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Abstract: The research described in this technical note looked at ways to help restore long-lived, shade tolerant species in a stand currently dominated by young, early successional gray birch and trembling aspen. The goal was to establish a uniform distribution of future seed trees that could restore late successional species more quickly over time. Openings in the canopy were created to release regenerating trees of late successional species. Where natural regeneration was lacking, large-stock red spruce and yellow birch were planted. Due to browsing concerns some of the planted trees were protected with metal mesh open-top cages. Five years after treatment, released natural red spruce and white spruce grew at rates that were statistically greater than unreleased controls. Released tolerant hardwoods also grew well, but there were no controls with which to make a comparison. Planted red spruce that were not protected with cages suffered high mortality due to browsing, while planted yellow birch protected with cages grew well with no mortality. Although released and planted trees were still well below dominant canopy height after five years, these trees have realized greater height growth than they would have if left unreleased - potentially shortening the time needed for stand transition.

Keywords: Forestry, silviculture, seed trees, restoration, late-successional species

1. Introduction

In 2013, the Department of Natural Resources and Renewables and Murray A. Reeves Forestry Ltd. established a trial in an early succession hardwood stand with the aim of restoring establishment of late successional species. In the new Nova Scotia Silvicultural Guide for the Ecological Matrix (SGEM), one of the main objectives is to restore late-successional species where they would naturally occur but are currently low in number (McGrath et al., 2021). The stand in this study was dominated by 20-year-old gray birch and trembling aspen overtopping a minor component of late successional species including sugar maple, yellow birch, white ash, red oak, red spruce, and white spruce. The presence of these late successional species provided a glimpse of what the stand might have been prior to harvest, and its future potential if currently suppressed trees survive to seed bearing age. However, the stand was beyond the stage when traditional weeding or pre-commercial thinning could be used to influence stand development, and trees were too small for commercial thinning.

1.1. Objective

To restore late successional species that would naturally occur on this site by establishing a uniform distribution of future seed trees that would enable the stand to transition more quickly over time through natural regeneration.

1.2. Site

The trial stand was an early successional intolerant hardwood type growing on rich, fresh to moist soil (Neily et al., 2013) (Table 1). At time of treatment in 2013, the stand was approximately 20 years-old with a dominant canopy height of 10 m. The location of the trial is in Forties, Nova Scotia (Figure 1).

Table 1. Site description at time of treatment.

Age: 20 years
Dominant Canopy Height: 10 m
Vegetation Type: IH5 Trembling aspen-white ash/Beaked hazelnut/Christmas fern
Soil Type: ST8/ST9 Rich, fresh to moist - medium to coarse textured soils
Ecosite: AC13/AC14 Fresh-Rich / Sugar maple - Beech Moist-Rich / Sugar maple - Yellow birch
Species Composition: Gray birch 30%, Trembling aspen 28%, Balsam fir 15%, Red maple 11%, White birch 10%, Pin cherry and Choke cherry 3%, White spruce 2%, Sugar maple 1%, Eastern larch 1%

