RESEARCH REPORT

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R.F. Newman, K.J. Cameron,
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ABSTRACT

Wounds were artificially applied to 2-year-old lodgepole pine seedlings in order to simulate the type of damage that commonly occurs when cattle trample or browse tree seedlings. Specifically, this study investigated the effects of basal scarring and leader damage on survival and growth of lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) seedlings, at two phenological stages (during and after terminal elongation).

Tree seedling survival was unaffected by the damage treatments. Observed seedling mortality in adjacent cattle-grazed pastures is therefore unlikely to be due to trampling or browsing damage alone. A combination of factors, such as sub-optimal growing conditions or vegetation competition, along with trampling and/or browsing damage, may explain seedling mortality on grazed pastures.

The damage treatments resulted in growth losses in lodgepole pine, depending on the timing of the damage. Basal scars exceeding 25% of the stem circumference reduced diameter increment by as much as 20% ($P \leq 0.05$) when applied after the completion of terminal elongation. Similarly, scars greater than 25% of the stem circumference, applied after the completion of terminal elongation, reduced height increment by as much as 28% ($P \leq 0.05$). Damage applied during terminal elongation did not affect growth.

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1 INTRODUCTION

Cattle may damage conifer seedlings directly by browsing, but damage more commonly occurs as basal scars from trampling (Sullivan et al. 1989; Wikeem et al. 1991). Wounds of this type have been reported to cause mortality, reduce seedling growth rates, and lengthen the time required to reach the free-growing stage (Lewis 1980a, b; Sullivan and Sullivan 1982; Sullivan 1984). Widespread disagreement and uncertainty still exist regarding the effects of basal scars on seedling survival and growth (Pitt 1987). In principle, growth rates of wounded seedlings should decline; however, specific data regarding the impact of basal scars and leader damage caused by cattle in British Columbia are not available. The objective of this study was to test the effects of basal scars and leader damage on the survival and growth of lodgepole pine seedlings. The study was intended to assist land managers in assessing immediate and long-term impacts of livestock grazing on reforestation.

The following null hypotheses were tested:

1. the size of scar does not affect lodgepole pine seedling survival and growth;
2. leader damage does not affect lodgepole pine seedling survival and growth;
3. the phenological stage of lodgepole pine at which damage occurs does not affect seedling survival and growth; and
4. the interaction of scar size, leader damage, and phenological stage does not affect seedling survival and growth.

2 STUDY SITE AND METHODS

2.1 STUDY SITE

The study site is located 50 km southwest of Kamloops, B.C. (50° 33′N, 120° 56′W), in the Very Dry Cool Montane Spruce (MSxk) biogeoclimatic subzone (Lloyd et al. 1990), at 1450 m elevation. Annual precipitation at Highland Valley (50° 31′N, 121° 1′W, 1554 m), 5 km southwest of the site, averages 355 mm, with peaks in December (45 mm) and June (36 mm). Highest mean daily maximum temperatures occur in July (20.5° C); lowest mean daily minimum temperatures occur in January (–12.6° C) (Environment Canada 1980).

The site has a northwest aspect and a 5–10% slope, and predominantly Dystric Brunisol soils. Before logging, the forest overstorey consisted of lodgepole pine and Engelmann spruce (*Picea engelmannii* Parry) in approximately equal proportions. Pinegrass (*Calamagrostis rubescens* Buckl.), heart-leaved arnica (*Arnica cordifolia* Hook.), and shiny-leaf spirea (*Spiraea betulifolia* Pall.) characterized the understorey. Plant taxonomic nomenclature follows Douglas et al. (1989).

2.2 SITE PREPARATION

The experiment was conducted in a 1.2-ha exclosure within a 32-ha clearcut. The area was logged and the slash windrowed in November 1986. In November 1987, the windrows were burned and the area drag-scarified using a bulldozer and three sharkfins at 2-m spacing. In May 1988, container-grown, 1-year-old lodgepole pine seedlings were planted at a density of 1400 seedlings/ha (2.7-m spacing). The experimental area was fenced using 3-m-high page-wire to exclude cattle and wild ungulates.

Vegetation in the experimental area was controlled before treatments were applied, to minimize the confounding effects of competition and to reduce the potential for rodent damage (Crouch 1982). All vegetation within a one-seedling-height radius of each experimental seedling was treated with the herbicide glyphosate (N-(phosphonomethyl)glycine). During herbicide application, seedlings were protected using plastic cylinders.

