stems for various components and factors and their interactions. The length of tap root below root collar had very significant effect on the number of stems per plot with an F-ratio of 5.28. The depth of planting and percentage of retention of rootlets were also important with respective F-ratio values of 4.58 and 3.5. Table 3 also shows the mean values for these factors and their interactions.

Stumps with full length of tap root had the highest mean number of stems per plot of 4.5 while stems from stumps of tap root length below root collar of 1 cm had the least value of 2.0.The percentage of retention of rootlets significantly affected the number of stems per plot. Stumps with uncut rootlets had the highest number of stems per plot of 4.0 while stumps with all the rootlets removed had the least number of stems per plot of 2.5. Similarly, the depth of planting of seedling stumps below root collar had significant effect on the number of stems per plot. Depth of planting of stumps below root collar of 1 cm had the smallest mean number of stems per plot of 2.3 among the other planting depths.

Effect of length of tap root, depth of planting and percentage of retention of rootlets of teak stumps on stem height

The variations in stem height ($16.75 \leq$ F-ratio≤ 33.51) among stumps of tap root length below root collar, percentage retention of rootlets and depth of planting of stumps below root collar were very significant and generally higher than variations in stems per plot ($3.50 \leq$ F-ratio≤ 5.28) as shown in Table 2. There were highly significant differences in mean stem height for stumps of tap root lengths below root collar. Stumps of untrimmed tap roots had the highest mean stem height of 1.85 m while stumps of tap root length below root collar of 1 cm had the least mean stem height of 0.60 m. Stumps with 100 % of retention of rootlets had the highest mean stem height of 1.52 m while stumps with all the rootlets removed had the

Table 2: F-ratio values from analysis of variance for number of stems per plot, mean tree height (m), mean tree collar diameter (cm), stem dry weight (gm) per plot, root dry weight (gm) per plot, leaf dry weight (gm) per plot, and total tree dry weight (gm) per plot for various sources of variation of blocks, length of tap root (L), percentage of retention of rootlets (R), depth of planting (D), LxR interaction, LxD interaction, RxD interaction and LxRxD interaction for teak

Sources variation	Mean number of stems per plot	Mean tree height	Mean tree collar diameter	Stem dry weight per plot	Root dry weight per plot	Leaf dry weight per plot	Total Tree dry weight per plot
Blocks	0.54^{ns}	16.53^{***}	9.60^{***}	18.78^{***}	1.78^{ns}	11.07^{***}	12.96^{***}
L	5.28^{***}	33.51^{***}	15.89^{***}	39.44^{***}	40.92^{***}	40.20^{***}	47.18^{***}
R	3.50^{*}	16.75^{***}	11.39^{***}	9.30^{***}	17.78^{***}	16.65^{***}	16.08^{***}
D	4.58^{*}	30.62^{***}	13.22^{***}	21.43^{***}	25.81^{***}	26.00^{***}	28.49^{***}
LR	0.34^{ns}	3.11^{**}	0.90^{ns}	2.41^{*}	2.61^{*}	1.86^{ns}	7.20^{**}
LD	0.43^{ns}	1.15^{ns}	0.82^{ns}	2.39^{*}	0.32^{ns}	0.39^{ns}	2.14^{ns}
RD	0.09^{ns}	2.33^{ns}	1.19^{ns}	2.03^{ns}	0.32^{ns}	0.39^{ns}	0.93^{ns}
LRD	0.18^{ns}	0.93^{ns}	0.48^{ns}	1.32^{ns}	0.55^{ns}	1.09^{ns}	1.08^{ns}

*Legend: *significant at 5 %; ** significant at 1 % ***; significant at 0.5 %; ns non-significant*
L is length of tap root below root collar, R is percentage of retention of rootlets and D is depth of planting.

Table 3: Plot means of number of stems, stem height, root collar diameter, stem dry weight, root dry weight, leaf dry weight, and total tree dry weight for teak for various factors

