Sierra-Cascade Intensive Forest Management Research Cooperative

Series Report No. 5

http://wric.ucdavis.edu.sierracascade/

ANNUAL REPORT 2004

TABLE OF CONTENTS

The year 2004 marked the fifth year as an organization for the Sierra Cascade Intensive Forest Management Research Cooperative. This year, as were the preceding four years, was a productive one for the Co-op. Two new proposals were presented to and accepted by the membership. Both of these proposals were funded and implemented during 2004. Five previously funded proposals were remeasured: one for third growing season values, and the other four for second growing season values. A presentation updating the status of the Co-op was made at the Forest Vegetation Management Conference held in Redding in January.

Five of the studies funded by the Co-op present updated results in this issue of the annual report. These include Exponential Fertilization (Timmer/Jopson), Stock Type/Fertilization (Fredrickson), Slow Release Fertilizer (Fredrickson), Competing Vegetation (Newton), and Western Pine Shoot Borer (Gillette/Webster). All of the plots in the first three studies had a release treatment during late summer/early fall. The two new studies that were funded in 2004, Verbenone Evaluation (Gillette) and Seed Dormancy/Soil Temperatures (Jacobs), report accomplishments in this issue. Plot establishment has been completed on the two sites (Sierra Pacific Industries and Roseburg Resources) selected for implementing the Agenda 2020 Study (Powers). The treatments will be applied in early 2005. Cal Forest Nursery is growing the weed species that are to be used in this study.

The Co-op hosted a field trip in October. The trip was centered on three sites in Oregon on which Mike Newton and Tim Harrington have been conducting research on interactions of conifers and three weed species, madrone, manzanita, and tanoak. All three studies are long term (20-23 years) and are of great value in the study of competing shrubs and conifers. The Co-op helped fund the latest remeasurements of these studies. Study results to date for the Newton plots are presented in this annual report. Mike and Tim did a masterful job in conducting the tour and are to be commended for their efforts.

Membership in our cooperative had a net decline during 2004, with two members dropping out and one new member added. Company reorganizations and hard economic times were the main reasons for this decline. The current membership of 18 consists of a mix of land-owners, forestry-related industries, and federal agencies.

We have finished the first full year with the California Forestry Association providing accounting/payment services for reimbursing contractors that work for the Co-op. The process continues to work very well. Contractors are getting paid within a week after they submit their invoices. Year-end accounting is much easier under this system.

The year 2005 looks to be a very active one for the Co-op. Full implementation of the Agenda 2020 study will be a major undertaking what with the variety of treatments being studied. The success of the verbenone study should lead to another proposal for funding from the Co-op and our assistance in study implementation. Both of these studies are pioneering research and merit the full consideration of the membership. Most of the other funded studies are scheduled for remeasurement in the fall.

The field trips that the Co-op has hosted during the last five years have been well received with much valuable information being presented. These "subject specific" tours allow the membership to get a more in-depth look at studies researching similar subjects and this approach seems to be valuable to participants. These field trips require a lot of work on the parts of the hosts and hopefully more members will offer to fill this role during 2005.

With the two new proposals funded this year (Gillette and Jacobs) the Sierra Cascade Intensive Forest Management Research Cooperative continues to fund studies related to the practice of intensive forestry. Hopefully more new proposals will be presented to the Co-op membership in 2005. We have an adequate budget to continue to fund good research proposals. This is an unusual situation in the research community, generally speaking. The Co-op membership should promote this opportunity. The results from the work we are funding are making a difference in forestry practices.

Cooperative Directors:

Ed Fredrickson
Roseburg Resources
Weed, CA

Joe DiTomaso
University of California
Davis, CA

Robert F. Powers
PSW Research Station
U.S. Forest Service
Redding, CA

Cooperative Manager

Gary Fiddler
Silviculture Development
USDA Forest Service
Redding, CA

Land Manager Membership:

Boise Cascade
Collins Pine Company
Fruit Growers Supply Co.
Roseburg Resources
Sierra Pacific Industries
Soper-Wheeler
Timber Products
W.M. Beaty & Associates

Associate Corporate Membership:

BASF
Cal Forest Nurseries
PRT

Affiliate Membership:

Dupont
Silver Butte Timber Company
IFA Nurseries

Supporting Members

California Forestry Association
PSW Research Station
University of California, Davis
USDA Forest Service

ORGANIZATION FUNDAMENTALS

The Sierra-Cascade Intensive Forest Management Research Cooperative was founded in February 1999. Its goal was to create a structure for ensuring and sustaining research in the areas of regeneration and early stand management. The SCIFMRC currently has 20 members.

The Cooperative is located at the Pacific Southwest Research Station in Redding, California. The membership is comprised of private, state and federal entities. The voting members pay yearly dues of $8,000 or $4,000, while non-voting affiliates pay $2,000. Research studies are approved by the full membership after review by the Board of Directors and the designated working groups. All members have full access to all the research results generated by the Cooperative.

MISSION STATEMENT

The SCIFMRC will conduct extensive research on conifer reforestation and young stand management in Northern California and Southwestern Oregon as a means of determining how trees react with their environment. The SCIFMRC will promote research on maximizing survival, growth and value while meeting other quality objectives of sound land stewardship.

OBJECTIVES

1. Develop, implement and evaluate intensive management methods to increase conifer productivity while protecting and enhancing other forest values.
2. Integrate various aspects of intensive management into one inclusive cooperative, focusing on improving establishment, growth and yield of forest plantations.
3. Focus research on problems of young stand management on interior forests of the Cascades and Sierra Nevada.
4. Inform members of current young stand management research.
5. Produce results that foresters can integrate into the decision process.

2004 Meetings and Field Trip

The 2004 annual business meeting was held at the Holiday Inn in Redding on January 19th. Approximately 25 Co-op members and guests attended.

Following introductions, some general items of business were covered:
Ed Fredrickson discussed the formation of the new company "Total Forestry". He and Jeff Webster are the founders and Vice President and President, respectively. The company will have offices out of Medford, Oregon and also locally out of Redding. Total Forestry will have the capability of doing most forestry jobs including planting, site prep/release spraying, brushing, slash work, etc. Ed explained to the Co-op that he would like to finish out 2004 as one of the Directors and we could revisit this matter in January of 2005. Since the new company is just getting on its feet, they will wait until next year to join the Co-op.

The new Roseburg Resources representative for the Co-op is Greg Johnson.

Another Co-op member, U.A.P., has had some changes since our last meeting. The west coast forestry staff has been taken over by the Helena Company. At this time, it is unclear about the status of several members of the U.A.P. staff. Bill Bailey is a Sales Specialist for Helena. (Bill was contacted following the meeting about Helena joining the Co-op and he will follow up on this matter).

The budget update for 2003 was the next item of business. The year ended with a surplus of about $67,108. The Co-op funds that are at UC Davis will be moved over to CFA shortly. These funds are included in the surplus figure. Ed Fredrickson suggested the Working Groups need to come up with more proposals as the Co-op has a lot of funds to direct toward research.

The next item of business was an update on the funded proposals (detailed write-ups can be found in the 2003 Annual Report):

Timmer/Jopson
This proposal was funded in 2000 to the amount of $30,000. Through the end of 2003, $10,086.57 has been spent. The measurements taken in the fall of 2003 were taken at the end of the second growing season.

Survival is still high for all species on all sites. In regards to caliper, height and volume, if there are significant differences, the 300 ppm treatment is always larger than the 50 ppm treatment. Significant differences between treatments are getting less common and when there is a significant difference, this difference is less than it was at the end of the first growing season.

It costs about $1500 to remeasure the plots in this proposal. The Co-op membership decided to review the complete data set as reported in the 2003 Annual report and decide if this study was to be remeasured at the end of the third growing season (fall 2004) or if it might be terminated.

Stock Type/Fertilization
This proposal was funded in 2000 in the amount of $20,640. The amount spent through 2003 is $8106.08. The fall 2003

measurements were taken at the end of the first growing season for this study.

Because of some problems at one of the nurseries, the original design of the study had to be changed. There will no longer be any white fir in the study. Survival of the Doug-fir at two of the sites is low and may become a problem if many more seedlings die in 2004.

The Annual Report for 2003 includes the complete data set for the first year of this study. Pre-planting and first year root/shoot ratios, 100 needle/dry weights, first year foliar analysis, as well as comparisons between treatments and within treatments are reported.

Slow Release

This proposal was funded in 2002 for $27,365. The amount spent through 2003 is $6,293.55. Since 2003 was the first year for this study, all of the treatments have not been put in. The spring treatments will be installed in March of 2004. End of the first growing season measurements will be made in fall of 2004. The pre-planting data for the fall treatment, which was installed in the fall of 2003, are reported in the 2003 Annual Report.

The membership discussed the possibility of the Co-op having its own greenhouse in order to raise the seedlings used for our trials. It was suggested that we could hire a grad student to do most of the work. Dave Sterns of IFA Nurseries volunteered space at one of his facilities. Tom Jopson of Cal Forest Nurseries has procedures for setting up trials. No formal decision was made concerning this possibility.

Newton Proposal

This proposal was original funded for $5000 in 2001. The original proposal's objective was to generate data to validate the SYSTEM-1 and CONIFERS growth models. Mike offered to expand the use of the data collected to satisfy the original proposal and produce some publications on the results of these long-term studies. In August of 2003, the Co-op increased the funding by another $5000 to do this additional work. Therefore the total funding for this proposal is $10,000. Mike has completed all of the work required for the original $5000 and is now in the process of writing the publications. The data collected have been given to Martin Ritchie of the Redding PSW staff. Martin will do the validation work for the two growth models.

Jeff Webster suggested that Mike's data should be shared with other modelers especially the Forest Biometrics Institute at the University of Montana. A general discussion of the values of growth models followed this suggestion.

Western Pine Shoot Borer

This proposal was funded for $7500 in 2002. This amount was used during the spring 2002 treatment. Results of this treatment are reported in the 2002 Annual Report. Plans were to apply a second treatment in the spring of 2003 if a better pheromone could be developed. The pheromone was in fact developed by 3M, but customs problems at the Canadian border prevented delivery of the new chemical in time for application in 2003. There was no treatment in that year. The investigators requested and received additional funding in the amount of $5000 from the Co-op at our January, 2004 meeting in order to apply a second treatment in the spring of 2004. A short discussion on some of the specifics of the 2004 application followed.

A general discussion among the membership concerning the amount of eucosma infestation in the Fountain Fire followed. It was agreed that the infestation was high. Scott Johnson asked if insecticides would work on eucosma species. The opinion was that due to these species being borers, an insecticide probably would not be too effective.

Agenda 2020 Proposal

This proposal was accepted by the Co-op in January of 2003. No funding is required from the Co-op as this proposal comes with its own funding from a competitive grant program.

Both sites were selected and logged in 2003. Plans are to lay out the plots for the study on both sites during 2004 with the actual treatments being installed in the spring of 2005. The brush species that are to be used for this study are being raised at Cal Forest Nursery in Etna. A more detailed update on this project can be found in the 2003 Annual report.

The next item of business was a report from the Working Groups. There were no meetings of either of the Working groups in 2003.

Tom Jopson, Chair of Working Group I, then discussed two new proposals that had been submitted to his group in 2004. The first one was submitted by Douglas Jacobs of Purdue University. It is titled "Evaluating the influence of seedling dormancy status and soil temperature in controlling new root growth of planted conifers". Tom presented the summary of the proposal and after some discussion by the membership, it was decided that Douglas should submit a complete proposal to the Co-op for possible funding (this was done in February).