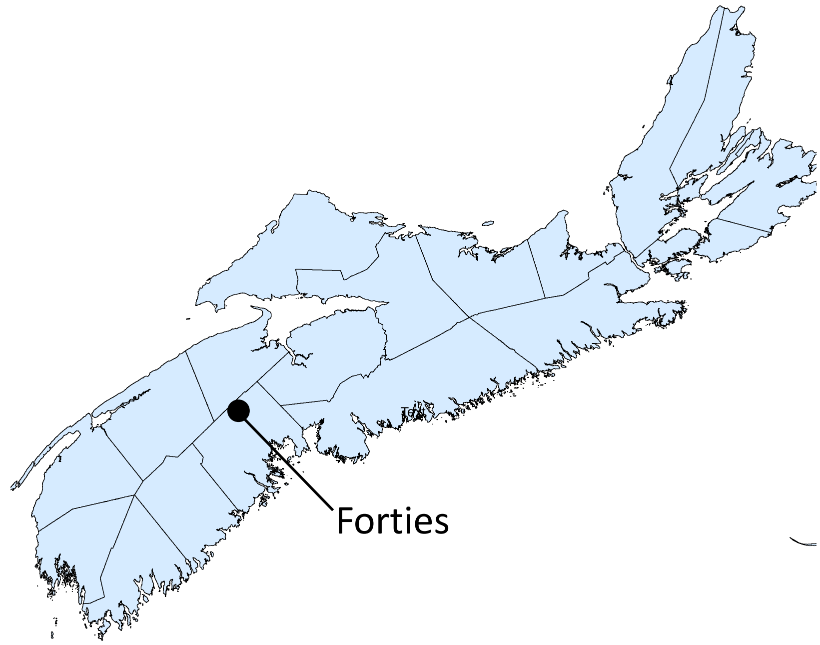


Fig. 1. The location of the trial in Nova Scotia.

2. Methods

The trial area of approximately 7.5 ha was subdivided into a grid containing 269 blocks, each 15m x 15m in size. The goal was for each block to contain a late successional tree species that could serve as a future seed tree. Within each block the best tree for release was identified. If no suitable tree existed, that block was identified as a potential planting site. If a dominant or co-dominant tree of a desired species already occupied a block, then no release was deemed necessary as survival to seed bearing age was already likely.

In total, 54 trees were released by cutting all competing trees whose crowns were within a 3 m radius. Forty-seven (47) of these released trees were classed as suppressed, while the other seven (7) were larger and best described as crop tree release size. A paired control, which was an unreleased tree of similar size, was identified for all released spruce trees (Table 2). However, due to low numbers, only larger crop tree sized hardwoods could be matched with unreleased controls (Table 2).

Table 2. Number of trees released or planted.

Natural Regeneration – Suppressed

Species	Released	Control
White spruce	29	29
Red spruce	12	12
Yellow birch	1	0
Sugar maple	1	0
White ash	4	0
Total	47	41

Natural Regeneration – Crop Tree Release

Species	Released	Control
Yellow birch	1	2
Sugar maple	2	2
White ash	1	1
Red oak	3	2
Total	7	7

Planted in Natural Openings

Species	Caged	Uncaged
Red spruce	2	26
Yellow birch	6	0
Total	8	26

Thirty-four (34) trees (28 red spruce and 6 yellow birch) were planted in blocks with natural openings and no potential release trees. Large planting stock was used to provide the greatest chance of survival (red spruce = 52 cm tall, yellow birch = 66 cm tall). Metal mesh open-top cages approximately 1.5 m tall were installed around two (2) red spruce and all yellow birch to prevent browsing (Table 2).

Two-sample *t*-tests were used to test for significant differences in diameter and height increments for naturally regenerating red spruce and white spruce. Sample sizes were not sufficient to statistically test tolerant hardwoods or surviving planted trees.

3. Results

3.1. Released Red Spruce

Over the five-year period after treatment, released red spruce grew in height at a rate of 29 cm/year (standard deviation SD 18 cm/yr) and unreleased controls at 8 cm/year (SD 5 cm/yr). Starting from approximately the same height, released red spruce were on average 4.3 m tall and the controls 3.4 m five years after treatment (Figure 2a). In terms of diameter, released red spruce grew at a rate of 0.5 cm/year (SD 0.2 cm/yr) and the controls 0.2 cm/year (SD 0.1 cm/yr). Starting from approximately the same diameter, released red spruce were on average 5.2 cm in diameter and the controls 3.8 cm five years after treatment (Figure 2b). One released red spruce died due to snow press and browsing. Differences in growth were statistically significant at $\alpha = 0.05$ for both diameter ($p < 0.001$) and height ($p = 0.03$) increment.

