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Growth performance of Teak (*Tectona grandis* Linn. f.) coppice under different regimes of canopy opening

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Abstract: Growth performance of *Tectona grandis* coppice was investigated under different canopy openings which is an important reforestation tool. Removal of single tree was done for small canopy opening; two trees for medium, and clear felling for large canopy opening. It was observed that, canopy opening did not affect survival rate and number of sprouts. However, stump height affected the number of sprouts; the maximum number of sprouts was found in 10-20 cm stump height from the ground level. In addition, number of sprouts was correlated ($p<0.05$) with tree and stump diameter. Both diameter and height of sprouts did not differ significantly in the earlier stage (in 6 months) with the space available due to canopy opening, whereas diameter and height growth of sprouts significantly varied when sprouts were getting old (1 year old and onward). Results indicated the potential of coppice management to restore the gaps in the prevailing plantations.

Resumen: El desempeño en el crecimiento de un bosquecillo formado por rebrote de *Tectona grandis* fue investigado bajo diferentes aperturas del dosel, las cuales son una herramienta importante de reforestación. Para una abertura pequeña se removió un solo árbol; se removieron dos árboles para una abertura mediana, y se realizó un aclareo total del rodal para la abertura grande del dosel. Se observó que la apertura del dosel no afectó ni la tasa de supervivencia ni el número de rebrotes. Sin embargo, la altura del tocón afectó el número de rebrotes; el número máximo de rebrotes fue encontrado para la altura del tocón de 10-20 cm a partir del nivel del suelo. Además, el número de rebrotes estuvo correlacionado ($p < 0.05$) con el diámetro del árbol y del tocón. Ni el diámetro ni la altura de los rebrotes difirieron significativamente en la etapa temprana (en seis meses) con el espacio disponible debido a la apertura del dosel, mientras que el crecimiento en diámetro y altura de los rebrotes variaron significativamente conforme envejecían los rebrotes (1 año de edad y más). Los resultados indican el potencial del manejo del bosquecillo rebrotado para restaurar claros en las plantaciones predominantes.

Resumo: A performance do crescimento da talhadia de *Tectona grandis* foi investigada sob diferentes regimes de abertura de copa, as quais são uma importante ferramente de reflorestação. A remoção de uma única árvore foi feita para uma pequena abertura de copa; duas árvores para média e abate raso para grandes aberturas de copa. Foi observado que, a abertura das copas não afectou a taxa de sobrevivência e o número de renovos. Contudo, a altura do cepo afectou o número de renovos; o número máximo de renovos foi encontrado em cepos de 10-20 cm de altura acima do nível do solo. Além disso, o número de renovos estava correlacionado ($p<0,05$) com o diâmetro da árvore e do cepo. Quer o diâmetro, quer a altura dos renovos, não diferem significativamente no estágio inicial (6 meses) com o espaço disponível devido à abertura do copado, enquanto que o diâmetro e a altura dos lançamentos variam significativamente à medida

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que os rebentos de toiça ficam mais velhos (1 ano e mais). Os resultados indicam o potencial da gestão da talhadia para restaurar as clareiras nas plantações.

Key words: Coppice, stem form, tree stump, *Tectona grandis*.

Introduction

Teak (*Tectona grandis* Linn. f.) belongs to the family Verbenaceae and is indigenous in Southeast Asia (Mayanmar, Thailand and Lao PDR) with a discontinuous or patchy distribution up to India. It is one of the most widely planted hardwood timber species in the world, covering 2.25 million ha (Ball *et al*. 1999). Teak is also considered a prime timber species in Bangladesh due to its high timber value, and accounts for 60-70% of the annual plantation area (MOEF 1993). Historically, plantation of teak was started in Bangladesh since 1860 directly from the seeds (Anon 1959). The current management system of teak in Bangladesh is clear cutting under forty years rotation, and plantations are raised from stump cutting with two metre by two metre spacing. Early stage (seedling) gaps are recovered through vacancy filling. Small to medium size gaps occur in the mature teak plantations of Bangladesh due to illicit felling and/or breakage after monsoonal cyclone. Gaps occurring in the later stages remain vacant up to harvesting which has negative implications for forest economy and carbon budget.