The second proposal was submitted by Mark Gray and concerned the possibility of taking advantage of summer rains when planting conifers. How much soil moisture is needed before freshly planted seedlings will grow? Is it feasible to plant in the summer with adequate soil moisture? If so, nurseries can supply seedlings in a matter of a couple of days. The membership expressed interest in this idea. This proposal now needs to be completed and then submitted to the Co-op for possible funding.

Tom then presented an idea his Working Group had discussed at their January 13, 2004 meeting. This concerned setting up some less structured studies by Co-op members. These studies could be initiated and installed in a matter of weeks and would usually be short-term studies. A set of designs for various study types would be available on the Co-op website; a co-op member could send in a proposal and a study design, with a list of equipment required to install the study, would be selected from those listed on the website. The Co-op could have a supply of instruments, corner posts, etc. to implement these studies. Tom will submit a full proposal for this idea.

Jeff Webster then presented a summary of a new proposal from Working Group II. This proposal concerned the application of verbenone for protection of pines from Western Pine beetle attack. The project would take place in the spring of 2004 and be located in the vicinity of Big Valley Mountain near Adin, California. There was much interest in this proposal from the membership. Jeff and his co-investigator, Nancy Gillette, will submit a complete proposal to the Co-op for possible funding (this was done in February).

Following the presentation of new proposals, plans for the 2004 field trip were discussed. It was decided that an email would be sent to the membership requesting volunteers for conducting the trip (this was done in February). Mark Gray expressed a preference for a spring field trip as opposed to one in the fall.

The 2004 Business meeting ended after this discussion.

Working Group Meetings

Working Group I held a meeting at Mt. Shasta on January 13th. Present were Tom Jopson, Chair; Mark Gray; Glenn Novak; Tom Young; and Gary Fiddler.

The first item of discussion was a "framework" for research. Tom Jopson expressed his belief that the Co-op needs to develop a framework that describes the activities that the Co-op members are engaged in, the information that they use to make decisions related to these activities, and the goals the members would like for the Co-op. Jopson believes that the process of developing such a framework would help focus members on a set of common goals and would also help the Co-op decide on which projects it should pursue.

Tom Young stated that an important objective of the Co-op's efforts should be to assist members in understanding the implications of what is learned from the Co-op's studies.

Glenn Novak and Tom Young expressed thoughts on the rigorousness of the "science" that results from Co-op research, and where on the spectrum from "cowboy science to full-blown university studies" the Co-op ought to position itself. Fiddler stated that all the work that the Co-op has conducted to date is statistically sound and will qualify for publication in referred journals.

A discussion on how the Co-op should serve its members followed. Suggestions emerged that the Co-op could prepare equipment and protocols for various types of trials, and would assist members in conducting such trials without the need to prepare full-blown proposals. Each of these trials would be presented to the membership for discussion prior to implementation. It was suggested that a framework could facilitate this process by validating proposals that fit within its priorities.

Tom Jopson volunteered to do a first run at the creation of a framework by attempting to put together a description of member activities as they relate to the goals of the Co-op. Gary Fiddler was asked to look into equipment needs and costs if the Co-op were to assist members in various trials.

The second discussion item was a suggestion by Mark Gray that the Co-op assist members in development of test sites with supplementary irrigation available. Mark suggested that such sites could be used to evaluate the moisture limits of summer and early fall planting. There was a discussion of using these sites to look at the relationship between herbicides, soil types, and rainfall amounts. The Working Group members were asked to look into the feasibility of developing such sites along with the associated costs.

The third item of discussion was a proposal from Purdue University professor Doug Jacobs to look in detail at the relationships between seedling dormancy status, soil temperature, and root growth. Members of the Working Group expressed concerns about how much of the proposed work might already have been done. Gary Fiddler was to look into the references that were accumulated as part of the literature review of fall planting to check on how much of this type of work was in existing literature (this was done and very little relevant information has been published on this topic). Members felt that information to be gained from the proposal would make a valuable contribution to our understanding of planting stock performance under a variety of conditions.

The Working Group, after some clarifying of a few items by the researcher, decided to present the proposal to the full membership at the annual business meeting with a recommendation that the Co-op fund the proposal (see notes from annual business meeting).

The meeting adjourned at this time.

Field Trip

The Co-op sponsored a field trip on October 13. Three different sites on Bureau of Land Management lands in Oregon served as the stops for the field trip. Research on long-term effects of shrub competition on conifer growth was featured on the three sites. About twelve Co-op members attended. Mike Newton, Tim Harrington, and Liz Cole conducted the tour

The first stop was in the Applegate Valley near Ruch, Oregon. This site featured ponderosa pine growing in conjunction with whiteleaf manzanita on a poor site.

The second site was near Glendale and the species combination here was Douglas-fir and tanoak.

The third stop was near Canyonville and demonstrated the relationships between Douglas-fir and madrone.

All three studies are long-term and show the effects of competing vegetation on the growth of conifers. The 23-year results of Mike Newton's studies at Ruch and Canyonville are reported in a manuscript that he provided to the Co-op this summer. Copies of the manuscript were sent to all Co-op members in August. Some of the results of Tim's study at Glendale are included in Mike's paper. Tim presented the results in more detail at the Forest Vegetation Management Conference in January 2004.

Mike will use data from these studies to provide the Co-op with a comprehensive report that does cutting edge analysis of mixed model anovas of how curves develop in time in response to initial densities of the weeds or changing levels thereof. This report would also have data about estimated increments of the brush with time in terms of where the brush or hardwood is going while the trees are developing.

Mike, Tim, and Liz did a great job in hosting the field trip and those that attended received a lot of good information. These long-term studies are invaluable in implementing intensive forest management and the investigators are to be commended for their efforts.

Improving Seedling Nutrition in the Nursery to Increase Seedling Performance in the Field

Victor R. Timmer and Thomas Jopson, Principal Investigators

Objectives: Determine optimal nutrition for planting stock of Douglas-fir, white fir, and ponderosa pine to ensure high field survival and rapid early growth. Secondly, identify nursery nutritional practices to accomplish the first objective.

Seedlings grown with constant and sufficient internal nutrient concentrations achieved through exponential fertilization are free of nutrient stress. Seedlings can be produced with balanced, high reserves of nutrients superior to those possible through late-season heavy fertilization. Presumably, balanced, surplus reserves of nutrients at planting affords growth that is rapid enough to offset weed competition and soil drought. Questions to be answered are: (1) what techniques are best for western species? (2) how does nutrition favoring rapid growth affect seedling resistance /susceptibility to drought, pests, and temperature extremes?

At one or more forest nurseries, seedlings will be raised according to various nutrient regimes including conventional fertilization and exponential fertilization. Growth and nutrient status of the seedlings will be assessed at 2-week intervals during the culture period to chart the progress and adjust nutrient supply schedules. At lifting, seedlings will have nutrient contents that vary incrementally from conventional to very high values, and should identify a treatment optimal for out-planting success. Survival and growth of these seedlings will be followed for at least 5 years, at which time a firm decision can be reached on the best treatment(s) to apply to operational planting.

Status: A trial run using the fertilization rates specified in the proposal was made during 2001 at Cal Forest Nursery in Etna, CA. Three Co-op members supplied seedlings for the test, Boise Cascade, Fruit Growers Supply Co., and Soper-Wheeler. Three species were grown, Douglas-fir, pondersoa pine, and white fir

Problems with pH complicated the study while the seedlings were in the nursery. Over all, the constant rate fertilized seedlings outgrew the exponentially fertilized ones. Mortality was excessive with the latter application technique.

Vic Timmer visited Cal Forest Nursery in January of 2002.

The foliar analysis done at Davis showed a range of nitrogen levels in the seedlings, but only in the constant feed application. Timmer believed that nutrient concentrations were too low in the early stages for the exponential treatments, and that seedlings were stunted and not able to catch up to those in the constant feed treatment. A later foliar sample from Scott's Lab showed minor but consistent differences in nitrogen levels among the constant feed treatments. Whole seedling nitrogen concentrations generally increased in proportion to nitrogen concentrations in the constant feed solution.

It was decided to out-plant only the two extreme treatments in the constant feed technique: 50 ppm and 300 ppm.

The seedlings were lifted in February. Seedling height and caliper were recorded for each treatment and needles were collected and sent to Scott's Laboratory for analysis. This data will serve as baseline data.

In order to make this and other studies under Working Group I more compatible with the needs from Working Group II, the original design for this study was changed (see meeting notes for February 19 –20). Six replications of each treatment were to be out-planted if there were sufficient seedlings available. Spacing was to be increased to 10' X 10'. Plot size was to be 70' X 70' with 25 measure trees surrounded by a row of buffer trees in each plot. Seedling protection was to be applied at time of planting. The sites on Boise Cascade and Fruit Growers had been ripped; the site on Soper-Wheeler had not. To overcome this difference, the seedlings for the Soper-Wheeler site were to be auger planted. Vegetation control would be applied chemically to all plots and the plots will be kept weed-free during the life of the study.

All plots were established by the last week in March, 2002. Plot corners were marked by metal conduit and planting spots were designated with wire stake flags. All three sites had been planted as of the first week in April. Only ponderosa pine had sufficient numbers of seedlings to be out-planted on the Boise Cascade site. Six replications of the 50 ppm and 300 ppm treatments were out-planted there. Fruit Growers had enough seedlings for 5 replications of each treatment for ponderosa pine and white fir; four replications of Douglas-fir were out-planted. Six replications of each treatment for ponderosa pine and white fir and five replications of Douglas-fir were out-planted on the Soper-Wheeler site.

Measurements for seedling height and caliper were taken at all three sites in October, 2002. Needle samples were taken at this time for foliar analysis. This foliar analysis is currently being done. Survival was noted at the time the measurements were being taken.

First year data were analyzed in December, 2002. The experimental design was completely randomized with one-way treatment structure. Two treatments were each replicated 4 to 6 times. To test for treatment effects and significant differences among treatments, one-way analysis of variance of treatment means and Tukey tests were applied. Statistical significance in all tests was at the 0.05 level.

Results: Survival at the end of the first growing season was uniformly high for both treatments with all species on the three sites. Survival was always higher for the 50 ppm treatment when compared to the 300 ppm treatment but not statistically higher. For the study as a whole (all three sites), ponderosa pine survival ranged from 97-100 percent; white fir from 91-100 percent; and Douglas-fir from 94-100 percent.

Caliper, height, and volume values for the seedlings are presented in Table 1 and Table 2. The first table shows values at the time of lifting at Cal Forest Nursery in February of 2002. The second table shows the values at the end of the first growing season after out-planting. These measurements were taken in October, 2002. Volume is derived by multiplying squared caliper by the height.

For ponderosa pine, the only significant differences at time of lifting were for caliper of the Boise Cascade seedlings, where the 50 ppm treatment seedlings were larger than those in the 300 ppm treatment (a 19% increase), and height of the Fruit Growers seedlings, where the 300 ppm treatment seedlings were taller than those in the 50 ppm treatment (17% taller)

White fir seedlings showed no significant differences in caliper at time of lifting. Seedling height and volume for the 300 ppm treatment were always significantly larger than their counterparts in the 50 ppm treatment, however. The height of the seedlings receiving the 300 ppm treatment was about 45% greater than the height of those that received the 50 ppm treatment. The volume of the 300 ppm seedlings was about 50% more than volume of the 50 ppm seedlings.