Levels of some factors	Mean number of stems per plot	Mean tree height (m)	Mean tree collar diameter (cm)	Mean stem dry weight (gm) per plot	Mean root dry weight (gm) per plot	Mean leaf dry weight (gm) per plot	Mean total tree dry weight per plot (gm)
L_1	2.0^{a}	0.60^{a}	1.48^{a}	77.4^{a}	43.9^{a}	94.0^{a}	215.4^{a}
L_2	2.9^{ab}	0.98^{b}	2.28^{b}	211.1^{b}	117.1^{b}	271.4^{b}	599.6^{b}
L_3	4.2^{bc}	1.46^{c}	3.00^{c}	304.9^{c}	184.0^{c}	384.5^{c}	873.4^{c}
L_4	4.5^{cd}	1.85^{d}	3.67^{d}	466.2^{d}	246.7^{d}	549.1^{d}	1262.0^{d}
R_1	2.5^{a}	0.86^{a}	1.83^{a}	197.8^{a}	94.9^{a}	205.6^{a}	498.3^{a}
R_2	3.8^{b}	1.29^{b}	2.73^{b}	261.7^{ab}	155.2^{b}	357.0^{b}	773.9^{b}
R_3	4.0^{bc}	1.52^{bc}	3.22^{c}	335.2^{c}	193.7^{c}	411.6^{bc}	940.5^{c}
D_1	2.3^{a}	0.72^{a}	1.76^{a}	148.2^{a}	78.9^{a}	174.9^{a}	402.1^{a}
D_2	4.1^{b}	1.38^{b}	2.77^{b}	297.2^{b}	176.8^{b}	369.0^{b}	843.1^{b}
D_3	3.8^{bc}	1.58^{bc}	3.25^{c}	349.3^{c}	188.0^{bc}	430.4^{bc}	967.6^{bc}

Letters a, b, c and d have been used to compare means for each cell. Comparisons are based on Duncan's multiple range test ($p \leq 0.05$). L is length of tap root below root collar (L_1 = 1 cm, L_2 = 5 cm, L_3 = 10 cm and L_4 = no cutting of tap root), R is percentage of retention of rootlets (R_1 = 0, R_2= 50 and R_3= 100) and D is depth of planting (D_1 = 1 cm, D_2= 5 cm and D_3= 10 cm) least mean stem height of 0.86 m (Table 3). Stumps planted below root collar of 10 cm had the greatest mean stem height of 1.58 m. The lowest mean stem height of 0.72 m was achieved by stumps planted below root collar of 1 cm (Table 3).

The interaction between length of tap root below root collar and percentage of retention of rootlets was significant, while the other interactions for tree height were not significant (Table 2). Stumps with full length of tap root had consistently the highest mean tree height over all percentage of retention of rootlets treatments, while stumps with tap root length below root collar of 1 cm had consistently the lowest mean tree height over all percentage of retention of rootlets treatments (Fig. 3). Stumps with full length of tap root and retention of all rootlets had the highest mean tree height of 2.44 m, while stumps with tap root length below root collar of 1 cm and no retention of rootlets had the lowest mean tree height of 0.55 m (Table 4).

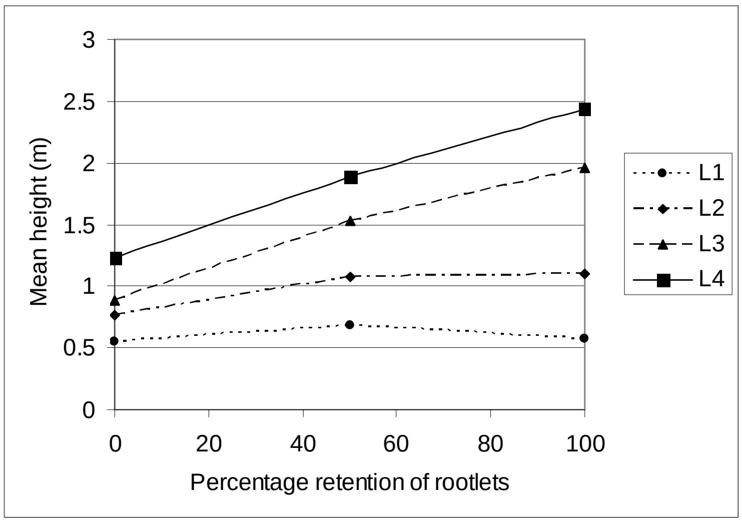

Fig: 3 Mean height of teak trees as affected by percentage of retention of rootlets for various lengths of tap root below root collar; L is length of tap root below root collar (L_1 = 1 cm, L_2 = 5 cm, L_3 = 10 cm and L_4 = no cutting of tap root)

Table 4: Mean stem height (m) and stem dry weight per plot for length of tap root (L) and percentage of retention of rootlets (R) interaction

