Growth and release of understory spruce in partially-cut pine stands

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Introduction

Clearcutting followed by planting has been the dominant stand-scale management practice in the sub-boreal forests of British Columbia. In the past 15 years, retention of 5-15% of canopy trees has become common, but growth projections are still based on open-grown planted seedlings. Simultaneously, the mountain pine beetle (MPB) epidemic has created vast areas of complex multi-storied stands and extensive areas of MPB damaged forest will remain unsalvaged. Future timber-supply in these stands will depend on some combination of future natural regeneration, under planting, and the release of surviving understory and sub-canopy trees. We have very limited data on the performance of underplanted trees under different levels of canopy retention because of the past dominance of clearcutting, yet the areas of senescent lodgepole pine throughout British Columbia, which can harbour important amounts of interior spruce in the understory, are increasingly dominating the landscape.

Adding to this issue, interior spruce regeneration in open sites proved in the past to be both a difficult and expensive endeavour (Lieffers and Stadt 1994; Stewart et al. 2000). Consequently, establishment of this species underneath an existing canopy, following a shelterwood model, might be preferable. Germination success and growth of interior spruce (or white spruce) seedlings in shelterwoods are subject to numerous factors such as site preparation, establishment method, season of establishment, overstory density, and site quality (Lieffers and Stadt, 1994; Stewart et al. 2001; Wurtz and Zasada, 2001; Paquette et al. 2006). Furthermore, these factors often interact (Granhus et al. 2008; Langvall and Löfvenius, 2002), explaining the wide range of results observed in earlier studies. Comparing establishment methods is relevant for management purposes since the cost associated with planting and seeding has to be weighed against risks and benefits.

To investigate this current issue, we used an old experiment [Experimental Plot 591 (EP 591)], established by Dave Armit in 1962-1963 to study natural, seeded and planted spruce performance in partially-cut lodgepole pine stands with overstory pine densities varying from approximately 400 to 1100 stems/ha. Most experimental stands were hit by the MPB between 2005 and 2007. This has allowed us to quantify and understand 1) long term survival and growth of understory spruce and 2) growth release of understory spruce after MPB attack.

Study sites and experimental design

Blocks are located in Northwestern British Columbia in mesic or submesic stands (Table 1) in the Sub-Boreal spruce zone (SBSdk) (Pojar et al. 1984) between 53°11', 54°61' N. and 125°73', 126°92' W (for an overview of the study sites, see Appendix 1). All sites are from fire-originated pine or pine-spruce stands that were partially logged before 1960.

Initially, the experiment included 15 sites where pine densities varied from approximately 100 to 1100 stems/ha and where seedlings of interior spruce were either planted or seeded in scarified and unscarified microsites. Each block was divided into two sub-blocks and 10 rows where a treatment was assigned. Rows were spaced between 1.8 to 3 meters. Treatments were randomly assigned to rows and consisted of: spring planted scarified (SPS), fall planted scarified (FPS), spring seeded scarified (SSS), fall seeded scarified (FSS), spring planted unscarified (SPU), fall planted unscarified (FPU), spring seeded unscarified (SSU), fall seeded unscarified (FSU), scarified only (S) and unscarified only (U). In each microsite of two square feet, two (2 years old) seedlings were planted, 25 to 35 viable seeds were seeded and rows assigned to natural regeneration were left untreated. Forest floor scarification was done manually with hand tools. After 5 years of establishment (in 1967), each microsite was thinned to two individuals.

Measurements

In the early phase of the project, height was measured for the tallest individual per microsite. In 1993, 2003, 2006 and 2009, height for experiment trees was measured using a hypsometer (Haglöf Vertex III), a height pole or a measuring tape depending on the individual's size. Diameter at breast height (DBH) was measured in cm at a height of 1.3m using a diameter tape or callipers. The overstory density was measured in the first and last phase of the project. In 1963, two circular plots of 0.2 ha or 50 stems (whichever was smaller in size) were used to assess stand residuals in each site. In 2003 and 2006, two circular plots 0.4 ha were established within each of the experimental blocks. Densities of original overstory trees were recorded and averaged for each block.

In each 3.99m regeneration plot, trees below 4m in height were measured and tagged. Diameter at 10 cm of height was measured, along with DBH for individuals over 1.3m. Tree height was measured with a hypsometer (Haglöf Vertex III), a pole, or a measruing tape. Height growth was calculated after measuring height increment of 2007, 2006, 2005, 2004 and 2003. Plots were 10m apart on a straight line in the buffer area, and alternated between picture and measurement plot. Hemispherical photos were taken at each plot center at 1.3m of height with a Nikon Coolpix digital camera. Each image had a resolution of 2560 by 1920 pixels and was analyzed with GLA (Gap Light Analyzer).

An understory of interior spruce growing under an MPB-attacked overstory of lodgepole pine characterizes most of the study sites in 2006-2009.

Table 1. Site characteristics for all blocks of the initial experiment

	Block 1*	Block 2*	Block 3	Block 4	Block 5	Block 6*	Block 7	Block 8*	Block 9	Block 10*	Block 11*	Block 12	Block 13	Block 14*	Block 15*
Slope	5%	0%	0%	2-5%	5%	0%	3-7%	4-8%	7%	0-2%	3%	1-5%	2%	4%	3-5%
Aspect	West		South-east	South east	West	West	West	South	South	North-east	South-east	West	North-west-west	North-west	North
Elevation	884	777	777	792	914	945	914	823	732	762	792	732	914	853	549
Soil texture	Silty-sand.	Sandy loam	Clay-sand loam	Gravel-sand	Clay sand loam	Sandy clay	Sand	Silty sand	Loam	Loam	Silty-clay.	Sandy silt loam	Silty clay.	Silty loam	Silty clay
drainage	Moderate to poor	Good to high	Poor	Good to high	Good	Good	good	High to poor	Good to high	Good to poor	Good to poor	Good to high	Good to poor	Good.	Good
Understory Vegetation cover	Light to moderate	Dense	Moderate	Moderate-dense	Almost complete moss cover	Moderate	Moderate	Light-sparse	Sparse to moderate	Almost complete moss cover	Light	Light	Moderate-dense	Light	Almost complete moss cover
Site index at 80 y.	23	23.5	23.5	20.5	20.5	20	20.5	21	21	23.5	21	24	23.5	25	24
Stem/ha	350	800	160	620	845	1126	650	500	10	637	700	346	13	87	570

*These blocks have been found and re-measured in 1993, 2003, 2006 and 2009.

Measurement history

During the early phase of the project, the Forest Service measured all blocks of the experiment in 1963, 1965 and 1967. The experiment was abandoned from 1967 to 1993, when 8 remaining sites were located and re-measured. The next re-measurements were completed in 2003, in 2006 and again in 2009, where most of the pine overstory had been attacked by the MPB.

In 1990, H. Dong (MoFR) relocated some of the 15 blocks established in the 1960's (1,2,3,4,6,8,10,11,14 and 15). Previous logging in block 2 had caused too much disturbance to allow proper re-measurement and block 3 had a perched water table that made tree recognition and re-measurement impossible. Experiment trees in blocks 1,2,6,8,10,11,14 and 15 were measured after the 1993 growing season, but the sample size had diminished in these blocks since the study was first established. Only blocks 2, 10 and 11 had 2 sub-blocks relocated and measured, and the others only had one, representing half of the original sample size.

In 2003, the experiment was re-measured by MoFR employees and contractors. In block 11, an additional sub-block is found, tagged and measured. Stem-mapping of two blocks (2 and 15) was also completed.

In 2007, the Forest Investment Account funded a three-year project, partially aimed at re-measuring this experiment and adding permanent regeneration plots on the block's periphery. Measurement of the experiment trees was conducted in 2007(spring) and 2009 (fall). During 2007 re-measurement a second sub-block was found at block 1, but was not measured. All blocks had a 50m. buffer perimeter put in place to protect from beetle harvesting. For blocks 6, 10, and 11, this was done in 2006, while for blocks 1, 2, 8, 14, and 15, it was completed during the re-measurement in 2007. A research plot sign was also hung in the middle of each of the four sides of the perimeter. In all blocks, except for block 1 which was unsuitable, permanent regeneration plots were installed and measured.

Table 2. Missing treatments in active blocks (as of 2009)

Block	Sub-Block	Missing Treatments*
2	1	NS, NU.
2	2	NU, SSU, SS.
6	1 & 2	NS, NU, SSU, FSS, FSU.
8	1	NS, SSS, FSU.
10	1 & 2	NU, SSS, FSS.
11	1	NS, NU, FSU, SSU, SSS.
11	2	NS, NU, FSS, FSU, SSU, SSS.
14	1	NS, NU, FSU.
15	1	NU.

*Treatment abbreviations: spring planted scarified (SPS), fall planted scarified (FPS), spring seeded scarified (SSS), fall seeded scarified (FSS), spring planted unscarified (SPU), fall planted unscarified (FPU), spring seeded unscarified (SSU), fall seeded unscarified (FSU), scarified only (S) and unscarified only (U).

