Forestry Research

FINAL OPERATIONAL REPORT

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Organization: Forest Sciences, UBC
Project title: Long-term effects of silvicultural treatments on productivity, biodiversity and ecosystem function in ericaceous-dominated sites in coastal BC
Reference No: R02-13

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1. Abstract

The goals of SCHIRP research this year were to study our existing silvicultural field trials to assess long-term gains in productivity arising from a variety of silvicultural treatments, to increase our understanding of the biological bases for the responses, and to assess the impacts of typical silvicultural treatments on biodiversity of soil organisms and vegetation. These factors were addressed in a coordinated, integrated, multidisciplinary research program involving partners from industry, government and academia. Recent trial re-measurements have indicated that fertilization may cause a long-term improvement in productivity of these sites, and that this hinges on the application of P along with N. This information assists in developing recommendations for best management practices on these sites and prediction of rotation-length improvements in wood supply as a result of silvicultural intervention. The stand development project is proceeding as planned, and the student now has the data needed to write the thesis. The belowground ecology research continues to provide us new insights into these organisms and their interactions. We have been successful in communicating our research results to foresters and scientists; extension activities this year included: SCHIRP workshop and field tours, SCHIRP Update #2 extension report, SCHIRP non-timber forest products newsletter, Stand Establishment Decision Aid, 4 conference presentations, 2 published journal papers, 4 papers accepted for publication, and 5 papers submitted for publication.

2. Keywords

Silviculture, forest fertilization, nutrition, salal, *Vaccinium*, foliar response, mycorrhizae, productivity, adaptive management, biodiversity, ecology, ecosystem function, *Ericaceae*, hemlock, fertility, site potential, yield, forest nutrition, nutrient cycling

3. Detailed summary of activities, results and outputs

SCHIRP research in the past year was centered upon three major objectives:

1. Continued monitoring of existing trials to assess tree growth responses and establish the optimum silvicultural treatments for CH and other ericaceous sites
2. Assessment of changes in crown closure, salal biomass, nutrient cycling rates and communities of soil organisms associated the silvicultural treatments
3. Extension of findings to forest practicioners and scientists.

These intensive studies will allow us to

1) understand the ecological basis of the tree response
2) determine if there appears to have been a long-term change in site productivity in response to treatments
3) assess the effects of the treatments on biodiversity of key ecosystem components.

The workplan for this study was submitted as follows:

Quarter	Task Activity
1	1. Prepare and submit year-end (2001-2002) report

Apr. - June	2. Organize and conduct the SCHIRP workshop and field tour 3. Publish SCHIRP extension document (SCHIRP Update #2) 4. Distribute (in conjunction with CFS) SCHIRP Update #2 5. Continue analyzing data from the three Plot Fertilization Trials 6. Continue analyzing data from the Organic Fertilization Trials 7. Prepare for field and laboratory work (high elevation trial) 8. Mycorrhizae collection trip to Vancouver Island 9. Train new personnel in morphological study of mycorrhizae 10. Morphological characterization of mycorrhizae 11. Sample tree selection for crown study 12. Neighborhood quantification at SCHIRP Installation 13. Complete RISA analysis of soil bacteria and fungi 14. PLFA analyses of soil microbial communities
2 **July - Sep.**	15. Incorporate Plot Fertilization Trial data into database 16. Incorporate Organic Fertilization Trial data into database 17. Begin preparing Plot Fertilization manuscript 18. Begin preparing Organic Fertilization Trials manuscript/note 19. Update and improve the SCHIRP website 20. Remeasure trees in the high elevation trial 21. Collect soils in high elevation trial for incubations 22. Mycorrhizae collection trip to Vancouver Island 23. Morphological identification of fungal fruiting bodies from fertilized and unfertilized plots. 24. Culture fungi from mycorrhizae. 25. Characterize mycorrhizae with DNA extraction from mycorrhizae 26. Ceptometer assessment of light levels in SCHIRP Installation 27. Salal clip plot measurement (SCHIRP Installation) 28. Root sampling (SCHIRP Installation) 29. Hemispheric photography for crown study (SCHIRP Installation) 30. Begin data analysis of DGGE, RISA, PLFA analyses of soil bacteria and fungi 31. Present soil microbe findings at the Ecological Society of America meeting 32. Sample soil from SCHIRP Installation for soil microbe study 33. Begin laboratory analyses of soils from SCHIRP Installation
3 **Oct. - Dec.**	34. Prepare and submit six-month report 35. Prepare Salal Fertilization Trial manuscript 36. Remeasure the SCHIRP Installation 37. Conduct foliar sampling (SCHIRP Installation) 38. Organize and check data from SCHIRP Installation remeasurements and foliage sampling 39. Carry out high elevation trial soil incubations 40. Continue morphological identification of fungal fruiting bodies 41. Continue culturing fungi from mycorrhizae 42. Continue characterizing mycorrhizae with DNA 43. Fell crown study sample trees for detailed biomass and leaf area determination 44. Conduct DGGE and RISA analysis for SCHIRP Installation

	45. Measure respiration, biomass, and PLFAs of soil microbes (SCHIRP Installation) 46. Begin writing thesis (soil microbes) 47. Begin root exudate trial 48. Collect forest floors and salal root exudates 49. Begin bioassay of salal root exudate effect on germination, conifer growth, N mineralization
4 **Jan. – Mar.**	50. Incorporate data from SCHIRP Installation remeasurements into database 51. Complete Plot Fertilization manuscript 52. Complete Organic Fertilization Trials manuscript 53. Prepare fertilization-at-planting manuscript 54. Organize and conduct SCHIRP annual meeting 55. Forward SCHIRP Installation data to data manager at UBC 56. Complete soil incubations from high elevation trial 57. Conduct chemical analyses of soils from high elevation trials 58. Continue morphological identification of fungal fruiting bodies 59. Continue culturing fungi from mycorrhizae 60. Continue characterizing mycorrhizae with DNA 61. Finish crown study sample tree analysis 62. Conduct analysis of tissue and soil from SCHIRP Installation 63. Begin statistical analysis crown study data 64. Complete laboratory analysis of soil microbes (SCHIRP Installation) 65. Conduct data analysis for the soil microbes (SCHIRP Installation) 66. Complete thesis (soil microbes) 67. Prepare manuscript (soil microbes) 68. Participate in SCHIRP annual meeting 69. Determine salal root exudate effect on microbial function, diversity, and community 70. Characterize salal root exudates (HPLC and GCMS)

***Objective 1:* Continued monitoring of productivity response to silvicultural treatments.**

Continued monitoring of the SCHIRP silvicultural trials allows us to determine the duration of response to silvicultural treatments hence the rotation-length benefits. The long-term effects on productivity are necessary to allow decision-making on the economic advantages of silvicultural investments on these problem sites. The silvicultural trials established as part of the SCHIRP program, and the schedule for re-measurement is shown in the following Gantt chart.

Deliverables	01/02	02/03	03/04	04/05	05/06
Spruce Demo Trial	■				
Cedar Demo Trial	■				
Hemlock Demo Trial	■				
Maple Leaf Trial	■				
Nutrient Loading Trial	■			■	
Fish/pulp/sludge Trial	■				
Sewage Sludge Trial	■				
Operational Fertilization 1997	■				
SCHIRP Installation (1988)		■			
Salal fertilization Trial		■			
High Elevation Trial		■		■	
Straw/ Compost Trial			■		
Fish Silage Trial			■		
Salal Eradication Trial				■	
Scarification Trial					■
Kennedy Lake Trial					■
Transitional Trials					■
Operational Fertilization 1996					■
Operational Hand Fertilization 1996					■

The silvicultural trials remeasured this year were the SCHIRP Installation (est. 1988) and the high elevation *Vaccinium* trial. **Numbers in parantheses relate to the 2002/2003 workplan presented above.**

Re-measurement and monitoring of the SCHIRP Installation

Heights and diameters of all test trees in the 128 plots in the SCHIRP Installation were measured and verified (36). Foliar nutrient contents of 128 samples from the SCHIRP Installation have been measured (37). Data are currently being organized and checked. The data will be forwarded to the data manager for inclusion in the database within two weeks (38, 55, 50). These results will be published in conjunction with PhD student Rod Negrave's in-depth study of tree and salal responses at the SCHIRP Installation (see Objective 1 below).

Re-measurement and monitoring of the high elevation *Vaccinium* trial

Trees and *Vaccinium* cover in the high-elevation trial were remeasured at the two installations (Jordan River and Holberg) in Quarter 2 (7, 20). Percent cover of *Vaccinium* was measured using a modified Braun-Blanquet method. Results suggest that the *Vaccinium* control treatment is still effective (Fig. 1), with most herbicided plots at Jordan River still *Vaccinium*-free (~90%), while in-growth at Holberg was greater (~45% of plots with <25% cover).

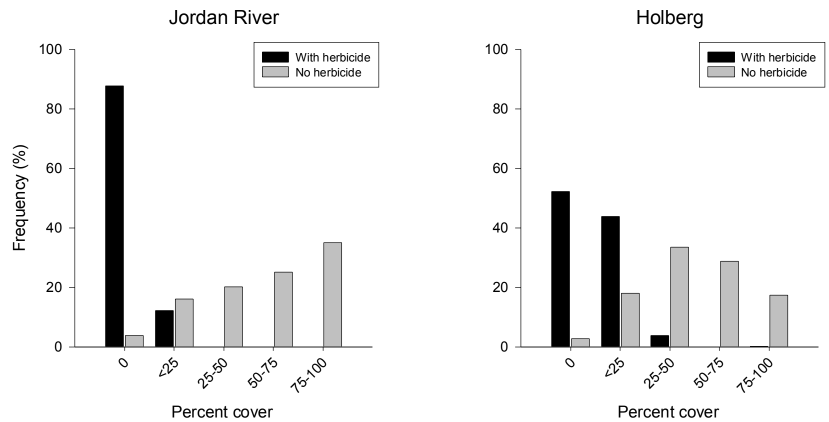


Figure 1. Third-year *Vaccinium* cover on herbicide and non-herbicide treatment plots.

Height and root collar diameter of all core trees were measured at both sites in September 2002, at the end of the third growing season. Results from factorial analyses showed effects of both fertilizer and herbicide, for all three species (Figs. 2-5).

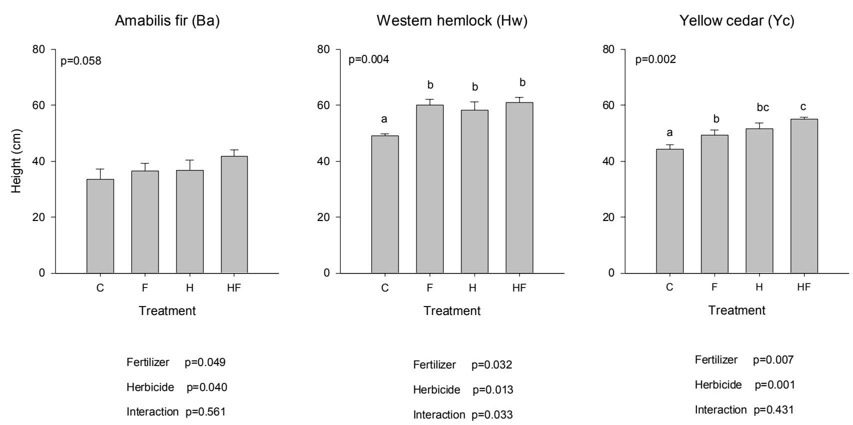


Figure 2. Total height of seedlings at Holberg after 3 growing seasons.