	Mean stem height (m)			**Mean stem dry weight (gm) per plot**		
	Percentage of retention of rootlets (R)			**Percentage of retention of rootlets (R)**		
	R_1	R_2	R_3	R_1	R_2	R_3
L_1	0.55 ^{a}	0.68 ^{abc}	0.57 ^{ab}	30.3 ^{a}	87.6 ^{ab}	144.4 ^{abc}
L_2	0.77 ^{abcd}	1.08 ^{abcdef}	1.10 ^{cdefg}	175.4 ^{bcd}	229.1 ^{cde}	228.8 ^{cdef}
L_3	0.89 ^{abcde}	1.54 ^{fghi}	1.96 ^{ijk}	252.1 ^{defg}	321.7 ^{defgh}	340.9 ^{fghij}
L_4	1.23 ^{defgh}	1.89 ^{hij}	2.44 ^{l}	333.5 ^{efghi}	408.5 ^{fghijk}	656.6 ^{l}

Letters a, b,…., l have been used to compare means of stem height and also stem dry weight. Comparisons are based on Duncan's multiple range test ($p \leq 0.05$). L is length of tap root below root collar (L_1 = 1 cm, L_2 = 5 cm, L_3 = 10 cm and L_4 = no cutting of tap root) and R is percentage of retention of rootlets (R_1 = 0, R_2= 50 and R_3= 100)

Effect of length of tap root, depth of planting and percentage of retention of rootlets of teak stumps on collar diameter

The variations in stem collar diameter (11.39 ≤ F-ratio≤ 15.89) among tap root length below root collar, percentage retention of rootlets and depth of planting of stumps below root collar were very significant and generally higher than similar variations in stems per plot but lower than variations stem height (Table 2). Stumps with full length of tap roots had the highest mean collar diameter of 3.67 cm. Stumps with tap root length below root collar of 1 cm had the least mean collar diameter of 1.48 cm (Table 3). Also stumps with 100 % of retention of rootlets had the highest mean collar diameter of 3.22 cm while stump with all the rootlets removed had the least mean collar diameter of 1.83 cm (Table 3). Depth of planting of stumps below root collar of 10 cm had the highest mean collar diameter of 3.25 cm. The lowest mean collar diameter of 1.76 cm was achieved by depth of planting of stumps below root collar of 1 cm (Table 3).

Effect of length of tape root, depth of planting and percentage of retention of rootlets of teak stumps on dry weight of tree components

Tap root length below root collar had the greatest and significant effect in variation of dry weight of stem, root, leaf and whole tree with F-ratio values ranging between 39.44 and 47.18, followed by depth of planting of stumps below root collar (21.43 ≤ F-ratio ≤ 28.49) and percentage retention of rootlets (9.30 ≤ F-ratio ≤ 17.78) as shown in Table 2. Untrimmed tap root had the largest dry weights of stem, root, leaf and whole tree ranging between 264.7 gm and 1262.0 gm, followed by depth of planting of stumps of 10 cm below root collar between 188.0 gm and 967.6 gm and full retention of rootlets of between 193.7 and 940.5. (9.30 ≤ F-ratio ≤ 17.78) as shown in Table 3. Whole tree dry weight increased with increase in length of tap root below root collar, depth of planting of stumps below root collar and percentage retention of rootlets (Table 3). In particular, the best relationship between whole tree dry weight (y) and percentage of retention of rootlets (R) was linear of the form

$$y = 4.42\,R + 516.51; \quad R^2 = 96.02\ \% \quad (p<0.05) \qquad (1)$$

However, the best relationship between whole tree dry weight (y) and depth planting of stumps below root collar (D) was quadratic of the form

$$y = -\,9.48121\,D^2 + 167.129\,D + 244.43; \quad R^2 = 99.99\ \% \quad (p<0.05) \qquad (2)$$

where the maximum whole tree dry weight of 981 gm was achieved when depth planting of stumps below root collar was 8.8 cm.

The interaction between length of tape root below root collar and percentage of retention of rootlets was significant for the dry weight of stem, root and whole tree (Table 2). The interaction between length of tape root below root collar and planting depth was also significant for stem dry weight (Table 2). Linear trends of mean dry weight for stem, root and whole tree over percentage of retention of rootlets for various tap root lengths below root collar can be seen in Table 4, Table 5 and Table 6. The highest respective mean dry weight for stem, roots and whole tree of 655.6 gm, 342.5 gm and 1746.1 gm were observed for stumps with full tape root length and full retention of rootlets. However, the lowest respective mean dry weight for stem, roots and whole tree of 30.3 gm, 13.2 gm and 81.5 gm were attained by stumps with tap root length below root collar of 1 cm and no retention of rootlets.