Results: Early Analysis

1962

During the earlier phase of the project, the Forest Service measured the experiment in 1963, 1965, 1967. Analysis of variance was conducted to account for the determinant factors affecting growth and survival of seeded and planted trees. The author suggested that the influence of the overstory density was not important compared to other treatments and site-specific factors, therefore it was not included as a factor in this analysis. It was suggested that overstory density will have an effect later (Armit, 1964).

Early results summary

Effect of site: survival of germinants, survival and height growth of planted seedlings varies between sites.

Effect of season (of planting or seeding): no effect on germination, and survival of germinants, but there is higher survival for seedlings planted in the spring and higher growth for seedlings planted in the fall.

Effect of scarification: strong positive relationship with germination, survival of germinants and planted seedlings, and growth of the planted seedlings.

Note: Older documents suggest that further analysis was conducted in 1967 but these results are not clearly understandable, and the variables were not very well identified.

1990

In 1990, H. Dong (MoFR) relocated and measured experiment trees in some of the 15 blocks established in the 1960's (1,2,6,8,10,11,14 and 15). However, the analysis was performed on early data (63 and 67) and not on the data measured in the 1990's. Analysis of variance was conducted to account for the determinant factors affecting growth and survival of seeded and planted trees (unpublished data, Smithers, BC).

Results summary

Effect of site: survival, stocking, height, height growth and mortality of planted and seeded trees varies between sites but not total germination.

Effect of season (of planting or seeding): survival, stocking, height, height growth and mortality of planted and seeded trees varies between season but not total germination. There is higher survival for seedlings planted in the spring and higher growth for seedlings planted in the fall.

Effect of scarification: the most important effect promoting seed germination, survival and stocking of seeded trees. For planted seedlings, it affected growth, mortality and stocking.

Effect of overstory: Results indicate that a high residual density improves early height growth and survival of planted trees and germination and survival of seeded trees. Conversely, a lower density improves height growth after 1 growth year for planted trees, and increases growth of seeded trees.

Statistical analysis for 1993, 2003, 2006 and 2009 data.

Based on results from this analysis we simplified the number of treatments in the experiment where no statistical difference between two treatments could be found. In particular, the effect of season was not significant. Treatment codes for the combined treatments are N: Natural, NS: Natural in scarified spots, S: seeded, SS: Seeded in scarified spots, P: Planted, PS: Planted in scarified spots.

Survival

All live experiment trees were compiled, including damaged ones, to report survival over years, for blocks, establishment method and site preparation.

Table 3: Sample size for experiment trees over years for each block.

Block	1967	1993	2003	2006	2009
1	606	231	206	205	205
2	565	392	387	387	384
3	568	-	-	-	-
4	452	-	-	-	-
5	510	-	-	-	-
6	569	97	88	83	83
7	483	-	-	-	-
8	583	108	101	98	92
9	481	-	-	-	-
10	587	452	428	423	414
11	436	112	214*	214	206
12	582	-	-	-	-
13	278	-	-	-	-
14	553	160	157	156	153
15	307	129	132	130	128

* This number is increasing compared to 1993 because a sub-block was found in this block 2003.

Table 4. Sample size for experiment trees over years for each establishment method.

Establishment method	1967	1993	2003	2006	2009
Natural	355	19	19	19	17
Planted	5266	1227	1274	1258	1251
Seeded	1939	434	419	419	396

Table 5. Sample size for experiment trees over years for each type of site preparation.

Site preparation	1967	1993	2003	2006	2009
Scarified	4587	977	986	981	964
Unscarified	2973	703	726	715	700

Table 6. Sample size for experiment trees over years for each treatment and block.

Year	Block	N	NS	S	SS	P	PS
	1	20	35	68	105	187	191
	2	2	13	36	141	177	196
	3	9	24	32	117	190	196
	4	3	10	5	83	169	182
	5	2	9	12	114	178	195
	6	8	9	18	149	193	192
1967	**7**	3	6	6	86	187	195
	8	12	28	34	136	185	188
	9	1	13	23	67	185	192
	10	**-**	22	24	148	195	198
	11	1	11	15	87	141	181
	12	19	45	32	121	175	190
	13	**-**	3	1	40	90	144
	14	13	29	48	133	162	168
	15	2	3	9	49	101	143

(Table 6 cont'd.)

Year	Block	N	NS	S	SS	P	PS
1993	**1**	-	-	36	45	81	69
	2	-	9	33	65	138	147
	6	-	-	-	11	38	48
	8	2	-	4	4	57	41
	10	1	4	15	116	152	164
	11	-	-	-	3	42	67
	14	-	--	13	49	43	55
	15	-	3	13	27	35	50
2003	**1**	-	-	33	41	79	65
	2	-	8	33	64	145	148
	6	-	-	-	9	35	44
	8	2	-	4	4	55	36
	10	1	4	15	115	149	161
	11	-	-	4	10	82	119
	14	-	-	12	48	42	55
	15	-	4	13	26	37	52
2006	**1**	-	-	33	37	75	60
	2	-	8	33	63	142	146
	6	-	-	-	9	32	42
	8	2	-	4	4	52	36
	10	1	4	15	112	141	153
	11	-	-	4	10	82	118
	14	-	-	12	47	42	55
	15	-	4	12	26	37	51
2009	**1**	-	-	28	36	78	63
	2	-	7	32	61	138	146
	6	-	-	-	10	30	43
	8	1	-	4	4	48	35
	10	1	4	14	103	141	151
	11	-	-	4	7	79	116
	14	-	-	12	45	42	54
	15	-	4	12	24	36	51

Survival of overstory trees

Residuals after the initial logging persisted year after year, but their density decreased overtime. Note that by 2009, numerous trees in the overstory were dead due to the MPB epidemic.

Table 7. Overstory densities (stem per hectare) by block overtime

Block	1963	2003	2006	2009
1	350	225	225	75
2	800	368.75	281.25	65.25
6	1127	662.5	662.5	162.5
8	500	500	475	150
10	638	462.5	381.25	50
11	700	481.25	456.25	143.75
14	88	62.5	50	50
15	570	312.5	262.5	37.5

History of disturbance and damage

After the experiment was abandoned in 1967, some of the study sites suffered significant damage. During the first relocation of the experiment in 1990 by H. Dong, it was recorded that: blocks 3, 5, 7 and 13 were logged, block 4 has a perched water table and previous measurements were uncertain, block 9 was not found and block 12 has burned in 1983. The remaining blocks were located and measured, but some were also partially affected by disturbances.

In 1983, a severe windstorm occurred and likely affected the overstory of site 2 and 10, although this was not recorded directly in the data.

Starting in 2002, the Mountain Pine Beetle epidemic started affecting the lodgepole pine trees in the overstory (although the impact was extremely low). By 2005, the epidemic had well progressed and most of the overstory pine had been attacked to some degree. Height and radial growths, pre- and post-MPB are reported in this study.

During winter 2006-2007, an abnormally high snow load from one storm in late October 2006 caused broad damage to experimental trees at many of the experimental sites. The damage was recorded on a tree-basis and was especially significant in blocks 2 and 10 where densities of the experiment trees are the highest.

Most important injuries recorded were broken tops and lean trees, and percent occurrence is presented in the figures below. Note that the sample size for natural trees is extremely low (<2). Other injuries such as: dead tops, sweeps , brooms, rust, double stems, forked top and basal scar were also present but in low numbers (not compiled here).

Figure 1. Percent of lean trees by year and by treatment (a) and (b) block. Treatments abbreviations are N: Natural, NS: Natural in scarified spots, S: seeded, SS: Seeded in scarified spots, P: Planted, PS: Planted in scarified spots.