For Douglas-fir, there were significant differences in height and volume at time of lifting for both Fruit Growers and Soper-Wheeler seedlings. The seedlings from the Fruit Grower's 300 ppm treatment also had significantly larger caliper than those seedlings in the 50 ppm treatment. Seedlings that were fertilized at the 300 ppm rate showed about a 30% increase in height over those fertilized at the 50 ppm rate. Volume was about 60% larger for the 300 ppm seedlings when compared to the 50 ppm seedlings.

It is obvious from the data presented in Table 1 that the seedlings are responding early on to the different levels of fertilization. For the most part, the seedlings that received the largest fertilizer rate (300 ppm) were bigger than those seedlings that received the smaller rate (50 ppm). At the time of their lifting in the nursery, white fir and Douglas-fir showed significant differences in height and volume for all seed lots. Those seedlings receiving the 300 ppm treatment were always larger than those receiving 50 ppm. Generally speaking, ponderosa pine seedlings did not show these differences.

The values shown in Table 2 represent the seedlings at the end of their first growing season after out-planting.

Even after one growing season in a plantation, ponderosa pine caliper does not differ significantly between the two fertilizer treatments. This is true for all three sites. The caliper for those seedlings receiving the 300 ppm treatment is always larger than that for the seedlings receiving 50 ppm, but not significantly so. Height and volume are a different story. Unlike at the time of lifting, these two values show significant differences between the two treatments after one growing season in a plantation. The values for the 300 ppm treatment are always significantly larger than those for the 50 ppm treatment. Height for the 300 ppm treatment shows about a 20% increase (average for the three sites) over the 50 ppm treatment. Volume shows about a 30% increase.

White fir seedlings showed significant differences in caliper, height, and volume between the treatments at the end of the first growing season on both sites. The 300 ppm treatment always had significantly larger seedlings than did the 50 ppm treatment. Caliper was about 17% larger, height about 43% larger, and volume about 97% larger for the seedling in the 300 ppm treatment when compared to those in the 50 ppm treatment.

Douglas-fir followed the pattern shown by white fir. In all instances except for the caliper of the Fruit Grower's seedlings, the values for the seedlings receiving the 300 ppm treatment were significantly larger than the values of those seedlings receiving the 50 ppm treatment. Height for the 300 ppm treatment was about 30% taller (two site average) than that of the 50 ppm treatment. Volume was about 65% more in the 300 ppm treatment than in the 50 ppm treatment.

In summary, after their first growing season, seedlings that were fertilized at the 300 ppm rate are always significantly taller and have significantly more volume than do their counterpart that received the 50 ppm rate. With the exception of ponderosa pine, this is also true for caliper. The percentage differences in height and volume that showed up at time of lifting are continuing to show after one year. The difference in volume is actually increasing. Survival is high regardless of treatment.

The seedlings will be measured at the end of their second growing season (fall 2003) to determine if these differences will continue to show. The higher level of fertilization does produce a larger seedling at least through the first growing season

2003: The seedlings were remeasured for caliper and height at all three sites in the fall of 2003 at the end of their second growing season. Survival was noted at the time the measurements were being taken.

Survival at the end of the second growing season was still uniformly high for both treatments with all species on the three sites. Unlike at the end of the first growing season, survival was not always higher for the 50 ppm as compared to the 300 ppm. For the study as a whole (all three sites), ponderosa pine survival ranged from 95-99 percent; white fir from 83-99 percent; and Douglas-fir from 85-91 percent. These percentages are lower than those reported at the end of the first growing season, but not significantly so.

Caliper, height, and volume values for the seedlings are presented in Table 3. Volume is derived by multiplying squared caliper by the height. These values represent the seedlings at the end of their second growing season after out-planting.

At the end of two growing seasons in a plantation, ponderosa pine caliper does not differ significantly between the two fertilizer treatments. This is true on all three sites. The caliper for those seedlings receiving the 300 ppm treatment is always larger than that for the seedlings receiving 50 ppm, but not significantly so. Ponderosa pine height is significantly taller for the seedlings receiving 300 ppm when compared to those seedlings receiving 50 ppm. This is true for all three sites. Height for the 300 ppm treatment showed about a 13% increase (average for the three sites) over the 50 ppm treatment. The ponderosa pines on the Fruit Growers site were the only ones to show significant differences for volume between the treatments. This is different than in 2002 when all three sites showed significantly more volume in the 300 ppm treatment as compared to the 50 ppm treatment. The 2003 volume for the seedlings receiving 300 ppm was about 35% more than the volume of the seedlings receiving 50 ppm.

Unlike at the end of the first growing season at which time both sites showed significant differences in white fir caliper, only the Soper-Wheeler site shows significant difference between the treatments in 2003. The caliper of the seedlings receiving 300 ppm was about 18% larger than the caliper of the seedlings receiving 50 ppm. As they were in 2002, height and volume for white fir is significantly larger on the 300 ppm treatment as compared to the 50 ppm treatment on both sites, although the differences are getting smaller. Height is about 27% larger and volume about 63% larger.

Douglas-fir showed no significant differences between treatments in caliper or volume on either of the sites. The values for the 300 ppm treatment were always larger than for the 50 ppm treatment but not significantly so. This is different than in 2002 at which time there were significant differences in volume on both sites and significant differences in caliper on one of the sites. Douglas-fir height was significantly different between the two treatments on both sites. For the study as a whole, height was about 24% larger in the 300 ppm treatment than in the 50 ppm treatment. This percentage difference is less than that found at the end of the 2002 growing season.

In summary, after their second growing season, seedlings that were fertilized at the 300 ppm rate are always significantly taller than are their counterparts that received 50 ppm. But the differences are less than at the end of the first growing season. Many of the significant differences among treatments in caliper and volume that showed up at the end of the first growing season are no longer there. The 300 ppm treatment always gives the higher values for these two variables but many of the differences among the two treatments are no longer statistically different. Survival continues to be high for all treatments.

2004: Seedlings were remeasured for caliper and height at all three sites in the fall of 2004 at the end of their third growing season. Survival was noted at the time the measurements were being taken.

Survival continues to be high for both treatments with all species on the three sites. Survival for the 50 ppm treatment is slightly higher than that in the 300 ppm treatment in 5 of the 7 comparisons. For the study (all three sites), ponderosa pine survival ranged from 96-99 percent, exactly the same as at the end of the second growing season; white fir from 79-89 percent, down slightly from the end of the second growing season; and Douglas-fir from 80-90 percent, also down slightly from the second growing season numbers.

Caliper, height, and volume values for the seedlings are presented in Table 4.

Volume is derived by multiplying squared caliper by height. These values represent the seedlings at the end of their third growing season after out-planting.

Caliper: At the end of three growing seasons in a plantation, ponderosa pine caliper does not differ significantly between the two fertilizer treatments. This is true on all three sites. The caliper for those seedlings receiving the 300 ppm treatment is always larger than for those seedlings receiving 50 ppm, but not significantly so. As was the case at the end of the second growing season, only the Soper-Wheeler white fir showed significant difference between the treatments in 2004. Douglas-fir showed no significant differences between treatments in 2004 on either site.

Height: Ponderosa pine height is significantly taller for the seedlings receiving 300 ppm when compared to those receiving 50 ppm on the Soper-Wheeler site only. Although there is a difference, it is not significant on the other two sites. This is a change from the 2003 results in which height was significantly taller with the 300 ppm treatment on all three sites. Only on the Soper-Wheeler site was height difference significant for white fir between the treatments. The seedlings receiving 300 ppm were always larger. In 2003 both sites having white fir showed significant differences in height. The only significant difference in Douglas-fir height was on the Fruit Growers site. In 2003 both sites having Douglas-fir showed significant differences in height.

Volume: There was no significant difference in volume between treatments for ponderosa pine on any of the sites. This differed from 2003 at which time the Fruit Growers site showed significant differences in pine volume. The Soper-Wheeler site was the only site showing significant differences in white fir volume between the treatments. Last year the Fruit Growers and the Soper-Wheeler sites showed significance differences. As was the case in 2003, Douglas-fir showed no significant differences in volume due to treatment on any of the sites.

In summary, after three years in a plantation, seedlings that were treated at the 300 ppm rate are always taller, have larger caliper, and have more volume than seedlings treated at the 50 ppm rate. But the majority of these differences are no longer significant. Of the 21 comparisons possible (fertilizer rates/species), only 5 show significant differences. In 2003 that number was 11. There seems to be an influence of site quality (most influence on higher sites) but even this generalization has problems. As far as tree species, white fir is the most influenced by fertilization rate. The most influenced dependent variable is tree height. Survival continues to be high on all sites for all treatments.

Total Funded: $30,000; Total Spent as of 12/31/04: $15,002.31.

Table 1-- Values for caliper, height, and volume for seedlings for the Timmer/Jopson Proposal at time of lifting, February, 2002.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Boise Cascade			
50 ppm	0.487a	15.000a	3.602a
300 ppm	0.409b	17.000a	2.928a
Fruit Growers Supply			
50 ppm	0.495a	16.200b	4.040a
300 ppm	0.457a	19.000a	3.909a
Soper-Wheeler			
50 ppm	0.476a	14.450a	3.295a
300 ppm	0.436a	16.850a	3.267a
White Fir			
Fruit Growers Supply			
50 ppm	0.347a	15.056b	1.842b
300 ppm	0.347a	23.889a	2.915a
Soper-Wheeler			
50 ppm	0.371a	16.600b	2.298b
300 ppm	0.384a	22.300a	3.313a
Douglas-fir			
Fruit Growers Supply			
50 ppm	0.383b	21.553b	3.229b
300 ppm	0.429a	30.580a	5.727a
Soper-Wheeler			
50 ppm	0.406a	26.000b	4.404b
300 ppm	0.440a	32.100a	6.252a

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 2-- Values for caliper, height, and volume for seedlings for the Timmer/Jopson Proposal at end of first growing season, October, 2002.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Boise Cascade			
50 ppm	0.756a	26.818b	16.948a
300 ppm	0.803a	29.170a	20.435a
Fruit Growers Supply			
50 ppm	0.896a	24.360b	21.178b
300 ppm	0.940a	29.976a	28.244a
Soper-Wheeler			
50 ppm	0.879a	19.977b	16.582b
300 ppm	0.921a	26.186a	24.009a
White Fir			
Fruit Growers Supply			
50 ppm	0.416b	20.628b	3.791b
300 ppm	0.484a	29.217a	7.282a
Soper-Wheeler			
50 ppm	0.490b	19.653b	5.045b
300 ppm	0.579a	28.399a	10.259a
Douglas-fir			
Fruit Growers Supply			
50 ppm	0.584a	28.475b	10.757b
300 ppm	0.659a	36.941a	17.544a
Soper-Wheeler			
50 ppm	0.592b	25.319b	9.663b
300 ppm	0.669a	33.945a	16.136a

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 3-- Values for caliper, height, and volume for seedlings for the Timmer/Jopson Proposal at end of second growing season, October, 2003.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Boise Cascade			
50 ppm	1.81a	43.79b	176.23a
300 ppm	2.02a	48.11a	219.36a
Fruit Growers Supply			
50 ppm	1.52a	38.89b	102.12b
300 ppm	1.65a	45.82a	137.57a
Soper-Wheeler			
50 ppm	1.97a	40.52b	176.53a
300 ppm	2.08a	45.83a	218.40a
White Fir			
Fruit Growers Supply			
50 ppm	0.77a	28.60b	18.74b
300 ppm	0.84a	36.69a	29.65a
Soper-Wheeler			
50 ppm	0.80b	27.31b	20.31b
300 ppm	0.94a	34.11a	33.88a
Douglas-fir			
Fruit Growers Supply			
50 ppm	0.83a	31.72b	27.52a
300 ppm	0.93a	40.40a	43.16a
Soper-Wheeler			
50 ppm	0.90a	33.46b	33.69a
300 ppm	1.00a	40.55a	45.42a

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 4-- Values for caliper, height, and volume for seedlings for the Timmer/Jopson Proposal at end of third growing season, October, 2004.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Boise Cascade			
50 ppm	3.64a	87.44a	1397.64a
300 ppm	4.04a	97.14a	1738.00a
Fruit Growers Supply			
50 ppm	3.06a	62.03a	690.63a
300 ppm	3.26a	67.88a	816.00a
Soper-Wheeler	2.96a	78.89a	797.10a
50 ppm	3.18a	85.60b	969.53a
White Fir			
Fruit Growers Supply			
50 ppm	1.41a	43.01a	100.07a
300 ppm	1.55a	49.19a	140.48a
Soper-Wheeler			
50 ppm	1.21a	44.07a	74.62a
300 ppm	1.51b	52.16b	132.71b
Douglas-fir			
Fruit Growers Supply			
50 ppm	1.51a	47.83a	143.25a
300 ppm	1.70a	56.82b	201.02a
Soper-Wheeler			
50 ppm	1.30a	50.15a	107.38a
300 ppm	1.37a	53.07a	116.66a

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Long-Term Competition Threshold Studies in Southwestern Oregon

Mike Newton, Principal Investigator; Ed Fredrickson, Co-op Sponsor

Objective: Determine the long-term (20 year) effects of various levels of shrub and herbaceous competition on planted ponderosa pine and Douglas-fir on four contrasting study sites.

