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Assessing the growth performance of teak (*Tectona grandis* Linn. f.) coppice two years after clearcut harvesting

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Abstract

The establishment of plantations has become an obvious option to mitigate the challenges placed on the worlds' natural forests due to anthropogenic factors. Teak is currently one of the most widely planted tree species used to curb deforestation especially, in Ghana. In this paper, we investigated the growth performance of teak coppice, two years after clearcutting. The results revealed that stump diameter and height significantly influenced the number of coppiced shoots. The maximum number of sprouts was found in stumps cut to a height of about 15 cm above ground. Also, stump diameter was positively correlated with number of sprouts as well as leader height. Though the models developed for average sprout height (16.0%) and leader height (8.5%) were significant, they did not account for most of the variation in the dataset based on their adjusted R-squared values. Hence, the management of coppice after clearcutting through thinning is important if better quality shoots are required to meet the purpose of production.

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Introduction

Teak (*Tectona grandis* Linn. f.) is considered the noblest among all woods not simply because of its golden hue and wonderful texture, but even more because of its durability, strength, attractiveness, workability, and superior seasoning capacity (Tewari, 1999). Teak is one of the most widely planted hardwood timber species in the world. In 2010, the global area of planted teak forests reported from 38 countries was estimated at 4.346 million ha, of which 83% grew in Asia, 11% in Africa, 6% in tropical America and less than 1% in Oceania. Countries of tropical Africa recorded about 470 000 ha of planted teak forests with Ghana having the largest area of approximately 214 000 ha (Kollert and Cherubini, 2012).

In Ghana, teak plantation establishment started in the 1960s but peaked in the early 1970s due to the dangers of deforestation and the inability of natural regeneration to keep up with the threat (Assabil, 1996). This led to the establishment of large plantation areas both in- and off- forest reserves by government and private sectors. So far, teak has proven to be a potentially compatible species in plantation forests that have relatively short rotations. Since coppicing remains an important reforestation tool, the ability of teak to sprout well may significantly contribute to rapid restoration (Pramono *et al.*, 2011) of forest cover after timber extraction or cyclone damage (Bellingham *et al.*, 1994). For example, many of the species that make up the timber wealth of tropical forests (e.g. *Khaya ivorensis* and *Entandophragma* spp.) have proved stubborn in plantation establishment for reasons such as exceedingly slow growth, susceptibility to mortality on cleared land (being climax rather than pioneer species) or vulnerability to pests and diseases.

A number of studies have been done on the regenerative potential of teak plants using coppices (Palanisamy and Subramanian, 2001; Chowdhury *et al.*, 2008; Husen, 2011). According to Lamprecht (1989) it is important to establish a relationship between some tree variables such as age, height and diameter which will increase knowledge and enhance proper management of forest plantations. Other researchers have also shown that parent tree age, diameter and site quality are important predictors of stump sprouting in tree species (Bruggink, 1988; Dey *et al.*, 1996). Though coppices allow for much shorter rotations compared to seedlings, teak coppice management in plantations of Ghana are virtually non-existent. This has become a serious challenge for small scale farmers and private plantation developers eventually leading to poor tree forms of the next crops after the first rotation. Thus, the objective of the study was to determine significant predictors of teak coppices (and coppice performance) to enable forest managers make informed decisions for the success of future stands.

Materials and methods

Study area

The study was carried out in Techiman Municipality located in the Brong Ahafo Region of Ghana. It lies between longitudes 1° 49' East and 2° 30' West and latitude 8° 00' North and 7° 35' South with an estimated land area of 669.7 km². It has a bimodal (major and minor rainy seasons) rainfall regime with a dry spell starting in November and lasting through to March (Techiman Municipal Assembly, 2006). The teak plantation used for this study was approximately 19 years old and had been harvested two years earlier using the clearcut method. Thus, teak stumps in the plantation had sprouts that were exactly two years old or lower. However, management practices that ensured proper coppicing or quality of coppices were not carried out on the plantation after harvests. The 0.3 hectare study plantation had a tree spacing of 3 x 3 m.