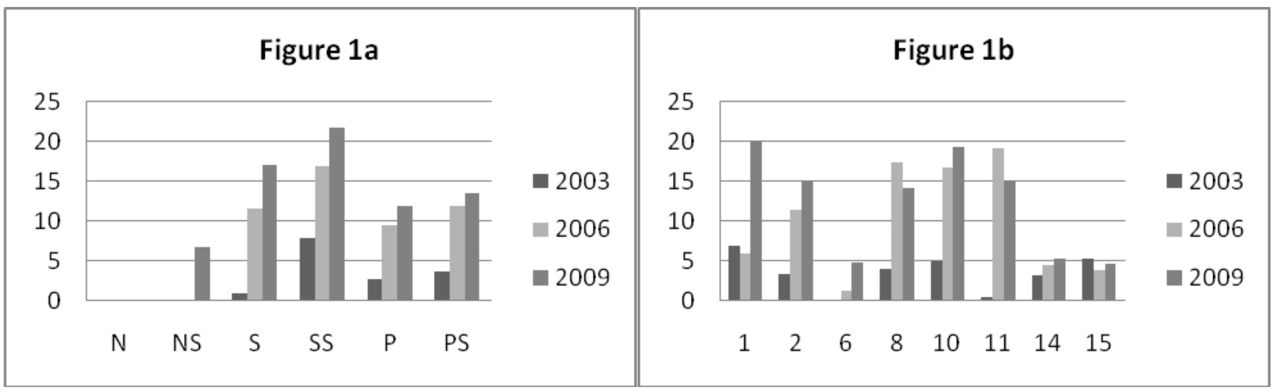
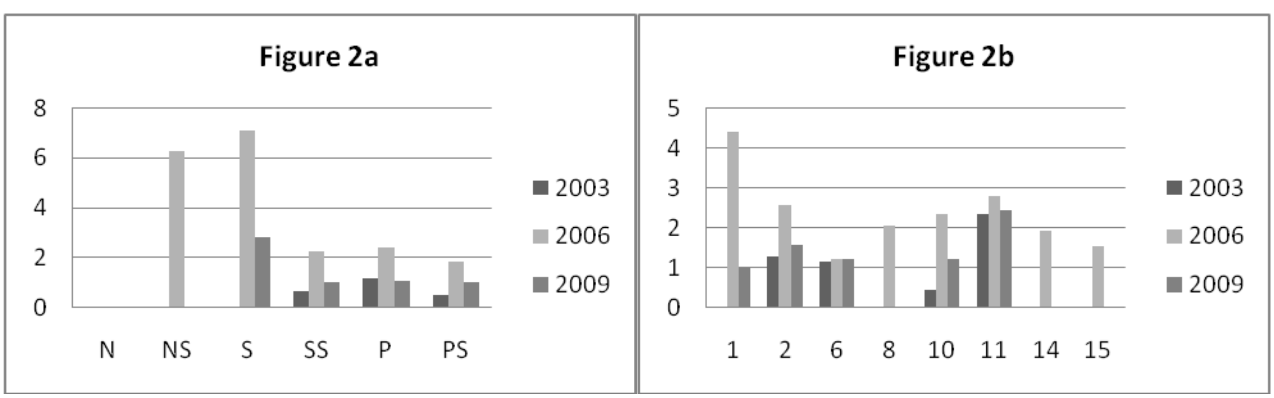


Figure 2. Percent of trees with broken tops by year and by treatment (a) and (b) block.



Early growth: height at 5 years

Individual height was compiled for all blocks by treatment and by block (diameter was not recorded since the individuals were too small in 1967). Planted trees have a clear advantage in height after 5 years (note that they were planted at 2 years of age).

Figure 3: Average tree height (m) by treatment after 5 years of growth. Treatments abbreviations are N: Natural, NS: Natural in scarified spots, S: seeded, SS: Seeded in scarified spots, P: Planted, PS: Planted in scarified spots.

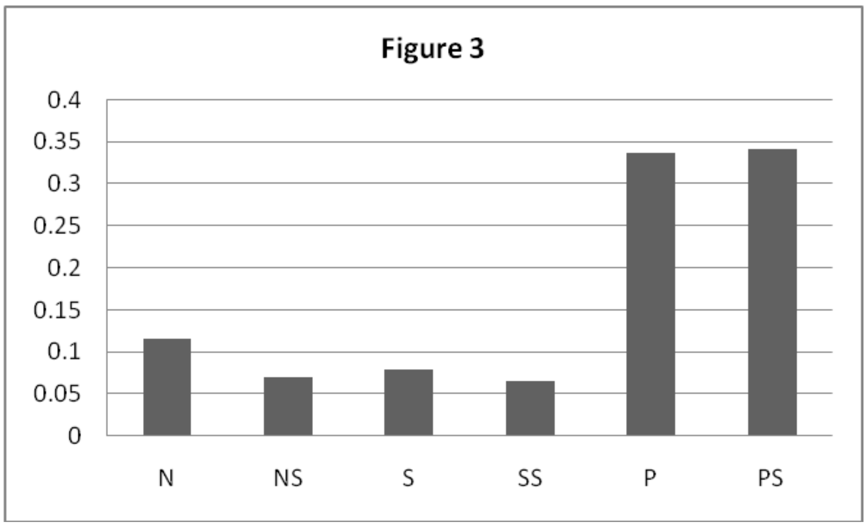


Table 8. Average tree height (m) by block and treatment after 5 years of growth.

Block	N	NS	S	SS	P	PS
1	0.13	0.07	0.09	0.08	0.34	0.36
2	0.18	0.09	0.07	0.07	0.37	0.39
3	0.13	0.07	0.07	0.07	0.37	0.37
4	0.14	0.05	0.13	0.05	0.28	0.28
5	0.09	0.05	0.04	0.06	0.32	0.32
6	0.08	0.06	0.06	0.05	0.26	0.25
7	0.06	0.05	0.05	0.05	0.28	0.26
8	0.09	0.04	0.08	0.04	0.26	0.24
9	0.13	0.07	0.10	0.09	0.40	0.37
10	-	0.09	0.08	0.08	0.41	0.47
11	0.06	0.05	0.05	0.05	0.29	0.31
12	0.10	0.06	0.09	0.06	0.38	0.35
13	-	0.06	0.05	0.06	0.31	0.32
14	0.16	0.12	0.08	0.09	0.36	0.37
15	0.11	0.06	0.06	0.06	0.47	0.46

Diameter over time

Diameter (DBH) measurements were limited to 2003, 2006 and 2009. Results show that planted trees are larger and that scarified sites generally improves radial growth. Note that when n=1, standard deviation =0.

Table 9. Average DBH (cm) and standard deviation by year and treatment

	N	NS	S	SS	P	PS
2003	1.73 (+/-2.31)	2.87 (+/-1.56)	4 (+/-2.53)	4.54 (+/-2.83)	7.57 (+/-4.02)	8.64 (+/-4.48)
2006	2.13 (+/-2.48)	3.03 (+/-1.84)	4.57 (+/-2.87)	4.97 (+/-3.13)	8.29 (+/-4.41)	9.42 (+/-4.97)
2009	3.9 (+/-4.1)	3.5 (+/-2.12)	5.03 (+/-3.29)	5.96 (+/-3.44)	9.29 (+/-4.74)	10.52 (+/-5.27)

Figure 4. Average DBH (cm) by year and treatment. Treatments abbreviations are N: Natural, NS: Natural in scarified spots, S: seeded, SS: Seeded in scarified spots, P: Planted, PS: Planted in scarified spots.

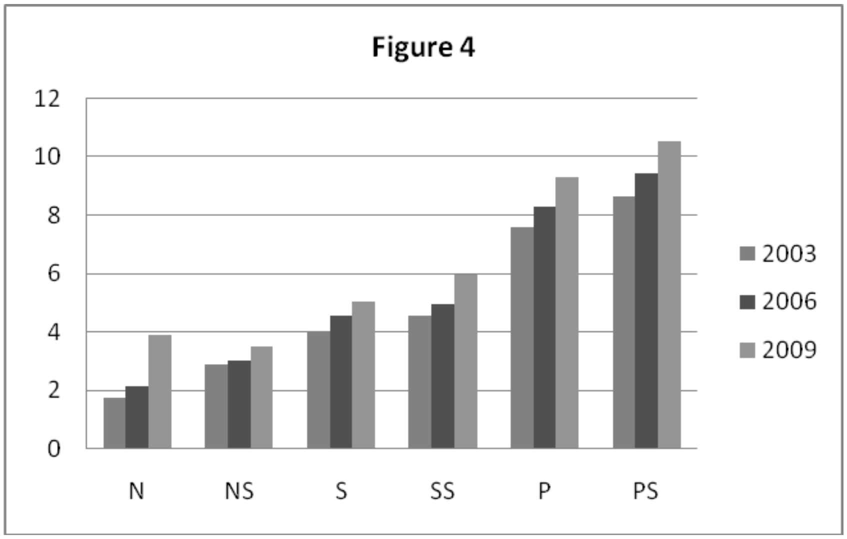


Table 10. Average DBH (cm) and standard deviation for experiment trees by block and treatment for each year.

