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Research Article

IMPROVED SILVICULTURAL PRACTICES THROUGH THINNING IN COOL BROADLEAVED FORESTS OF YOESEL-PELRI COMMUNITY FOREST, TALI, ZHEMGANG: BHUTAN

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ABSTRACT
In an effort to improve the productivity of community forest management, we evaluated the thinning response of three medium to large tree species in a cool broadleaved forest in central Bhutan, Zhemgang. The species investigated were *Schima khasiana* (dbh 3 -16 cm), *Symplocos ramosissima* (dbh 4 -9 cm) and *Beilschmiedia gammieana* (height 15 -135 cm). We selected 20 individuals of size for each of the target species and randomly assigned half of them to undergo thinning treatment and half of them to the control treatment with no intervention. The thinning treatment was applied once and involved removing of one to three immediate competitors of ten individuals of each targeted species. Four years after the thinning treatment, no significant differences in diameter or height between treated and control trees could be detected.

Keywords: *Cool Broadleaved Forests, Thinning, Competitors, Release, Bhutan*

INTRODUCTION
Silvicultural practices are generally applied to meet one or more specific forest management objectives (Olson *et al.*, 2013). In many hardwood silvicultural systems, the main aim is to produce high quality timber and other forest produce (Rytter, 2013). Management strategies in hardwood species have shown significant effects on crown and stem development. Evidence from the literature suggest that thinning operations enhance diameter development, which in turn reduces the rotation period without compromising wood quality (Simard *et al.*, 2004; Rytter and Sterner, 2005).

Trees at narrow spacing grow slower than at wide spacing (Oliver and Larson, 1990). Thinning lowers the stand density and redistributes the growing space to fewer retained trees. These retained trees benefit from the increased availability of resources such as light, water and nutrients and grow faster (Smith *et al.*, 1997; Forrester and Baker, 2011). Intensive silvicultural methods like pre-commercial and commercial thinning have been used successfully around the world to increase biomass production in even aged forests (Oliver and Larson, 1990). Thinning which consists of removing the small diameter trees is widely used as a silvicultural method in densely stocked stands to speed up growth rates of the retained – mostly larger - trees (Eyre *et al.*, 2015). Multiple thinning entries may lead to increased height growth, as documented for seedlings and saplings of western hemlock (Shatford *et al.*, 2009) and may be effective during later (pole and stem exclusion) stand development phases as well. Results from the thinning studies conducted for mid-canopy western hemlock and western red cedar indicated the ability to increase their growth rates rapidly within 3-6 years in response to increased resource availability associated with thinning (Comfort *et al.*, 2010). Positive results were also obtained with aspen in Canada (Prevost and Gauthier, 2012), birch in southern Sweden (Rytter, 2013), Norway spruce in southern and central Finland (Mäkinen and Isomäki, 2004), and European beech (Maaten, 2013).

Thinning provides an opportunity to combine multiple stand management objectives through increased stand stability, improved timber quality, concentrated growth on fewer elite individuals and reduced mortality. Early results from a blue pine thinning trial established in 1988 above Hurchi in Chumey valley indicated that regular thinning from early stand age onwards can improve stand stability, quality, diameter and volume growth of the remaining stand (Rosset and Rinchen, 1997; Rai *et al.*, 2007). Similar results were also reported from western Bhutan (Desmond and Norbu, 1998).

Forests in Bhutan represent the single largest natural resource. Large tracts of the natural forests which cover 72 % of the land area are still intact. Of the total forest cover, 52% falls under broadleaf forests including tropical, sub-tropical, warm temperate and cool temperate broadleaf forest types (Norbu, 2002). These forest types are poorly understood and there has been little prior silvicultural experience in the appropriate management of these forests (Davidson, 2000).

The study was conducted in a community forest following social survey where in important tree species were identified by the community members (Rai *et al.*, 2009a). Low intensity manual thinning was applied to the targeted important tree species as management intervention.

In this study we examine the effects of low-intensity selection thinning by removing the immediate competitor(s) in a cool temperate broadleaved forest for medium to large tree species.

Specific research questions were:

Does thinning treatment by removing the immediate competitor(s) lead to positive effects to the targeted individual in terms of diameter and height growth?