3.2. Released White Spruce

Over the five-year period after treatment, released white spruce grew in height at a rate of 21 cm/year (SD 9 cm/yr) and unreleased controls at 11 cm/year (SD 7 cm/yr). Starting from approximately the same height, released white spruce were on average 4.3 m tall and the controls 3.7 m five years after treatment (Figure 2c). In terms of diameter, released white spruce grew at a rate of 0.4 cm/year (SD 0.1 cm/yr) and the controls 0.2 cm/year (SD 0.1 cm/yr). Starting from approximately the same diameter, released white spruce were on average 5.9 cm and the controls 4.7 cm five years after treatment (Figure 2d). Figure 3 shows a released white spruce and a control white spruce in year one and again in year five. Differences in white spruce growth were statistically significant at $\alpha = 0.05$ for both diameter ($p < 0.001$) and height ($p < 0.001$) increment.

3.3. Released Tolerant Hardwood

Over the five-year period after treatment, suppressed tolerant hardwoods that were released grew in height at a rate of 38 cm/year (SD 26 cm/yr) and were on average 6.7 m tall at the end of the 5 years (Figure 2e). In terms of diameter, growth rate was 0.5 cm/year (SD 0.1 cm/yr) with an average diameter of 4.8 cm at the end of 5 years (Figure 2f). One released white ash died due to snow press and browsing. For crop tree size hardwoods, released trees grew in diameter at a rate of 0.9 cm/year (SD 0.3 cm/yr) and the controls 0.5 cm/year (SD 0.3 cm/yr) (Figure 2g).

3.4. Planted Yellow Birch

All planted yellow birch were protected with cages and all survived (Figure 4a). Over the five-year period after planting, height growth was on average 42 cm/year (SD 25 cm/yr) and trees were on average 2.8 m tall at the end of five years (Figure 4b).

3.5. Planted Red Spruce

All planted red spruce that were not protected with cages suffered severe browsing damage, with 81% mortality and essentially no growth on surviving trees (Figures 4cd). The two trees that were protected grew in height at a rate of 10 cm/year (SD 1 cm/yr) and were 1.1 m tall five years after planting (Figure 4d). Figure 5 shows a planted red spruce that was protected with a cage and one that was not.