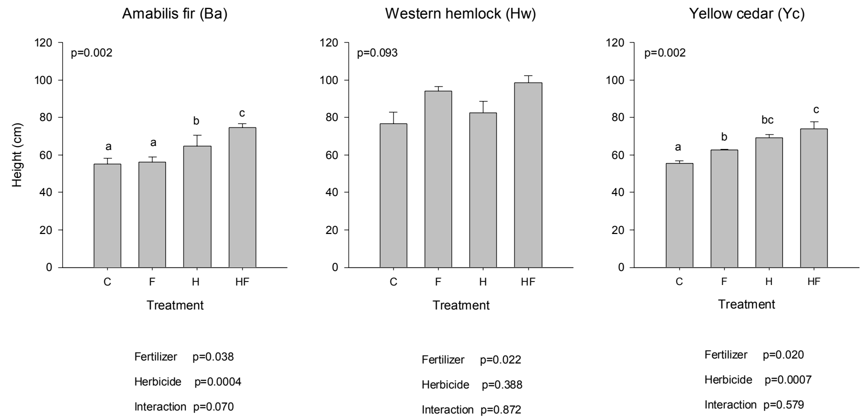


Figure 3. Total height of seedlings at Jordan River after 3 growing seasons.

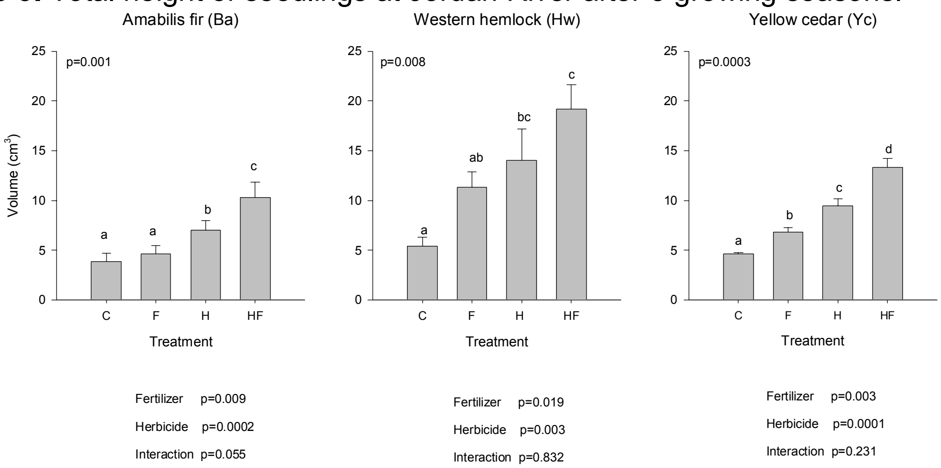


Figure 4. Stem volume of seedlings at Holberg after 3 growing seasons.

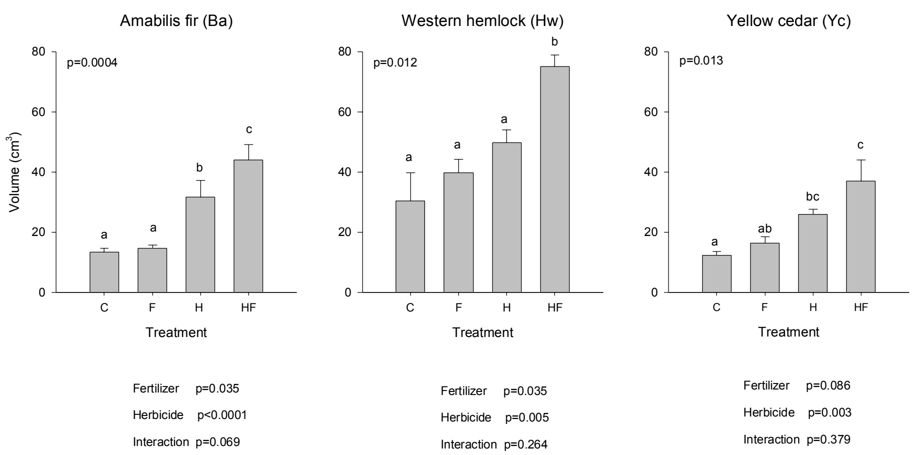


Figure 5. Stem volume of seedlings at Jordan River after 3 growing seasons.

In addition, 10 seedlings per treatment plot were harvested from plot buffers for determination of aboveground biomass. These seedlings were chosen to represent the range of assessment core seedlings, so that regressions could be used to estimate aboveground biomass of assessment core seedlings. Seedlings were also ground and concentrations of N, P and K were measured. These estimates will be combined with biomass data for each seedling to estimate seedling nutrient contents. Processing of seedlings was arduous and time-consuming; as a result, the chemical analyses have only recently been completed and the data are currently being analyzed.

The chemical analysis of soils is complete (57), and the data are currently being analyzed.

A humus incubation experiment was planned to estimate N mineralization rates in the treated and control plots (21, 39, 56). However, an initial incubation using humus from Jordan River indicated that treatment differences were not yet evident (Figure below; 9 plots per treatment). This suggested that the incubation would not give us the estimate of nutrient availability that we sought. After discussion among the team members involved, we decided that the best integrative measure of nutrient availability was the total nutrient content of seedlings, which is superior to the measures of foliar concentrations that we had planned. Thus, the funds were used for total seedling chemical analysis, which should provide a better indication of the nutritional conditions in the experimental plots.Also see Section 7: Explanation for changes from the original workplan.

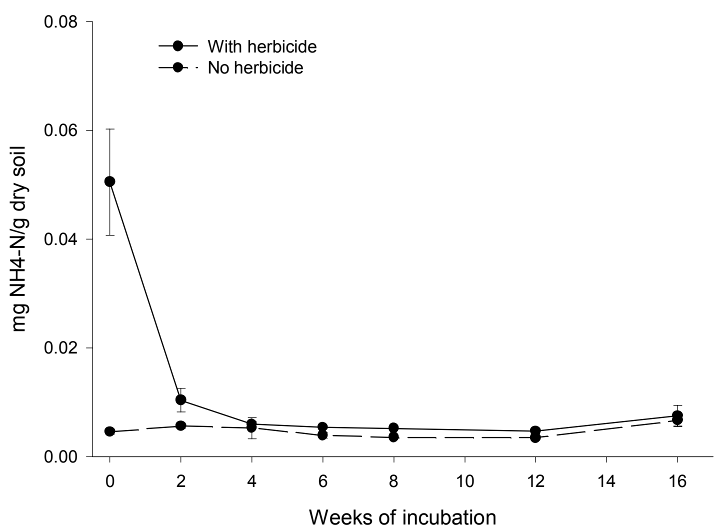


Figure 6. Nitrogen mineralization rates in humus from herbicided and non-herbicided plots.

Other accomplishments related to remeasurement of SCHIRP trials:
A manuscript describing results from the SCHIRP salal fertilization trial was prepared and submitted to the Canadian Journal of Forest Research (35). *Bennett et al.*

Response of salal (Gaultheria shallon) and fireweed (Epilobium angustifolium) to large additions of nitrogen and phosphorus fertilizer Can J For Res, in review. A copy of the manuscript is attached.

A manuscript describing the 13-year results from the salal eradication trial was accepted for publication*. Bennett, et al. 2003. Long-term improvement in productivity and nutrient availability following fertilization and vegetation control on a cedar-hemlock cutover. Can J For Res, in press.*

<u>Objective 2:</u> Understanding the effects of silviculture on stand development, biodiversity, and soil organisms

<u>Tree Crown Development and Vegetation Analysis (SCHIRP Installation)</u>

Sample tree selection for crown study and detailed analysis of sample trees at the SCHIRP Installation was completed during the second quarter (11, 43, 61). Permanent sample plot boundaries were located and flagged. A trail system was also located and flagged through the trial area for brushing. Seventy-three red cedar sample trees were located in all three densities, described above, of both the fertilized and unfertilized CH and the fertilized HA stands. Eight or nine trees were located for sampling at each experimental level.

A total of 73 red cedar trees wee felled and sampled to determine total and dry mass of foliage, stem, branches and bark. Total height, 2002 height increment and diameter at breast height were determined for each tree. From these sample trees, individual branches were sampled from recorded heights within the crown. Total branch length, 2002 length increment and basal diameter were determined for each branch. Total and dry mass of each branch was also determined. Leaf area samples were taken from 62 of the 73 trees. Stem sections were collected at 30 cm from the root collar and thence every 1.0 m up the bole. All field analysis of sample trees was completed in this quarter.

Analysis of the sample tree data has begun (63). Summary statistics from preliminary analysis of cedar crowns are presented in Table 1. Individual tree crown mass (fresh mass of branches and foliage combined) shows strong trends to both increase with fertility level and decrease with tree density (Figure 7). Current (2002) height growth increment, or leader extension, shows a moderate trend to increase with fertility level (Figure 8). However, the effect of density is unclear at this stage of the analysis.

Table 1. *Crown mass and height growth increment (terminal length) of cedar* (SCHIRP Installation)

Treatment	Crown Mass		2002 Height Growth	
	Mean (kg)	**Standard Deviation**	**Mean** (cm)	**Standard Deviation**
Unfertilized CH, 500 sph	14.94	4.98	50.00	5.55
Unfertilized CH, 1500 sph	8.49	3.52	43.50	6.32
Unfertilized CH, 2500 sph	6.97	3.18	39.25	7.11
Fertilized CH, 500 sph	26.41	7.00	55.63	5.55
Fertilized CH, 1500 sph	16.71	7.05	47.38	9.75
Fertilized CH, 2500 sph	12.50	7.18	53.50	12.88
Fertilized HA, 500 sph	42.82	11.03	59.33	10.44
Fertilized HA, 1500 sph	31.97	8.09	64.50	12.80
Fertilized HA, 2500 sph	19.70	11.03	50.14	10.83

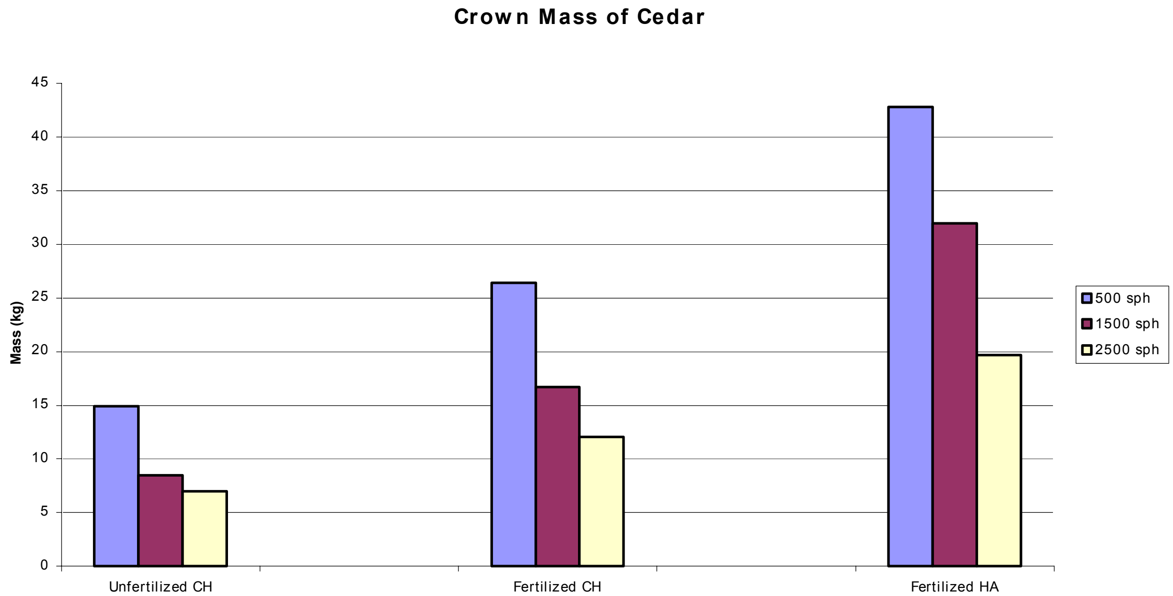


Figure 7. Individual tree crown mass of cedar.