In the early 1980s, Mike Newton established a series of studies in southwestern Oregon designed to look at how the growth of planted conifers was affected when the conifers were grown with various levels of competition. Four separate studies are still intact and have been measured regularly, but they have not been evaluated since 1994. The Applegate Study consists of ponderosa pine and Douglas-fir growing in various levels of manzanita competition. The study looks at no competition, 25%, 50%, 75%, and full competition from the manzanita. The Shoestring Study looks at Douglas-fir growth at four levels of competition from pacific madrone (none, low, medium, and high). The Fir Point and Squaw Studies are similar in design but focus on Douglas-fir growth with varying densities of tanoak cover. Three of the studies also look at the interactions with herbaceous cover (with and without).

These studies present an excellent opportunity to obtain growth and yield information based on various levels of competition which could be used to either validate, or make projections using the growth simulators SYSTUM-1 or its later variant, CONIFERS. These data would allow us both to improve these young stand simulators and to make projections as to what these treatments might produce farther down the line.

Proposal: Re-measure all trees in those study sites which have not been compromised by subsequent management activities. Collect the type of measurements needed in order to make long-term projections using SYSTEM-1 or CONIFERS. Martin Ritchie of the Pacific Southwest Research Station at Redding will work with Mike as to what measurements need to be made.

Provided that sufficient data were collected to either validate, or make projections using the growth simulators, the Co-op agreed to funding at a level of about $5000 for 2002. Some of the study sites may have been compromised. In one case, some of the numbered trees and tanoak have been cut by the landowner. In another, some of the plots have been brushed recently. Thus, some of the original group of study sites may have been lost. Mike will determine which of the study sites remain viable and report to the Co -op.

Status: The principal investigator received permission from the Co-op to measure these plots in the winter of 2003 (instead of 2002 as originally planned).

The measurements on the Doug-fir plots were finished by February 11, 2003. The pine plots were scheduled to be finished by February 26th. Mike met with Martin Ritchie of PSW earlier in the month on some of the plots to show Martin what kind of data he would be receiving. This data will be forwarded to Martin when Mike gets it entered and verified.

The forwarding of this data to Martin was done in the fall of 2003 and this fulfilled the obligations under the original contract Mike had with the Co-op.

In January, 2003 Mike was in discussion with the Directors of the Co-op regarding some other benefits that could be derived from the data being collected. He offered to provide some additional outputs from the data collection funded by the Co-op combined with data collected earlier from the sites. These included a straight-forward report on methods and what initial regressions show in terms of conifer yield at a variety of ages under the influences of various levels of competition.

A second output would be a comprehensive report that does cutting edge analysis of mixed conifer anovas of how curves develop in time in response to initial densities of weeds or changing levels thereof. This report would also have data about estimated increments of the brush with time in terms of where the brush or hardwood is going while the trees are developing. Guesses can be made as to whether the trees have dominated the brush completely, or whether the brush is still beating up on the trees and whether that situation is changing. Is it the same for ponderosa pine as Doug-fir?
The second output would be in a manuscript form and would follow the initial report by a number of months. Preparation of a final publication would come later but would be well underway with the comprehensive report.

Mike offered to do this additional work for another $5,000 from the Co-op.

This proposal was presented to the membership in August and was approved by the voting members by the end of the month. Mike has been notified and the Co-op has started the process of getting the second installment of funds allocated. Results will be reported in 2004.

2004: In July, Mike delivered the first of the outputs agreed to in the new proposal accepted by Co-op membership in August 2003. This was the report on methods and what initial regressions showed in terms of conifer yields at a variety of ages under the influences of various levels of competition. Copies of this report were mailed to the Co-op membership in August. Mike, Liz Cole, and Tim Harrington used these results as the basis for the field trip they hosted for the Co-op on October 13th.

Total Funded: $10,000; Total Spent as of 12/31/04: $10,000.

Evaluation of New Formulation for Mating Disruption of the Western Pine Shoot Borer

Nancy Gillette and Jeff Webster, Principal Investigators

Introduction: The western pine shoot borer (WPSB), *Eucosma sonomana*, is a pest that causes severe height reduction in several pine species in western North America. Forest industry has invested considerable resources in planting sites subjected to wildfire, but the incidence of WPSB is on the increase, probably as a result of the increased acreage devoted to large, even-aged pine plantations. Many plantations are experiencing infestation levels of 30-40% of stems and in some cases, such as parts of the Pondosa plantation, infestation levels are in the 80-90% range. Attacks occur when tree heights are between 1 – 15 m tall. Female moths prefer terminal shoots and can reduce height growth more than 20% per year (Sower et al. 1984). This reduction in height growth results in considerable volume loss. Past studies showed that WPSB selectively attacks the fastest growing trees in the stands, and that elimination of WPSB can increase volume growth over a five-year period by 17-24%, depending on the background level of infestation (based on actual tree measurements) (Williams et al. 1989). Several different types of dispensers are effective for mating disruption with synthetic semiochemicals (Sower et al. 1982, Sower et al. 1984, Williams et al. 1989). However, the older pheromone release systems are limited because of their physical characteristics: Hercon® luretapes must be applied from the ground, when sites are often inaccessible, and Hercon® flakes require specialized aircraft that are no longer available. A new, microencapsulated (MEC) pheromone release system has been developed that shows promise for other forest pests (Rappaport et al. 2001). The MEC is a water suspension of microscopic beads containing the pheromone, and it is fully compatible with existing pesticide aerial application equipment. Thus, no specially equipped aircraft are needed to spray the MECs, and application can be made regardless of season, snow-pack, or road conditions. A MEC pheromone registered for eastern pine shoot borer (*Eucosma gloriola*) (Grant et al. 1994) is essentially the same as the pheromone for the WPSB, and thus is likely to also be effective against WPSB. We propose to test the MEC formulation of the eastern pine shoot borer pheromone as an aerial application for mating disruption of the WPSB.

Objectives:

- Evaluate a microencapsulated blend of Z-9 and E-9-dodecenyl acetate for mating disruption of WPSB.
- Determine reduction in host damage levels.
- Establish guidelines for operational use.

Justification: Cost-benefit analyses clearly demonstrate the value of prophylactic treatments for the control of WPSB damage in pine plantations; for young stands, the return on the investment was seven-fold (Williams et al. 1987, Daterman, unpublished).

Estimates of infestation rates in the Pondosa plantation average 70-80% of the standing trees, with a concomitant potential height loss of 20% per year (i.e. a 5% loss in volume at harvest). There currently exist hundreds of thousands of acres of pine plantations in the Pacific Northwest that are susceptible to WPSB or that will soon become susceptible. These plantations resulted from catastrophic wildfires such as the Pondosa, Scarface, Day and Fountain Fires, and are of necessity pine monocultures. As such, they are particularly susceptible to plantation pests, and steps must be taken to prevent further losses before these younger plantations reach the vulnerable stage. The new pheromone product is already registered with the US EPA, so very little expense or regulatory work will be required to implement this product for use in forest stands once efficacy is demonstrated.

Methods: The test sites will be located in pine plantations in northern California or southern Oregon that are heavily infested with WPSB, such as the Pondosa, Day, or Scarface plantations. Sites will be selected with trees that are 10-20 years old and range up to 7m tall. Two treatments (untreated controls, pheromone at 12g ai/A) will be replicated as five 50 acre plots (larger plots are better than smaller plots because of the risk of immigrating mated females from outside the treated area; however, 50 acres is the maximum we can treat without triggering an EUP requirement). Application will be made using standard procedures using helicopters or fixed-wing aircraft (as required by the terrain) equipped with booms for pesticide spray application. Plots will be separated by 1 kilometer for maximum isolation from treatment influence. A monitoring subplot of nine acres will be located in the center of each of the ten plots (5 treated and 5 control plots). Within each subplot, efficacy of mating disruption will be measured using 5 randomly placed male response traps ("sentinel" traps baited with the equivalent of one female moth's pheromone), monitored at biweekly intervals. Damage reduction will be assessed by measuring height and diameter growth of 50 randomly selected trees per nine-acre subplot. Post treatment impact evaluation will occur during the month of August 2002. Subsequent measurements will be made at two 5-year intervals if funding or in-kind services are available to cover the labor costs for the measurements. If results warrant, more 5-year or 10-year measurements could be taken until the end of the rotation. FHTET, in concert with the MEC manufacturer, will assess release rates of the formulation over the winter to ensure that release rates match those of Hercon® luretapes and flakes, which have demonstrated efficacy for western pine shoot borer. The treatments will be considered successful if the rate of damage reduction equals or exceeds that of the Hercon® flake release system (i.e. a 70% reduction in infested terminals).

Principal Investigators/Cooperators: Nancy Rappaport – Pacific SW Research Station; Jeff Webster – Roseburg Resources Co.; Ed Frederickson – Sierra-Cascade Forest Intensive Management Research Cooperative; Gary Daterman – Pacific NW Research Station; Gary G. Grant – Canadian Forest Service; John Stein and Richard Reardon – Forest Health Technology

Enterprise Team; Grant Oliver – 3M Canada.

Duration: October 2001 – December 2003. We will conduct just a single application of the microencapsulated pheromone (March 2002). Post-treatment measurements will be done for one year post-treatment, but may continue for 5 years or more if treatment is sufficiently successful to warrant extra follow-up costs. Efficacy of mating disruption will be summarized and reported by November, 2002; impact on height and volume growth in 2002 will be reported by December 2002.

References cited:

Grant G.G. 1994. Practical considerations in the use of pheromone and semiochemicals for management of insect pests of seed orchards. Pp. 71-82 *in* Turgeon JJ and de Groot P (eds.), Biology, Damage and Management of Seed Orchard Pests, *Canadian Forest Service Pest Management Institute Report* FPM-X-89.

