Notice of intention to publish

We intend to publish the results described in this report in refereed journals. Therefore we request that the FII or the Province not post this report on the Internet for 12 months after the end-date of the project.

Analysis and extension of results on nursery and site preparation treatments, and their effects on field growth performance of interior lodgepole pine seedlings (R2003-0189)

Annual Operational Report

Submitted by:
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Project title: Analysis and extension of results on nursery and site preparation treatments, and their effects on field growth performance of interior lodgepole pine seedlings

Reference No: R2003-0189

Abstract

In this project we completed the final analysis of two studies in which (i) lodgepole pine seedlings were produced in Styroblocks™, Copperblocks™, or AirBlocks™, inoculated or not with one of two ectomycorrhizal fungi, and planted under different site preparation treatments, including landing rehabilitation treatments; and (ii) the hydraulic conductivities of Douglas-fir colonized to differing extents by ectomycorrhizal fungi were compared in the field. We have revised a previously-submitted extension paper, written three manuscripts for peer-reviewed internationally-respected journals, and given two presentations at the Winter SISCO and one at the annual meeting of the Ministry of Forests soil science researchers. Our major conclusions are (i) that the productivity of landings can be increased to higher than that of surrounding cutblocks by incorporating burn-pile debris and topsoil into the landing; (ii) inoculation effects were inconsistent but, in some cases, resulted in increased seedling growth in the nursery and higher absolute growth rates in the field; (iii) growing seedlings in AirBlocks™ requires extra irrigation in the nursery in order to produce seedlings of equivalent size to conventional Styrofoam block types; (iv) Copperblock™ seedlings tended to be larger in the nursery and, thus, had higher absolute growth rates in the field; AirBlock™ seedlings had highest relative growth rates; (v) hydraulic conductivity of Douglas-fir root systems was influenced by the community of ectomycorrhizal fungi present on the root system.

Keywords: lodgepole pine, nursery, container types, landing rehabilitation, mycorrhizae, inoculation, forest floor planting, screefing, water relations, Douglas-fir

Detailed summary of activities, results and outputs completed during the year in relation to the workplan

This section is organized around the project objectives and the outputs associated with each objective. After consultation with FII, the project objectives were modified slightly from those in the original proposal, to those listed below.

Objective 1. Enter and analyze the data on root system architecture, hydraulic conductivity and mycorrhizal status.

This has been completed and the results incorporated into the resulting manuscripts. The root system architecture data are found in Table 3 of the *New Forests* manuscript and in Table 2 of the *Canadian Journal of Forest Research* manuscript. The hydraulic conductivity data are found in Figures 1 to 3 in the *Tree Physiology* manuscript. The mycorrhizal data are presented in Figures 4 to 7 of the *New Forests* manuscript, in Figures 3 to 6 in the *Canadian Journal of Forest Research* manuscript, and in Table 1 and Figures 1 to 3 of the *Tree Physiology* manuscript.

Objective 2. Correlate the above with respect to field growth performance data and stock quality assessment data.

This has been completed and presented in the *New Forests* and *Canadian Journal of Forest Research* manuscripts. In brief, we found that:

- when tested at lifting, more roots emerged from the upper portions of Copperblock™ and AirBlock™ plugs than Styroblock™ plugs. Surprisingly, this was not as obvious in the field;
- although colonization rates did not significantly affect either root hydraulic conductance or root hydraulic conductivity, increased ectomycorrhizal richness and diversity correlated with a decrease in root hydraulic conductivity and increased ectomycorrhizal evenness correlated with an increase in root hydraulic conductivity;

- seedlings planted in the cutblock exhibited higher ectomycorrhizal colonization and richness than seedlings planted on landings, even when the landings were rehabilitated; seedling growth was highest on fully rehabilitated landings;
- seedlings planted into the forest floor produced more new emergent roots, more new root growth from the top portion of the root plug and were colonized by ectomycorrhizal fungi to a greater extent than seedlings planted into screefed planting spots; seedlings planted into screefed spots were marginally larger.

Objective 3. Publish the extension document on above-ground response already submitted to the BC Journal of Ecosystems and Management.

This manuscript was revised according to the comments of the referees and returned to the journal. We have paid the publication charges and expect to see the proofs shortly.

Objective 4. Write three papers on the above-ground and below-ground results of the study and submit them to peer-reviewed international journals: one on the spring-plant pine grown in different container types with or without mycorrhizal inoculum and grown on cutblocks and landings with different types of rehabilitation in southern BC, including soils data on landing rehabilitation treatments; one on the summer-plant pine grown in different container types with or without mycorrhizal inoculum and planted on spot-screefed or unscreefed sites in northern BC; and one on the hydraulic conductivity, photosynthesis and respiration of Douglas-fir seedlings during the first year after outplanting and how this was affected by mycorrhizal colonization.

We have completed these three manuscripts. They are attached to this report.