MATERIALS AND METHODS

Study Site

The study was conducted in a cool temperate broadleaf forest in Zhemgang district, central Bhutan at an altitude of 1700m. The site is located north of Tali village in Yoesel-Pelri Community forest, which became operational in 2004.

There are 23 households as beneficiaries to this forest (Rai *et al.*, 2009b).

For ease of management, the whole community forest with an area of 106 acres has been divided into five management blocks. Of the five management blocks, two blocks (Thonka Om and Budigang) are managed for water source protection. The rest of the blocks, Norbuling, Trashiling and Chhu-yur Tag are managed for construction timber production; fire wood and enrichment planting respectively.

Commercially important species occur throughout the community forest, though occurrence of some is rare. Common species, which are utilized by community members are *Schima khasiana*, *Beilschmiedia gammieana* , *Michelia doltsopa*, S*ymplocos ramosissima*, *Castanopsis tribuloides*, *Quercus lamellosa*, *Quercus semiserrata* and *Toona ciliata* (Rai *et al.*, 2009b). These species represent dominant tree species of the cool-temperate broad leaved forest in the country (Grierson and Long, 1983). According to the Management Plan (2004), single tree selection has been recommended as the main silvicultural option for the community forest of Yoesel-Pelri.

Treatment

Schima khasiana, S*ymplocos ramosissima* and *Beilschmiedia gammieana* which are important to the local community were selected for thinning treatment. The importance of these species for the community, along with the specific silvicultural problems faced in management of these species, have been identified applying PRA exercise (Rai *et al.*, 2009b). The treatments were applied in the spring of 2009 and evaluated in the spring of 2013.

(a) *Schima Khasiana and* S*ymplocos Ramosissima*.

Healthy, straight and superior quality pole size trees were favored by removing immediate competitors, partially of the same species, which were of inferior quality. Depending on circumstances, two or more competing trees were removed. Diameters at breast height and height were measured and trees were numbered serially. For each species, ten trees were thinned and 10 trees served as control treatment.

(b) *Beilschmiedia Gammieana*.

20 seedlings of 20cm to 50 cm height growing underneath the thickets of *Strobilanthes himalayana* were selected. Height was measured for each seedling and they were numbered with a strong peg placed at 50 cm distance from the seedling. For every second randomly selected seedling release treatment was applied by removing overhead shading by *Strobilanthes himalayana* in a circular pattern with an approximate radius of 1.5 meters.

Four years after the application of treatments, the height and diameter of seedlings and saplings were measured.

Data Analysis

Growth Patterns

The data was analyzed using ANCOVA with growth response variables (height, diameter) as dependent variables and release treatment as independent factor. Initial height and diameter were included as a covariate in the analysis. Only the samples which were available in the spring of 2013 were included in the analysis. Some of the treated as well as the control samples were removed by the local users. IBM SPSS, version 23 was used for the analysis.

RESULTS AND DISCUSSION

Results

Effect of Treatment on Diameter at Breast Height (DBH) of Schima Khasiana and Symplocos Ramosissima

Prior to application of the release treatment, there were no significant differences in DBH between trees randomly assigned to release treatment and control treatment (data not presented). Four years after application of the treatment, no significant differences in DBH were detected neither for *Schima khasiana* (*p>0.05)* nor for *Symplocos ramosissima* (*p>0.05),*). Non-significant trends indicated greater DBH with the control group, as compared to the treated group (Figure 1).