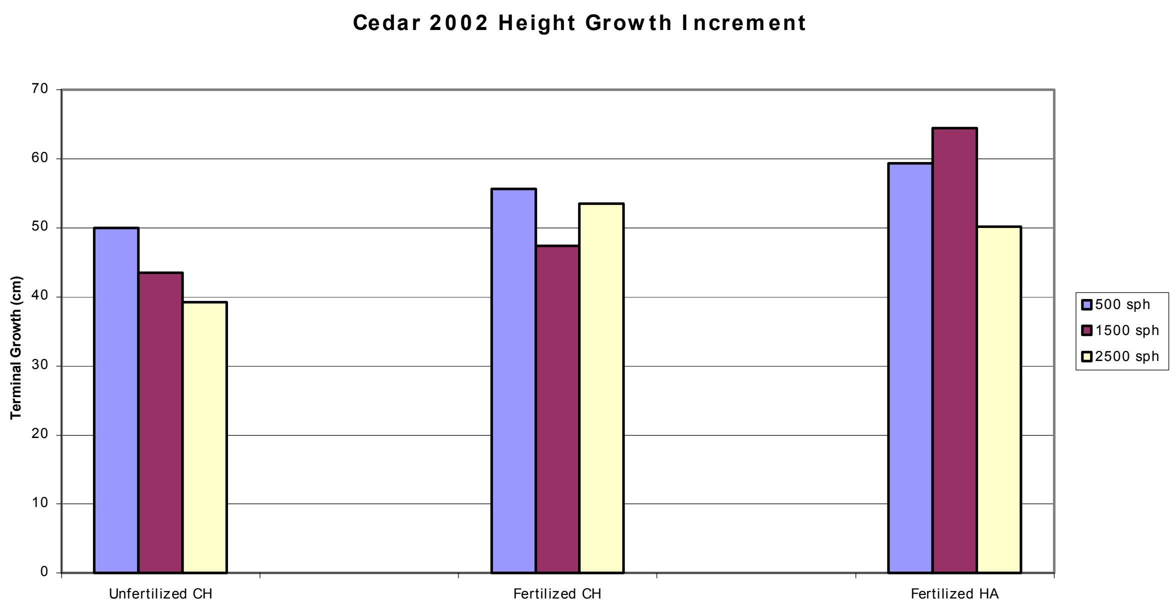


Figure 8. 2002 height increment (leader extension) of cedar.

The Neighborhood Quantification at the SCHIRP Installation (12) was completed in conjunction with the Sample Tree Selection during the second and third quarters. The neighboring environment of each of the 73 sample trees was assessed. This assessment consisted of measuring height of salal at four points around each tree, determination of the sample tree's micro-position, measurement and recording of species and diameter at breast height (dbh) of trees at least 1 cm dbh within a 4.3m radius of the sample tree and the acquisition of a hemispheric photograph immediately over the cut stump of the sample tree (see below for procedure).

One-hundred and forty-four 0.75 m^2 salal plots were sampled (27) by clipping across three overstory densities (500, 1500 and 2500 sph) in both fertilized and unfertilized red cedar treatments on the CH portion of the study site, for a total of 24 clip plots per experimental level (6 plots per each of 4 replicates). Clipped material was separated by species. All species were sampled to determine dry mass and sub-sampled to determine leaf areas. Salal was sub-sampled to determine dry mass by components (old and current stem and leaf growth) and stem architecture (height increment for years 2002, 2001 and 2000; branching order). Micro-position of plots was also determined. Foliar samples of salal leaves were also collected from each treatment replicate (24 samples, 4 per treatment level).

Understory Biomass, Growth and Structure

Salal biomass, height and growth were greater in the fertilized plots and in the plots with the lowest density of conifers (Tables 2 and 3).

Table 2. Salal biomass and growth (grams per 0.75 x 0.75 m plot).

Treatment	**Vegetation Mass**		**Total Salal Mass**		**2002 Salal Growth**		**Salal Stem Density**	
	Mean (g)	**Standard Deviation**	**Mean** (g)	**Standard Deviation**	**Mean** (g)	**Standard Deviation**	**Mean** (#)	**Standard Deviation**
Unfertilized CH, 500 sph	442.34	214.84	402.69	218.44	71.76	23.56	69.50	26.14
Unfertilized CH, 1500 sph	372.84	56.88	318.34	47.40	43.18	12.09	51.46	17.16
Unfertilized CH, 2500 sph	356.69	89.50	300.25	99.15	48.53	3.90	47.29	8.13
Fertilized CH, 500 sph	1000.09	401.70	899.29	376.49	97.24	35.32	72.79	19.18
Fertilized CH, 1500 sph	837.90	98.58	791.87	80.07	91.17	15.59	40.04	13.22
Fertilized CH, 2500 sph	921.08	210.07	820.01	220.46	72.18	11.85	52.62	21.01

Table 3. Dominant height of salal in each treatment.

Treatment	Salal Height	
	Mean (cm)	Standard Deviation
Unfertilized CH, 500 sph	71.50	47.34
Unfertilized CH, 1500 sph	53.75	18.03
Unfertilized CH, 2500 sph	67.50	22.37
Fertilized CH, 500 sph	109.00	20.28
Fertilized CH, 1500 sph	119.40	15.39
Fertilized CH, 2500 sph	144.00	41.02
Fertilized HA, 500 sph	158.00	32.12
Fertilized HA, 1500 sph	131.67	38.55
Fertilized HA, 2500 sph	151.33	18.01

Total standing vegetation dry biomass shows evidence of being increased by fertilization, 9 years after the last fertilizer application (Figure 9). There does not appear to be any effect due to variation in overstory density at this stage of the analysis. A similar trend is evident for total salal biomass (Figure 10), however, a slight trend to reduced salal biomass with increasing overstory density may be evident. Salal 2002 growth increment also shows a strong trend to be greater in fertilized areas (Figure 11). A moderate trend for overstory density to reduce salal growth increment appears evident, as well. Salal stem density does not show a response trend to fertilization (Figure 12) but a weak trend to reduction in stem number s with overstory density may be present, particularly in regards to unfertilized areas. Dominant height of salal (greatest height of salal within the sample plot) shows a strong trend to increase with fertility level (Figure 13). No effect of density on dominant height is evident.

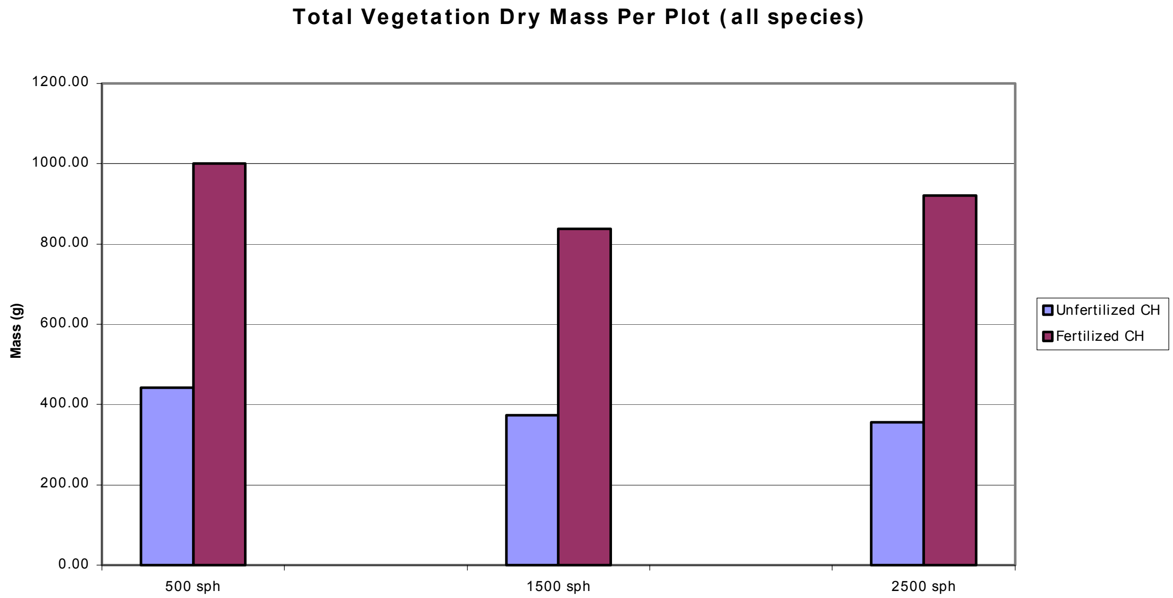


Figure 9. Understory vegetation biomass (grams per 0.75 x 0.75 m plot).