Objective 5. Present the results at the winter SISCO 2003.

Two presentations were made in the poster session of SISCO on the evening of March 10th. In addition, the results of this study were presented at the annual meeting of the soil

scientists of the Ministry of Forests and at the meeting of the Association of BC Professional Foresters.

Evaluation of project outcomes

The outcomes of this project are a poster presentation and four manuscripts: one that will be published in the *BC Journal of Ecosystems and Management* (JEM), the extension journal published by FORREX, and three that will be published in internationally respected, peer-reviewed journals. The titles, journals and abstracts are reproduced below and the manuscripts are attached to this report. The file of the poster is also attached.

The measurable indicators of the success of the project in achieving the desired objectives are that five written documents have been produced, which publicize the results of the research project to the whole spectrum of interested parties. When we consulted with the industrial partners who facilitated the original research, they unanimously requested that we present the results at the winter SISCO. They said that this would be more useful that workshops at their places of work or at OUC. We have done that.

The long-term success of the project will depend on whether the research results are widely read. We have increased our chances of success in this regard by selecting the most appropriate venues for publication. One of the manuscripts is due to be published in BCJEM, an electronic and print publication, which is distributed widely amongst operational foresters, Ministry of Forests district staff, and researchers with the Ministry, universities and colleges. Announcements of upcoming articles are distributed by email so these results are widely known amongst the forestry community in BC. We also selected appropriate journals to reach a national and international audience and to provide this research with the credibility that comes with peer review. *New Forests* is a journal dedicated to research on the production and establishment of tree seedlings; the *Canadian Journal of Forest Research* is a highly regarded journal covering a wide range of topics in forest biology and forestry, and *Tree Physiology* is widely respected for publishing

research on the physiology of trees. By publishing in these four journals, we expect our results to reach most potential end-users.

Manuscript 1. *British Columbia Journal of Ecosystems and Management* – above-ground results

Two year field performance of lodgepole pine seedlings: Effects of container type, mycorrhizal fungal inoculants, and site preparation treatments.

D. Bruce Campbell, Melanie D. Jones, Steven Kiiskila, Chuck Bulmer

Interior lodgepole pine (*Pinus contorta* var. *latifolia*) seedlings were grown in Styroblocks™, Copperblocks™, or Airblocks™, and inoculated with *Rhizopogon rubescens, Hebeloma longicaudum,* or left as non-inoculated controls. Seedlings were planted into different rooting environments in two separate locations, encompassing two separate experiments. In experiment one, seedlings were planted into fully rehabilitated (burn-pile debris and topsoil incorporated) landings, ripped landings, and unprepared cutblocks in the spring. In experiment two, seedlings were planted in a cutblock in manually (i.e. boot) screefed planting sites or undisturbed forest floor planting sites in the summer. Growth performance, as measured by seedling height and diameter, and assessment of seedling vigour, was assessed after two field seasons for both experiments. Differences in rooting environments elicited significant differences in seedling growth over the initial two summers following planting. Seedlings in ripped landings that received topsoil and burn-pile debris were 21% taller, had 45% larger diameters, and were more vigourous than seedlings in landings that were simply ripped; seedlings planted in the adjacent cutblock were taller, but with a smaller diameter, than those on the rehabilitated landings. Seedlings in screefed microsites grew significantly larger (5%) than seedlings planted directly in the forest floor. Spring-planted seedlings grown in Copperblocks™, were at least 13% larger than seedlings from other container types and had higher growth increments, but summer-planted seedlings produced in Copperblocks™ and Styroblocks™ were similar in size. After two years in the field, the

sizes of spring-planted, non-inoculated seedlings and seedlings inoculated with ectomycorrhizal fungi were not significantly different. Inoculated summer-planted seedlings were approximately 5% larger than non-inoculated control seedlings, but this seemed to be only a carry-over of size differences in the stock at the time of planting. Amongst the variables we manipulated, planting environment had the greatest influence on seedling growth. In particular, incorporation of burn-pile debris and recovered topsoil into landings was an effective method of increasing early performance of seedlings planted on landings. Based on early growth results, these trials suggest no benefit to the use of Airblock™ containers over Styroblock™ containers for the production of interior lodgepole pine, and it is too early to know whether they will influence future tree stability. Results presented here build upon those previously reported by Jones *et. al.* 2002b (JEM: 2/1: art5), and represent the second portion of a two part study.

Manuscript 2. *Canadian Journal of Forest Research* – spring-plant results

Two-year field growth of (1+0) *Pinus contorta* var. *latifolia* seedlings planted on rehabilitated landings, tilled landings, or cutblocks

Campbell, D.B., Bulmer, C.E., Philip, L.J., Zwiazek, J.J., Jones, Melanie D.