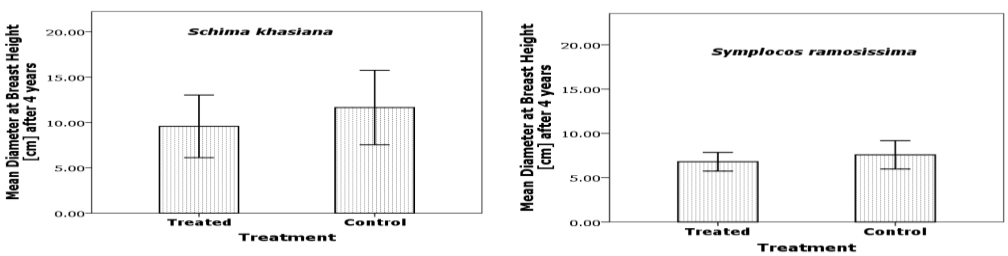

Figure 1: Mean DBH [cm] after 4 Years with 95% Confidence Intervals

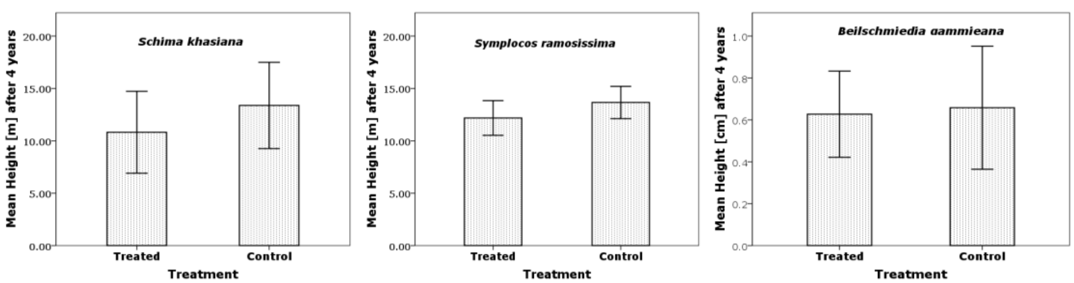

Figure 2: Mean Height after 4 Years with 95% Confidence Intervals

Effects of Treatment on Height Increment for Schima Khasiana, Symplocos Ramosissima and Beilschmiedia Gammieana

There were no significant effects of the release treatment on the height increment of *Schima khasiana* (*p>0.05 Symplocos ramosissima* (*p>0.05,*) and *Beilschmiedia gammieana* (*p>.05)* Non-significant trends indicated stronger height growth of control trees as compared to treated trees (Figure 2).

Discussion

Thinning represents a manipulation of stand density aimed to increase tree growth or improve its quality on a sustainable basis (Zeide, 2004). In our investigation, selection thinning by removing immediate competitors did not lead to positive effects to the targeted trees. No increased resource allocation in above ground biomass in terms of height and diameter growth after thinning was detected four years after thinning. Drastic physical changes and leaf shedding were reported after stem density reduction in young blue pine forest in central Bhutan (Rosset *et al.,* 1997), and with Douglas fir in Wind River Experimental forest, USA (Harrington and Reukema, 1983). Short term retardation of height and diameter growth soon after thinning, a sign of "thinning shock" is additionally reported (Harrington and Reukema, 1983). Residual trees may become unstable and experience physiological strain when over story canopy is removed thus, will not be able to adapt to abrupt environmental change (Mard, 1997).

Additional resources may have led to allocation of carbon towards root development to enhance the efficient use of available soil resources needed to subsequently rebuild the crown cover (Simard *et al.*, 2004).

Trees assign higher priority to root diameter growth than to height and stem diameter growth following release (Kneeshaw *et al.*, 2002; Claveau *et al.*, 2006). Strong root growth was detected in residual trees when thinned (Ruel *et al.*, 2003) and roots responded immediately to overstory release while stem growth was retarded (Kneeshaw *et al.*, 2002). Trees are unable to provide water to foliage unless they produces enough new fine roots and conducting tissue, which enable them to respond with increased height growth (Kneeshaw *et al.*, 2002).

In many studies, the positive effects of thinning were apparent only after five years or beyond (Harrington and Reukema, 1983; Simard and Hannam, 2000; Medhurst *et al.*, 2001; Simard *et al.*, 2004; Prévost and Gauthier, 2012).

Furthermore, thinning response is often unpredictable and can vary with stand density, tree species, stand age and thinning methods (Nowak, 1996).

Conclusion

Results of this study show that low-intensity thinning in cool-temperate broadleaf forest targeting *Schima khasiana,* S*ymplocos ramosissima* and *Beilschmiedia gammieana* may not bring positive effect to the residual trees within the initial four years. In order to confirm long-term thinning effects, repeated application and long-term follow-up and the investigation of root development is necessary.

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