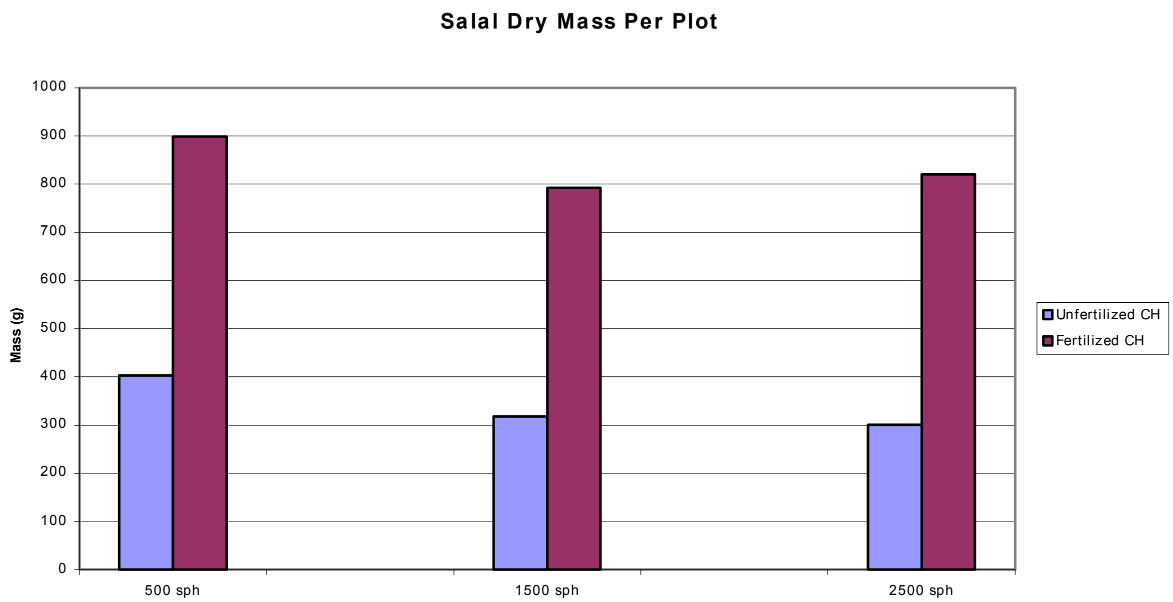


Figure 10. Salal biomass (grams per 0.75 x 0.75 m plot).

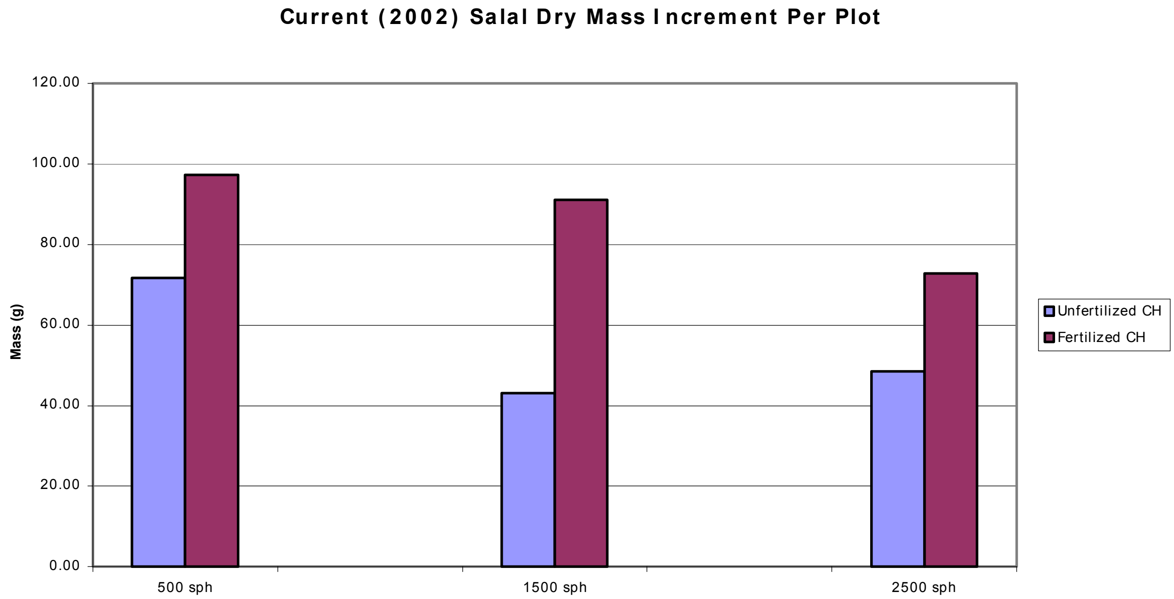


Figure 11. 2002 Salal aboveground biomass increment (grams per 0.75 x 0.75 m plot).

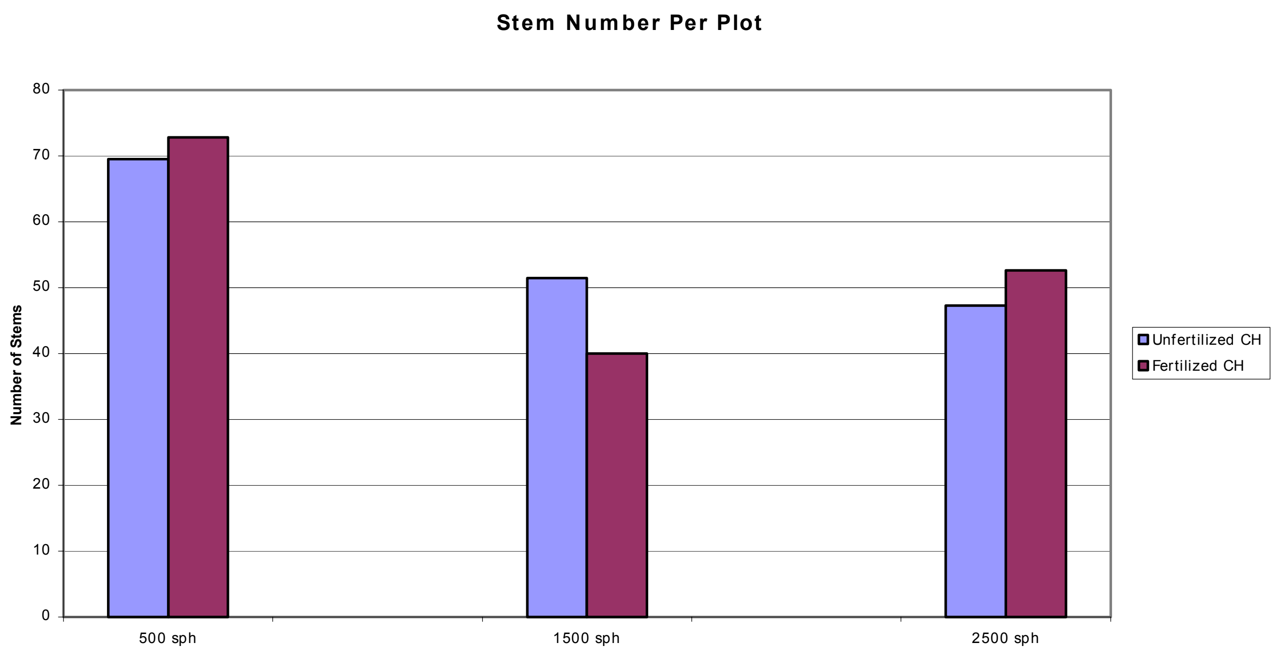


Figure 12. Salal stem density (number per 0.75 x 0.75 m plot).

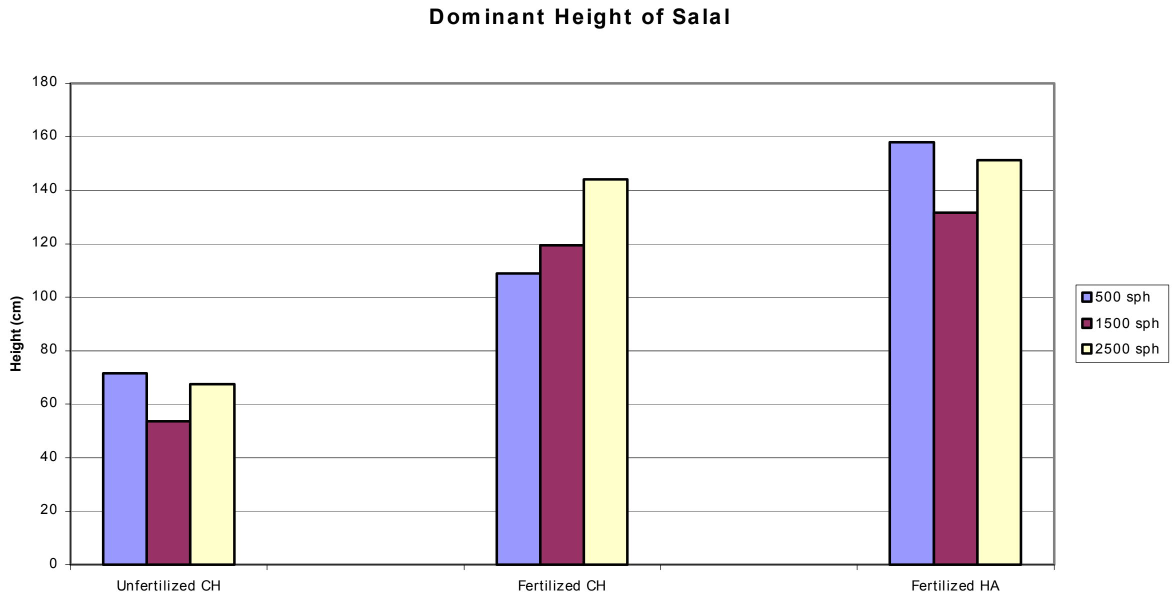


Figure 13. Dominant height of salal.

Roots were sampled in the third quarter (28). Forest floor samples (7.5 cm x 15 cm) were extracted from each salal clip plot site. A total of 144 plugs were collected. Ceptometer assessment of light levels (26) was not carried out – see section 7.

Hemispheric photography was conducted during the third quarter (29). A total of 144 hemispheric photographs were obtained immediately over the salal clip plots, which were harvested during the second quarter. Photos were taken approximately 1.3 m above the forest floor surface. Hemispheric photographs will be used to determine light climate experienced by individual salal clip plots and to examine differences in light regime associated with different treatments. Tree foliage samples were collected and analyzed by Western Forest Products, Ltd., during the third quarter. Analysis of salal foliage is planned for the next year (62).

Rod Negrave has begun to prepare his dissertation and manuscripts on these data from the SCHIRP Installation. An additional technique, modular component analysis, has been added to the work plan in order to better understand the contributions of various tree components (stem, branches, foliage) to growth and the effects of environmental and stand conditions on components. The information presented in the Manuscript will be useful to forest practitioners re-establishing forests on CH and HA sites (CWH vm 01).

Soil Organisms

Mycorrhizae

In May, we hired Paul Kroeger as a half-time technician to work on morphological characterization of mycorrhizae. Kroeger worked with S. Berch for one week of intensive training in mycorrhizal morphotyping. With two root collections from the UBC campus and from the SCHIRP site, and examination of over a hundred hemlock root tips, Kroeger has learned to characterize mycorrhizal types and has been working out techniques to obtain the pure fungal cultures from the mycorrhizae (9).

Kroeger and Berbee traveled to Port McNeill and collected samples of mycorrhizal root tips from previously sampled plots, and four samples of fungal fruiting bodies (June and July).Given the dry summer, there were no fruiting bodies to identify from either the fertilized or unfertilized plots. Despite the lack of hemlock mycorrhizal fruiting bodies Paul Kroeger and Shannon Berch collected several hundred mycorrhizal root tips, and Kroeger has characterized them morphologically (8, 22, 23, 40, 58).