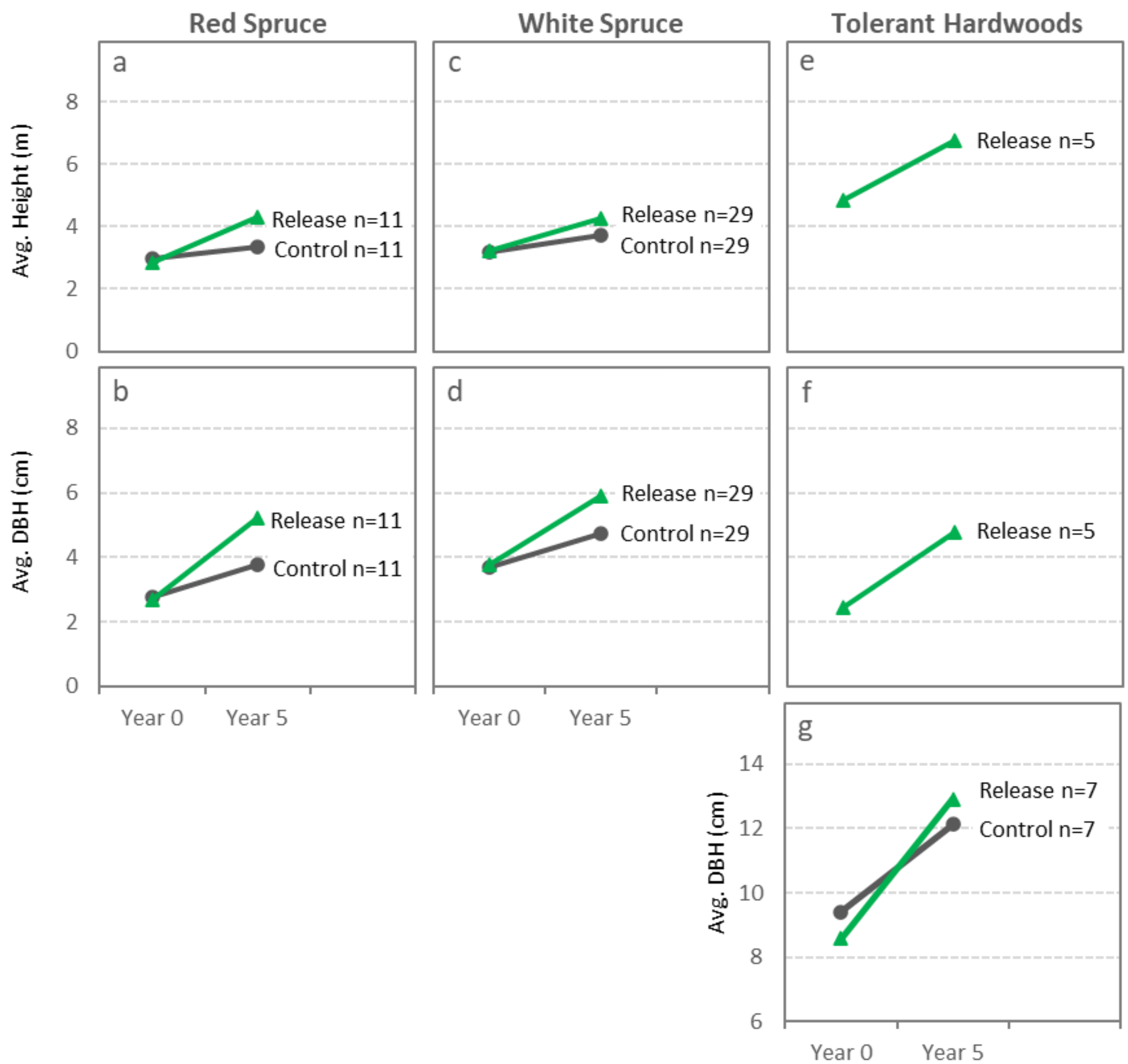
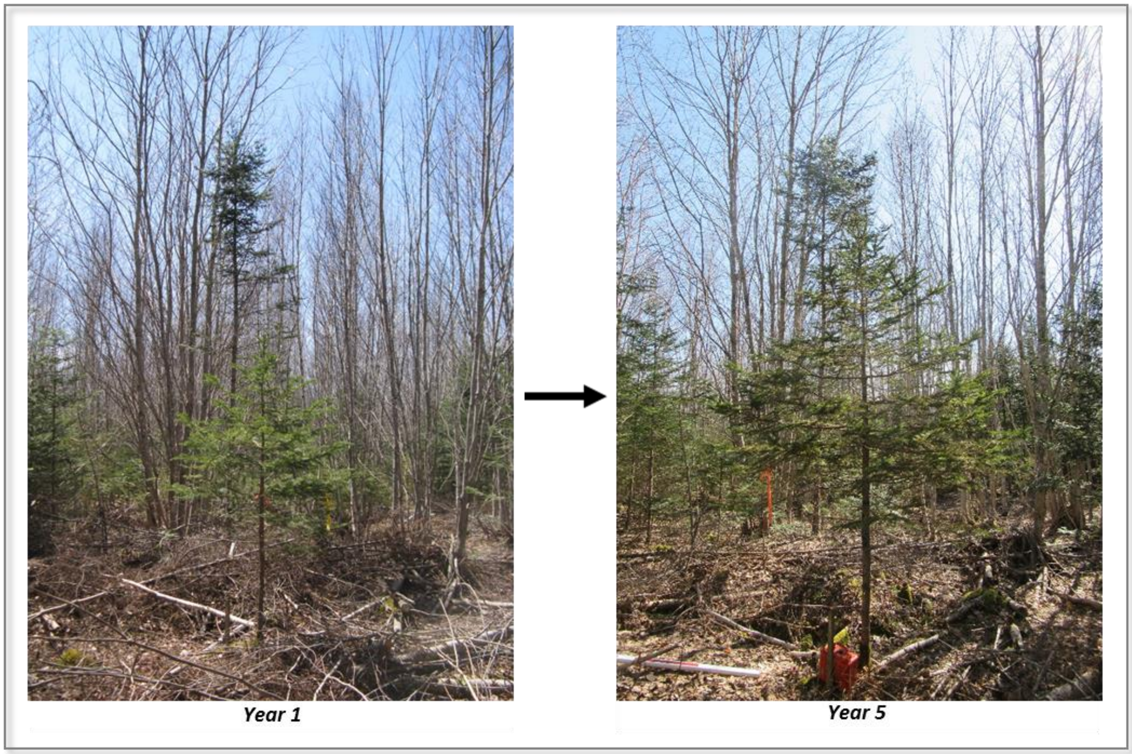