Year	Block	N	NS	S	SS	P	PS
2003	1	-	-	3.42 (+/-2.66)	2.95 (+/-2.33)	7.55 (+/-2.57)	7.77 (+/-2.78)
	2	-	2.65 (+/-0.89)	5.11 (+/-2.89)	5.32 (+/-2.93)	8.29 (+/-2.9)	8.89 (+/-2.75)
	6	-	-	-	0.5 (+/-0)	-	1.03 (+/-0.84)
	8	0.4 (+/-0)	-	1.4 (+/-0)	1.3 (+/-0)	1.81 (+/-1.55)	2.37 (+/-1.09)
	10	4.4 (+/-0)	1.9 (+/-0.99)	4.13 (+/-2.19)	4.1 (+/-2.46)	8.09 (+/-2.83)	10.58 (+/-3.89)
	11	-	-	1.2 (+/-0)	0.97 (+/-0.51)	3.62 (+/-1.76)	3.47 (+/-2.21)
	14	-	-	3.34 (+/-1.46)	5.8 (+/-3.07)	11.43 (+/-3.84)	11.09 (+/-3.28)
	15	-	3.58 (+/-2.19)	3.43 (+/-1.56)	4.89 (+/-2.6)	13.4 (+/-4.11)	13.35 (+/-4.81)
2006	1	-	-	3.84 (+/-2.88)	3.34 (+/-2.63)	8.25 (+/-2.93)	8.6 (+/-3.08)
	2	-	2.95 (+/-1.04)	5.77 (+/-3.23)	5.6 (+/-3.25)	9.4 (+/-3.05)	9.86 (+/-2.91)
	6	-	-	-	0.5 (+/-0)	-	0.79 (+/-0.62)
	8	0.7 (+/-0.14)	-	1.5 (+/-0)	1.7 (+/-0)	2.04 (+/-1.55)	2.25 (+/-1.55)
	10	5 (+/-0)	1.7 (+/-1.35)	4.82 (+/-2.53)	4.73 (+/-2.84)	8.95 (+/-3.1)	11.88 (+/-4.24)
	11	-	-	1.6 (+/-0)	0.87 (+/-0.67)	4.03 (+/-2)	3.94 (+/-2.48)
	14	-	-	3.6 (+/-1.61)	6.27 (+/-3.25)	11.96 (+/-4.14)	11.64 (+/-3.52)
	15	-	4.1 (+/-2.39)	4.18 (+/-2.17)	5.33 (+/-2.88)	14.51 (+/-4.58)	14.44 (+/-5.52)
2009	1	-	-	4.72 (+/-3.09)	4.58 (+/-3.1)	9.14 (+/-3.07)	9.59 (+/-3.23)
	2	-	3.93 (+/-1.07)	6.32 (+/-3.94)	6.96 (+/-3.63)	10.46 (+/-3.32)	10.83 (+/-3.08)
	6	-	-	-	0.7 (+/-0)	-	0.71 (+/-0.67)
	8	1 (+/-0)	-	1.55 (+/-0.64)	2.6 (+/-0)	2.58 (+/-1.96)	2.05 (+/-1.63)
	10	6.8 (+/-0)	2.05 (+/-1.53)	5.64 (+/-2.84)	5.48 (+/-3.17)	10.44 (+/-3.3)	13.72 (+/-4.21)
	11	-	-	1.35 (+/-1.2)	1.32 (+/-0.59)	4.95 (+/-2.36)	5.07 (+/-2.69)
	14	-	-	3.91 (+/-1.74)	7.04 (+/-3.28)	12.56 (+/-4.28)	12.12 (+/-3.77)
	15	-	4.63 (+/-2.68)	4.39 (+/-2.65)	6.38 (+/-3.37)	15.6 (+/-4.68)	15.66 (+/-5.68)

Tree height over time

Tree height measurements were available for 1967, 1993, 2003, 2006 and 2009. Results show that planted trees grow higher and that scarified site generally improves height growth. Note that when n=1, standard deviation =0.

Table 11. Average tree height (m) and standard deviation by year and treatment

	N	NS	S	SS	P	PS
1967	0.12 (+/-0.06)	0.07 (+/-0.05)	0.08 (+/-0.05)	0.07 (+/-0.03)	0.34 (+/-0.12)	0.34 (+/-0.13)
1993	1.33 (+/-1.39)	1.31 (+/-0.67)	2.28 (+/-1.33)	2.74 (+/-1.78)	4.69 (+/-2.59)	5.16 (+/-2.77)
2003	2.67 (+/-2.11)	2.36 (+/-1.6)	3.84 (+/-2.3)	4.51 (+/-2.89)	7.17 (+/-3.94)	7.71 (+/-4.36)
2006	3.18 (+/-2.72)	2.81 (+/-1.92)	4.4 (+/-2.65)	5.02 (+/-3.21)	7.97 (+/-4.39)	8.53 (+/-632)
2009	4.98 (+/-4.56)	3.29 (+/-2.25)	4.89 (+/-2.93)	6.01 (+/-3.6)	9.04 (+/-4.69)	9.61 (+/-5.13)

Figure 5: Average tree height (m) by year and treatment. Treatments abbreviations are N: Natural, NS: Natural in scarified spots, S: seeded, SS: Seeded in scarified spots, P: Planted, PS: Planted in scarified spots.

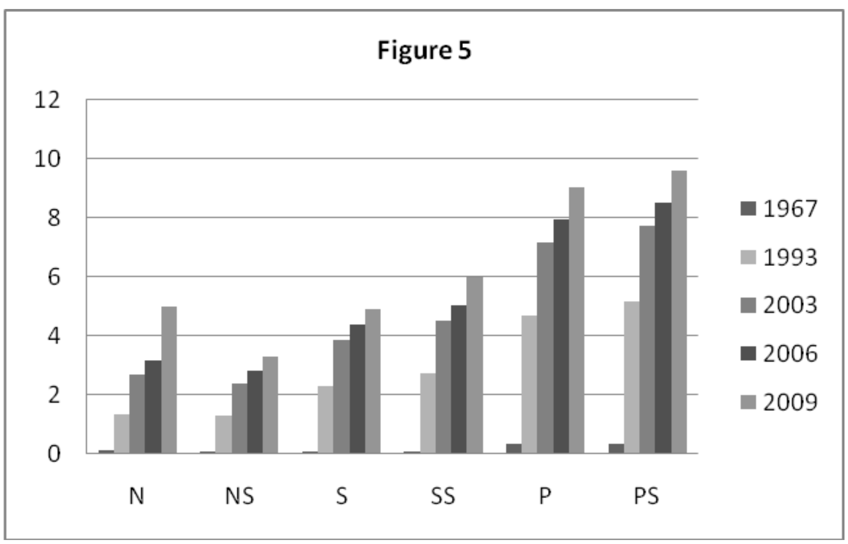


Table 12: Average tree height (m) and standard deviation for experiment trees by block and treatment for each year.

Year	Block	N	NS	S	SS	P	PS
	1	0.13 (+/-0.06)	0.07 (+/-0.05)	0.09 (+/-0.05)	0.08 (+/-0.05)	0.34 (+/-0.11)	0.36 (+/-0.13)
	2	0.18 (+/-0.03)	0.09 (+/-0.02)	0.07 (+/-0.03)	0.07 (+/-0.03)	0.37 (+/-0.11)	0.39 (+/-0.12)
	3	0.13 (+/-0.06)	0.07 (+/-0.03)	0.07 (+/-0.04)	0.07 (+/-0.03)	0.37 (+/-0.13)	0.37 (+/-0.13)
	4	0.14 (+/-0.08)	0.05 (+/-0.02)	0.13 (+/-0.11)	0.05 (+/-0.03)	0.28 (+/-0.09)	0.28 (+/-0.1)
	5	0.09 (+/-0.02)	0.05 (+/-0.02)	0.04 (+/-0.01)	0.06 (+/-0.03)	0.32 (+/-0.09)	0.32 (+/-0.09)
	6	0.08 (+/-0.04)	0.06 (+/-0.03)	0.06 (+/-0.04)	0.05 (+/-0.02)	0.26 (+/-0.08)	0.25 (+/-0.06)
1967	7	0.06 (+/-0.01)	0.05 (+/-0.03)	0.05 (+/-0.02)	0.05 (+/-0.02)	0.28 (+/-0.08)	0.26 (+/-0.08)
	8	0.09 (+/-0.06)	0.04 (+/-0.01)	0.08 (+/-0.05)	0.04 (+/-0.02)	0.26 (+/-0.07)	0.24 (+/-0.06)
	9	0.13 (+/-0)	0.07 (+/-0.03)	0.1 (+/-0.04)	0.09 (+/-0.04)	0.4 (+/-0.15)	0.37 (+/-0.11)
	10	-	0.09 (+/-0.05)	0.08 (+/-0.04)	0.08 (+/-0.03)	0.41 (+/-0.12)	0.47 (+/-0.15)
	11	0.06 (+/-0)	0.05 (+/-0.02)	0.05 (+/-0.02)	0.05 (+/-0.02)	0.29 (+/-0.1)	0.31 (+/-0.09)
	12	0.1 (+/-0.04)	0.06 (+/-0.03)	0.09 (+/-0.04)	0.06 (+/-0.02)	0.38 (+/-0.12)	0.35 (+/-0.12)
	13	-	0.06 (+/-0.01)	0.05 (+/-0)	0.06 (+/-0.03)	0.31 (+/-0.1)	0.32 (+/-0.12)
	14	0.16 (+/-0.1)	0.12 (+/-0.09)	0.08 (+/-0.06)	0.09 (+/-0.05)	0.36 (+/-0.13)	0.37 (+/-0.13)
	15	0.11 (+/-0.01)	0.06 (+/-0.01)	0.06 (+/-0.03)	0.06 (+/-0.02)	0.47 (+/-0.16)	0.46 (+/-0.15)
	1	-	-	2.01 (+/-1.32)	1.97 (+/-1.17)	4.99 (+/-1.58)	5.21 (+/-1.68)
	2	-	1.13 (+/-0.56)	2.78 (+/-1.41)	3.08 (+/-1.79)	5.49 (+/-1.62)	5.63 (+/-1.6)
	6	-	-	-	0.49 (+/-0.18)	-	0.72 (+/-0.23)
1993	8	0.6 (+/-0.78)	-	0.85 (+/-0.47)	0.9 (+/-0.45)	1.14 (+/-0.61)	1.13 (+/-0.71)
	10	2.81 (+/-0)	1 (+/-0.56)	2.56 (+/-1.33)	2.49 (+/-1.46)	5.36 (+/-1.96)	6.66 (+/-2.32)
	11	-	-	-	0.61 (+/-0.18)	1.69 (+/-0.81)	2.42 (+/-1.1)
	14	-	-	2.64 (+/-1.14)	4.54 (+/-1.92)	7.61 (+/-1.51)	7.3 (+/-1.45)
	15	-	2.25 (+/-0.1)	1.47 (+/-0.66)	2.4 (+/-1.11)	7.86 (+/-2)	7.71 (+/-1.79)
	1	-	-	3.32 (+/-2.13)	3.14 (+/-2.01)	7.69 (+/-2.31)	7.98 (+/-2.36)
	2	-	2 (+/-1.24)	4.99 (+/-2.54)	5.12 (+/-2.99)	8.45 (+/-2.4)	8.97 (+/-2.38)
	6	-	-	-	0.83 (+/-0.25)	-	0.96 (+/-0.32)
2003	8	1.45 (+/-0.07)	-	1.18 (+/-0.62)	1.18 (+/-0.39)	1.55 (+/-0.94)	1.37 (+/-0.84)
	10	5.1 (+/-0)	1.5 (+/-0.68)	4.25 (+/-2.15)	4.27 (+/-2.26)	8.46 (+/-2.72)	10.46 (+/-3.16)
	11	-	-	1.13 (+/-0.46)	1.18 (+/-0.45)	3.37 (+/-1.47)	3.2 (+/-1.55)
	14	-	-	3.86 (+/-1.9)	7.21 (+/-3.01)	11.46 (+/-2.05)	11.02 (+/-2.14)
	15	-	3.95 (+/-2.01)	3.34 (+/-1.43)	4.52 (+/-2.48)	12.84 (+/-2.88)	11.89 (+/-3.69)