Our culturing (24, 41, 59) and DNA sequencing studies of the mycorrhizae of hemlock and salal revealed that hemlock and salal actually share many of the same mycorrhizal fungi. Of the eight different 'DNA species' of fungi isolated from hemlock mycorrhizae from the SCHIRP site, five have also been found among salal mycorrhizal fungi from our previous studies (Fig. 1).

Paul Kroeger isolated fungi from hemlock trees from the SCHIRP site. DNA extracted from fungal isolates was amplified and sequenced. As shown in the phylogenetic tree DNA sequences of many of the hemlock isolates matched isolates DNA from salal mycorrhizal fungi. Paul's cultures are in yellow in this tree (Fig. 14).

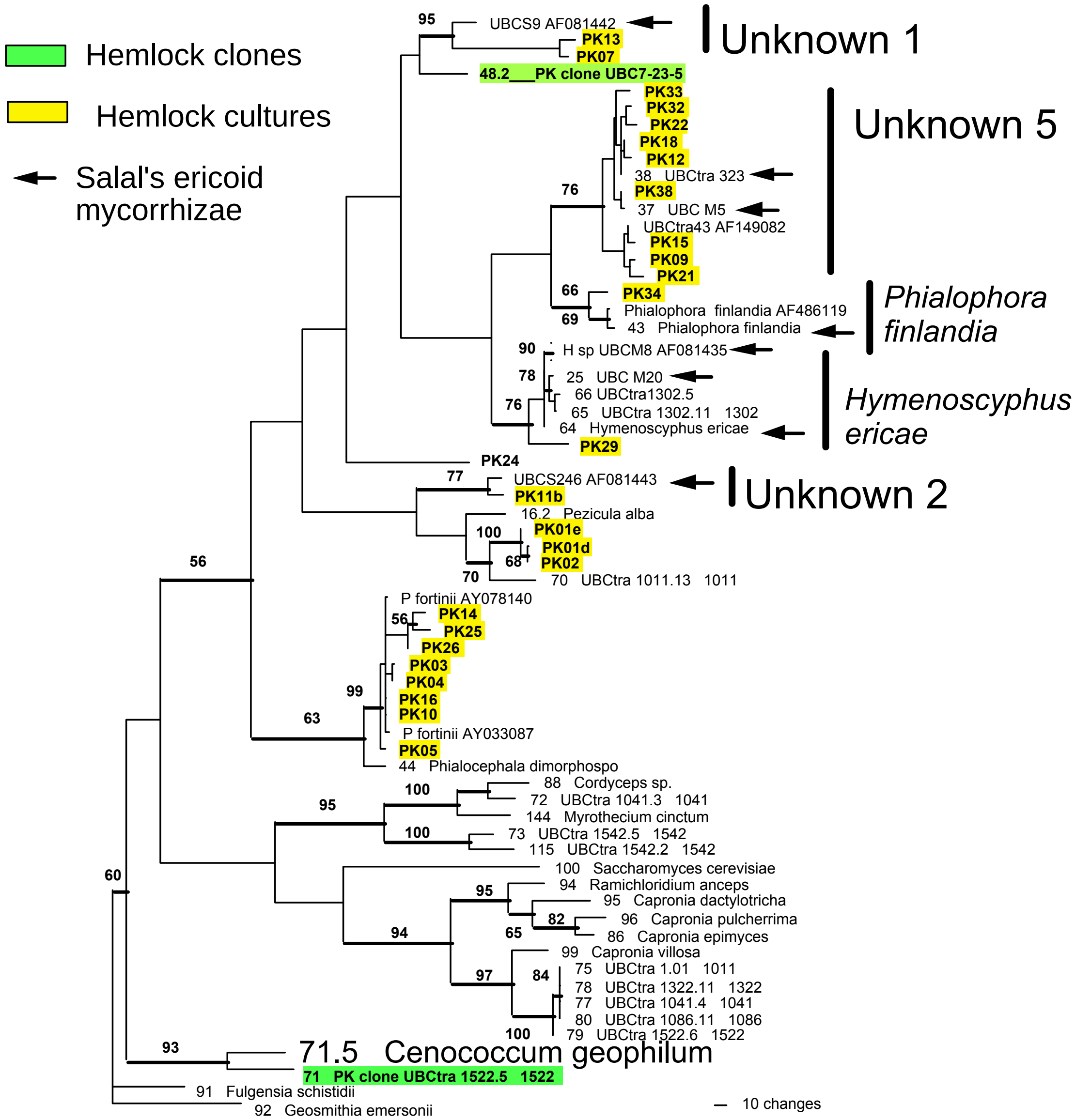


Figure 14. Phylogenetic comparison of fungal isolates and clones from hemlock and from salal.

The morphological characters of each mycorrhiza used for culturing or cloning was recorded. This is leading to correlation of morphotype and DNA-sequence-based identity (10, 40)

Solveig Adair examined the DNA populations in hemlock roots and found DNAs from two known ectomycorrhizal fungi, a *Lactarius* sp. and *Cenococcum geophilum* (25, 42, 60). In addition, she found an ascomycete related to ericoid mycorrhizal fungus *Hymenoscyphus ericae*. The *Hymenoscyphus*-like DNA in a hemlock mycorrhiza was interesting, because similar fungi were common mycorrhizal associates with salal. Two of Solveig's sequences are represented by the green in the tree above. Solveig completed an Honours thesis based on this work entitled “Diversity of ascomycetous ectomycorrhizal fungi on *Tsuga heterophylla* (western hemlock).”

Soil Microbial Diversity

The RISA and PLFA analyses (13, 14) and data analyses of DGGE, RISA, and PLFA for bacteria and fungi (30) were completed and incorporated into Sara Leckie’s thesis, which was successfully defended on March 10, 2003. Two manuscripts have also been completed earlier than anticipated and submitted for publication (46, 66, 67) (see Appendix).

We assessed the relative effects of site type (CH and HA), tree species (western hemlock and western redcedar) and fertilization treatments (unfertilized or fertilized with NKP at planting and NP seven years later) on forest floor microbial communities in the SCHIRP Installation, 14 years after establishment of the experiment (32, 33, 45, 64).

Community level physiological profiling (CLPP) and phospholipid fatty acid (PLFA) analyses of forest floor microbial communities in the SCHIRP Installation have been completed and preliminary data analysis has been conducted (65).

Both of these analyses discriminated microbial communities in the F and humus layers of the forest floor. Since these cutovers were burned prior to the establishment of the experiment, the F layer has developed with the new forest. The effects of the site type (CH and HA), tree species, and fertilization treatments contributed to patterns in the composition of the F-layer microbial community, as assessed by PLFA. The humus layer, however, most likely developed under the previous stand and the humus microbial communities did not differ greatly among treatments. There were more Gram-positive bacterial PLFAs in humus of HA than CH sites and more arbuscular mycorrhizal fungal PLFAs in humus of plots with cedar than hemlock, consistent with results from the research undertaken in unharvested CH and HA forests.

CLPP provides an indication of potential functional differences in the bacterial communities. There were clear differences in carbon utilization of F-layer and humus-layer bacterial communities. Communities in the F-layer of hemlock plots had greater utilization of sugars than those in cedar plots, and there was greater utilization of neutral amino acids on CH sites than HA sites. In the humus layer, there was greater utilization of carboxylic acids on cedar than hemlock plots and greater utilization of acidic amino acids on CH than HA sites.

These results indicate that the effects of the site type (CH and HA) persist to some degree 15 years after harvesting and regenerating a new forest. This may indicate that any possible environmental differences between CH and HA sites are important for determining the composition of the microbial community and/or that the effect of the silvicultural practices was not so large as to overcome these initial site differences. The fact that there was little discrimination of microbial communities in the humus layer suggests that the tree species and fertilization did not greatly affect the communities in forest floor that was remaining from the prior stand. Litter inputs and tree activities in the different treatment plots are likely related to differences detected in the F layer, but did not stimulate a change in the communities in the humus below.

Root Exudates

Dr. Grayston was not able to arrive at UBC until February 1 (rather than in October as anticipated), due to responsibilities at the Macaulay Institute. As a result, this study was delayed, and will be completed within the next 4-5 months using other funds. We were able to build the microcosms and have the equipment and materials ready when she did arrive, so the experiment was quickly established and is well underway.

Sterile microcosm systems in which to axenically grow salal were constructed using mason jars (Hodge et al., 1996). Salal seeds were surface-sterilized using the hydrogen peroxide technique and germinated on sterile filter paper in petri plates. After 6 weeks of growth, seeds were transferred to microcosms (4 seedlings/microcosm) and allowed to establish for 4 weeks. Microcosms have been continually supplied with 1mmol N – nutrient solution throughout the experiment. Exudate solution has been collected weekly and will continue to be collected for six weeks (47, 48, 49).

The collected exudate solution volume has been split. One half of the solution is being analyzed for total organic carbon, protein, phenolic acids, amino acids, and free carbohydrates (70). Sub-samples are also being applied to conifer (western red cedar, western hemlock, sitka spruce and fir) seeds and seedlings to determine if there is a direct inhibitory effect of salal exudates on conifer germination and growth. The other half of the collected exudate solution is sent via a pump mechanism to drip into receptor microcosms containing 30 g forest floors (at a bulk density of 0.07 g/cm^3) collected from the CH and HA forest types at the SCHIRP installation. At the conclusion of the experiment, these soils will be sampled and the microbial community structure and function analyzed using phospholipid fatty acid profiling (PLFA), community level physiological profiling (CLPP) and plating (69). We will then be able to assess whether the presence of salal changes microbial communities in these forest floors, selecting for the growth of particular organisms through its root exudates, which could account for salals improved competitveness on these sites compared to the conifers.

Hodge A, Grayston SJ and Ord BG 1996. A novel system for characterisation and quantification of plant root exudates. *Plant and Soil* **184**, 97-104.

<u>Objective 3:</u> Communicating findings to forest practitioners and forest scientists

Our five-year plan for extension and communication includes a combination of journal manuscripts, research synthesis reports, field guides, workshops and field tours. The schedule for extension activities is as follows.

Deliverables	01/02	02/03	03/04	04/05	05/06
Pine as nurse species manuscript					
Workshop and Field Tour					
Silvicultural Trials Report (Update#2)					
Salal Eradication manuscript					
Demo Trial manuscript					
Organic Trials manuscript					
Field Guide					
Fertilization-at-planting manuscript					
Mycorrhizae manuscripts (2)					
Forest succession manuscripts (1)					
SCHIRP Installation manuscript					
Workshop and Field Tour (CSC)					
Summary Report for 2001-2005					
Ericaceous Plant Meeting (international)					

Extension to forest practitioners

SCHIRP workshop (2)
The SCHIRP workshop and field tour was held in Port McNeill on May 7 and 8, 2002. Over 50 people from industry, government, and academia participated in the workshop. Western Forest Products hosted the workshop, and Annette van Niejenhuis (WFP) organized the event. The evening session was held on the 7th in the Port McNeill Community Hall. There was a poster session describing research from several ongoing SCHIRP projects. Posters included "Salal Cedar Hemlock Integrated Research Program: Management through understanding," "Molecular investigations of soil microbial communities in forests of northern Vancouver Island," "Does clearcutting alter the abundance of soluble organic nitrogen in forest soils?" and "Fertilization and vegetation control to reduce conifer growth check on Vaccinium-dominated cutovers at high elevations in coastal BC." Annette van Niejenhuis presented the results from the Suquash Drainage Trial. Cindy Prescott discussed investigations into the underlying causes of poor nutrition on CH sites. Tamara Allen and Sara Leckie presented their research on the microbial communities of CH forests and their potential contribution to poor forest regeneration and growth.