Fig. 2. The average height and diameter of released and control trees before treatment and five years after treatment (n=sample size).

Released - Tree 18 - Natural White Spruce



Control - Tree 191 - Natural White Spruce

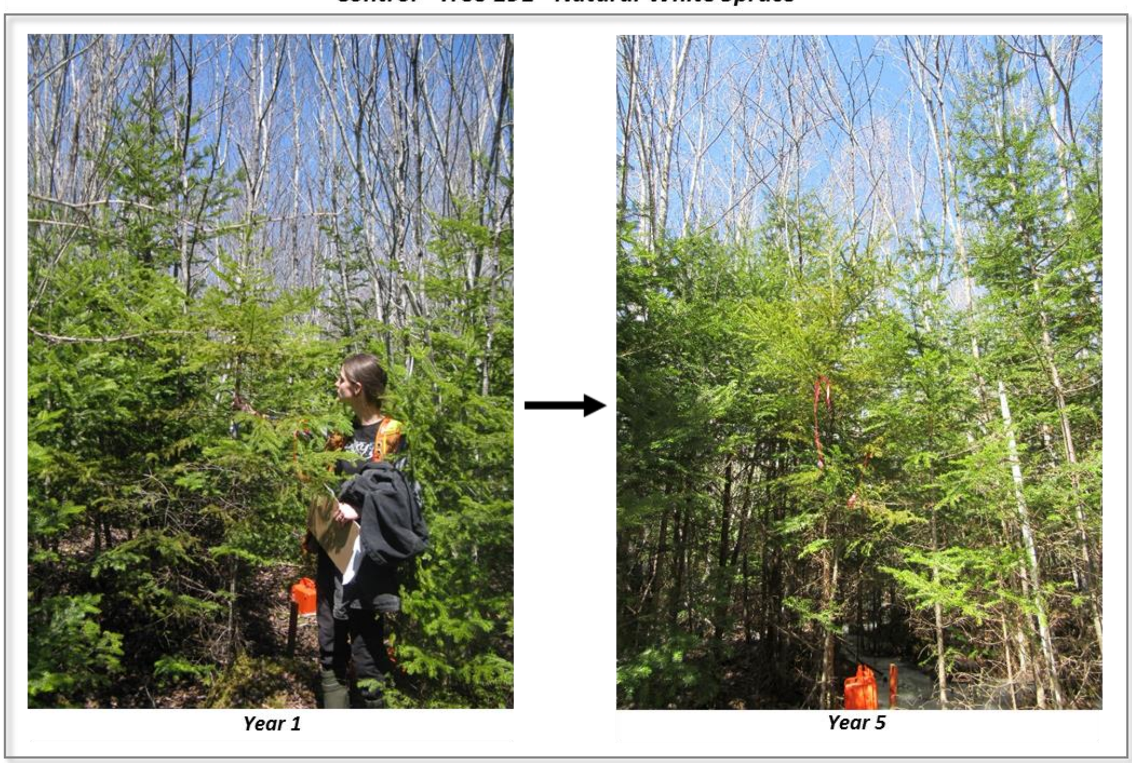


Fig. 3. A released white spruce tree (tree 18) and a control white spruce tree (tree 191) in year 1 and again in year 5.