Sprouting ability of teak may contribute to rapid restoration of forest cover in the gaps after timber extraction or cyclone damage (e.g. Bellingham *et al.* 1994; Riswan & Kartwawinata 1991). Where sprouts are able to grow into mature trees, sprouting may be a more effective means of re-establishment than the slow-growing seedlings (Harcombe & Marks 1983; Ohkubo 1992). Rapid production of sprouts can get benefits from the established root system and may enable the species to re-establish in the gap (Rijks *et al*. 1998), which is also important for wildlife habitat (Solomon & Blum 1967). Moreover, coppice grows faster than the seedlings which enable much shorter rotation (Thaiutsa 1999). However, the ability to coppice declines with the age and the ability to coppice may also vary with the local environmental conditions and the felling season (Grundwald & Karchon 1974; Jacobs 1955).

Considering costs and administrative/ management complicacy, coppicing would be an essential tool for restoration of the gaps created after seedling stage. We predicted that light would be a more crucial resource for development of the coppice because of pioneer character of teak (Troup 1921; Zabala 1990). Studying growth performance of teak coppice under different light regime is important exploring the potential of multi-storey (existing even-aged trees along with coppice) management system in teak plantations. The objective of this research was to examine the survival and growth of coppice under different light regimes. In this study, differential light regimes were created by removal of standing trees. Small gaps were exposed to only overhead direct sun light, medium gaps to direct as well as diffuse sun light and large gaps to full light exposure.

Material and methods

Study site

The study was carried out at Khadim Nagar beat of North Sylhet 1 range of Sylhet Forest Division, Bangladesh (Fig. 1). The area is situated between 23^0 55´ and 25^0 02´ north latitude and between 90^0 55´ and 92^0 30´ east longitude. The soils of the area are sandy to clayey loam and have moist tropical climate characterized by a period of high precipitation from April to September and five months of relatively dry period from November to March. With minor variations, humidity remains high at 70% to 85% throughout the year with minor variations (FMP 1998).

Experimental design and intervention

A latin square design with three treatments (small, medium and large canopy gap) and five replications were used in this experiment. The stand was 20 year old and tree spacing was 2 x 2 m in each treatment. Sizes of sample plots were 40 x 40 m each. Small canopy gaps were created through

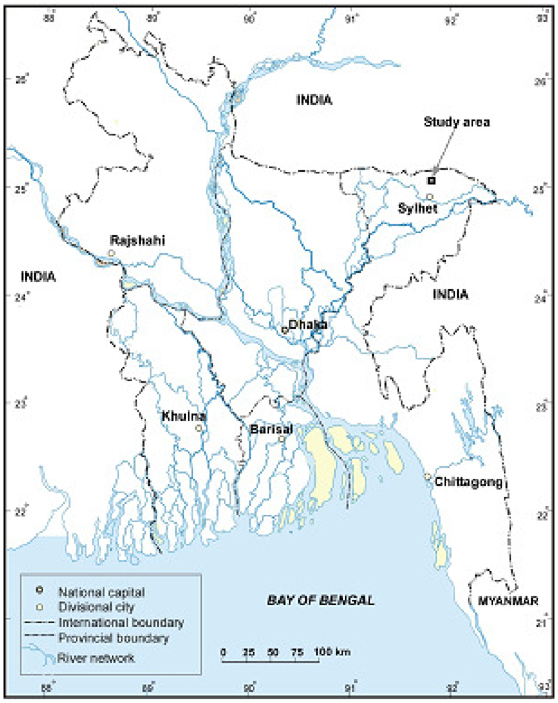

Fig. 1. Study area.

removal of single tree; medium gaps two trees and large gap through clear felling. Trees were felled at different stump height. In small gap there was only overhead direct light, in medium gap there was both direct as well as diffuse light and the large gaps experienced full light exposure. Tree diameter and height as well as stump diameter and height were recorded. Number of sprouts as well as diameter and height of the sprouts were measured at age of 6 months, 1 year and 1.5 year, respectively.

Statistical analysis

Group variation was analyzed by ANOVA followed by post-hoc (Tukey-HSD) test and correlation analysis was done with SPSS (version 12; SPSS Inc., Chicago, IL, USA).

Results and discussion

Sprouting pattern

Sprouting occurred in all gaps by nearly 100% and no difference was found in sprouting success among different treatments (p = 0.58). Moreover, differences in the number of sprouts were not significant among the treatments, although the number of sprouts was higher in the large canopy gap area in comparison to other treatments (Fig. 2). It indicated that the number of sprouts was not dependent on light alone. Further, the decrease in number of shoots with time was due to natural thinning (Fig. 2). This is in agreement with earlier studies on teak (Thaiutsa 1999). It is assumed that tree vigour (tree and/or stump diameter and tree height) is an indicator of the biomass potentially available for translocation to the sprouts. Kahn & Tripathi (1989) also mentioned that parent tree vigour is important for sprout production. Correlation between diameter (tree and stump) and number of sprouts in this study was significant but only at 5% level, whereas tree height did not correlate with number of sprouts significantly (Table 1). Even though in our study diameter of trees in the three treatments was similar, the number of sprouts was higher in the large canopy gaps (Fig. 2). This indicates that interaction of tree and/or stump diameter and light has a positive impact on coppicing in teak.