Grant G.G., MacDonald L, Frech D., Hall K., and Slessor K.N. 1985. Sex attractants for some eastern species of *Rhyacionia*, including a new species, and *Eucosma gloriola* (Lepidoptera: Tortricidae). *The Canadian Entomologist* 117: 1498-96.

Rappaport, N.G., D.R. Owen and J.D.Stein. 2001. Interruption of semiochemical-mediated attraction of *Dendroctonus valens* (Coleoptera: Scolytidae) and selected nontarget insects by verbenone. Environmental Entomology

Sower, L.L., D.L. Overhulser, G.E. Daterman, C. Sartwell, D.E. Laws, and T.W. Koerber. 1982. Control of *Eucosma sonomana* by mating disruption with synthetic sex attractant. Journal of Economic Entomology 75: 315-318.

Sower, L.L. and M.D. Shorb. 1984. Effect of western pine shoot borer (Lepidoptera: Oelthreutidae) on vertical growth of ponderosa pine. Journal of Economic Entomology 77: 932-935.

Williams, C.B., E.L. Smith and T.W. Koerber. 1989. Damage appraisal and management of the western pine shoot borer, *Eucosma sonomana*, in pine plantations in California: a case study. Pp. 110-123 in: R.I. Alfaro and S.G. Glover, Insects affecting reforestation: Biology and Damage. Forestry Canada, Pacific Forestry Centre, Victoria, British Columbia, Canada.

***Proposed Budget - FY 2002 (only):**

Source	Contributed Resources
FHTET	$14,000
3M Canada	$10,000
PSW	$8,000
PNW	$5,000
Cooperative (Sierra-Cascade)	$7,500
Roseburg Resources	$2,000
Total	$46,500

* Alternative budget, below, assumes that Coop will do post-treatment measurements.

Alternative Proposed Budget - FY 2002 (only):

Source	Contributed Resources
FHTET	$14,000
3M Canada	$10,000
PSW	$8,000
PNW	$5,000
Cooperative (Sierra-Cascade)	$5,000
Roseburg Resources	$2,000
Total	$44,000

2002: A new study was initiated this year (2002) in northern California to test mating disruption of the western pine shoot borer (*Eucosma sonomana*). This moth is a serious pest, known to reduce height growth of pines up to 20% per year in western North America. A synthetic pheromone registered for the eastern pine shoot borer (*E. gloriola*) is also effective against the western pine shoot borer. This year, FHTET sponsored a new microencapsulated formulation of the pheromone for aerial application, and tested it for an area-wide effect on five 50-acre plots.

Preliminary results indicate that 12g/acre, applied aerially as a microencapsulated formulation of the active pheromone ingredient, significantly reduced early season trap catch (we report only results for the first month post-treatment, since moth flight was nearly over by that point).

The effect on infestation level was variable, with the best results seen in the two Pondosa plots and the worst results seen in the two Scarface plots (Table 2):

The reduction on infestation level varied between 21.1% and 77.4%, with the best results seen in the two Pondosa plots and the worst results at Scarface 2.

We have not yet determined the reason for the differences in efficacy at the different plots, but there are several possible explanations. First, differences in temperature and humidity may have caused the active ingredient to release at a more rapid rate on the Scarface and Crank plots than at Pondosa. Second, differences in weather may have caused differential degradation of the active ingredient (this possibility is not likely considering the nature of the pheromone). Third, there were different WPSB population pressures at the different sites (Scarface 2, in particular, started out with a very low pre-treatment infestation rate (2%), but infested leaders at the control site increased astronomically (to 38%), between 2001 and 2002) (Table 3).

Fourth, and probably most likely, differences in temperature and/or snow cover may have resulted in later emergence at some sites, thus missing the window of pheromone elution from the microcapsules. Results from the monitoring traps (Table 1), support this conclusion. For example, if the higher levels of infestation in treated plots resulted simply from increased population pressure, then we would expect Pondosa 1 to have had a high infestation level, because by one month following treatment the Pondosa 1 control plot had one of the highest trap catches. But in fact, Pondosa 1 had the second-lowest level of infestation in the treated plot. We conclude, therefore, that the greater levels of control seen at the Pondosa plots resulted from better synchrony of local phenology with spray timing. This conclusion suggests a need for a longer-releasing microcapsule, perhaps on the order of just 7-14 days longer.

The striking increase in background populations at Scarface 2 suggests that those plots constituted a stronger challenge to the treatments than did the Pondosa plots, where background populations were either flat or only increased moderately. A second year of testing and statistical analyses is necessary to determine stand growth benefits. We will clearly need to assess treatment effects using the annual increase in infestation as a covariate, since it appears that rapid increases in background populations can affect efficacy.

These results, while somewhat disappointing, compare favorable in terms of efficacy with results from the luretape technology. We feel that the technology still has promise for use in western plantations, because it remains the only formulation that can be aerially applied using conventional spray equipment. We are currently trying to recruit funding for a second application, which we hope would further suppress moth populations.

Table 1. Numbers of moths responding to pheromone-baited traps, by week

	2 Weeks	2 Weeks	4 Weeks	4 Weeks
Location	**Treatment**	**Control**	**Treatment**	**Control**
Pondosa 1	0	15	2	127
Pondosa 2	0	82	0	41
Scarface 1	0	182	1	141
Scarface 2	0	24	19	168
Crank	0	96	7	44

Table 2. Percent infestation of leaders by WPSB, treatment vs. control plots

Location	Treatment	Control	% Reduction
Pondosa 1	14	62	77.4
Pondosa 2	6	48	75.0
Scarface 1	32	70	54.3
Scarface 2	30	38	21.1
Crank	20	56	64.3

Table 3: Percent infestation of leaders by WPSB, 2001 vs. 2002 (control plots only):

Location	2001	2002
Pondosa 1	54	62
Pondosa 2	48	48
Scarface 1	64	70
Scarface 2	2	38
Crank	50	56

2003: The Principal Investigators reported on the results of the 2002 application at the January 2003 business meeting of the Co-op. If 3M could develop a better/longer lasting formulation, the Investigators were proposing a second treatment in the spring of 2003. In March, the Co-op membership was notified that the new formulation had been developed and the Investigators were requesting funding amounting to $1850 from the Co-op for this 2003 application. Funding for the second application was approved by the membership on March 24, 2003.

The pheromone got held up in customs (it was coming from Canada) and by the time it cleared customs and reached the researchers, the weather on the test site had deteriorated and prevented the application. By the time the weather improved, the insects were already flying and it was too late to apply the treatment in 2003. The plan is to store the pheromone and apply for Co-op funding for a spring 2004 application. This request will be made at the January 2004 business meeting in order to distribute the funds to the researchers in time to apply the treatment in early spring.

2004: The second of two applications of a microencapsulated formulation of western pine shoot borer (*Eucosma sonomana* Kearfott) pheromone, 80:20 Z:E-9-dodecenyl acetate, was conducted in 2004 to disrupt moth mating in a northern California ponderosa pine plantation. The first application was conducted in 2002 (see above). The pheromone proved to be behaviorally active for another pest species, (*Rhyacionia bushnelli* Busck), so its effect on that species was measured as well. Five 20.25-ha plots were treated with the pheromone, and five 20.25-ha untreated plots served as controls. The 2002 application was made at the rate of 20.5 g AI/ha, and the 2004 application was made at twice that rate, or 59.0 g AI/ha. Sentinel traps baited with western pine shoot borer lures were placed in treated and control stands in both 2002 and 2004 to assess efficacy of mating disruption of both moth species. *E. sonomana* infestation levels were tallied at the end of the season. Both applications effectively shut down mating by both moth species for several weeks, with the 2002 application lasting about 45 days and the 2004 application for fully 75 days. Both applications significantly reduced infestation levels by western pine shoot borer, but the lower application rate provided greater absolute reductions in infestation level, perhaps because infestation levels were far higher before the 2002 treatments than before the 2004 treatments. In any case, the infestations were reduced to similar levels in both years, suggesting that while increasing the application rate may prolong mating disruption, it may not provide greater efficacy in terms of tree protection from moth attack. The incidence of moth infestations even in plots with complete mating disruption suggest either that the treatments missed a few early emerging females or that mated female moths immigrated into treated plots; thus operational testing should be timed earlier in the season and should comprise much larger plots to decrease the edge effect. In both 2002 and 2004, moth emergence began considerably earlier than reported in previous studies, indicating that mating disruption programs should account for potentially warmer climates in timing applications. The active ingredients in this pheromone blend have also shown behavioral activity for 13 other species of *Rhyacionia* and six other species of *Eucosma*, so the approach may have broad application for control of many damaging pest species.

Total Funded: $12,500; Total Spent as of 12/31/04: $11,938.40.

Evaluation of Microencapsulated Verbenone for Protection of Pines from Western Pine Beetle Attack

Nancy Gillette, Principal Investigator

Introduction: The western pine beetle (WPB), *Dendroctonus brevicomis*, is a native insect of western conifer forests (Furniss and Carolin 1977). Its primary hosts are ponderosa pine and Coulter pine. WPB populations are cyclic, with outbreaks increasing in severity during periods of drought. In order for WPB larvae to develop successfully, the parent beetle population must kill the tree, ensuring that the tree is incapable of "pitching out" the beetle progeny. WPB has an aggregation pheromone that enhances its ability to concentrate large numbers of beetles during the attack phase. During outbreaks, large numbers of pines are mass-attacked and killed; for example, it is estimated that 60-90% of some extensive ponderosa pine stands were killed by WPB during the drought of the 1920s (Furniss and Carolin 1977).

Management Options: Currently, the only registered control methods for *Dendroctonus* bark beetles are verbenone pouches and the insecticides carbaryl (Sevin SL® and Sevimol,®), lindane, permethrin, and injected metasystox-R. The use of lindane, a chlorinated hydrocarbon, is controversial at best (Koerber 1976), and metasystox-R is marginally effective (Haverty et al. 1997). The continued availability of carbaryl for forestry uses is in question, and the use of such carbamate pesticides is problematic anyway because of human health and wildlife concerns. The use of verbenone pouches, while effective in some situations, is problematic because the treatment requires placing individual pouches on tree trunks. This process is extremely labor-intensive, and stands are often not accessible by road or by foot. In addition, unless pouches are applied high on the trunk, they remain accessible to children. They may also present a hazard to wildlife. The only other option for controlling pine bark beetles is the manipulation of forest stand structure to make trees less susceptible to bark beetle attack. Such manipulations require harvesting trees at a younger age than is commonly done on most National Forest lands.

Insect behavioral chemicals offer a more environmentally benign option for preventing tree mortality caused by WPB. A large body of basic research has shown that verbenone is an effective repellent/inhibitor for many *Dendroctonus* species, including WPB (Bertram and Paine 1994, Miller et al. 1995, Paine and Hanlon 1991, Payne and Billings 1989, Rappaport et al. 2001, Sun et al. 2002). Verbenone pouches are now registered for use in preventing damage by bark beetles in the genus *Dendroctonus*, but these pouches are of use only in situations where the pouches can be deployed by hand, because the pouches must be individually stapled to the trunks of pine trees. The pouches are not practical, therefore, for large-scale treatment of forests where access by roads is limited. There is also some concern that pouches may represent a health hazard to humans and wildlife, because the pouches can be torn open, releasing concentrated verbenone. The microencapsulated formation, on the other had, is a water-based suspension of 25-

micron microcapsules that can be sprayed from aircraft using conventional spray equipment. The residue on foliage or trunks is much more dispersed and is contained in the microcapsules, and is slowly released over time. Furthermore, we expect that the microencapsulated formation, because it more closely mimics natural release of pheromone by beetles in a forest ecosystem, may more effectively disrupt host location by *D. brevicomis* than do pouches. Microencapsulated formulations release pheromones from million of point-sources per acre, as compared to less than 100 point-sources per acre for pouches and bubblecaps. An aerial application of the formulation would leave deposits in the foliage and branches, and might therefore repel beetles before they even enter the stand, unlike pouches, which are applied to the trunks.