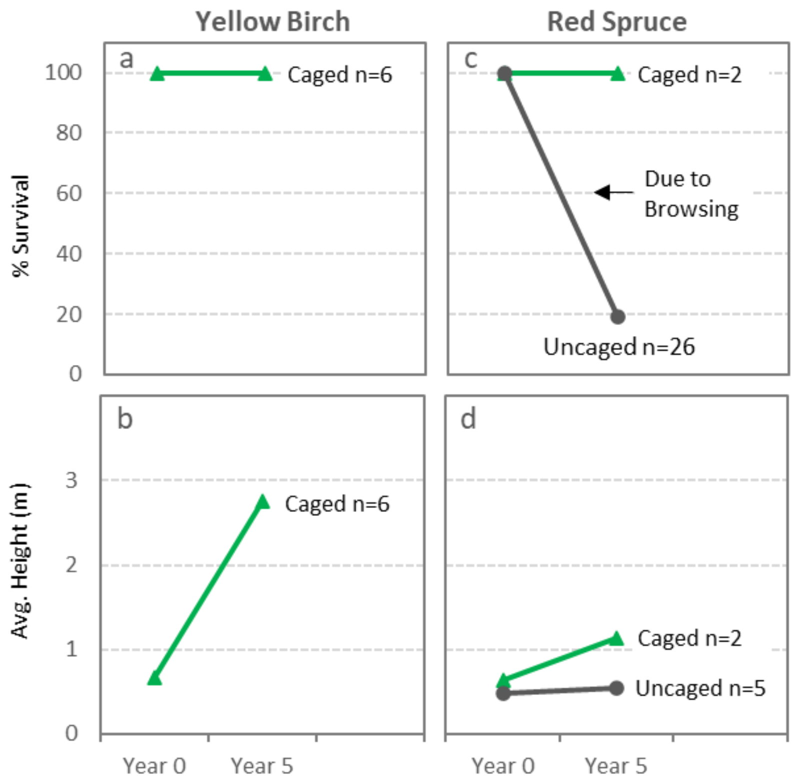


Fig. 4. Survival and average height of planted yellow birch and planted red spruce at time of planting and five years later (n=sample size).

