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ACCLIMATIVE GROWTH IN DOUGLAS-FIR

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Extended Abstract

In uniform canopied stands, susceptibility to damage increases with mean stand slenderness (e.g. Becquey and Riou-Nivert 1987; Cremer et al. 1982) and stand height. Damage is typically highest in recently exposed edges (Mitchell et al. 2001) and thinned stands (Laiho 1987; Lohmander and Helles 1987). Stands on fertile sites are more susceptible (Harris 1989; Mitchell et al. 2001), and nitrogen fertilization increases stand susceptibility to windthrow and snow damage (e.g. Laiho 1987; Valinger and Lundqvist 1992). The patterns of stand instability noted above suggest that stand conditions exist where competitive effects on photosynthate availability and allocation over-ride increasing mechanical stimuli as trees grow. A better understanding of the interaction between acclimative growth and competition and the role of site fertility would improve our understanding of the biological basis for tree instability. The objective of this study was to evaluate mechanical stimulus, shading, and nitrogen fertilization under controlled conditions where their effects on morphology and bending resistance could be analysed separately and in combination.

Coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings were grown to age 3 in a commercial bare-root nursery on Vancouver Island from open-pollinated seed orchard seed from lower elevation east coast Vancouver Island parents. A total of 216 trees were planted, with additional buffer trees. The seedlings were slender at the time of planting, averaging 57 cm (range 44-73 cm) in height and 10 mm in stem basal diameter (range 6-15 mm) and had fully foliated lateral branches to the base of the stems. The study site was located on a tilled research field at the University of British Columbia (UBC) campus in a wind exposed location on the end of Point Grey peninsula, Vancouver BC. The installation was irrigated as necessary between heavy rainfalls throughout the growing season to ensure that no more than 2 weeks passed between the soil returning to field capacity. The experiment was layed out in a randomized block split-plot design (Table 1). To account for a prevailing wind from the south, the site was blocked from south to north in 3 east-west rows of 3 plots each. Within each row, each plot was randomly assigned to one of 3 levels of shade (S=0, 30, 60%). Shade was produced with shade cloth suspended 1m above the seedling tops. Each shade plot was split into 2 subplots, one of which was randomly selected for fertilization with 200 kg/ha nitrogen as urea at the time of planting (F=0, 1). Within each subplot, 12 seedlings were planted 80 cm apart on a square grid surrounded by a row of buffer trees. Each of the 12 trees/subplot was randomly assigned to one of 3 mechanical treatments, staked, free-standing, and bent (M=S, F, B). For the bending treatment, trees were held at 1/3 of initial height and bent side to side to a 45º angle from vertical 35 times at a speed just faster than the natural sway period of the tree, sufficient to produce curvature along the upper stem. This was carried out twice per week throughout the growing season, and was alternated between east-west and north-south on each successive visit to provide symmetric stresses. Changes in dimensions (c*VAR*) were calculated by deducting the initial measurement from the year-end measurement. Relative changes in dimensions (rc*VAR*) were calculated by dividing the change by the initial measurement. Bending resistance at the end of the growing season was measured by attaching a spring scale to the stem at ½ height and pulling the stem horizontally such that the point of attachment was displaced to a distance equivalent to 1/6 of tree height.

Seedlings increased in height by 30% to an average height of 74 cm (range 54-107 cm) and in diameter by 64% to an average diameter of 17 mm (range 11-23 mm). Because the relative diameter increment exceeded the relative height increment slenderness decreased by 21%. Mechanical stimulus reduced height increment, reduced the diameter at the base of the leader and increased the reduction in stem slenderness, but did not change volume increment (Table 1). Laterals of bent trees were shorter and had smaller diameters but were equivalent in slenderness to other mechanical treatments. Mechanical treatments did not change resistance to bending. Shading reduced diameter increment but did not affect height increment, consequently, slenderness reduction was 56% greater in unshaded trees than in heavily shaded trees. Stem volume increment was 37% greater in unshaded trees than in heavily shaded trees. Shaded trees had smaller diameters at the base of the leader and more slender leaders. Shading did not affect branch length, but lateral branches in the topmost whorl were at a lower angle and were more slender. Resistance to bending was lower for shaded trees. For all measures in which the shading effect was significant, the 0 and 30% shade were similar. Nitrogen fertilization did not change growth increments or slenderness, but branch angles were higher in fertilized trees. In general the effects of shading and mechanical stimulus on increment and morphology were additive. Bending enhanced the decrease in slenderness for all levels of shading (Figure 1a). Staking had the opposite effect but the differences were not statistically significant. Bending increased basal diameter increment for all levels of shade. Staking had no effect on diameter increment (Figure 1b). In the 0 and 30% shade treatments, height increment decreased with increased mechanical stimulus (Figure 1c). However in the 60% shade this only occurred with bending.