The following day (May 8) the field tour was held and included the following five stops: the SCHIRP Installation (hosted by John Barker), the Hemlock Plot Fertilization Trial (hosted by Leandra Blevins), 1997 Operational Fertilization Trial (hosted by Annette van Nijenhuis), the Salal Eradication Trial (hosted by Cindy Prescott), and the Suquash Drainage Trial (hosted by Annette van Niejenhuis).

The SCHIRP workshop and field tour was featured in an article that appeared in the summer 2002 issue of LINK. The article provides a summary of the management issues being examined by SCHIRP and details the stops in the field tour.

SCHIRP Update #2 (3, 4)
The SCHIRP extension document entitled Salal Cedar Hemlock Integrated Research Program Update #2: Silvicultural Practices for Regeneration of Cedar-Hemlock Sites in Coastal British Columbia was published in May. The report describes findings from fifteen key silvicultural trials. Eight of these trials are more than 10 years old. The report also includes an economic analysis of management options for CH sites and makes recommendations for improving forest regeneration and growth on salal-dominated sites. One thousand copies of the report have been printed and a downloadable version (PDF format) will be placed on the website. An announcement that the Update was available was made at the workshop and in the LINK article about the workshop. A copy of the Update is included in the appendices of this report.

Five hundred copies of the SCHIRP Update were sent to the Pacific Forestry Centre (CFS) on June 25. CFS has agreed to help distribute the report to foresters throughout coastal BC, greatly reducing the distribution costs to the project. The remaining 500 copies will be available from UBC (upon request) and will be distributed at conferences and meetings, including the Coastal Silviculture Committee Meeting.

SCHIRP and Non-timber Forest Products
The October issue of Beneath the Trees: The non-timber forest demonstration project newsletter (Royal Roads University) also featured an article about SCHIRP and non-timber forest product research being conducted by Brian Titus. The article describes research currently underway to determine the effect of fertilization on salal and whether or not stands can be managed for improved conifer growth and improved salal for the floral greens industry.

Stand Establishment Decision Aid (SEDA)
A SEDA is currently being developed published in conjunction with FORREX and Western Forest Products (through FIA funding). It will provide forest practitioners with a concise “field guide” for regenerating CH sites (CWHvm1 01s, 06s, and 03) and will specifically address the need for information on forest green-up (SIFERP, 1999).

SCHIRP website
Some changes were made to the website in April (19). We plan to add more information including the latest SCHIRP update and journal article abstracts in the next quarter.

Extension to forest scientists

SCHIRP field tour for SMC
Although it was not listed as a deliverable/activity, a field tour of SCHIRP was given to the Stand Management Cooperative from the University of Washington on September 17. Approximately 40 people from the US and BC participated in the tour. Annette van Niejenhuis of Western Forest Products planned the field tour with Louise de Montigny of the BC Ministry of Forests. Eric Gagne of Western Forest Products led the group around the forest trail at Beaver Lake and led a discussion about HA and CH sites. The group

then visited the SCHIRP Installation (the focus of the research conducted with this award). John Barker provided an overview and the background of the study and of the SCHIRP research program. Rod Negrave, Annette van Niejenhuis, and Leandra Blevins led the groups around the study site so that they could see the effects of fertilization, scarification, and planting density on both HA and CH sites. All attendees were also given a copy of the SCHIRP Research Update #2. The new trails installed by WFP allowed access to the HA sites. A summary if the field tour is currently being prepared by Jennifer Turner (FORREX) for the next edition of the LINK newsletter.

Scientific presentations
Sara Leckie presented a poster at the Ecological Society of America annual meeting in Tucson, Arizona (August 5-9, 2002) (31). The poster was titled “Homogeneity of soil microbial communities in adjacent forests differing in nitrogen cycling.” Sara won the award for best student presentation in the Soil Ecology Section of the ESA.

Brian Titus won an award for best presentation in the Forest Soils division for his presentation entitled “Early Plantation Treatment Improves Nutritional Site Quality 13 Years After Application on Salal-Dominated Sites on Vancouver Island, BC, by J. Bennett, C. Prescott, R. Bradley, B. Titus, L. Blevins, and C. Preston” The presentation was given at the 2001 Annual Meeting of ASA-CSSA-SSSA, Charlotte, NC, 22-25 Oct. 2001.

Leandra Blevins visited Oregon State University on December 10, 2002 and presented an overview of SCHIRP to faculty and staff. The talk was entitled “SCHIRP: Salal Cedar Hemlock Integrated Research Program”

Berch, SM, Allen, TR Berbee, ML & McLean C Aug. 2002. Invited symposium presentation 'Community Structure and Phylogeny of Ericoid and Epacrid Mycorrhizal Fungi' 7th International Mycological Congress, Oslo, Norway.

Scientific Journal articles
Research from SCHIRP has been presented in over 55 journal articles.

The following papers have been recently published or are in press:

Bennett, J.N., B. Andrew, and C.E. Prescott. 2002. Vertical fine root distributions of western redcedar, western hemlock, and salal in old-growth cedar-hemlock forests on northern Vancouver Island. Can. J. For. Res. 32:1208-1216.

Berch SM, Allen TR, Berbee ML. 2002. Molecular detection, community structure and phylogeny of ericoid mycorrhizal fungi. Plant and Soil 244: 55-66.

Bennett, et al. 2003. Long-term improvement in productivity and nutrient availability following fertilization and vegetation control on a cedar-hemlock cutover. Can J For Res, in press.

Brunner A. and J.P. Kimmins 2003. Nitrogen fixation in coarse woody debris of Thuja plicata and Tsuga heterophylla forests on northern Vancouver Island. Can J For Res, in press.

Hannam, K.D. and C. E. Prescott 2003. Soluble organic nitrogen in forests and adjacent clearcuts in British Columbia, Canada. Can J. For Res. in press

Weber et al. 2003. Factors limiting the early survivorship of western redcedar on northern Vancouver Island. Can J For Res, in press.

The following papers are currently in review:

Monreal, M., Berch, S. M. and Berbee, M. 2002. Taxon specific primers to iIdentify ericoid mycorrhizal fungi. Can. J. Bot. in review

Bennett et al. Response of salal (Gaultheria shallon) and fireweed (Epilobium angustifolium) to large additions of nitrogen and phosphorus fertilizer Can J For Res, in review.

Leckie, S.E., Prescott, C.E., Grayston, S.J., Neufeld, J.D., and Mohn, W.W. Comparison of chloroform fumigation-extraction, phospholipid fatty acid, and DNA methods to determine microbial biomass in forest humus. Soil Biology and Biochemistry, *in review*

Leckie, S.E., Prescott, C.E., Grayston, S.J., Neufeld, J.D., and Mohn, W.W. Characterization of humus microbial communities in adjacent forest types that differ in nitrogen availability. Microbial Ecology, *in review*.

Allen TR, Millar T, Berch SM, Berbee ML. 2003. Culturing and direct DNA extraction find different fungi from the same ericoid mycorrhizal roots. New Phytologist, submitted March 2003.

Papers to be submitted in 2003:
Based on work completed in the past year, we will also be submitting 3 manuscripts in 2003. These manuscripts include the Plot Fertilization trial manuscript (5, 15, 17, 51), which will describe the 18-year responses to factorial combinations of N and P fertilizer. The Plot fertilization trials (also called Demonstration Trials) are some of the SCHIRP oldest trials. Analyses were completed and data from these trials has been incorporated into the SCHIRP database. A manuscript describing the 15 year findings from the fertilization trial in western hemlock and western redcedar has been prepared and is included with this report. Results to date indicate that P fertilizer applied in 1987 is still improving conifer nutrition and may enhance site productivity for at least 15 years.

Another manuscript, which will be ready for submission in the next year, describes the10-year responses to organic fertilizers (6, 16, 18, 52). During the last year, the planted trees on these trials were remeasured, data were analyzed and incorporated into the database. During the analysis, some unexpected observations suggested that the productivity of the plots was not being captured by the growth data of the measurement trees. In particular, planted amabilis fir volume was quite low, which would provide opportunity for ingress of other trees. Discussions with our field technicians confirmed that natural regeneration in these plots may contribute a large proportion of the overall increase in productivity associated with organic fertilizers. We decided to return to the study site and measure the naturally regenerated trees as well as the planted trees. Our suspicion that ingress was an important component of these stands appears to have been confirmed. We are currently in the process of analyzing these additional data and will continue preparing a manuscript for publication in the next year.

The first Organic Trial that we will include in a manuscript was established in 1990 in a 9-year-old plantation of western redcedar, western hemlock, and amabilis fir. Plots were either left untreated (control), fertilized with N+P, or fertilized with sewage sludge. Remeasurement of his trial will allow us to assess the duration of response to organic fertilizers as compared to inorganic fertilizers. Preliminary results indicate that for hemlock fertilization with N+P or biosolids may enhance growth for 5-11 years after treatment (Figure 15). Amabilis fir growth has been greatest on plots fertilized with biosolids.