Microencapsulated formulations of other pest pheromones have already been registered (e.g. eastern pine shoot borer, *Eucosma gloriola* pheromone), so the technology for the end-use device raises no concerns regarding registration. The new microencapsulated formulation of verbenone has been tested as a single-tree protection treatment (sprayed to run-off onto the trunks of pine trees), and has shown considerable promise (Rappaport et al. 2001, Sun et al. 2002).

Project Objective: Test effectiveness of the microencapsulated bead formulation of verbenone against western pine beetle field populations. This study will depend upon laboratory and field results involving the formulation and release rates conducted during the fall and winter of 2002/3. Verification of formulation and release rates will allow Tier I testing to proceed.

Methods: Field plots will consist of host tree stands located in areas of California with suitable population levels of WPB (a suitable site has been located on Roseburg Resources lands in Siskiyou County, CA). Ten 50-acre plots will be established with a minimum of one kilometer between plots. The treatments and untreated controls will be randomly assigned to the 10 experimental plots. The field trial will be conducted with a single formulation (3M microcapsules) of (S)-verbenone and an untreated control. Each treatment will have five replicates. The dose rate will be determined by the results from ongoing laboratory tests. A helicopter equipped with conventional spray tanks, booms and spray nozzles will be used for application of the microencapsulated beads.

Efficacy will be determined by baiting five trees within each sprayed and each control plot with the commercially available WPB lure as a challenge to the repellency of verbenone. The variables of interests will be the proportions of trees mass-attacked and killed by WPB. Data will be analyzed with SAS using the general linear model of ANOVA (McCullough and Nelder 1989, SAS Institute 1997).

Equipment and facilities available: Forest Service staff in our Redding, CA laboratory has extensive experience with formulation and aerial application of pesticides. Our industry cooperators have an existing contract with aerial pesticide applicators. Our Placerville, CA laboratory is equipped with a capillary GC for assessment of pheromone release rates, should that need arise.

Potential benefits: The target pest, *D. brevicomis*, is distributed across California, Nevada, Utah, Oregon, Washington, Arizona and New Mexico (Furniss and

Carolin 1970). We ultimately expect that this formulation may be applicable to the most serious pests, nation-wide, of forest ecosystems (*D. frontalis and D. ponderosae*) because verbenone is a fairly broad-spectrum beetle repellent (Rappaport et al. 2001). We expect this formulation to be more acceptable to users in many situations, because it can be applied aerially and does not leave a large volume of concentrated pheromone that can be accessed by children or wildlife. We do not expect it to raise concerns about nontarget effects, because earlier tests show that it does not attract predators or secondary pests (Rappaport et al. 2001). The formulation could be expected to be used both in aerial applications over forest stands and for individual tree protection in campgrounds, homes, and the urban landscape (parks, golf courses, etc.).

Commercialization: This research proposal supports registration by testing efficacy of the microencapsulated formation of verbenone as an aerial application rather than as a hydraulic spray to individual tree trunks. This type of application represents the real promise of microencapsulated formulations for forestry use, and the real promise for management of pine bark beetles.

2004: The Western pine beetle (WPB) is the most destructive insect pest of ponderosa pine in the western United States, Canada and Mexico. There is a long record of efficacy of verbenone as an interruptant; however, available release systems for verbenone over large areas have previously been limited to beads, bubblecaps, and pouches. Aerially applied beads (5 mm diam. polyethylene beads) were successful in one application, but subsequent tests failed to achieve control. This failure may have resulted from the relatively short release period of the beads, which have verbenone adsorbed on the exterior of the bead. In an attempt to achieve better control of western bark beetle species, Hercon Environmental (Emigsville, PA) has produced a new formulation of verbenone, the 1/8 inch square verbenone Disrupt® flake, to our specifications for field testing. In contrast to the polyethylene bead tested in the past, the verbenone flake system has verbenone sandwiched between impermeable polymer layers, so release is both more sustained and more even (closer to a "zero-order" release). Laboratory tests using artificially high temperatures show 45 days of release of verbenone from flakes (Fig. 1).

The laminated flake is likely safer than verbenone pouches because it is a far smaller dispenser, with the AI contained inside the hard plastic laminate reservoir. It has the added advantage that it can be applied by aircraft, so high-value landscapes (i.e. scenic road corridors) and sensitive wildlife habitat in remote and otherwise inaccessible regions can be protected from bark beetle mortality. In addition, there is evidence that increasing the number of point-sources from 40/acre (pouches) to ca. 20,000/acre (Flakes) may greatly improve efficacy of pheromone-based control strategies in forest environments. Also, verbenone (like many anti-aggregation pheromones) has been shown to be slightly attractive at very low release rates. We feel that a strategy that does not rely upon stapling the release device to tree trunks, as does the pouch, may thus have greater efficacy. Climate trends suggest that western pine stands will be subjected to even further stress in the future, so bark beetle populations are likely to grow accordingly.

We assessed efficacy of verbenone flakes for reducing WPB populations by applying 150 g AI/acre of verbenone flakes to five 50-acre plots with moderate to high WPB populations. Five untreated 50-acre plots with comparable beetle infestations and similar stand structures served as controls. The study was conducted in the Big Valley Mountains on Roseburg lands using fixed-wing aircraft fitted with metered dispensing hoppers to achieve even flake distribution. Baited traps were placed in each plot to assess beetle populations in treated and untreated plots, and efficacy was assessed by measuring beetles/trap, tree attack rate and tree mortality by visually evaluating all susceptible hosts along three transects per 50-acre plot. The variables of interest were numbers of beetles trapped, numbers of trees attacked, numbers of trees killed, and rate of attack/tree. These variables are expected to be Poisson distributed, so the treatment effects will be compared using SAS GenMod procedures for over-dispersed Poisson-distributed counts, and multiple comparisons will be made using the Bonferroni approach.

Results: The treatment was considered a success based on beetle trap catch data (Fig. 2) and preliminary tree mortality data, which showed that while 75% of baited trees died in the control plots, only 20% died in the treated plots. Baiting trees is an extremely strong challenge for the treatment, so we expect that unbaited trees will show much greater protective effective of the verbenone flake treatment. The trap based results (Fig. 2) show a much longer field life than the laboratory data. This difference is probably a result of the artificially high temperatures used for the laboratory analysis. In addition, the laboratory results were based on a sustained temperature for the entire exposure period, whereas the field data resulted from normal diurnal temperature fluctuation, which can well be expected to result in longer release periods.

Total Funded: $10,000; Total Spent as of 12/31/04: $10,000.

Figure 1: Laboratory analysis of release of Verbenone from Verbenone Disrupt® Flakes (data provided by Hercon Environmental)

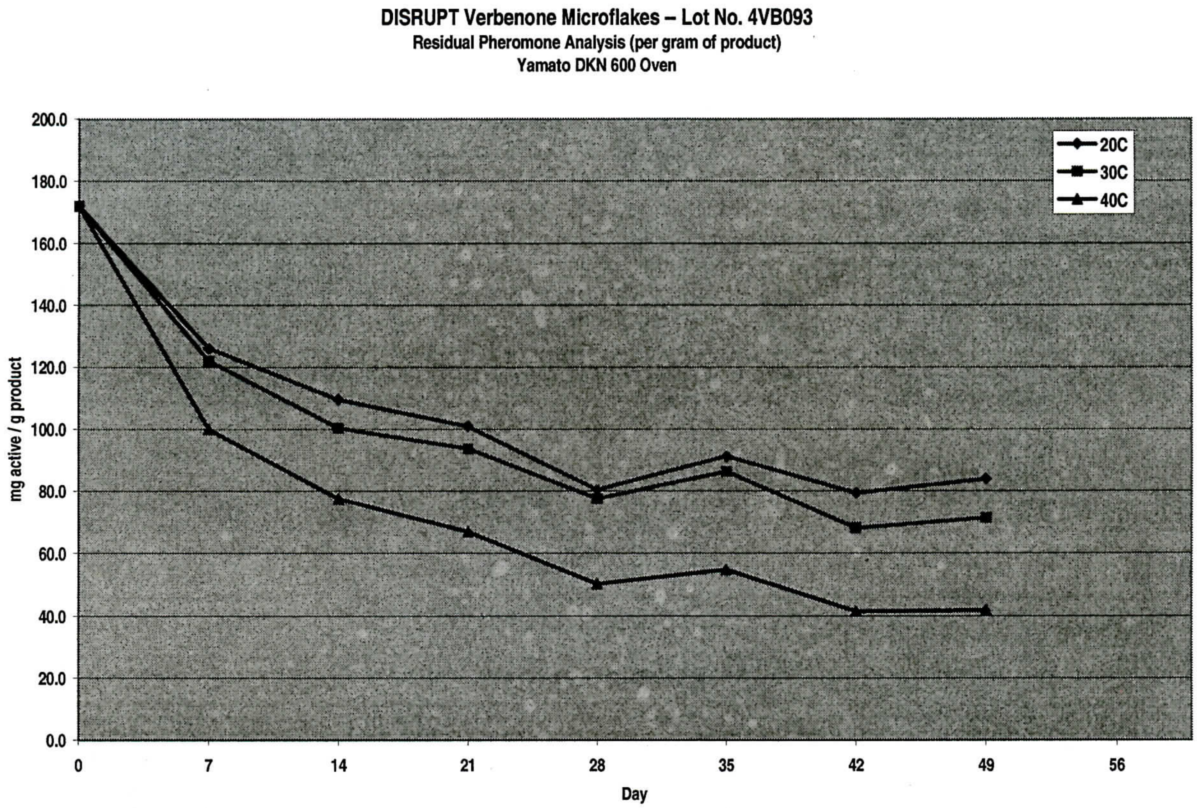
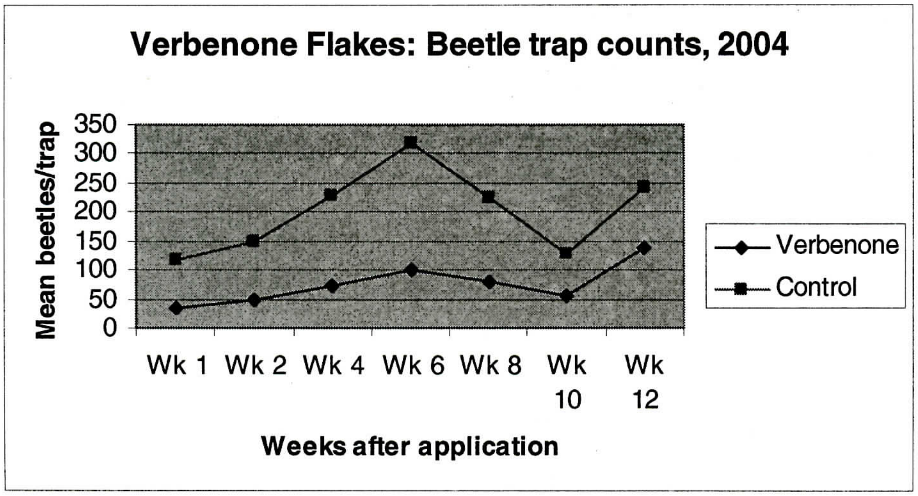


Figure 2: Verbenone Flake aerial application, Lassen County, CA, 2004



Improving the Establishment and Growth of Douglas-fir and White Fir On Dry Sites Through Fertilization and Stock Type

Ed Fredrickson, Principal Investigator

Objectives: (1) To determine the partial contributions of stock size and fertilization to Douglas-fir and white fir survival, growth and total above ground biomass on dry sites in the interior Sierra Cascade region of northern California and southwest Oregon under vegetation-free conditions. (2) To determine the partial contributions of stock size and fertilization on initial root growth and total root volume (dry weights) after the first growing season in the field. (3) To determine differences attributable to site based on low and high precipitation zones.