DISCUSSION

The quadratic reciprocal model appears to be one of the excellent forms of modeling the trends in the number of shoots production on sprouted teak stumps over time. The trend for many germination and sprouting cuttings is supported by Mead *et al*. (1993). The differences in the levels of the mean number of stems

Table 5: Mean stem height (m) and stem dry weight per plot for length of taproot (L) and depth of planting below root collar (D) interaction

	Mean stem dry weight (gm) per plot			Mean root dry weight (gm) per plot		
	D_1	D_2	D_3	R_1	R_2	R_3
L_1	38.5 ^{ab}	78.5 ^{abc}	115.4 ^{abcd}	13.2 ^{a}	62.1 ^{abc}	56.5 ^{ab}
L_2	32.0 ^{a}	269.7 ^{ef}	331.7 ^{efghi}	82.8 ^{abcd}	141.8 ^{defg}	126.8 ^{bcde}
L_3	248.4 ^{e}	310.2 ^{efgh}	356.1 ^{fghij}	131.5 ^{bcdef}	171.5 ^{efghi}	248.9 ^{ijk}
L_4	274.0 ^{efg}	530.6 ^{k}	593.9 ^{l}	152.1 ^{defgh}	245.5 ^{ij}	342.5 ^{l}

Letters a, b,…., l have been used to compare means of stem dry weight and also root dry weight. Comparisons are based on Duncan's multiple range test (p ≤0.05). L is length of tap root below root collar (L_1 = 1 cm, L_2 = 5 cm, L_3 = 10 cm and L_4 = no cutting of tap root), R is percentage of retention of rootlets (R_1 = 0, R_2= 50 and R_3= 100) and D is depth of planting (D_1 = 1 cm, D_2= 5 cm and D_3= 10 cm)

Table 6: Mean total tree dry weight per plot for length of taproot (L) and percentage of retention of rootlets (R) interaction

	Mean dry weight of stems (gm) per plot		
	R_1	**R_2**	**R_3**
L_1	81.5 ^{a}	265.1 ^{ab}	299.6 ^{abc}
L_2	437.3 ^{bcd}	693.9 ^{defg}	667.6 ^{def}
L_3	637.4 ^{de}	934.1 ^{efghi}	1048.6 ^{fghij}
L_4	837.1^{efgh}	1202.7 ^{k}	1746.1 ^{l}

Letters a, b,…., l have been used to compare means. Comparisons are based on Duncan's multiple range test (p ≤0.05). L is length of tap root below root collar (L_1 = 1 cm, L_2 = 5 cm, L_3 = 10 cm and L_4 = no cutting of tap root) and R is percentage of retention of rootlets (R_1 = 0, R_2= 50 and R_3= 100)

for the various sets of factor levels in most cases are maintained over time. The results indicate that the mean number of shoots per plot for various tap root length below root collar and depth of planting of stumps can be estimated with high precision.

The best tap root treatment of teak stumps is not to cut any part of the tap root yielding an increase of 120 % of shoots over the usual practice of trimming the tap root to a length of 1 cm below root collar (Owusu, Personal communication) over a twelve week period. Also using uncut tap root helps achieve an increase of 125 % in the number of stems, 208 % in height, 149 % in collar diameter, 502 % in stem dry weight, 462 % in root dry weight, 484 % in leaf dry weight and 486 % in total tree dry weight over the normal tap root length below root collar of 1 cm used by many tree planters in Ghana.

The amount of photosynthate, mainly in the form of carbohydrates reserve, in a stump together with auxins and nutrients exerts great influence in the propagation, survival and biomass production of the stump (Boateng *et al.*, 2003). The carbohydrates are needed for energy. According to Hartman *et al.* (1997), stumps must produce and (or) rely on stored carbohydrates in excess of its maintenance requirements for successful rooting to occur. Mesén *et al*. (1997 a) observed that stumps can form roots only when they have positive carbon balance. This means that the stumps should produce assimilates faster than losing them through respiration.