(Table 12 cont`d).

Year	Block	N	NS	S	SS	P	PS
	1	-	-	3.69 (+/-2.47)	3.54 (+/-2.32)	8.6 (+/-2.71)	9.04 (+/-2.83)
	2	-	2.37 (+/-1.47)	5.65 (+/-3.01)	5.9 (+/-3.39)	9.73 (+/-2.62)	10.12 (+/-2.69)
	6	-	-	-	0.87 (+/-0.27)	-	1.01 (+/-0.37)
2006	**8**	-	-	1.47 (+/-0.55)	1.3 (+/-0.54)	1.75 (+/-1.1)	1.47 (+/-0.9)
	10	6.32 (+/-0)	1.8 (+/-0.9)	4.95 (+/-2.28)	4.77 (+/-2.55)	9.33 (+/-2.98)	11.64 (+/-3.52)
	11	-	-	1.3 (+/-0.67)	1.45 (+/-0.54)	3.88 (+/-1.79)	3.65 (+/-1.84)
	14	-	-	4.23 (+/-2.06)	7.52 (+/-3.4)	12.28 (+/-2.54)	11.91 (+/-2.47)
	15	-	4.58 (+/-2.47)	3.83 (+/-1.85)	5.01 (+/-2.83)	14 (+/-3.14)	12.95 (+/-4.41)
	1	-	-	4.69 (+/-2.76)	5.08 (+/-2.92)	9.57 (+/-2.87)	10.23 (+/-2.89)
	2	-	2.67 (+/-1.81)	6.05 (+/-3.37)	7.11 (+/-3.78)	10.76 (+/-2.78)	11.04 (+/-2.73)
	6	-	-	-	0.89 (+/-0.28)	-	1.09 (+/-0.43)
2009	**8**	1.75 (+/-0)	-	1.44 (+/-0.71)	1.47 (+/-0.64)	2.14 (+/-1.39)	1.65 (+/-0.91)
	10	8.2 (+/-0)	2.35 (+/-0.88)	5.56 (+/-2.41)	5.43 (+/-2.83)	10.73 (+/-3.09)	13.01 (+/-3.56)
	11	-	-	1.49 (+/-0.74)	1.86 (+/-0.36)	4.56 (+/-2.08)	4.52 (+/-2.22)
	14	-	-	4.63 (+/-2.38)	8.5 (+/-3.48)	13.18 (+/-2.55)	12.72 (+/-2.7)
	15	-	5.18 (+/-2.98)	4.46 (+/-2.25)	6.24 (+/-3.31)	15.11 (+/-3.16)	14.11 (+/-4.31)

Diameter growth pre- and post-MPB attack

Diameter growth increment for the 2004, 2005 and 2006 growth period was divided by 3 to obtain annual average growth pre-MPB attack. The same was done with the 2007-2009 growing seasons for the post-MPB attack. Result show that radial growth generally slightly increases post-MPB attack, except for block 1, 14 and 15 (Table 13). Note that the sample size for natural trees is extremely low (<4).

Figure 6. Average annual radial growth (cm) by treatment pre- and post-MPB. Treatments abbreviations are N: Natural, NS: Natural in scarified spots, S: seeded, SS: Seeded in scarified spots, P: Planted, PS: Planted in scarified spots.

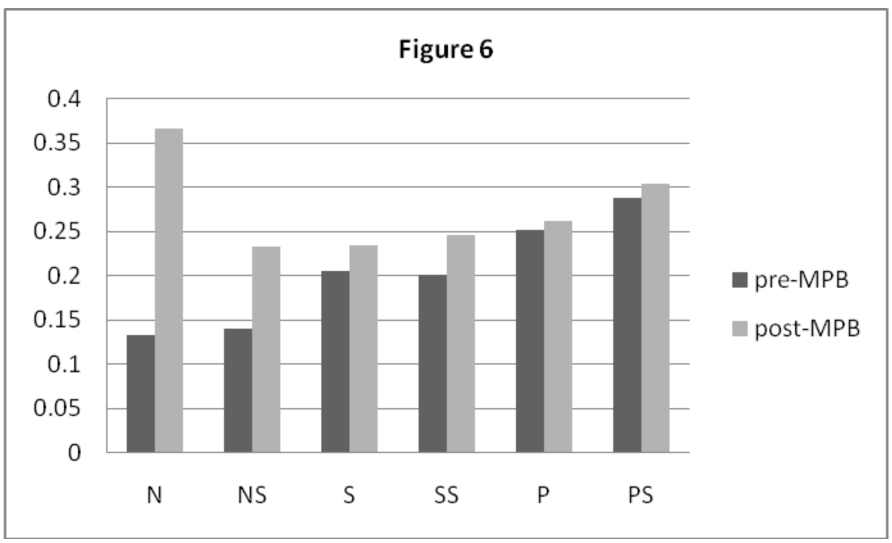


Table 13. Average radial growth (cm) by block and treatment, pre- and post-MPB.

Block		N	NS	S	SS	P	PS	average
1	pre-MPB	0.00	0.00	0.16	0.15	0.26	0.26	0.14
	post-MPB	0.00	0.00	0.20	0.16	0.21	0.22	0.13
2	pre-MPB	0.00	0.10	0.27	0.22	0.27	0.27	0.19
	post-MPB	0.00	0.22	0.29	0.29	0.24	0.27	0.22
6	pre-MPB	0.10	0.00	0.00	0.00	0.09	0.08	0.05
	post-MPB	0.13	0.00	0.00	0.07	0.10	0.07	0.06
8	pre-MPB	0.10	0.00	0.03	0.13	0.15	0.14	0.09
	post-MPB	0.13	0.00	0.17	0.30	0.27	0.18	0.17
10	pre-MPB	0.20	0.15	0.21	0.24	0.30	0.41	0.25
	post-MPB	0.60	0.32	0.34	0.33	0.33	0.41	0.39
11	pre-MPB	0.00	0.00	0.13	0.11	0.17	0.17	0.10
	post-MPB	0.00	0.00	0.20	0.24	0.31	0.35	0.18
14	pre-MPB	0.00	0.00	0.09	0.13	0.18	0.18	0.10
	post-MPB	0.00	0.00	0.07	0.10	0.15	0.17	0.08
15	pre-MPB	0.18	0.00	0.25	0.23	0.37	0.42	0.24
	post-MPB	0.18	0.00	0.24	0.21	0.29	0.33	0.21

Height growth pre- and post-MPB attack

Height growth increment for the 2004, 2005 and 2006 growth period was divided by 3 to obtain annual average growth pre-MPB attack. The same was done with the 2007-2009 growing seasons for the post-MPB attack. Results show that height growth generally decreases post-MPB attack, except for block 10, and block 6 and 8 to a lesser extent (Table 14). Note that the sample size for natural trees is extremely low (<4).