2.3 TREATMENTS

Scarring and leader damage treatments were applied to 240 seedlings in complete factorial combinations at two phenological stages in 1989 when the seedlings were 2 years old. One hundred and twenty seedlings were treated during terminal elongation (rapid growth of the dominant shoot), about mid-June on the study site, and the remaining 120 seedlings were treated after the completion of terminal elongation (bud set stage), at about mid-August.

Basal scars were applied by removing 4.0-cm sections of bark near the base of the seedlings at widths of 0 (control), 25, 50, or 75% of the stem circumference. The scar was polished with a cloth to remove any remaining phloem and vascular cambium. Leader damage treatments were applied by removing the apical bud only, or by clipping off 50% of the terminal leader. An equal number of seedlings received no leader damage.

2.4 MEASUREMENTS AND DATA ANALYSIS

Seedling diameters and heights were measured before the treatments were applied, and annually thereafter in September. Diameters were measured at the soil surface, and seedling heights were taken from the soil surface to the highest living bud. Survival was recorded at each sampling date. All analyses were performed on a 5-year growth increment, calculated from June 1988 to September 1993. Data for seedling height and diameter were analyzed separately using ANOVA (SAS Institute 1979). The experiment was a completely randomized design with a factorial arrangement of treatments with 10 replicates. Sums of squares for the scarring treatment were partitioned into linear (l), quadratic (q), and cubic (c) effects, and orthogonal contrasts were used to test for differences among leader treatments ($P \leq 0.05$).

3 RESULTS AND DISCUSSION

3.1 SEEDLING SURVIVAL

Seedling survival was unaffected by any of the treatments. In fact, only one seedling died over the course of the study (99.6% survival over all treatments). This result corresponds to similar studies on slash pine (*Pinus elliotti* Engelm.), which found that simulated basal scars caused no significant increase in mortality (Hughes 1976; Lewis 1980b).

The high survival rate of damaged lodgepole pine seedlings may be partly related to an observed ability to activate dormant buds in cases where all existing living buds were destroyed by the damage treatment. In 1989, 69% of the seedlings on the study site developed buds near the base, regardless of the damage treatment applied. Several heavily damaged seedlings were observed to regrow from these basal buds alone. Similar observations were made by Zalasky (1978) on 2-year-old lodgepole pine seedlings that produced basal buds in cases where all other buds were permanently damaged by frost.

The high survival rate of lodgepole pine seedlings in our simulated damage study conflicts with results from an adjacent, large-scale, forest-grazing study involving cattle (Wikeem et al. 1991). Lodgepole pine survival in the cattle-grazed pastures varied from 21 to 97%, depending largely on cattle-stocking rates. It is apparent that seedling mortality in studies involving cattle may be affected by factors other than physical wounding. Physical wounding, combined with other stresses, such as sub-optimal growing conditions or vegetation competition (which are often controlled in simulated studies), may be responsible for observed discrepancies in seedling survival.

3.2 DIAMETER INCREMENT RESPONSE

Scarring resulted in significant effects on diameter growth only when applied after the completion of terminal elongation (Table 1: SxP). Seedlings were largely unaffected by scars applied during terminal elongation (Figure 1), while scars applied after the completion of terminal elongation reduced growth by as much as 20% (Table 2).

3.2.1 Phenological effects

The varying responses to scarring at the two phenological stages may be related to factors such as differences in the speed of phellogen restoration (Mullick and Jensen 1976) and differences in resistance to infection (Hudler 1984; Uotila 1990). Phellogen restoration is more rapid early in the growing season and is negligible during the dormant season (Mullick and Jensen 1976). Therefore, seedlings damaged early in the growing season may have a greater opportunity to heal completely.

Little is known, however, about the relationship between the speed of phellogen restoration and subsequent growth. Unhealed scars possibly increase desiccation, leading to reduced seedling vigour. This may explain reduced diameter

TABLE 1 *ANOVA and single-df tests on 5-year growth of lodgepole pine seedlings damaged by scar and leader treatments applied at two phenological stages*