Carbohydrates reserves are positively correlated with size (or volume) of cuttings such as tap root and rootlets (Boateng *et al.*, 2003). Veierskov (1988) observed a positive relationship between carbohydrates contents and root number and biomass. Hence the significant order of biomass production measures of tree height, collar diameter and tree biomass of length of tap root below root collar of 1 cm < length of tap root below root collar of 5 cm < length of tap root below root collar of 10 cm< untrimmed tap root; and also percentage of retention of rootlets of 0 % < percentage of retention of rootlets of 50 % < percentage of retention of rootlets of 100 % are perhaps as a result of the quantity of carbohydrates positively proportional to the volume of roots for these root treatments.

The results indicate that tap root pruning has more negative influence on biomass production than rootlets possibly because tape roots are more voluminous (and thus greater carbohydrate reserves) than rootlets. Smith (1986) observed that tap roots and root hairs or rootlets help the tree absorb water and nutrients and any pruning of the roots jeopardize survival and growth of the stem. Hence biomass production of the stem also depends on the degree to which tap roots and rootlets are retained on the teak stumps as reflected in the positive relationship between biomass production and the quantity of roots in the stem. The results from this work are in conformity with the works of other workers.

Mexal and South (1991) and also Harrington and Howell (1998) noted that the pruning of roots can reduce growth and survival of the stumps. Using teak stumps with untrimmed rootlets, there is gain of 63 % in the number of stems, 77 % in height, 77 % in collar diameter, 69 % in stem dry weight, 104 % in root dry weight, 100 % in leaf dry weight and 141 % in total tree dry weight over stumps with completely removed rootlets usually practiced by many tree planters. These values conform to the records of Smith (1986), Mexal and South (1991) and Harrington and Howell (1998).

Many studies have reported high dependence of tree survival and growth on planting depth. Maxal and Burton (1978) reported a positive correlation between planting depth and height of two-year old *Pinus taeda* trees. The quadratic relation between planting depth and dry matter weight indicating a rise and fall of dry matter weight with a plateau is in conformity with other authors. Seiler *et al*. (1990) and South (1991) reported increased seedling mortality for shallow planting, while VanderSchaaf and South (2003) reported smaller diameter growth at breast-height and stem volume growth for deep planting. Wells *et al*., (2006) also noted that deep planting is a significant source of stress in landscape trees.

Leakey (2004) observed that for successful rooting and survival the rooting medium (soil) should provide sufficient moister and also high level of aeration comprising exchange of oxygen and carbon dioxide at the base of the cutting. At shallow soil depth, especially during drought periods, air circulation is high whereas water availability is low. Conversely at high soil depth the cutting can access higher amount of water but with lower level of aeration.

Leakey (2004) suggests a soil suitable air to water ratio to optimize the growth of the cutting. These observations suggest a planting depth when biomass production is maximized for individual species. For teak the results show an optimal planting depth of about 9 cm. For instance, planting at a depth of 10 cm (close to the ideal of 9 cm) ensures gain of 63 % in the number of stems, 119 % in height, 85 % in collar diameter, 136 % in stem dry weight, 138 % in root dry weight, 146 % in leaf dry weight and 141 % in total tree dry weight over stump planting depth of 1 cm.

CONCLUSIONS

The trend analysis of the study indicated that the reciprocal model ($79 \leq R^2 \leq 95$ %) is precise and biologically sound in predicting the number of shoots on teak stumps that sprout over time. The umber of trees, tree height, tree collar diameter, stem dry weight, root dry weight, leaf dry weight and total tree dry weight were significantly affected by length of tape root below collar diameter, percentage of retention of rootlets and depth planting The length of tape root below collar diameter was the most important factor controlling the variation in biomass growth of teak stumps. The best biomass production was observed for non-treated stump tape root and rootlets and planting at 9 cm soil depth ensuring a gain of about 486 % of tree dry weight over the traditional method of stump preparation and planting. Finally, the study showed the root and rootlet preparation methods and the depth of planting of teak stumps required to achieve maximum biomass production to ensure its high survival rate and if adopted by tree growers can reduce planted teak stump mortality considerably.

ACKNOWLEDGEMENTS
The data collection of the study was assisted by Mr. Mark Owusu and Mr. Samuel Bartels of Silviculture and Forest Management Department, Faculty of Renewable Natural Resources, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

REFERENCES
Boateng P. Y., Asare, C. M., and Adjei, P. Y. (2003). Effect of length and mode of setting of cuttings on the sprouting and seedling development of black pepper (*Pipernigrum* L.) vines. *Ghana Journal of Horticulture 2: 45-49*.