Table 1. Analysis of variance results (p-values) for shade (S), nitrogen fertilization (F) and mechanical stimulus (M) effects and interactions.

Variable	S	F	FS	M	MS	MF	MFS
cHT*	0.2546	0.0902	0.5885	0.0412	0.9494	0.0282	0.3093
cCAL	0.0056	0.2992	0.2535	0.1329	0.7947	0.1028	0.9864
cHDR	0.0018	0.4218	0.7260	0.0049	0.7929	0.8561	0.5450
cSTEMVOL	0.0203	0.4262	0.3562	0.7587	0.3476	0.0259	0.9386
CALTL*	0.0374	0.8226	0.8531	0.0094	0.4880	0.1806	0.8135
LDRHDR	0.0103	0.4518	0.5351	0.5475	0.9682	0.2726	0.5460
BANGLE	0.0050	0.0200	0.8325	0.1646	0.3066	0.2165	0.1811
BLENGTH	0.5277	0.1184	0.7574	0.0081	0.8619	0.0008	0.0578
BCAL*	0.1954	0.8605	0.5452	0.0059	0.3693	0.1078	0.0976
BHDR	0.0031	0.0819	0.3920	0.4737	0.4013	0.8723	0.6181
RESIST	0.0106	-	-	0.9153	0.4432	-	-

Note: 'Resist' was measured only for unfertilized treatments.
* Transformed prior to analysis using a square root transformation.

The results of this experiment point towards the biological basis for the development of tree instability. While shading does not negate the effect of bending on tree form, neither does bending offset the effect of shading. While the adjustments in form indicate that trees are sensitive to bending stresses, these form modifications did not improve stability. Heavily shaded trees had only half the bending resistance of unshaded trees regardless of mechanical stimulus. If the overriding effect of shade on tree stability persists in older trees it would explain the increasing vulnerability of high density stands to routine peak winds as they grow in height.

References

Becquey, J., and Riou-Nivert, P., 1987: "L'existence de zones de stabilite des peuplements. Consequences sur la gestion", Revue Forestiere Francaise, 39, pp. 323-334

Cremer, K.W., Borough, C.J., McKinnel, F.H., and Carter, P.R., 1982: "Effects of stocking and thinning on wind damage in plantations", New Zealand Journal of Forest Science, 12, pp. 245-268

Harris, A.S., 1989: Wind in the forests of southeast Alaska and guides for reducing damage, U.S.D.A. Forest Service, PNW-GTR-244

Laiho, O., 1987: "Susceptibility of forest stands to windthrow in Southern Finland", Folia Forestalia, 706, pp. 23-24

Lohmander, P., and Helles, F., 1987: "Windthrow probability as a function of stand characteristics and shelter", Scandinavian Journal of Forest Research, 2, pp. 227-238

Mitchell, S.J., Hailemariam T., and Kulis, Y., 2001: "Empirical modeling of cutblock edge windthrow risk on Vancouver Island, Canada, using stand level information", Forest Ecology and Management, 154, pp.117-130

Valinger, E. and Lundqvist, L., 1992: "The influence of thinning and nitrogen fertilisation on the frequency of snow and wind induced stand damage in forests", Scottish Forestry, 46, pp. 311-320

Note: a full article will be published in the Canadian Journal of Forest Research.