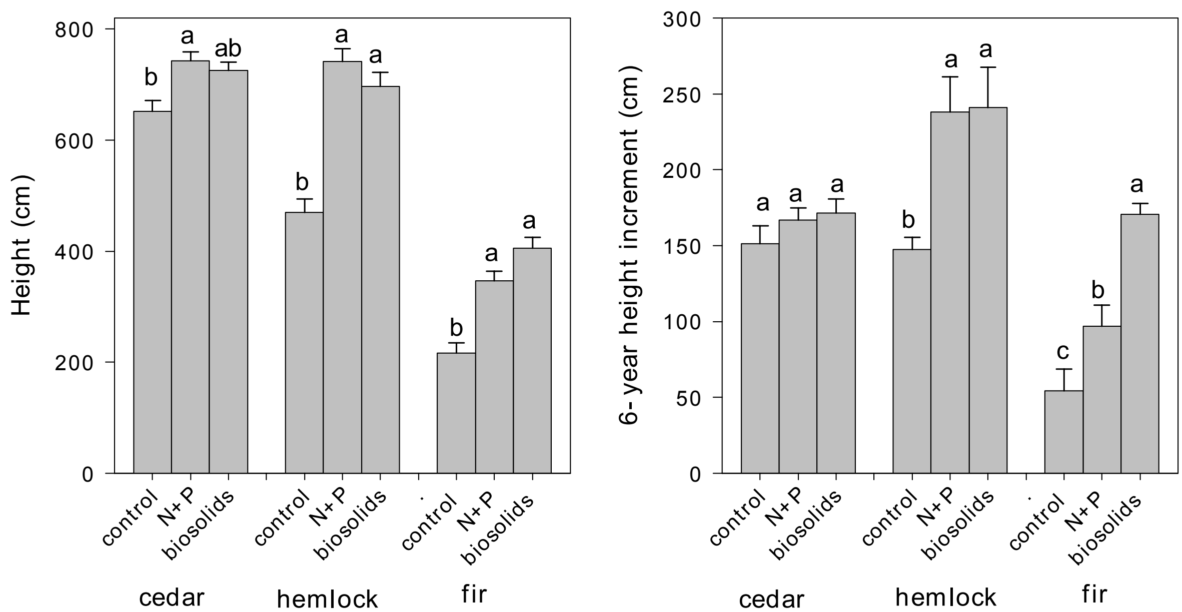
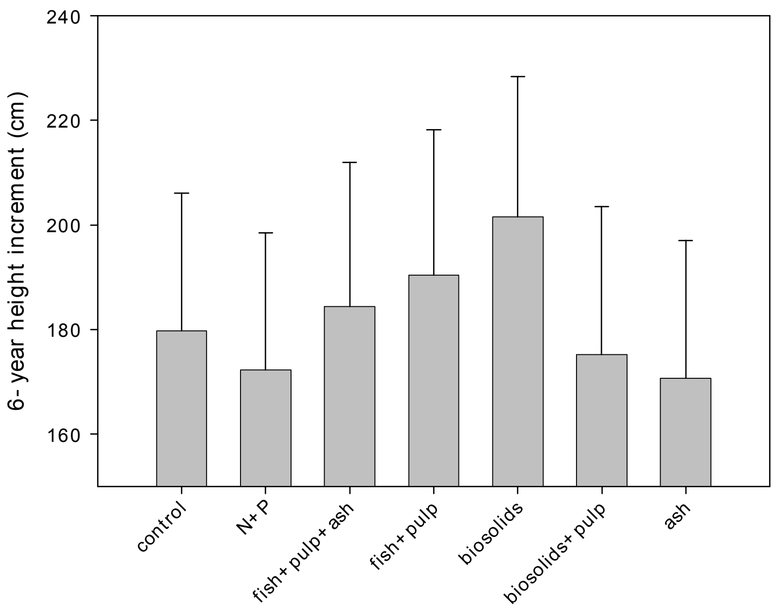


Figure 15. Cumulative height 11 years after treatment and height growth between 5-11 years after treatment.

The second Organic Fertilization trial was also established in 1990 in a western redcedar plantation. Treatments included a control, biosolids (542 kg N and 162 kg P/ha), biosolids+pulp (610 kg N as biosolids mixed with pulp sludge), fish silage+ash (504 kg N/ha as fish silage mixed with wood ash), fish silage+pulp+ash (504 kg N/ha as fish silage mixed with ash and pulp sludge), ash (5 Mg/ha wood ash), N+P (225 kg N/ha and 75 kg P/ha as ammonium nitrate and triple superphosphate). This trial will allow us to determine the efficacy of fertilization with sludge and fish farm waste. We will also be able to determine if organic fertilizers provide a prolonged response, and if response can be further prolonged by the incorporation of carbon rich components such as pulp sludge.

Height growth of planted western redcedar was greatest in the plots treated with biosolids (Figure 16). As with the other organic fertilization trial, we expect that total conifer volume has been greatly increased by fertilization. Incorporation of the ingress will allow us to present a more complete view of the effects of organic fertilizers on site



productivity.

Figure 16. Cumulative height of planted western redcedar 11 years after treatment.

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We will also submit fertilization-at-planting manuscript (53). Preliminary analysis has been completed. It is clear that fertilization-at-planting enhances conifer growth, but we are currently deciding which of the 40 treatments tested on northern Vancouver Island should be included in the publication.

Other activities

Two theses based on SCHIRP research were written and defended in the last year:

Leckie, S. A comparison of soil microbial communities in adjacent forest types that differ in nutrient cycling rates. MSc thesis, UBC Faculty of Forestry.

Adair, S. Diversity of ascomycetous ectomycorrhizal fungi on *Tsuga heterophylla* (western hemlock). BSc Honour's thesis, UBC Department of Botany.

The final report was completed and submitted to Science Council on April 15, 2002. All other quarterly reports have been submitted to FII as required and on time (1, 34).

The SCHIRP Annual meeting was held at UBC on February 7th (54, 68). This year's agenda included a number of speakers who are involved in other projects of interest to the SCHIRP team, including Caroline Preston (CFS), Kevin Brown (private consultant), Rob Guy (UBC) and Louise de Montigny (UBC). Marty Krannabetter (MoF) was unable to attend due to a flight cancellation. The meeting was an excellent opportunity for SCHIRP researchers to relate their research to other projects being conducted in coastal BC and to discuss current and future SCHIRP research. The agenda for the meeting is included below.

SCHIRP ANNUAL MEETING AGENDA

Friday, February 7th, 2003

Rm. 2916 (Caseroom), Centre for Advanced Wood Processing, UBC

9:30	beverages (including coffee and tea) and muffins

SCHIRP research updates

10:00	Leandra Blevins – salal fertilization
10:30	Brian Titus – high elevation trials
11:00	Rod Negrave – crown development
11:30	Cindy Prescott - business meeting
12:00-12:30	*Lunch provided*
12:30	Sara Leckie – soil microbial communities
1:00	Mary Berbee, Paul Kroeger and Sea Ra Lim – mycorrhizae
1:30	Caroline Preston – tannins and ericaceous plants

Other research updates

1:45	Sue Grayston – salal root exudates
2:15	Marty Krannabetter - N and P availability on the north coast
2:45	Kevin Brown – hemlock fertilization
3:15	*Break*
3:30	Rob Guy – hemlock physiology
4:00	Louise de Montigny – STEMS
4:30	Cindy Prescott – EP 571
4:45	Brian Titus – salal picking
5:15	wrap-up and adjourn

4. Evaluation of objectives, outcomes and measurable indicators of success

Objective 1: Continued monitoring of productivity response to silvicultural treatments.
Continued monitoring of the long-term silvicultural trials proceeded as planned. This effort has recently provided indications that fertilization may cause a long-term improvement in productivity of these sites, and that this hinges on the application of P along with N. This information assists in developing recommendations for best management practices on these sites and prediction of rotation-length improvements in wood supply as a result of silivcultural intervention. We have also been successful in making our results known, through the workshop and field tours, extension report, presentations and publications.

Objective 2: Understanding the effects of silviculture on stand development, biodiversity, and soil organisms
The stand development project is proceeding as planned, and the student now has the data needed to write the thesis. We expect some deliverables from this project next year. The belowground ecology research continues to provide us new insights into these organisms and their interactions. These studies are proceeding as planned, as evident in the student theses and publications completed this year.

Objective 3: Communicating findings to forest practitioners and forest scientists

We have been successful in communicating our research results to foresters and scientists, and have maintained the extension plan outlined in our 5-year plan. This year we had extension activities on all fronts, including:

- SCHIRP workshop and field tours
- SCHIRP Update #2 extension report
- SCHIRP non-timber forest products newsletter
- Stand Establishment Decision Aid
- 4 conference presentations to members of the international forest science
- 2 published journal papers
- 4 papers accepted for publication
- 5 papers submitted for publication

5. Assessment of the applicability of results including identification of end-users and/or how results can be implemented

As a result of our close cooperation with industry, and vigorous extension program, the results of SCHIRP long-term silvicultural trials are being applied by forestry operations throughout Vancouver Island. Western Forest Products continues to broadcast-fertilize salal-dominated CWHvm1 and closely related ecosystems on the basis of growth responses and economic analyses of SCHIRP installations. To date, over 11,000 ha have been fertilized and a network of monitoring plots has been established to track operational responses. Operational fertilization monitoring in the South Island District confirmed the findings of SCHIRP. Most licensees including Western Forest Products are also fertilizing at time of planting on these sites, based on the findings of this research. Fertilization at planting decreases the time to free growing and green-up, resulting in reduced liability and improved access (reduced adjacency constraints).

SCHIRP results can also be used to improve forest polices in BC. SCHIRP research has demonstrated that stands benefit from fertilization both in terms of faster green-up and in long-term increases in forest productivity. This calls into question the current policy of requiring free-growing thresholds must be met or exceeded before approvals are given for spending FIA funds on broadcast fertilization. This is costing the government of BC in lost growth potential on these sites.

Results of the High Elevation Trial are applicable to forest managers planning reforestation of high elevation sites dominated by *Vaccinium*. Results show that seedlings of 3 species (amabilis fir, hemlock, yellowcedar) respond to either herbicide application or fertilizer at planting through increased growth by 3 years. However, it is not known if early differences will be sustained in the long-term. Managers can make species and treatment choices, based on results, accepting that results are short-term.

Results of the crown development project will be used by forest managers, modelers and other researchers. Forest managers will gain information on the effect of silvicultural treatments on early growth and yield of cedar and hemlock stands on CH and HA sites. The influence of salal on crop tree growth and the need for further treatment will also be determined. Results of the crown structure part of the study will be use in the further development of process-based growth and yield models, such as TASS. Examination of development of size hierarchies will yield insight into mechanisms of competition operative in the stand development on these sites and as influenced by these treatment regimes. Information on net assimilation will also result from this project and can be used for certification and carbon sequestration modeling.

Our research to identify the mycorrhizal species of salal (previous years) and hemlock (this past year) has led to previously unknown and intriguing results, which will be of considerable interest to the international scientific community, and will also prompt foresters to rethink our perception of the interactions between salal and conifers. Culturing and DNA sequencing studies of the mycorrhizae of hemlock and salal revealed that hemlock and salal actually share many of the same mycorrhizal fungi. Of the eight different 'DNA species' of fungi isolated from hemlock mycorrhizae from the SCHIRP site, five have also been found among salal mycorrhizal fungi from our previous studies. These findings may have very important implications for forestry and forest ecology. This observation that salal and hemlock may be linked by a mycorrhizal network raises the possibility that there may be carbon and/or nutrient transfer through this network. If salal is “taking” resources from hemlock, these results may help to explain the poor performance of hemlock on CH sites and influence hemlock management where it occurs with salal.

Our research into mycorrhizae of salal and hemlock has led to over 400 DNA sequences being deposited in GenBank. These sequences are now part of a permanent database. Our sequence can be used and compared by scientists anywhere in the world. They allow recognition and identification of fungal diversity based on environmental DNA extracts.

The study of microbial communities on CH and HA sites and under various silvicultural treatments provides novel scientific information important to our fundamental understanding of the functioning of forest ecosystems. This research has contributed substantially to our limited understanding of the composition and function of soil microbial communities.

The ecological studies conducted under SCHIRP, in particular the emphasis on soil ecology and soil processes, will allow us to assess if management of these forests is ecologically sustainable, which could assist licensees in the certification process. FSC standards specifically include the maintenance of soil fertility and soil processes to ensure sustainability of the natural cycles that affect forest productivity.