Erez, A. and Yablowitz, Z. (1981). Rooting of peach hardwood cuttings for the meadow orchard. *Scientia Horticulture 15:137-144*.

Hall, J. B. and Swaine, M. D. (1981). Distribution and ecology of vascular plants in a tropical rain forest - Forest vegetation in Ghana. Dr. W. Junk Publishers, London.

Hambrick, C. E., Davis, F. T. Jr. and Pemberton, H. B. (1991). Seasonal changes in car-bohydrates/nitrogen levels during field rooting of *Rosa multiflora* 'Brooks 56' hardwood cuttings. *Scientia Horticulture 46:137-146.*

Harrington, T. B. and Howell, K. D. (1998). Planting cost, survival and growth one to three years after establishing loblolly pine with straight, deformed or pruned taproots. *New Forests 15: 193-204.*

Hartmann, H. T., Kester, D. E. and Davis, F. T. Jr, Geneve, R. L (1983). Plant propagation, 4th edition. Prentice Hall, New Jersey.

Hartmann, H. T., Kester, D. E., Davis, F. Jr. and Geneve, R. L. (1997). Plant propagation, 6th edition. Prentice Hall, New Jersey.

Henry, P. H.., Blazich, F. A. and Hinesley, L. E. (1992). Nitrogen nutrition of containerized eastern red cedar, II Influence of stock plant fertility on adventitious rooting of stem cuttings. *J. American Society of Horticultural Science 117:568-570*.

Leakey, R. R. B. (2004). Physiology of vegetative reproduction. In: Burley, J., Evans, J., Youngquist, J. A. (editors) Encyclopaedia of Forest Science, Academic Press, United Kingdom, pp 1655-1668.

Mead, R., Curnow, R. N. and Hasted, A. M. (1993). Statistical methods in agriculture and experimental biology, 2nd edition. Chapman and Hall, London.

Mesén F., Newton, A. C., Leakey, R. R. B. (1997a). The effects of propagation environment and foliar areas on the rooting physiology of *Cordia alliodora* (Ruiz and Pavon) Oken cuttings. *Trees 11:401-411*.

Mexal, J. and Burton, S. (1978). Root development of planted loblolly pine seedlings. In: Venden, E., Kinghorn, J. M. (editors), Proceedings of Root form of planted trees, Joint Report of British Columbia, Ministry of Forests, Canadian Forestry Service, Victoria BC, Report Number 8, pp 85 – 89.

Mexal, J. and South, D. B. (1991). Bare root seedling culture. In: Duryea, M. L., Dougherty, P.M. (editors.) Forest Regeneration Manuel, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp 89-111.

Sarkodie-Addo, H. K., Adu-Dapaah, N., Ewusi-Mensah N., Asare, E. (2006). Evaluation of medium-maturing soyabeans (*Glycine max* (L) Merrill) lines for their nitrogen fixation potentials. *J. Science and Tech. 26 (2):34-39*.

Seiler, J. R., Paganelli, D. J., Cazell, B. H. (1990). Growth and water potential of J-rooted loblolly and eastern white pine seedlings over three growing seasons. *New Forests 4:147-153*.

Shiver, B. D., Borders, B. E., Page, H. H., Raper, S. M. (1990). Effect of some seedling morphology and planting variables on seedling survival in the Georgia Piedmont. Southern Journal of *Applied Forestry 14:109-114*.

Smith, D. M. (1986). The practice of silviculture, 8th edn. John Williey and Sons, New York.

South, D. B. (1991). Which loblolly pine seedling has a higher survival potential – a deep planted J–root or a shallow planted J-root? In: Haywood JD (ed) Proceeding of Tenth Biennial Southern Silvicultural Research Conference, USAD Forest Service, General Technical SRS-30, pp 350-354.

VanderSchaaf, C. L., South, D. B. (2003). Effect of planting depth on growth of open - Rooted *Pinus elliottii* and *Pinustaeda* seedlings in the United States. Review paper, School of Forestry and Wildlife Sciences and Alabama Agricultural Experimental Station, Auburn University, Alabama, USA.

Veierskov, B. (1988). Relationship between carbohydrates and adventitious root formation. In: Cutting Vol. 2, Dioscorides Press, Portland, pp 70 – 78.

Wells, C., Townsend, K., Caldwell, J., Ham, D., Smiley, T., Sherwood, M. (2006). Effects of planting depth on landscape tree survival and girdling root formation. *Arboriculture and Urban Forestry, 32(6):305 -311*.