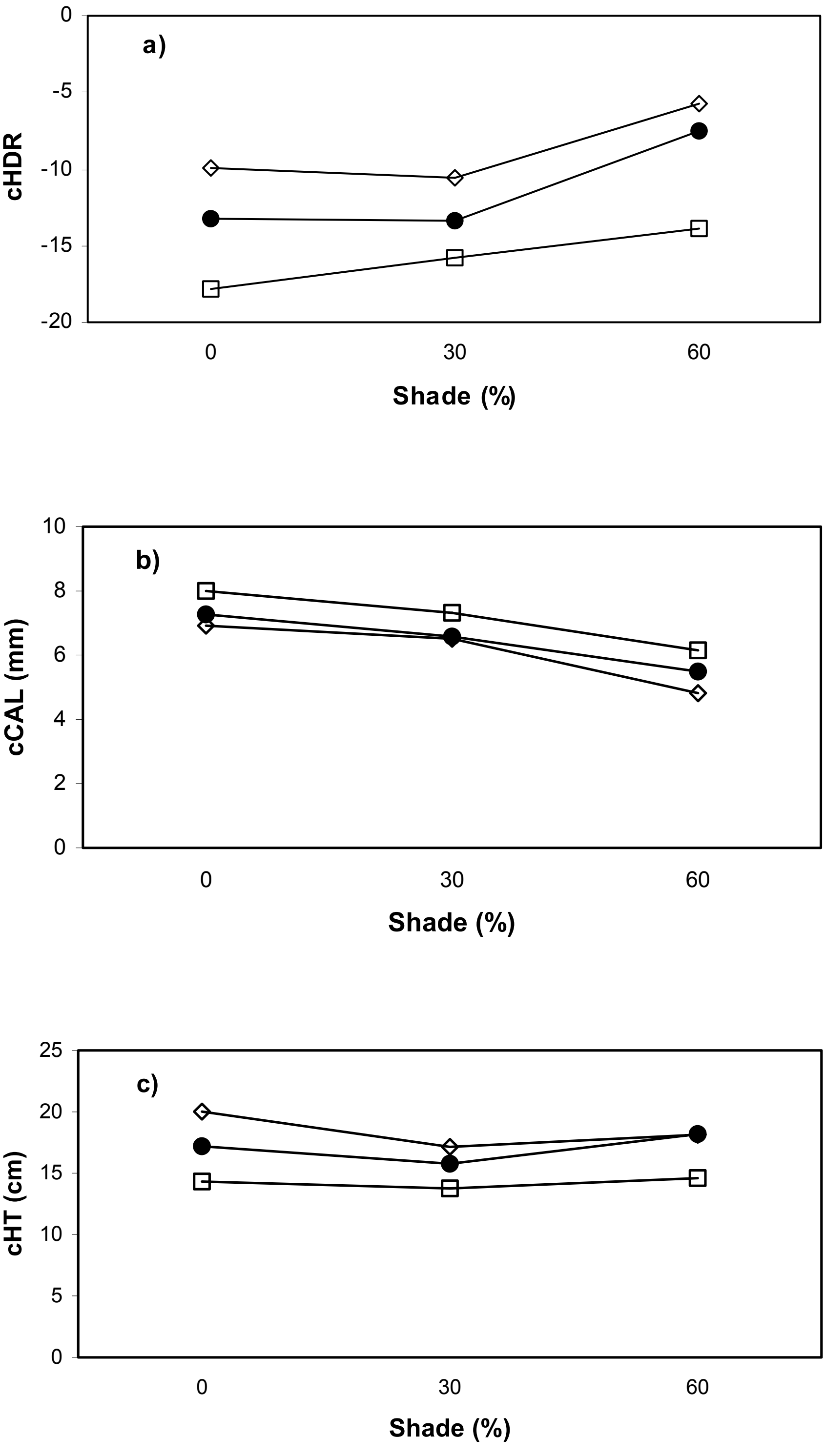

Fig. 1: a) Change in slenderness (cHDR), b) basal stem diameter increment (cCAL, mm) and c) height increment (cHT, cm) for free-standing (●), staked (◊) and bent (□) trees under 0, 30 and 60% shade.