This study also showed that teak could coppice at different height level of the stump. Maximum number of sprouts per stump (15 sprouts per stump) was in 10 to 20 cm stump height from the ground level and lowest number of sprouts (4 sprouts per stump) was found at the stump height level of 90 to 100 cm (Fig. 3). But number of sprouts decreased with an increase in the stump height. The number of sprouts was not good enough near the soil level (up to 10 cm stump height) and this could be due to the competition of resources with upper position sprouts. This may also have resulted in reduced

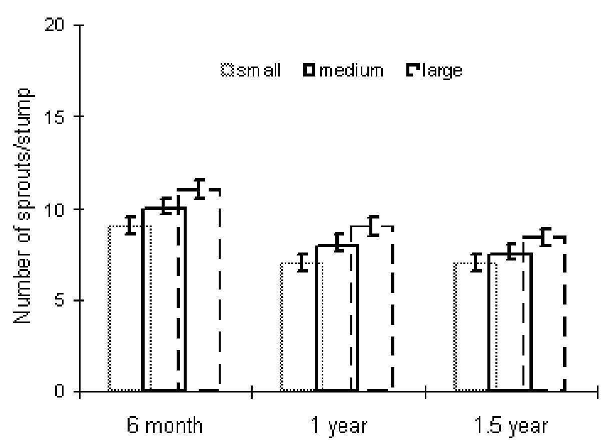

Fig. 2. Average number of sprouts per stump; vertical bar indicates standard deviation.

Table 1. Mean values, standard deviation and correlation with number of sprouts.

Variables	Mean	Standard Deviation	Significance level
Tree diameter (cm)	15.4	2.4	*
Stump diameter (cm)	16.5	2.7	*
Tree height (m)	15.3	3.2	ns

*, denotes significant level at p<0.05; ns, denotes not significant

number of active buds after a certain height. Fig. 3 clearly indicates a polynomial correlation between number of sprouts and stump height ($p<0.01$). This can suggest that in areas where teak trees have been damaged by animals, illegal harvesting or natural catastrophe, trees should be cut again above to the optimum level (10-20 cm from the ground) for re-sprouting. Winahyudi (1990) also mentioned that teak stump should be cut at ground level for re-sprouting. Evolutionary strategy of a plant is to regenerate or coppice only when there is a premature damage and not when the tree is fully grown. In addition, stump diameter is also important for number of buds and its potential to regenerate.

However, larger number of sprouts has little commercial importance and it should be reduced to a single sprout per stump. This will reduce the competition for resources within a stump and selection should be done at an early stage based on vigour and stem form of coppice. In teak, more than three sprouts typically grow from each stump (Bailey & Harjanto 2005), which offers a better opportunity to select and maintain quality stems over time and the sprouts should be thinned to leave only one per stump. Management decision is, therefore, a trade-off between the size of the timber of economic importance and the number of sprouts.

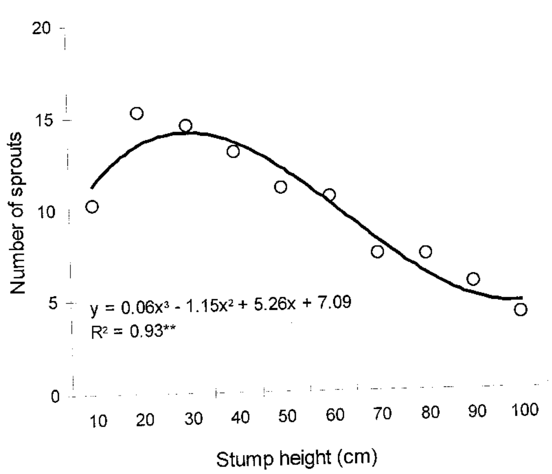

Fig. 3. Number of sprouts in different stump height level; solid line indicates polynomial model fitted in the average values; ** significant at 1% level.