Source of variation	df	Diameter increment (MS)[a]	Diameter increment P	Height increment (MS)	Height increment P
Scar (S)	3	106.8	0.24	2370.3	0.08
Linear (l)	1	240.0	0.08	5359.6	0.02 [b]
Quadratic (q)	1	5.5	0.79	940.5	0.34
Cubic (c)	1	74.5	0.32	775.0	0.39
Leader (L)	2	54.2	0.49	927.8	0.41
Control vs. Others (C vs. O)	1	19.1	0.62	466.2	0.50
Bud vs. Terminal (B vs. T)	1	89.6	0.28	1395.7	0.25
Phenology (P)	1	135.2	0.18	3100.4	0.09
S x P	3	242.8	0.02 [b]	3257.3	0.03 [b]
S(l) x P	1	403.0	0.02 [b]	5336.9	0.02 [b]
S(q) x P	1	33.4	0.51	185.0	0.67
S(c) x P	1	291.0	0.05 [b]	4232.1	0.04 [b]
S x L	6	136.1	0.10	1370.7	0.25
S(l) x L (C vs. O)	1	0.7	0.93	2.6	0.96
S(l) x L (B vs. T)	1	358.0	0.03 [b]	3186.6	0.08
S(q) x L (C vs. O)	1	1.1	0.90	550.0	0.47
S(q) x L (B vs. T)	1	312.7	0.04 [b]	2922.6	0.09
S(c) x L (C vs. O)	1	46.9	0.43	920.6	0.35
S(c) x L (B vs. T)	1	91.8	0.27	598.1	0.45
L x P	2	4.9	0.94	154.6	0.86
L (C vs. O) x P	1	7.0	0.76	186.3	0.67
L (B vs. T) x P	1	2.7	0.85	121.7	0.73
S x L x P	6	44.8	0.74	473.0	0.84
S(l) x L (C vs. O) x P	1	84.7	0.29	1455.7	0.24
S(l) x L (B vs. T) x P	1	17.7	0.63	25.2	0.88
S(q) x L (C vs. O) x P	1	0.1	0.97	0.1	0.99
S(q) x L (B vs. T) x P	1	62.4	0.37	903.8	0.35
S(c) x L (C vs. O) x P	1	21.7	0.59	215.3	0.65
S(c) x L (B vs. T) x P	1	81.1	0.30	236.9	0.63
Error	215 [c]	75.9		1037.7	

[a] Mean square.

[b] Significant at $P \leq 0.05$

[c] Error degrees of freedom are reduced due to missing values.

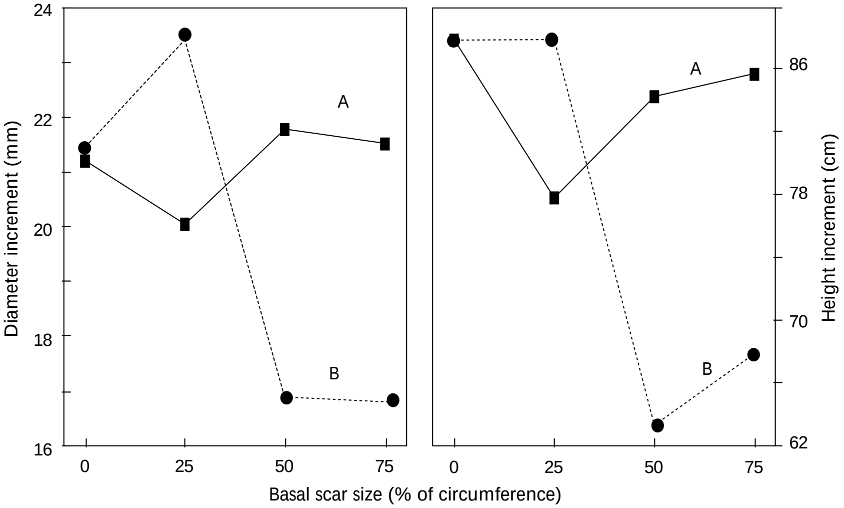

FIGURE 1 *Effect of basal scar treatments applied at two phenological stages on 5-year growth of lodgepole pine seedlings at Tunkwa Lake, British Columbia, 1988–1993. (A) Scars applied during terminal elongation. (B) Scars applied after terminal elongation.*

growth in seedlings scarred after the completion of terminal elongation, compared to seedlings scarred during terminal elongation.

3.2.2 Scarring damage effects

Scars larger than 25% of the stem circumference reduced 5-year diameter growth when applied after the completion of terminal elongation (Figure 1). Cook and Hain (1987) showed that defence reactions in response to wounding decrease the energy reserves of trees. Theoretically, larger scars may lead to greater energy reserve losses, which may explain the observed decreases in diameter growth.