6. Identify how the research contributed to a knowledge gap and what further research (if any) is needed

Research contribution to knowledge gap

The long-term volume information from CH and HA sites is improving our understanding of response to silvicultural treatment and assisting in quantifying the response. Further verification of long-term growth and productivity data is required to refine and calibrate the growth models underlying Allowable Cut calculations. Additionally, this data is required to verify the cost-benefit analysis of the treatment regimes.

There is little information available about the effect of silvicultural treatments on high elevation sites, and it its likely that harvesting on these sites will become increasingly important. During the past year, the high elevation trials were re-measured. Seedling growth and *Vaccinium* cover were assessed. Chemical analyses of the soils were also conducted. Results from this study have been presented to forest practitioners at SCHIRP extension events. This new data will provide further information for foresters regenerating high elevation *Vaccinium*-dominated sites. Results are presented in Section 5 of this report.

The research will also provide information on the effects of silvicultural treatments on other components of the ecosystem that are critical to nutrient cycling hence productivity of these sites. Although there have been studies of the effects of forest harvesting, little is known about the effects of silvicultural treatments such as fertilization and scarification on other components of the ecosystem. Rather than a negative “impact” of management, silvicultural practices may aid restoration of biodiversity and ecosystem function to pre-harvest levels. By examining the diversity of soil microorganisms and rates of key soil processes, the research will enable us to better understand the ecosystem changes associated with enhanced tree growth in response to silvicultural treatments.

We have seen indications from the silvicultural trials that there may be an extended response, analogous to long-term improvement of the site. Such effects have rarely been reported, and most of these reports have come from other sites dominated by ericaceous shrubs. If our predictions of an extended response are borne out by continued monitoring, we will have to revisit the widely-held belief that silvicultural effects are temporary.

Stand and crown development research will bridge knowledge gaps by providing insight into these processes and early stand dynamics on these sites. Little work has been done on the crown dynamics of cedar in response to stand and environmental conditions. Comparable work needs to be done for hemlock and can be done on this installation. This work will also answer fundamental questions regarding the response of cedar and hemlock to competition. The influence of stand conditions on the development of size hierarchies and the growth efficiency of size classes will also address questions relating to early stand development and the role of further silvicultural activities.

Knowledge of forest soil microbial communities has been identified as a critical gap that needs to be addressed if we are to assess the impact of forestry practices on biodiversity and ecosystem functioning (Staddon et al 1996, Environmental Reviews 4: 267-275). Soil organisms, including decomposer bacteria and fungi, mycorrhizal fungi, and soil fauna have critical functions in the cycling of nutrients, availability of nutrients to trees, tree productivity, and maintenance of forest ecosystem function. Soil organisms are also important for regeneration and the resilience of the forest ecosystem to disturbance. There is, however, very little known about the composition and functioning of soil communities and almost nothing known about the potential effects of tree harvesting, and recovery from those disturbances. This critical knowledge gap precludes certainty about the sustainability of current and proposed forestry practices.

SCHIRP research in the past year has contributed substantially to our understanding of the composition of forest soil microbial communities within and between forests that have marked differences in soil process rates and how these differences in composition may arise through variation in carbon availability. Moreover, we have information contributing to our understanding of the long-term effects of silvicultural practices on microbial communities.

Our contributions to knowledge of soil ecology and the contribution of salal to the poor nutrient cycling on CH sites has continued through the root exudates study. Dr. Grayston recently developed a new technique for collecting exudates, and its application to salal will propel SCHIRP to the forefront of this field. Salal exudes different carbon compounds from its roots than cedar, hemlock and spruce, which could inhibit the growth of these conifers; a) directly – through the production of phenolic acids, which inhibit the germination and growth of these trees and also immobilise N; b) indirectly – through changing microbial community structure and function in the rhizosphere.

Further research needed

Further work is required to refine and optimize the best practices for CH sites. This includes optimizing establishment densities, and timing and rates of fertilizer applications, particularly phosphorus. Verification of the transferability of these results to additional CWH ecosystems throughout coastal BC is also required. Linking these findings to the production of non-timber forest products including salal and cedar boughs is needed. Recent concerns regarding cedar harvesting and a perceived lack of regeneration must be met with information from this program.

There is little information regarding site treatments at high elevations, especially fertilization at planting, for western hemlock, amabilis fir, and yellow cedar. In particular, this is the only known yellow cedar fertilization experiment. Continued monitoring is required to obtain long-term results.

One of the early SCHIRP hypotheses to explain the poor nutrition and growth of western hemlock on CH cutovers was that salal, by virtue of its ericoid mycorrhizal association, was able to use organic forms of nitrogen and thus outcompete hemlock, which has only ectomycorrhizal associates. This hypothesis was called into question when Jennifer Bennett found that we could not distinguish between N forms used by salal, hemlock and cedar. In the next year, we have proposed using a combination of molecular, microscopic, and culturing methods to establish whether salal fungi are the predominant fungi in individual hemlock mycorrhizae. We have discovered that we can do this by dividing individual mycorrhizae, about 0.5-2 mm long, into two segments, one segment for microscopy, and the other segment for either culturing or for DNA extraction. We will establish correlations between fungi cultured from the roots and the fungi detected as DNAs. If we find salal mycorrhizal fungi regularly in cultures, presenting a uniform microscopic appearance, and as predominant fungal DNAs in the roots, we will have strong evidence that these fungi are important for hemlock. If not, the combination of DNA sequencing and microscopic, morphological correlation will give us a convincing suite of fungi that may be important to hemlock but not shared with salal.

Given that so little is known about this soil microbial communities, this area remains a critical knowledge gap. Future research will characterise root exudates from the main conifer species in these forests and assess their effect on soil microbial community structure and function. This will enable direct links between carbon release and microbial communities to be ascertained, which would enable management strategies for sustainable forestry to be developed on a basis of greater understanding. Continued research investigating the range of variability of soil communities within and among different forest ecosystems, as well as achieving a better understanding of the link between community composition or key groups of organisms and soil processes is essential to our ability to evaluate and improve forest practices.

Early results of SCHIRP fertilization experiments suggested that N was the nutrient most limiting plant growth on CH sites, but recent observations from long-term SCHIRP silvicultural trials suggest that P may play an important role in long-term improvement of productivity on CH sites. Further research into the role of P in nutrient cycling and conifer growth and nutrition would help to understand possible long-term benefits of fertilizer applications and to refine our recommendations concerning costly P fertilization.

Although CH and HA forests were initially determined to be successional stages of the same ecosystem with no differences in site position or topography (Lewis 1985), there is increasing evidence to the contrary from SCHIRP ecological studies. Research undertaken to test the successional hypothesis found no evidence supporting a successional transition from HA to CH forests (Weber et al. *in press*). We have several indications that there may be differences in slope position and moisture regime of CH and HA forests. The effect of excessive moisture on nutrient dynamics and tree growth has been extensively studied in forested and drained peatlands (Macdonald and Lieffers 1990; Humphrey and Pluth 1996), however it has received less attention in non-wetland ecosystems. Research is needed to determine if excess moisture is cause of low productivity on CH sites, in conjunction with field drainage trials. This work would significantly improve management recommendations for these sites.

7. An explanation for changes from the original workplan

Humus incubations from the high elevation trial: As part of the high-elevation *Vaccinium* trial, a humus incubation was planned, but an initial incubation revealed that there were no treatment differences for herbicide and non-herbicide plots, suggesting that humus manipulation would be unlikely to provide fruitful results. As the objective of incubations was to estimate nutrient availability, funding was used to determine seedling nutrient uptake instead, as indicated by total nutrient content. This is arguably a better indication of nutrient availability as it obviously includes plant-available nutrient forms and integrates availability over the life of the seedling, as opposed to a single-time incubation. We are satisfied that this change in the plan will provide us better data for the same amount of money.

SCHIRP Installation ceptometer assessment of light levels: During the past year, published research has indicated that hemispheric photography coupled with image analysis software and above-canopy solar energy prediction models are clearly superior to Ceptometer assessments of light climate, in terms of accuracy and convenience. Therefore, it was decided to rely solely on hemispheric analysis of light climate. This decision will save time and financial resources, while still producing a high quality deliverable.

Foliar analysis of salal on SCHIRP Installation: Salal foliar samples have been collected and stored from each treatment unit and experimental level. However, their analysis is currently in abeyance pending a committee meeting of the PhD student, at which time we will assess the necessity of these data in the context of understanding treatment differences and mechanisms.

Morphological identification of fungal fruit bodies: The unusually dry October prevented the usual seasonal flush of mushrooms, and so collection and identification was not possible.

DGGE and RISA of soil microbial communities from CH and HA forests: The analyses planned for forest floor samples from the SCHIRP Installation were modified based on information learned from the soil microbial study in unharvested cedar-hemlock and hemlock-amabilis fir forests. In that study, it was determined that data from the phospholipid fatty acid (PLFA) analysis was more informative than data from the denaturing gradient gel electrophoresis (DGGE) or ribosomal intergenic spacer (RISA) analyses. All the analyses were successful at detecting patterns in the soil microbial community based on forest floor layers, however, only the PLFA analysis distinguished the two forest types. It was surprising that the molecular analyses did not detect those differences, but subsequent discussions with other researchers in the field suggest this is becoming a common finding. It was decided that it would not be efficient use of funds or time to undertake DGGE and RIS analyses given that they were not likely to contribute additional information. The above techniques do not provide information about the potential functioning of the community, so an additional analysis, community-level physiological profiling (CLPP) was used to assess functional differences among communities. CLPP was used to compare the potential physiological capability of the microbial communities in the different SCHIRP Installation treatments and has previously been shown to be useful for comparing soil microbial communities.

Salal Root Exudate Study: The root exudate experiment is not completed because the start date was delayed 4 months until Dr Grayston's arrival from Scotland in February.

The equipment for this experiment proved more costly than our initial estimates, but these costs are offset by the substantial contributions of the Macaulay Land Use Research Institute and the British Royal Society who are funding all of Dr. Grayston's salary, travel and accommodation while she works on this project at UBC.

Appendices

Copies of manuscripts that were submitted to journals this year are included in the appendices. Articles that were published this year or accepted for publication this year were included in pervious final reports, but are available on request.

1. Response of salal (*Gaultheria shallon*) and fireweed (*Epilobium angustifolium*) to large additions of nitrogen and phosphorus fertilizer (Salal fertilization manuscript)

2. The role of N and P in increasing western hemlock and western redcedar productivity on northern Vancouver Island (Demo Trial/Plot Fertilization manuscript)

3. Characterization of humus microbial communities in adjacent forest types that differ in nitrogen availability (1st manuscript from microbial community project)

4. Comparison of chloroform fumigation-extraction, phospholipid fatty acid, and DNA methods to determine microbial biomass in forest humus (2nd manuscript from microbial community project)

5. Culturing and direct DNA extraction find different fungi from the same ericoid mycorrhizal roots (manuscript from mycorrhizae project. NOTE: The Summary of this paper is included in this file. The entire paper is included with the report in three PDF files beginning with "Allen"