Figure 7. Average annual height growth (m) by treatment, pre- and post-MPB. Treatments abbreviations are N: Natural, NS: Natural in scarified spots, S: seeded, SS: Seeded in scarified spots, P: Planted, PS: Planted in scarified spots.

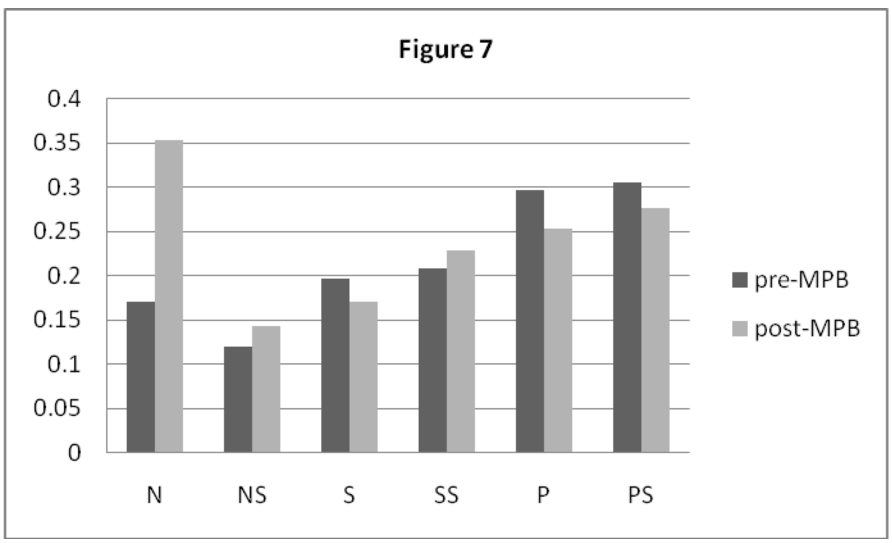


Table 14. Average height growth (m) by block and treatment, pre- and post-MPB.

Block		N	NS	S	SS	P	PS	average
1	pre-MPB	0.00	0.00	0.17	0.14	0.33	0.37	0.17
	post-MPB	0.00	0.00	0.15	0.19	0.25	0.30	0.15
2	pre-MPB	0.08	0.00	0.27	0.29	0.39	0.39	0.24
	post-MPB	0.08	0.00	0.22	0.28	0.28	0.28	0.19
6	pre-MPB	0.00	0.00	0.00	0.01	0.03	0.02	0.01
	post-MPB	0.00	0.00	0.00	0.02	0.04	0.03	0.02
8	pre-MPB	0.05	0.00	0.06	0.09	0.09	0.06	0.06
	post-MPB	0.08	0.00	0.08	0.06	0.11	0.07	0.07
10	pre-MPB	0.41	0.10	0.21	0.22	0.35	0.40	0.28
	post-MPB	0.63	0.18	0.21	0.27	0.33	0.37	0.33
11	pre-MPB	0.00	0.00	0.04	0.09	0.17	0.14	0.07
	post-MPB	0.00	0.00	0.06	0.12	0.20	0.25	0.10
14	pre-MPB	0.00	0.00	0.14	0.18	0.34	0.30	0.16
	post-MPB	0.00	0.00	0.09	0.19	0.30	0.32	0.15
15	pre-MPB	0.00	0.21	0.19	0.27	0.40	0.46	0.26
	post-MPB	0.00	0.20	0.20	0.23	0.31	0.34	0.21

Performance of larger trees

The calculation of the 50% larger trees in the experiment was made based on the median of the DBH. Only DBH and height values above this threshold were selected for every year of data, across treatments and blocks. The DBH median for 2003 was 3.9 cm, for 2006, 4.8 and for 2009, 4.3.

Figure 8. Average DBH (cm) by year and treatment for the 50% larger trees. Treatments abbreviations are N: Natural, NS: Natural in scarified spots, S: seeded, SS: Seeded in scarified spots, P: Planted, PS: Planted in scarified spots.

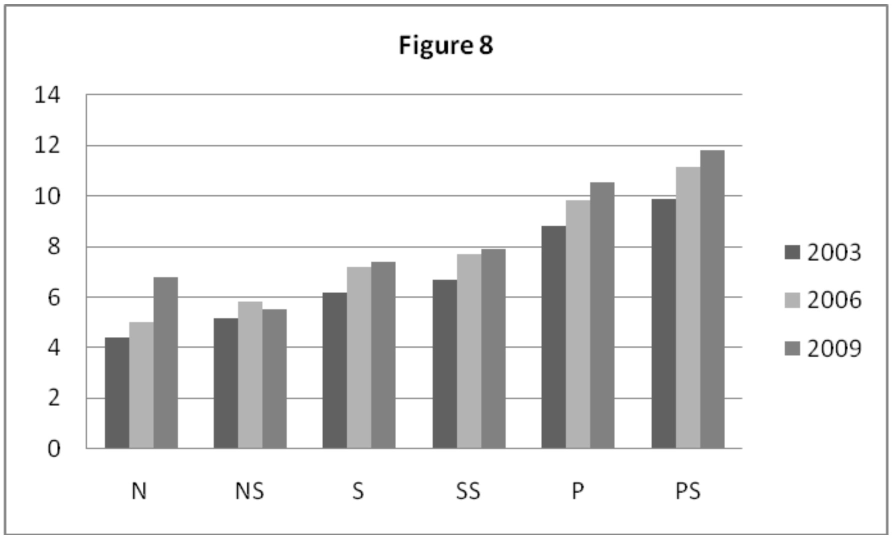
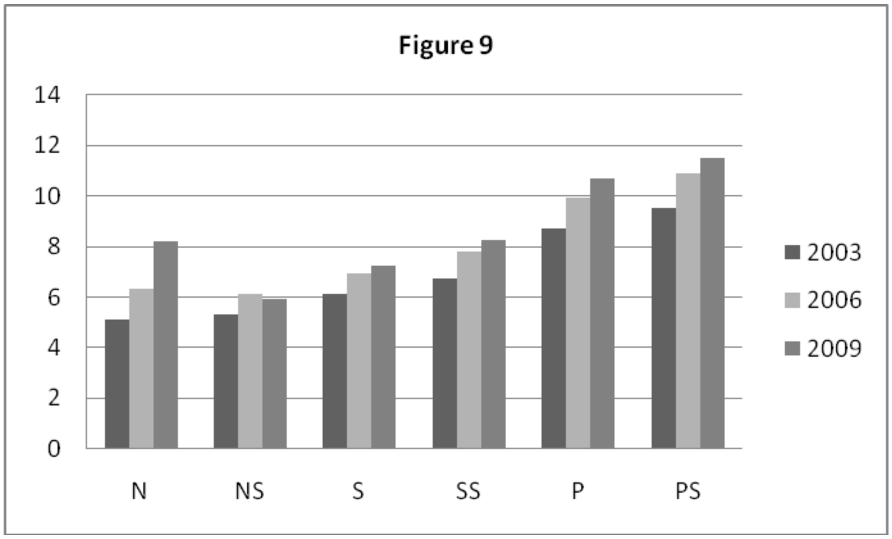


Figure 9. Average tree height (m) by year and treatment for the 50% larger trees.



Results for the best performing trees indicate that significant yield is attained in certain blocks and treatments. For example, planted trees in scarified sites in block 15 (1 and 14 also) have height and DBH values comparable to yield projections (with TIPSY) based on local site index for white spruce for individuals of similar age (~45 years). Most importantly, these individuals were established under medium-density overstories (350 sph for block 1 and 570 sph for block 5), and now compare in size to individuals established in clearcut plantations.

Table 15. Average DBH (cm) for treatment in blocks for the larger 50% trees.