Experimental design and statistical analysis

In this study, 8 plots were sampled following a “W” path method (ie. two plots per pattern). Thus, the “W” pattern starts at one corner and crisscrosses the site four times reaching the other corner on the same side of the plantation. Sizes of sample plots were 20 x 20 m each. Ten teak stumps were randomly selected from each sample plot following the exclusion of two outer 'guard' rows. Stump height, stump girth, leader length and number of sprouts were then measured for each selected stump. Thus, any sprout forking within 2 cm from the point of origin was counted as two or more. The girth of each stump was later converted to a diameter estimate using the formula $d = g/\pi$ (Mathews and Mackie, 2006) for further analysis. where; d=diameter, g=girth and π=Pi. The GLM procedure of SAS version 9.2 was used to investigate the effect of stump diameter and height on the number of coppice shoots, leader height and average height of sprouts. All other statistical analysis performed in this study was done using the SAS software (version 9.2).

Results and discussion

Preliminary findings

The descriptive statistics for teak stumps and their yield components based on coppices are presented in Table 1. The results indicate that the minimum and maximum number of sprouts recorded during the study were two (2) and eight (8) respectively, with an average of 4.55 sprouts occurring per stump. The low numbers of sprouts recorded per stump after two years of harvests is confirmed in studies elsewhere (Crowther and Evans, 1986; Thaiutsa, 1999; Chowdhury *et al*., 2008). For instance, Crowther and Evans (1986) reported that a large number of shoots emerge in the first year, but self/natural-thinning takes place and each year some of the smaller shoots die leaving 5-15 live stem per stool. Stump diameter and leader height had the least values of coefficient of variation (CV) indicating that data for these categories were more evenly distributed than the others. Furthermore, there was a statistically significant negative relationship between stump height and number of sprouts(r=-0.72, p-value=<0.0001). Contrarily, stump diameter was positively correlated with number of sprouts and this relationship was statistically significant (r=0.49, p-value=<0.0001) (Table 1). This suggests that an increase in stump diameter will result in an increase in number of sprouts.

Table 1. Descriptive statistics of stumps (height and diameter) and their respective correlation (r) values with number of sprouts.

Variable	Mean	Std. Dev.	CV (%)	Min.	Max.	No. of Sprouts	
						r	p-value
Stump height	20.15	4.01	19.90	15.00	28.00	-0.72	<0.0001
Stump diameter	29.61	3.72	12.55	18.00	38.70	0.49	<0.0001
No. of sprouts	4.55	1.57	34.42	2.00	8.00	-	-
Leader	124.10	11.12	8.96	94.00	181.00	-	-

Effect of stump diameter and height on yield/coppice components

The regression analysis conducted on the dataset revealed that both stump diameter and height had strong significant effects on sprout numbers. However, the findings for leader height indicated that stump height had no significant effect on it (p=0.347) while stump diameter did (Table 2). The positive parameter estimate for stump diameter based on the leader analysis suggests that a unit change in stump diameter will result in a corresponding change in leader height (Table 3). The contour plot of Fig. 1 indicates a decline in number of sprouts as stump height progressively increases. Per the results, maximum numbers of sprouts occur when teak trees are cut to stump heights of about 15 cm corroborating the findings of Chowdhury *et al.* (2008). Their study revealed that teak trees when cut to stump heights between 10 and 20 cm above the ground achieved higher coppicing ability. Our findings further emphasize that with increasing diameter; stumps should be cut slightly above the ground (10–20 cm) to obtain greater shoot numbers (Table 3 and Fig. 1).

Table 2. Effect of stump diameter and height on yield components of two years old coppiced teak (p-values of regression anova).

Variable	No. of Sprouts	Leader Height	Avg. Sprout Height
Stump diameter	<0.0001	0.005	0.006
Stump height	<0.0001	0.347	0.001

Also, Ralph (1995) observed that larger stumps often produced more sprouts than smaller ones for trees of the same age. Thus, these factors may be indicators of the quantity of biomass that is likely available for translocation for sprout growth and development.