Douglas-fir and white fir seedlings in four stock sizes will be subjected to two fertilization regimes and out-planted on three sites. Treatments will be replicated four times per site. Twenty-five trees will be planted per replication. Assume 3 years complete vegetation control for all treatments. Root volume measurements will be made at time of lifting and at the end of the first growing season in the field. Trees will be measured (ground-line diameter, height, survival) when planted and at years 1, 2, 3, 4, and 5. Foliar nutrient samples and dry weights per 100 needles will be collected and analyzed at years 1, 3, and 5.

Status: Seedlings were grown at Pelton Reforestation, Cal Forest Nurseries, PRT, IFA Nurseries, and Fowler Nursery for outplanting in the spring of 2003. Co-op members in this study include Roseburg Resources, Sierra Pacific Industries, and Boise Cascade.

Plot establishment and lay-out was completed on the first two sites in the fall of 2002 and on the third site prior to planting in February, 2003.

All three sites were planted during March, 2003. All sites had adequate soil moisture at time of planting and there was no snow on the ground. Each site received substantial moisture following the planting, so the seedlings got off to a good start.

The sites were set up according to the revised specifications: 10' X 10' spacing, 56 trees/plot, etc.

Preplanting measurements of caliper (1 inch above ground line) and height (from ground line to tip of bud) were taken on 50 randomly selected seedlings from each stock type/fertilization treatment for every species that was to be planted on each company's land. Twenty of these seedlings were taken back to Redding where they were oven dried and root/shoot ratios determined.

The two bare root stock types that were to receive the fertilization treatment were fertilized at the time of planting by placing one Wil-Gro briquette (9-9-4) in the bottom of the planting hole.

Boise Cascade

Two clearcut blocks were used for this installation – one for the pine and one for the Doug-fir. Both blocks are located near the town of Prospect, OR, which is about 50 miles east of Medford, OR.

The plug-1s and the 1-1s were shovel planted; all other stock types were planted with hoedads. All pine stock looked fine, although the plug-1s were very large. With the Doug-fir, the plug-1s and the styro 8 unfertilized were slightly yellow; the rest of the stock types looked fine.

The pine block has 5 replications of each treatment. There was just enough room in the Doug-fir block for 4 replications of each treatment.

Sierra Pacific Industries
Two clearcut blocks were used at this site, also, one for the Doug-fir and one for the white fir. The blocks are located near the town of Feather Falls, CA which is east of Oroville. All stock types were shovel planted. The styro 8 Doug-fir (both fertilized and unfertilized) were slightly yellow.

The Doug-fir block has 5 replications of each treatment.

The 1-1 stock type for the white fir looked very poor. Size variability was large. There were not enough good trees to plant all the replications needing 1-1s, so only the 5 replications of the unfertilized treatment were planted. The 5 plots set up for the 1-1 fertilized treatment were left unplanted.

All styro 20 white fir were fertilized despite the boxes being labeled as fertilized or unfertilized. All boxes labeled as unfertilized were opened and sampled: all were fertilized. The boxes labeled as fertilized were also fertilized. The planting was done as if the labels on the boxes were correct – seedlings from the boxes labeled unfertilized were planted in the 5 plots designated for the unfertilized treatment and seedlings from boxes labeled fertilized were planted in the 5 plots set up for that treatment. In reality, these 10 plots have the same treatment = fertilized styro 20 white fir.

The white fir styro 8 and plug-1 treatments each have 5 replications.

Roseburg Resources
Both species (Doug-fir and white fir) were planted in the same clearcut at this site. The planting site is located near Nubieber, CA.

All stock types were shovel planted.

The Doug-fir has 5 replications of each treatment.

As was the case with the stock for the Sierra Pacific site, the 1-1 white fir Roseburg stock looked very poor. There were not enough good seedlings to plant all replications needing 1-1s, so only the 5 plots of the unfertilized treatment were planted. The 5 plots designated to receive fertilized 1-1s were left unplanted.

The white fir plug-1 and styro 8 treatments each have 5 replications.

None of the styro 20 white fir were fertilized even though some of the boxes were labeled as being fertilized. A Wil-Gro briquette was placed in the bottom of the planting hole in the 5 plots designated to receive fertilized styro 20s. The 5 plots designated to receive unfertilized styro 20s received the proper seedlings.

In July, foliar samples for each species/stock type/treatment combination from all three study sites were collected. These samples were sent to the J.R. Peters Laboratory for nutrient analysis. In addition, dry weights per 100 needles were determined from these samples.

In October, representative seedlings from each species/stock type/treatment combination were dug up from each of the three sites. These samples were taken to Redding where they were washed and oven dried. Root/shoot ratios were determined from this procedure.

First year growth measurements were take on all three sites during October – December. Measurements taken included caliper (at 1 inch above ground line) and height (ground line to tip of bud). Seedling volume will be calculated from these measurements. Survival was noted at this time as well as any pest problems.

The results from the various measurement and data collection operations that were done in 2003 are reported in nine tables found at the end of this narrative.

Table 1 shows dry weights of 100 needles by treatment and species collected from the sites at the end of the first growing season in August, 2003. In general, the fertilized treatments had the larger values when compared on a stock type basis.

Table 2 shows plant tissue analysis results for selected macro nutrients. These samples were collected at the end of the first growing season in August, 2003. Other macro nutrients and a full set of micro nutrients were run. A full data set is on file at PSW in Redding and is available on request.

Table 3 shows seedling survival by treatment and species at the end of the first growing season in August, 2003. The survival of the pine on the Boise Cascade site ranged from 94-100%; the Doug-fir ranged from 71-100%. The Doug-fir on the Roseburg site ranged from 38-96%; the Doug-fir on the Sierra Pacific site ranged from 42-68%. On the Roseburg site in 3 out of the 4 stock types, the seedlings in the unfertilized treatment had better survival than those in the fertilized treatment. This was reversed on the Sierra Pacific site where in 3 out of the 4 stock types, the seedlings in the fertilized treatment had a higher survival rate than did their unfertilized counterparts. On the Boise pine site, the seedlings that were fertilized generally had a lower survival rate than did the unfertilized ones in the various stock types. On the Boise Doug-fir site in two of the stock types the fertilized seedlings had a better survival rate than the unfertilized ones. In the remaining two stock types, the unfertilized seedlings survived better. There was only minor browsing damage to the seedlings on the Roseburg and Sierra Pacific sites. The Doug-fir on the Boise site showed browsing damage on 12 percent of the seedlings. The pine on the Boise site showed little browsing.

Table 4 shows root/shoot ratios by treatment and species at the time of lifting in February, 2003. Significant differences between treatments are indicated. The bare root fertilized treatments have no values as these treatments were fertilized at the time of planting.

Table 5 shows root/shoot ratios by treatment and species at the end of the first growing season in October, 2003. Significant differences are indicated by letters following the numerical values. On the Boise and Roseburg Doug-fir sites there were no significant differences between the treatments. There are significant differences between treatments on the Sierra Pacific site and the Boise pine site.

Table 6 shows values for caliper, height, and volume at time of lifting in February, 2003. Significant differences within a stock type between fertilized and unfertilized seedlings are indicated. The 1-1 fertilized and the plug 1 fertilized treatments have no values as these treatments were fertilized at the time of planting. Volume is calculated by multiplying squared caliper by height. There were no significant differences in volume between fertilized and unfertilized treatments within a stock type for any species or land owner. All seedlings started out equal at planting time.

Table 7 shows values for caliper, height, and volume at the end of the first growing season, October, 2003. Significant differences within a stock type between fertilized and unfertilized seedlings are shown by letters following the numerical values. Only Boise Cascade pine showed any significant differences in volume within a stock type between fertilized and unfertilized seedlings. Plug 1 fertilized seedlings were significantly larger than their counterpart unfertilized ones. With this exception, as at time of lifting, at the end of the first growing season, the seedlings within a stock type whether fertilized or not were still equal.

Table 8 shows significant differences between treatments for caliper, height, and volume at the time of lifting in February, 2003. Volume is calculated by multiplying squared caliper by height. Volume for the bare root treatments (1-1 fertilized and plug 1 fertilized) are missing as these two treatments were fertilized at time of planting. For all ownerships and all species, volume is always significantly higher for the bare root treatments than for the container treatments. With the exception of the Doug-fir on the Roseburg site where there is no difference, in all ownerships and species plug 1 volume is always significantly higher than 1-1 volume.

Table 9 shows significant differences between treatments for caliper, height, and volume at the end of the first growing season in October, 2003. As was the status at the time of lifting, for all ownerships and all species, volume is always significantly higher for the bare root treatments than for the container treatments. But different from the results at the time of lifting, in the bare root treatments, plug 1 volume is not always significantly higher than 1-1 volume at the end of the first growing season. By land owners, the treatments with the most and the least volume were: Boise Cascade pine = plug 1 fertilized and styro 8 fertilized; Boise Cascade Doug-fir = 1-1 fertilized and styro 8 fertilized; Sierra Pacific Doug-fir = plug 1 fertilized & nonfertilized and styro 8 fertilized; Roseburg Doug-fir = 1-1 fertilized and styro 8 unfertilized.

This study is scheduled for remeasurement at the end of its second growing season which would be the fall of 2004. In general, at the end of the first growing season, the treatments that had the biggest seedlings at the time of planting still have have the biggest seedlings. The fertilized seedlings are not always larger than their unfertilized counterparts. Considering volume only, in about 60 percent of the time are fertilized seedlings larger than their counterpart unfertilized ones.
Since several of the seedlings, although still alive, were not very thrifty when measured in October 2003, survival could continue to be an issue on the Roseburg and Sierra Pacific sites for the container treatments, both fertilized and unfertilized.

2004: Second year growth measurements were taken on all sites during the fall of 2004. Measurements taken included caliper (at one inch above ground line) and height (ground line to tip of bud). Seedling volume will be calculated from these measurements. Survival was noted at this time as well as pest problems.

Survival of container and plug-1 stock was poor on the Roseburg site (**Table 10**). Survival of bareroot Douglas-fir was significantly greater than container stock at the Boise site. At the Sierra Pacific site, survival of 1+1 stock was greater than the other three types.

Survival of ponderosa pine was good for all stock types (> than 92%).

Overall, there were no effects of fertilization on survival, although the styro 8 fertilized seedlings at Roseburg has greater survival than the unfertilized styro 8 seedlings.

Significant differences among the Douglas-fir stock types were found for height, caliper, and volume, and rankings varied by site **(Table 11)**. At the Roseburg and Boise Cascade sites, the 1+1 bareroot seedlings were larger than the plug-1; at the Sierra Pacific site, the 1+1 and plug-1 stock were similar in size. At all three sites, the container stock tended to be somewhat smaller than the transplant stock, although there were instances where the differences were not significant.

In general, there were no significant effects of fertilization on the Douglas-fir. As with survival, at the Roseburg site, the fertilized styro 8 seedlings were significantly larger in caliper and volume than the unfertilized seedlings.