Year	Block	N	NS	S	SS	P	PS
	1	-	-	6.24 (+/-2.1)	5.67 (+/-1.56)	8.13 (+/-2.15)	8.19 (+/-2.51)
	2	-	0 (+/-0)	6.92 (+/-2.15)	6.88 (+/-2.38)	8.49 (+/-2.76)	8.88 (+/-2.7)
2003	8	-	-	-	-	5.37 (+/-1.06)	4.1(+/-0)
	10	4.4(+/-0)	-	5.85 (+/-1.32)	6.3 (+/-2.05)	8.34 (+/-2.65)	10.85 (+/-3.65)
	11	-	-	-	-	5.18 (+/-0.97)	5.81 (+/-1.72)
	14	-	-	5.05 (+/-0.21)	7.42 (+/-2.45)	11.43 (+/-3.84)	11.24 (+/-3.13)
	15	-	5.15 (+/-0.78)	4.88 (+/-0.71)	6.46 (+/-1.73)	13.28 (+/-4.11)	13.58 (+/-4.43)
	1	-	-	7.59 (+/-2.35)	6.91 (+/-1.71)	9.23 (+/-2.24)	9.11 (+/-2.75)
	2	-	0 (+/-0)	7.86 (+/-2.44)	7.84 (+/-2.44)	9.45 (+/-2.86)	10.02 (+/-2.67)
2006	8	-	-	-	-	6 (+/-1.11)	5.2 (+/-0.42)
	10	5(+/-0)	-	6.71 (+/-1.41)	7.44 (+/-2.31)	9.34 (+/-2.85)	12.22 (+/-3.93)
	11	-	-	-	-	6.08 (+/-1.02)	7.12 (+/-1.81)
	14	-	-	5.53 (+/-0.38)	8.16 (+/-2.47)	11.96 (+/-4.14)	11.94 (+/-3.22)
	15	-	5.8 (+/-1.27)	5.92 (+/-1.18)	7.52 (+/-1.74)	14.51 (+/-4.58)	15.41 (+/-4.56)
	1	-	-	7 (+/-2.67)	6.84 (+/-2.1)	9.58 (+/-2.73)	9.71 (+/-3.14)
	2	-	4.55 (+/-0.07)	8.53 (+/-3.4)	8.5 (+/-2.89)	10.65 (+/-3.15)	10.89 (+/-3.04)
	8	-	-	-	-	-	5(+/-0)
2009	10	6.8(+/-0)	-	7.24 (+/-2.33)	7.45 (+/-2.98)	10.5 (+/-3.26)	13.8 (+/-4.14)
	11	-	-	-	-	6.33 (+/-1.44)	6.79 (+/-2.16)
	14	-	-	5.68 (+/-0.3)	8.29 (+/-2.81)	12.56 (+/-4.28)	12.29 (+/-3.61)
	15	-	6.45 (+/-2.19)	6.38 (+/-1.52)	8.06 (+/-2.4)	15.6 (+/-4.68)	16.42 (+/-4.96)

Table 16. Average height (m) for treatment in blocks for the larger 50% trees.

Year	Block	N	NS	S	SS	P	PS
	1	-	-	5.71 (+/-1.78)	5.55 (+/-1.51)	8.21 (+/-1.94)	8.29 (+/-2.15)
	2	-	-	6.84 (+/-1.55)	6.42 (+/-2.91)	8.17 (+/-2.87)	8.86 (+/-2.51)
2003	**8**	-	-	-	-	4.13 (+/-1.71)	2.6 (+/-0)
	10	5.1 (+/-0)	-	5.7 (+/-1.94)	6.35 (+/-1.96)	8.65 (+/-2.55)	10.64 (+/-2.96)
	11	-	-	-	-	4.73 (+/-1.04)	4.83 (+/-1.45)
	14	-	-	6.18 (+/-0.81)	8.7 (+/-2.06)	11.31 (+/-2.24)	11.14 (+/-1.94)
	15	-	5.3 (+/-1.56)	4.7 (+/-0.69)	5.53 (+/-2.18)	12.84 (+/-2.88)	11.88 (+/-3.76)
	1	-	-	6.86 (+/-2.16)	6.45 (+/-1.9)	9.33 (+/-2.21)	9.52 (+/-2.39)
	2	-	-	7.63 (+/-2.08)	7.81 (+/-3.08)	9.75 (+/-2.49)	10.25 (+/-2.49)
2006	**8**	-	-	-	-	4.84 (+/-2.11)	3.14 (+/-0.11)
	10	6.32 (+/-0)	-	6.43 (+/-1.83)	7.13 (+/-2.21)	9.54 (+/-2.77)	11.8 (+/-3.35)
	11	-	-	-	-	5.75 (+/-1.28)	5.93 (+/-1.61)
	14	-	-	6.68 (+/-1.06)	9.53 (+/-2.27)	12.18 (+/-2.58)	12.1 (+/-2.14)
	15	-	6.15 (+/-2.33)	5.63 (+/-0.53)	6.96 (+/-2.4)	14 (+/-3.14)	13.64 (+/-3.51)
	1	-	-	6.88 (+/-2.32)	7.3 (+/-1.88)	10 (+/-2.5)	10.36 (+/-2.77)
	2	-	4.8 (+/-0.71)	8.03 (+/-2.74)	8.59 (+/-3.25)	10.93 (+/-2.6)	11.07 (+/-2.7)
	8	-	-	-	-	4.5 (+/-2.03)	3.27 (+/-0)
2009	**10**	8.2 (+/-0)	-	6.96 (+/-1.85)	7.25 (+/-2.6)	10.73 (+/-3.09)	13.09 (+/-3.45)
	11	-	-	-	-	5.69 (+/-1.58)	5.89 (+/-1.96)
	14	-	-	7.05 (+/-1.17)	9.99 (+/-2.63)	13.18 (+/-2.55)	12.87 (+/-2.48)
	15	-	7.05 (+/-3.04)	6.25 (+/-1.13)	7.69 (+/-2.85)	15.11 (+/-3.16)	14.74 (+/-3.63)

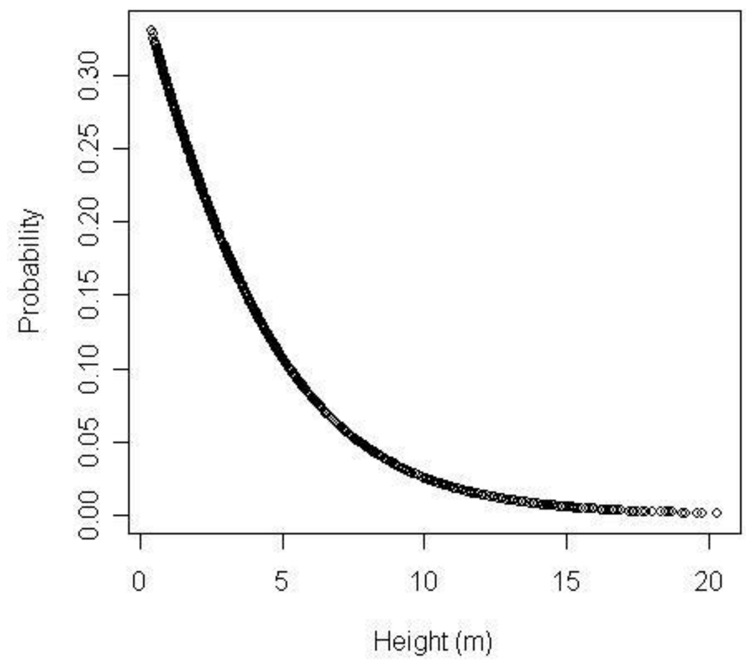
Effect of snowpress in understory spruce

During the summer of 2007, two Co-op students from University of Victoria (M. Bryan and M. Adams) worked on the project as field assistants. Their undergraduate assignment reported the "*Factors influencing frequency of snowpress in understory spruce*". The effects of establishment treatment, plot location, stem taper, understory height, overstory basal area and the combination of height and basal area with regards to was analysed using logistic regression analysis and model selection with AIC. The height of the understory tree was the greatest predictor for vulnerability to snowpress.

Table 17. Summary of hypotheses and AIC values determined using logistic regressions

Model Number	Hypothesis	AIC
1	Tree height is the best predictor of understory tree susceptibility to snowpress	**950.15**
2	Basal area of the overstory is the best predictor of understory tree susceptibility to snowpress	1061.40
3	A combination of tree height and basal area serves as the best predictor of understory tree susceptibility to	951.64

Figure 8. Graphic output of Model 1. The probability of a tree being damaged by snow decreases exponentially with an increase in tree height.



An example of a snowpressed tree in the experiment (Block 10).

Stem-maps

Blocks 2 and 15 were stem-mapped during the summer of 2003. Experiment trees coordinates were recorded, as well as overstory trees and trees in the buffer.

During the summer of 2008, a likelyhood analysis was performed on this data (by M.L. Lefrançois). 2003-2006 height growth and radial growth were calculated and used as dependent variables. Predictors were previous size (2003 height and DBH divided by the stand's average) and light availability, computed with the model SORTIE-ND for each experiment tree according to their plot location and neighbours.

Different models were tested, a power function, including only previous size as a predictor, a linear function, two forms of Michealis-Menten functions and a logistic function, all including previous size and light availability. Model selection was done using AIC.