3.2.3 Leader damage effects

Leader damage, in the absence of basal scarring, caused no reductions in diameter growth at any phenological stage. Significant scar x leader interactions (Table 1: SxL) indicate that the diameter response to scarring was different when

TABLE 2 *Effect of scarring and leader treatments applied at two phenological stages on 5-year growth of lodgepole pine seedlings*

Damage treatment		Phenological stage			
		During terminal elongation		After terminal elongation	
Basal scar (%)	Leader removal	Diameter (mm)	Height (cm)	Diameter (mm)	Height (cm)
0	Control	20.0[a] ± 3.3[b]	85.6 ± 11.6	22.5 ± 3.0	96.3 ± 10.7
0	Apical bud	23.3 ± 2.3	92.9 ± 8.8	25.4 ± 3.0	96.2 ± 11.4
0	50% of terminal	20.3 ± 2.8	85.1 ± 11.2	16.4 ± 2.7	71.1 ± 8.8
	Mean	21.2 ± 1.6	87.8 ± 5.9	21.4 ± 1.8	87.8 ± 6.2
25	Control	20.1 ± 2.2	76.8 ± 9.5	25.9 ± 2.5	96.1 ± 7.1
25	Apical bud	18.8 ± 3.0	73.4 ± 11.0	18.3 ± 2.5	73.0 ± 10.1
25	50% of terminal	21.2 ± 2.7	83.2 ± 7.3	25.9 ± 2.5	94.6 ± 7.0
	Mean	20.0 ± 1.5	77.8 ± 5.3	23.4 ± 1.6	87.9 ± 5.0
50	Control	22.1 ± 3.6	82.4 ± 14.3	15.9 ± 3.6	57.2 ± 16.1
50	Apical bud	19.5 ± 2.6	78.6 ± 11.8	15.9 ± 2.9	59.6 ± 11.1
50	50% of terminal	23.7 ± 1.7	91.8 ± 7.9	18.9 ± 3.2	73.1 ± 10.4
	Mean	21.8 ± 1.6	84.3 ± 6.6	16.9 ± 1.8	63.3 ± 7.2
75	Control	22.9 ± 2.6	93.6 ± 8.8	16.7 ± 2.4	70.1 ± 10.3
75	Apical bud	19.1 ± 2.1	73.9 ± 8.0	15.0 ± 3.3	63.2 ± 11.9
75	50% of terminal	22.5 ± 2.2	89.4 ± 6.5	18.5 ± 2.6	70.0 ± 7.0
	Mean	21.5 ± 1.3	85.7 ± 4.7	16.8 ± 1.6	67.9 ± 5.5
	Grand mean	21.1 ± 0.7	83.9 ± 2.8	19.6 ± 0.9	76.7 ± 3.2

[a] Mean (n = 10)

[b] Standard error

the bud was removed, compared to when the terminal was removed. Seedlings that were unscarred with the leader removed showed greater reductions in diameter than did scarred seedlings at any level (Table 2).

3.3 HEIGHT INCREMENT RESPONSE

Height growth response to scarring treatments closely reflected that of diameter response (Figure 1). Height growth was reduced by as much as 28% when scarring treatments were applied after the completion of terminal elongation (Table 2), but seedlings were unaffected by scarring treatments applied during terminal elongation. As with diameter response, only those scars 50% of the stem circumference or greater reduced height growth. The biological mechanisms responsible for the observed height responses are most likely similar to those postulated for the diameter response.

4 CONCLUSIONS

Our results indicate that the survival of lodgepole pine seedlings was unaffected by the simulated cattle damage treatments that were applied. Observed seedling mortality in adjacent cattle-grazed pastures may therefore be due to cattle damage combined with other factors such as sub-optimal growing conditions or adverse vegetation competition.

Simulated basal scars of 25% of the stem circumference did not reduce the 5-year growth of lodgepole pine seedlings. This suggests that growth loss should be minimal on cattle-damaged seedlings with basal scars of 25% of stem circumference or less. Further study is needed to determine if this relationship holds for seedlings experiencing sub-optimal growing conditions or adverse vegetation competition.

There is evidence that trampling damage during the period of terminal elongation will result in less seedling growth loss than damage inflicted after terminal elongation is completed. Seedling growth was unaffected by basal scars applied during terminal elongation. This information is useful in situations where it is practical to control the timing of livestock grazing on young lodgepole pine plantations.

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