Rehabilitation of all landings and temporary roads, is now required in British Columbia; however, little is known regarding practical methods to return landings to productive forest using materials found on site. Interior lodgepole pine (*Pinus contorta* var. *latifolia*) seedlings were planted into fully rehabilitated landings (burn-pile debris and topsoil incorporated), tilled landings, and unprepared portions of the adjacent cutblock. Seedlings were grown in Styroblocks™, Copperblocks™, or Airblocks™, and inoculated with *Rhizopogon rubescens* Tul., *Hebeloma longicaudum* (Pers.:Fr.) Kumm., or left as non-inoculated controls. After two seasons of field growth, seedlings planted on fully rehabilitated landings were larger, more vigorous, and exhibited greater growth

rates than seedlings planted either on tilled landings or seedlings planted in the adjacent cutblock. Seedlings planted in the cutblock exhibited higher ectomycorrhizal colonization rates, as well as greater ectomycorrhizal richness. Copperblock™ seedlings were larger at planting and continued to exhibit greater absolute growth, while Airblock™ seedlings exhibited the highest relative growth rates. Inoculation with ectomycorrhizal fungi did not affect seedling field growth; however, control seedlings and seedlings inoculated with *Hebeloma* were more heavily colonized with all kinds of ectomycorrhizal fungi after two years in the field. Our results indicate that landing rehabilitation, through the incorporation of recovered topsoil and burn-pile debris via mechanical ripping, provides an adequate rooting environment for successful reforestation.

Manuscript 3. *New Forests* – summer-plant results

Forest floor planting of *Pinus contorta* var. *latifolia* seedlings in a high-elevation site (ESSF) in north-central British Columbia

D. Bruce Campbell, Steven Kiiskila, Leanne J. Philip, Janusz J. Zwiazek, Melanie D. Jones

A two-year field trial was conducted to determine the growth response and mycorrhizal status of 1+0 interior lodgepole pine (*Pinus controrta* var. *latifolia*) seedlings planted into manually screefed planting spots or directly into the forest floor in a high-elevation cutblock located in the Engelmann Spruce Subalpine Fir biogeoclimatic zone of north-central British Columbia. Seedlings were grown in Styroblocks™, Copperblocks™, or Airblocks™, and inoculated with *Rhizopogon rubescens*, *Hebeloma longicaudum*, or left as non-inoculated controls. After two seasons field growth, seedlings planted into manually screefed planting spots exhibited marginally greater growth rates. Seedlings planted into the forest floor produced more new emergent roots, and more new root growth from the top portion of the root plug. Additionally, forest-floor-planted seedlings were colonized by ectomycorrhizal fungi to a greater extent than seedlings planted into screefed planting spots. Airblock™ seedlings exhibited the greatest relative growth rates,

while Copperblock™ seedlings exhibited the greatest absolute growth rates during the second growing season in the field. Inoculation of seedlings with either mycorrhizal fungus resulted in a significant increase in seedling volume in the nursery with the size differences maintained over two seasons of growth in the field.

Manuscript 4. *Tree Physiology* – field hydraulic conductivity measurements

The effect of ectomycorrhizal community structure on root hydraulic conductivity in outplanted *Pseudotsuga menziesii* var. *glauca* seedlings

Campbell, D.B., Jones, M.D., Philip, L.J., Zwiazek, J.J.

Interior Douglas fir (*Pseudotsuga menziesii* var. *glauca*) seedlings were outplanted on a small cutblock to examine the effects of ectomycorrhizal colonization and community structure on root hydraulic conductivity. Colonization rates did not significantly affect either root hydraulic conductance or root hydraulic conductivity. Increased ectomycorrhizal richness and diversity coincided with a decrease in root hydraulic conductivity. Increased ectomycorrhizal evenness corresponded with an increase in root hydraulic conductivity. This is the first time that aspects of ectomycorrhizal community structure have been analyzed with respect to their potential affects upon root hydraulic conductivity.

Assessment of the applicability of research results and contribution to a knowledge gap

The end users of these results are nursery operators, silviculturists and policy makers. Our results are the first independent comparisons of the three kinds of container types, including the new AirBlocks™. We also evaluate two commercially-available ectomycorrhizal fungal inocula. Our results will allow nursery operators to be more knowledgable in advising their customers about the correct stock types to order and

whether the additional costs of inoculation are worthwhile. From our results, silviculturists can learn about the relative growth of the various stock types as well as valuable information about landing rehabilitation and forest floor planting. This information is valuable in terms of reaching green-up as quickly as possible. Policy makers will also be interested to know that incorporating topsoil and burn-pile debris into ripped landings increases their productivities to levels even higher than those of adjacent cutblocks.

Key operational variances

All the publications and presentations have been completed as planned. We made two additional presentations that were not scheduled in the original workplan: one to the Ministry of Forests soil scientists annual meeting and one to the Association of BC Professional Foresters. The manuscripts will be submitted once we receive comments back from the co-authors. We do not expect these to involve major changes.