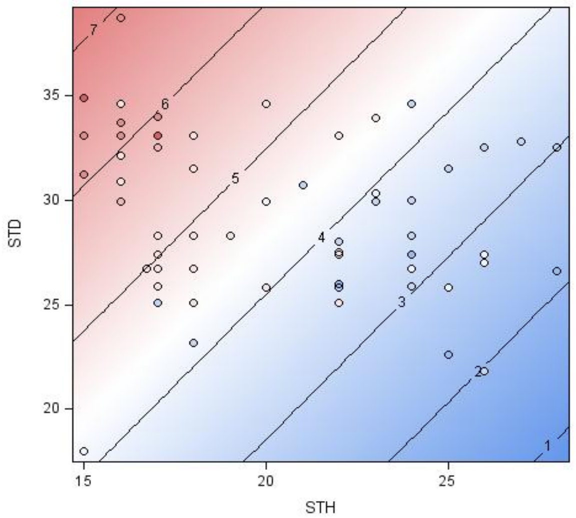

Fig. 1. Contour fit plot for sprout number based on stump height (STH) and diameter (STD).

The significantly positive relationship for both parameter estimates suggest that for an increase in either stump diameter or height there is a corresponding increase in the average height of coppiced sprouts (Table 3). Thus, taller and larger stumps produced sprouts that were on the average higher in terms of height than shorter and smaller stumps. We however argue that the small number of sprouts produced by taller stumps could have accounted for their success in terms of mean sprout height. This is in agreement with Dale and Barton (1967) who mentioned that excessive competition considerably reduced the average height of sprouts per stump. In addition, Thevathasan and Gordon (2004) showed that lack of coppice management generally led to teak coppice wastage due to poor quality of coppiced shoots. Hence, the best method to increase growth is to remove competition (Weaver, 1993) since all members of a plant community utilize the same reserve of growth resources such as light, nutrients, water, and carbon dioxide during competition (Neuman, 1983). This therefore offers teak growers the opportunity to employ thinning to selectively leave few quality and vigorous sprouts per stump to successfully achieve their production goals.

Table 3. Parameter estimates for models developed for yield components of two years old coppiced teak

Variable	No. of sprouts	Leader Height	Avg. Sprout Height
Intercept	5.338	96.551	65.413
Stump diameter	0.144	0.930	0.970
Stump height	-0.250	-	0.710

The model diagnostic plots for average sprout height (Panel 1), leader height (Panel 2) and number of sprouts (Panel 3) are presented in Fig. 2. All histogram and quantile plots of the residuals signify that the residuals are approximately normally distributed. However, the leader (8.5%) and average sprout height (16.0%) models developed did not account for most of the variation in the dataset based on their estimated adjusted R-squared values. On the other hand, the number of sprouts model revealed that 61.4% of variability was accounted for by it. This suggests that other factors may significantly contribute to the predictive nature of the models especially, in the first two cases (leader and average sprout height). For instance, studies elsewhere have revealed that harvest season, and age (Longhurst, 1956; Ralph, 1995) as well as environmental factors such as site quality (Johnson, 1977) influence the sprouting ability and or quality of stumps.

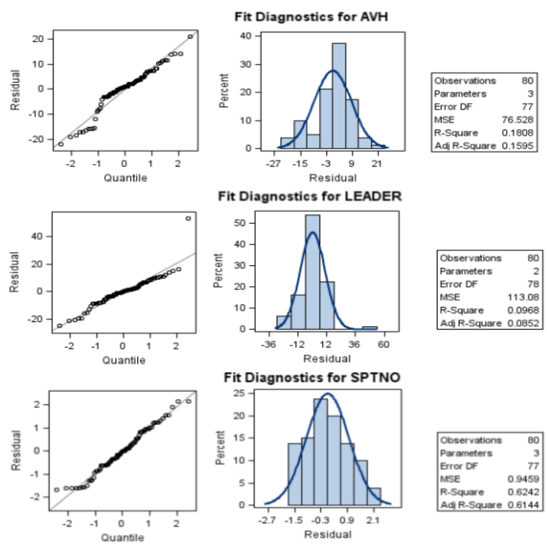

Fig. 2. Diagnostic plots for fitted models of teak stump yield components (coppices).

Conclusion

Stump diameter and height significantly influenced the yield components of teak coppices. Whereas stump diameter was positively correlated with number of sprouts, stump height showed a negative relationship with it. Teak stumps cut at ground level to about 15 cm produced the highest number of sprouts. Though the model developed for average sprout height was significant, it did not properly account for variation in the dataset. Thus, competition for resources (among sprouts) may have led to taller stumps having higher averages in sprout height since they recorded fewer sprout numbers. To avoid unnecessary wastage, sprouts should be thinned to select and maintain quality stems over time based on management production goals.

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