Table 18. Summary of model functions explaining radial growth, parameter values and AIC values.

model	**function**	**a**	**b**	**c**	**max L**	**R2**	**AIC**
power	{a*x1^b}	0.702261	0.870916	-	-184.591	0.268537	**375.2677**
linear	(a*x1)+(b*x2)	8.086101	0.011643	-	-844.674	0.175397	1695.435
MM add	(a*x2)+(x1^c)/((a/b)+ x2)	9.858354	8.836763	6.105164	-837.655	0.215384	1683.454
MM mult	(a*x2)*x1^c)/((a/b)* x2)}	9.846031	96.27024	0.577182	-831.869	0.246935	1671.883
logistic	a+(b*x1)/1^x2	4.290982	5.339546	-	-819.444	0.310444	1644.975

Note: x1 represents previous size and x2 represents light availability.

Table 19. Summary of model functions explaining height growth, parameter values and AIC values.

model	function	a	b	c	max L	R2	AIC
power	{a*x1^b}	0.706607	1.265045	-	-131.797	0.468347	**269.6798**
linear	(a*x1)+(b*x2)	1.267397	1.00E-05	-	-143.098	0.423978	292.2832
MM add	(a*x2)+ x1^c)/((a/b)+ x2)}	1.126635	0.459248	6.646355	-194.651	0.169719	397.4455
MM mult	(a*x2)*x1^c/((a/b)* x2)	16383.78	1.266575	0.707967	-131.8	0.468339	**271.7446**
logistic	a+(b*x1)/1^x2	0.250872	0.998949	-	-132.878	0.464256	**271.8412**

Note: x1 represents previous size and x2 represents light availability.

Results show that in the case of radial growth, the best fit is attained with a power function with previous size as a predictor, and in the case of height growth, a power function is also appropriate but so is a Michealis-Menten multiplicative function and a logistic function, including both previous size and light availability as predictors.

Factors influencing understory growth

To investigate the effect of treatments and overstory density on tree size, a Generalized Linear Mixed Model (GLMM) analysis was performed on height and DBH values for different years. Note that since overstory density was not measured at all years, 1967 data is regressed against 1963 overstory, and 1993 data against 2003 overstory. Results show that overstory density is generally important, except in 2006 and for natural regeneration. Scarification is a strong predictor, but not season of establishment. 5 year-old planted trees are not affected by any factors compared to seeded trees.

Table 20. Result summary (*P*-values) for the Generalized Linear Mixed Models, where height is the dependent variable and scarification, establishment season and overstory density are fixed-effects and block is a random effect (not shown).

		Predictors		
Year	**Establishment method**	**Overstory density (st/ha)**	**Scarification**	**Season of establishment**
1967	Planted	0.1987	0.2323	0.2249
	Seeded	0.0058	0.0005	0.0208
	Natural regeneration	0.1100	0.0000	-
1993	Planted	0.0219	0.0000	0.9271
	Seeded	0.0512	0.0097	0.4120
	Natural regeneration	0.1681	0.0155	-
2003	Planted	0.0292	0.0007	0.9876
	Seeded	0.0207	0.0430	0.4316
	Natural regeneration	0.1669	0.0504	-
2006	Planted	0.2612	0.0030	0.9047
	Seeded	0.1478	0.0098	0.1394
	Natural regeneration	0.8872	0.0722	-
2009	Planted	0.0001	0.0082	0.7901
	Seeded	0.0010	0.0038	0.3188
	Natural regeneration	0.0956	0.0177	-

Table 21. Result summary (*P*-values) for the Generalized Linear Mixed Models, where DBH is the dependent variable and scarification, establishment season and overstory density are fixed-effects and block is a random effect (not shown).

		Predictors		
Year	**Establishment method**	**Overstory density (st/ha)**	**Scarification**	**Season of establishment**
2003	Planted	0.0372	0.0000	0.6788
	Seeded	0.6788	0.1411	0.5977
	Natural regeneration	0.2590	0.5291	-
2006	Planted	0.3845	0.0000	0.8103
	Seeded	0.4891	0.3419	0.1563
	Natural regeneration	0.8121	0.2130	-
2009	Planted	0.0004	0.0001	0.3829
	Seeded	0.0093	0.0631	0.3165
	Natural regeneration	0.1502	0.1019	-

Conclusion

This long-term study highlights some valuable results applicable to the science of complex stand management. First, the performance of trees established 47 years ago underneath a partial canopy of pine (shelterwood) proved to be comparable to plantations yields of clearcut sites. Shelterwoods would be a valuable system to consider for the establishment of spruce, and is more ecologically viable and socially accepted than clearcuts (Paquette et al. 2006).

Based on the study results, differences in growth between planted, seeded and naturally regenerated trees persist with time, and overall higher stand growth can be achieved when regeneration is planted in scarified microsites. Our results, in terms of spruce growth release in response to MPB-attack overstory, should be considered only preliminary as they only consider 3 years of growth post-epidemic. However, the importance of the overstory on tree growth suggests that some stands that have been attacked by the MPB will likely provide good regeneration possibilities for interior spruce by offering the shelter of a partial canopy during the early growth phase, and by ensuring a natural release that will allow spruce individuals to reach to overstory.

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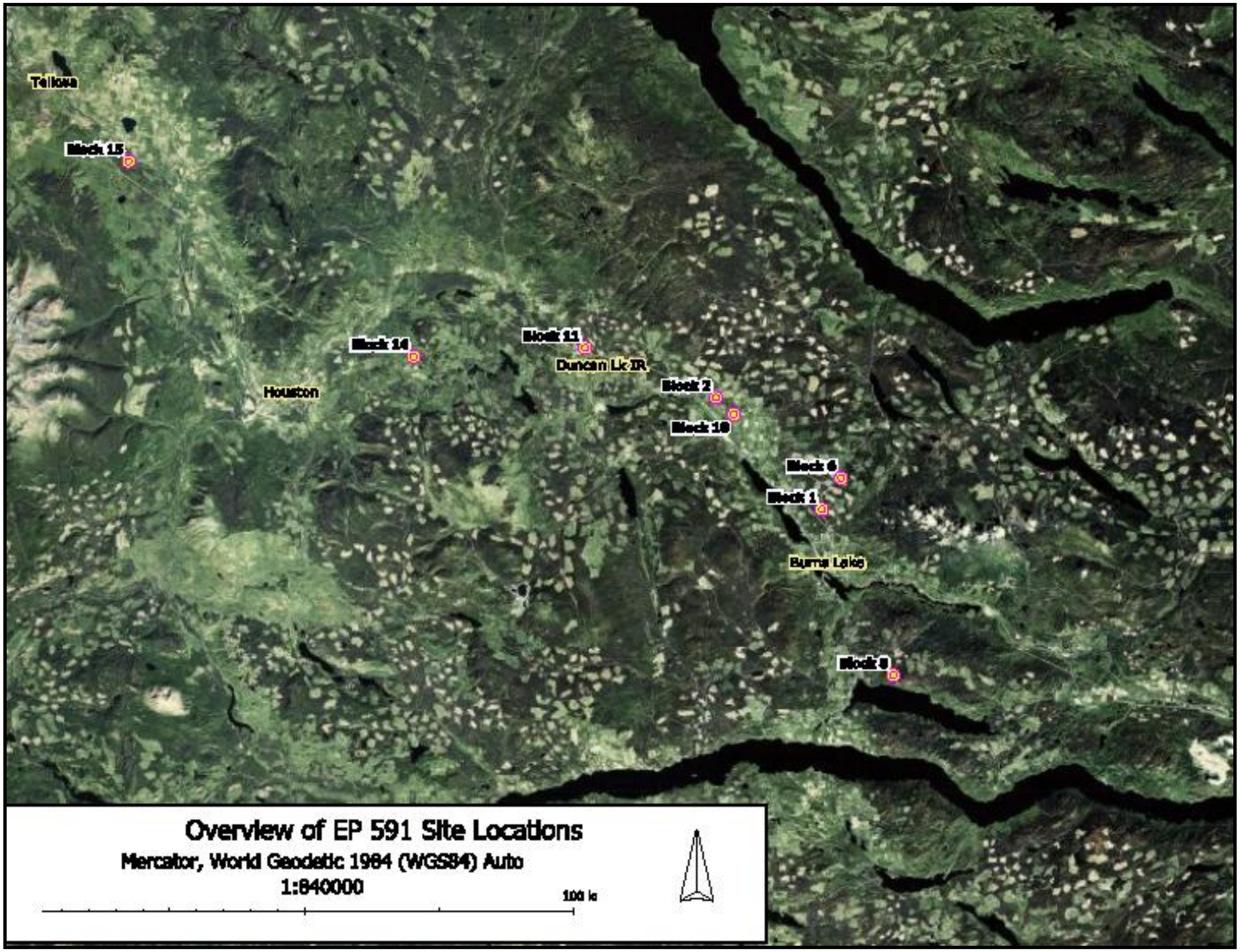
APPENDIX 1



Telkwa
Block 15
Block 14
Block 11
Duncan Lk IR
Houston
Block 2
Block 10
Block 6
Block 1
Burns Lake
Block 8
Overview of EP 591 Site Locations
Mercator, World Geodetic 1984 (WGS84) Auto
1:840000