Growth patterns of sprouts

Growth of the sprouts depends on available resources, for instance light. As this resource diminishes, slower growth is expected. Diameter and height of coppice increased with time and gap size (Fig. 4). The difference was due to variation of sunlight in different gaps. In the early stage (6 months) growth was not significantly different in all treatments ($p = 0.53$). But in the later stages (one year and onward) the differences were significant among the treatments at $p<0.05$ (Fig. 4). Partial shade from the over-storey influenced development of the sprouts in the small and medium gaps. Possibly a portion of the stored energy and nutrients of the stump are available for investment in the rapid early growth of sprouts and this can be assumed for all treatments. Bailey & Harjanto (2005) also reported that diameter growth as well as height of coppiced teak was higher than the seed-originated teak and this is due to stored food reserves in the mother stumps (Troup 1921). Beyond the differences in growth performance and vigour, damages due to grazing are also less due to the advantages conferred by early growth differences between sprouts and seedlings. Furthermore, rapid development of sprouts is important for wildlife habitat (Thaiutsa 1999).

Stem form and implications for wood quality

A potential drawback of coppicing is increased amount of sweep in the bottom log of the coppiced trees relative to the seed-origin trees (Bailey & Harjanto 2005). A typical bend was created when sprouts develop on the'neck'of the stumps and grew away from that central position. Moreover, the amount of tension wood in coppice would be higher, if more than one shoot is left to grow per stump and the trees lean away from each other. This type of bending will reduce future wood quality; especially

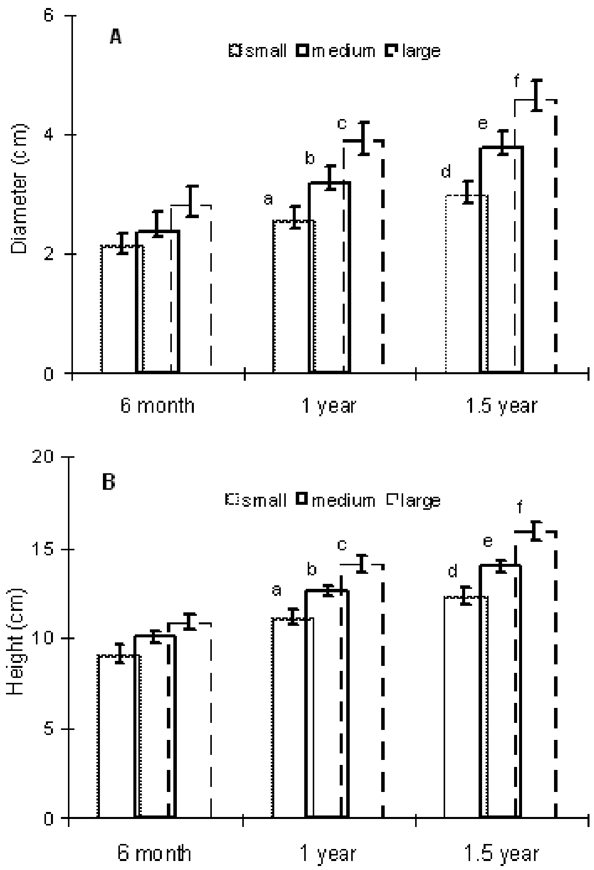

Fig. 4. Average diameter (A) and height (B) of the shoots; Different letters denote significant differences at $p<0.05$; vertical bars indicates standard deviation.

in the bottom log. The sweep log decreases logging and milling efficiency (Haygreen & Bowyer 1996). Careful sprout selection in a good point of origin (preferably in the lower level) and minimal degree of sweep can minimize future wood quality problems associated with early tension wood formation. Therefore, the level of outward deviation from straightness in the coppiced plantation is not expected to be a major management problem because these coppiced sprouts will grow older and their stems would assume a position closer to upright. Moreover, pruning is required to keep the stem free from knots which also reduce wood quality, and to increase its straight merchantable height (Keogh 1987). It is best to prune coppice teak before the branches get too thick and produce large knots.

Conclusions and perspectives

Different gap size did not affect either survival rate of coppice or number of sprouts. In addition, number of sprouts was correlated with tree and stump diameter. Both diameter and height of sprouts did not differ significantly in the earlier stage due to the canopy opening whereas diameter and height growth of sprouts significantly varied when sprouts were getting old. A 10-20 cm stump height produced maximum number of shoots and this height should be maintained after harvesting the tree. Selection of better sprouts should be done in the first year of growth with minimum sweep/neck to promote the growth. Results demonstrated the potential of coppice management to restore the small to medium size gaps in teak plantations. Coppicing saves time and money associated with seed collection and transportation, nursery production of seedlings, bureaucratic delays to restore the gaps in the plantation. However, future research should be directed towards the growth dynamics of coppice in comparison with wide range of diameter class of the prevailing trees under different climatic conditions.

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