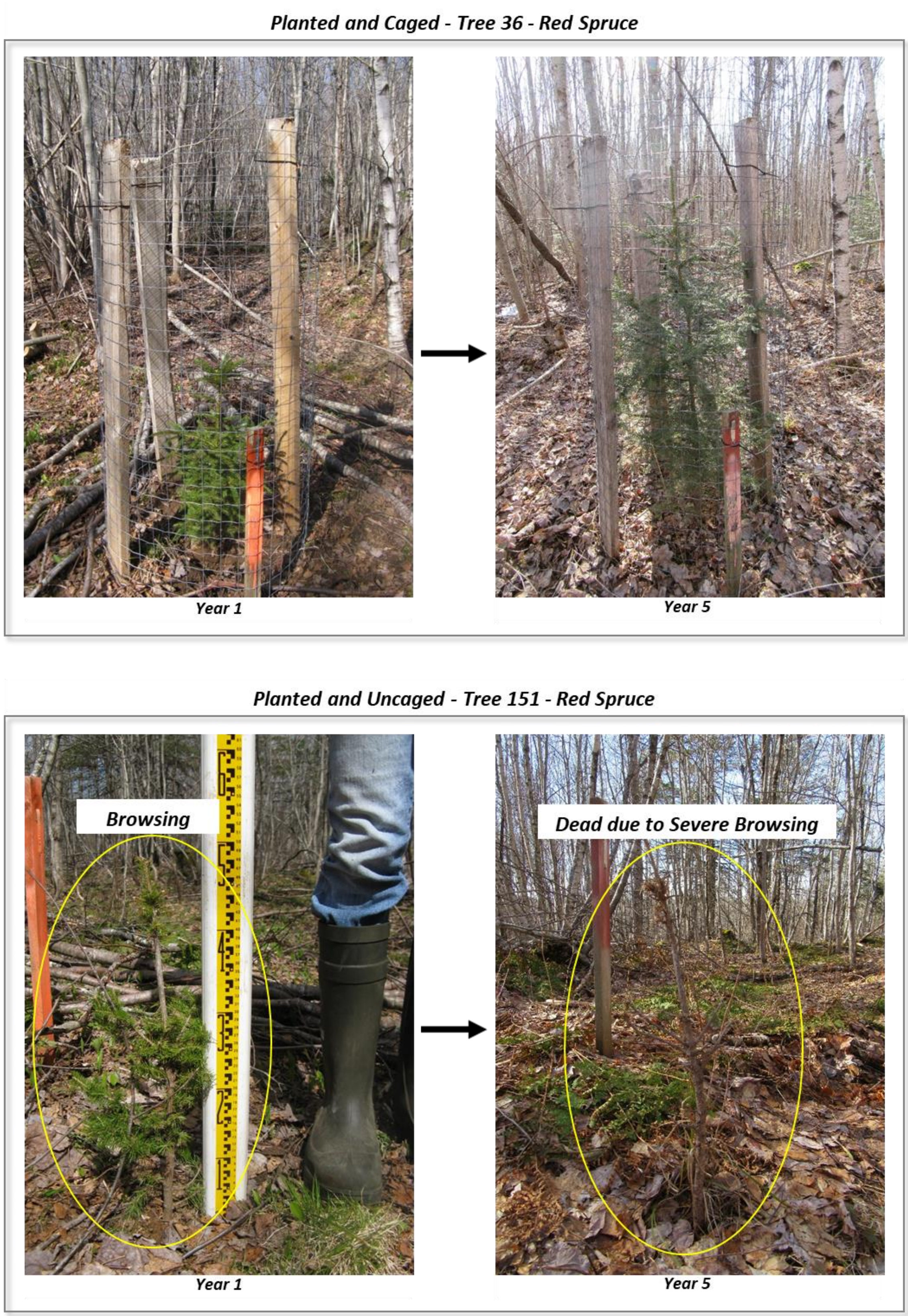


Fig. 5. A planted and caged red spruce (tree 36) and a planted and uncaged red spruce (tree 151) in year 1 and again in year 5.

3.6. Crown Closure

Table 3 shows the percent crown closure by treatment over time. This measurement encompassed a 2-m radius directly above the target tree and is intended to quantify overhead competition. The higher the number the more overhead competition and therefore less available light. There was minimal competition directly above released natural regeneration one year following treatment (13%); however, by year 5, the crowns of competing trees started to encroach (41%). Thirty-four (34) trees were planted in natural openings with an average crown closure of 65%. After five years, the average crown closure over planted trees was 86%.

Table 3. Percent crown closure by treatment.

Natural Regeneration

Treatment	Pre-Treatment	Year 1	Year 5
Control	94%	94%	94%
Released	95%	13%	41%

Planted in Natural Openings

Treatment	Pre-Treatment	Year 1	Year 5
Planted	65%	65%	86%

4. Discussion

The objective of this trial was to explore different options to restore late successional species in a stand dominated by 20-year-old gray birch and trembling aspen. The goal was to establish a uniform distribution of future seed trees that would enable the stand to transition more quickly.

One option that was explored was planting red spruce, but unfortunately there was high mortality (81%) due to browsing. Therefore, using planted stock to transition a stand at this stage of maturity (~20 years old) is probably not advisable.

Another option that was explored was planting red spruce and yellow birch protected with metal open top cages. Planted stock thrived using this method; however, on a large scale this option is likely not feasible as cages are costly and cumbersome to establish in a forest setting.

Another option that was explored was the release of naturally established late successional species. Red spruce, white spruce, white ash, sugar maple, and yellow birch were released after being suppressed for up to 20 years under a canopy of gray birch and trembling aspen. Despite being suppressed for so long, these trees responded well, and height growth doubled or tripled in some cases compared to controls. Five years after treatment, the average height of released natural red spruce (4.3 m), white spruce (4.3 m), and tolerant hardwoods (6.7 m) were still below canopy height (11 m) but were in a better position than they had been five years earlier. It is likely that an additional release will be necessary to ensure these future seed trees achieve a competitive position within the canopy. Despite the success of release treatments, it will still take decades to produce any significant transition in these young, early successional stands.

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