For ponderosa pine, stock types were significantly different from each other for height, caliper, and volume **(Table 12)**. The rankings, from largest to smallest, were plug-1, 1+1. styro 20, and styro 8.

For the pine, fertilized seedlings were significantly taller and larger in caliper and volume than unfertilized seedlings. At this point in time, the differences are slight.

Third year growth measurements will be taken in the fall of 2005. Survival of the styro 20 and plug-1 stock on the Roseburg site is very low. These treatments may fall out as viable treatments after the 2005 remeasurements.

Table 1—Dry weight values of 100 needles from seedlings of the Stock Type/Fertilization Proposal at end of the first growing season, August, 2003.

	Roseburg Doug-fir	SPI Doug-fir	Boise Doug-fir	Boise Pine
	Dry Weight/100 needles (grams)			
Plug 1 No/Fert.	0.16	0.18	0.24	1.68
Plug 1 Fert.	0.17	0.21	0.18	1.92
1-1 No/Fert	0.19	0.24	0.23	1.74
1-1 Fert.	0.19	0.23	0.26	2.12
Styro 8 No/Fert.	0.14	0.21	0.22	1.68
Styro 8 Fert.	0.20	0.23	0.24	1.57
Styro 20 No/Fert.	0.15	0.18	0.21	2.49
Styro 20 Fert.	0.19	0.23	0.28	2.83

Table 2—Plant tissue analysis results for selected macro-nutrients listed by the treatments showing the high and low values for seedlings of the Stock Type/Fertilization Proposal at the end of the first growing season, August, 2003.

	Nitrogen		Phosphorus		Potassium	
			Percentage			
Boise Doug-fir						
	Plug 1 F	2.25	Plug 1 N/F	0.188	St 8 N/F	0.822
	St 8 F	1.50	1-1 F	0.109	Plug 1 N/F	0.511
Boise Pine						
	St 8 F	1.59	St 20 F	0.194	Plug 1 N/F	1.090
	1-1 N/F	1.05	1-1 F	0.134	1-1 F	0.972
SPI Doug-fir						
	Plug 1 F	2.13	Plug 1 F	0.182	St 8 N/F	0.738
	St 20 F	1.49	1-1 F	0.105	Plug 1 F	0.516
Roseburg Doug-fir						
	Plug 1 F	2.64	St 20 N/F	0.190	St 20 N/F	0.663
	St 8 N/F	1.47	1-1 F	0.121	1-1 F	0.519

F = fertilized; N/F = not fertilized.

Table 3—Seedling Survival by treatment and species for the Stock Type/Fertilization Proposal at end of first growing season, August, 2003.

	Roseburg Doug-fir	SPI Doug-fir	Boise Doug-fir	Boise Pine
		Percent Survival		
Plug 1 No/Fert.	61	47	85	98
Plug 1 Fert.	46	42	77	98
1-1 No/Fert	96	65	97	100
1-1 Fert.	86	68	100	99
Styro 8 No/Fert.	49	42	75	95
Styro 8 Fert.	82	56	71	94
Styro 20 No/Fert.	44	53	70	98
Styro 20 Fert.	38	58	78	94

Table 4 – Root/shoot ratios by treatment and species for seedlings from the Stock Type/Fertilization Proposal at time of lifting, February, 2003.

Ratio	Roseburg Doug-fir	SPI Doug-fir	Boise Doug-fir	Boise Pine
Plug 1 No/Fert.	1.61ab	1.58bc	1.40c	1.51b
Plug 1 Fert.	*	*	*	*
1-1 No/Fert.	1.91a	1.52c	1.90a	2.07a
1-1 Fert.	*	*	*	*
Styro 8 No/Fert.	1.42b	1.60bc	1.89a	1.56b
Styro 8 Fert.	1.38b	2.01ab	1.69abc	1.21bc
Styro 20 No/Fert.	1.74ab	2.12a	1.80ab	1.08c
Styro 20 Fert.	1.85a	2.20a	1.47bc	1.04c

* Fertilized at time of planting.

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 5 – Root/shoot ratios by treatment and species for seedlings from the Stock Type/Fertilization Proposal at end of first growing season, October, 2003.

	Roseburg Doug-fir	SPI Doug-fir	Boise Doug-fir	Boise Pine
Ratio				
Plug 1 No/Fert.	1.89a	1.86ab	1.72a	1.87b
Plug 1 Fert.	1.84a	1.55b	1.72a	1.71b
1-1 No/Fert.	1.82a	1.49b	1.73a	2.06b
1-1 Fert.	1.66a	1.59ab	1.94a	1.83b
Styro 8 No/Fert.	1.46a	1.65ab	1.87a	3.04a
Styro 8 Fert.	1.62a	2.25a	1.83a	2.47ab
Styro 20 No/Fert.	2.01a	1.60ab	1.92a	2.05b
Styro 20 Fert.	2.00a	1.61ab	2.00a	2.48ab

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 6—Values for caliper, height, and volume of seedlings for the Stock Type/Fertilization Proposal at time of lifting, February, 2003.

Boise Pine

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.05	24.51	29.93
1-1 Fertilizer	*	*	*
Plug -1 No Fertilizer	1.53	36.04	89.56
Plug -1 Fertilizer	*	*	*
Styro 8 No Fertilizer	0.55b	25.82b	8.03a
Styro 8 Fertilizer	0.43a	17.33a	3.37a
Styro 20 No Fertilizer	0.54a	22.35a	6.72a
Styro 20 Fertilizer	0.57a	20.46a	6.99a

Boise Doug-fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	0.97	43.83	44.73
1-1 Fertilizer	*	*	*
Plug -1 No Fertilizer	1.17	37.97	53.76
Plug -1 Fertilizer	*	*	*
Styro 8 No Fertilizer	0.37a	31.82a	4.46a
Styro 8 Fertilizer	0.35a	29.27a	3.82a
Styro 20 No Fertilizer	0.57a	37.57a	12.84a
Styro 20 Fertilizer	0.56a	42.17b	13.94a

* Fertilized at time of planting.

This table shows significant differences within a stock type between fertilized and non-fertilized seedlings. For land-owner and species, treatment means within a stock type followed by the same letter do not differ significantly at the 0.05 level.

Table 6 contd.

Roseburg Doug-fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.06	45.72	57.02
1-1 Fertilizer	*	*	*
Plug -1 No Fertilizer	1.12	35.76	49.50
Plug -1 Fertilizer	*	*	*
Styro 8 No Fertilizer	0.37a	22.11a	3.12a
Styro 8 Fertilizer	0.37a	23.00a	3.22a
Styro 20 No Fertilizer	0.56a	32.30a	10.73a
Styro 20 Fertilizer	0.52a	34.27a	9.73a

SPI Doug-fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	0.96	35.08	34.46
1-1 Fertilizer	*	*	*
Plug -1 No Fertilizer	1.17	39.70	63.24
Plug -1 Fertilizer	*	*	*
Styro 8 No Fertilizer	0.34a	21.86a	2.55a
Styro 8 Fertilizer	0.34a	26.13b	3.12a
Styro 20 No Fertilizer	0.54a	35.54a	11.01a
Styro 20 Fertilizer	0.55a	35.47a	11.28a

* Fertilized at time of planting.

This table shows significant differences within a stock type between fertilized and non-fertilized seedlings. For land-owners and species, treatment means within a stock type followed by the same letter do not differ significantly at the 0.05 level.

Table 7—Values for caliper, height, and volume of seedlings for the Stock Type/Fertilization Proposal at end of the first growing season, October, 2003.

Boise Pine

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.38a	30.17a	65.85a
1-1 Fertilizer	1.49b	31.45a	77.08a
Plug -1 No Fertilizer	1.65a	42.87a	125.37a
Plug -1 Fertilizer	1.79b	45.11a	154.52b
Styro 8 No Fertilizer	0.85a	30.11a	24.70a
Styro 8 Fertilizer	0.83a	27.24a	20.29a
Styro 20 No Fertilizer	1.04a	35.19a	41.19a
Styro 20 Fertilizer	1.07a	33.79a	44.37a

Boise Fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.06a	44.56a	55.46a
1-1 Fertilizer	1.10a	45.96a	60.95a
Plug -1 No Fertilizer	1.07a	35.24a	46.84a
Plug -1 Fertilizer	1.17b	36.41a	55.17a
Styro 8 No Fertilizer	0.62a	31.43b	13.39a
Styro 8 Fertilizer	0.54a	23.66a	7.97a
Styro 20 No Fertilizer	0.76a	41.83a	26.30a
Styro 20 Fertilizer	0.76a	39.20a	25.16a

This table shows significant differences within stock types between fertilized and non-fertilized seedlings. For land-owners and species, treatment means within a stock type followed by the same letter do not differ significantly at the 0.05 level.

Table 7 contd.

Roseburg
Doug-fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.15a	45.53a	67.33a
1-1 Fertilizer	1.21a	48.91a	78.44a
Plug -1 No Fertilizer	1.13a	35.24a	55.21a
Plug -1 Fertilizer	1.06a	31.02a	39.92a
Styro 8 No Fertilizer	0.52a	23.64a	7.19a
Styro 8 Fertilizer	0.61a	27.49a	11.26a
Styro 20 No Fertilizer	0.69a	34.81a	18.57a
Styro 20 Fertilizer	0.64a	34.38a	16.00a

SPI
Doug-fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.02a	40.88a	47.32a
1-1 Fertilizer	1.07a	39.75a	51.51a
Plug -1 No Fertilizer	1.20a	45.19a	77.01a
Plug -1 Fertilizer	1.28a	43.38a	78.92a
Styro 8 No Fertilizer	0.58a	26.59a	9.93a
Styro 8 Fertilizer	0.57a	26.96a	9.76a
Styro 20 No Fertilizer	0.67a	32.59a	16.45a
Styro 20 Fertilizer	0.79b	39.19b	26.40a

This table shows significant differences within stock types between fertilized and non-fertilized seedlings. For land-owners and species, treatment means within a stock type followed by the same letter do not differ significantly at the 0.05 level.

Table 8—Values for caliper, height, and volume of seedlings for the Stock Type/Fertilization Proposal at time of lifting, February, 2003.

Boise Pine	Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
	1-1 No Fertilizer	1.05b	24.51bc	29.93b
	1-1 Fertilizer	*	*	*
	Plug -1 No Fertilizer	1.53a	36.04a	89.56a
	Plug -1 Fertilizer	*	*	*
	Styro 8 No Fertilizer	0.55c	25.82b	8.03c
	Styro 8 Fertilizer	0.43d	17.33e	3.37c
	Styro 20 No Fertilizer	0.54c	22.35cd	6.72c
	Styro 20 Fertilizer	0.57c	20.46d	6.99c

Boise Doug-fir	Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
	1-1 No Fertilizer	0.97b	43.83a	44.73b
	1-1 Fertilizer	*	*	*
	Plug -1 No Fertilizer	1.17a	37.97b	53.76a
	Plug -1 Fertilizer	*	*	*
	Styro 8 No Fertilizer	0.37d	31.82c	4.46d
	Styro 8 Fertilizer	0.35d	29.27c	3.82d
	Styro 20 No Fertilizer	0.57c	37.57b	12.84c
	Styro 20 Fertilizer	0.56c	42.17a	13.94c

* Fertilized at time of planting.

This table shows significant differences between treatments. For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 8 contd.

Roseburg Doug-fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.06a	45.72a	57.02a
1-1 Fertilizer	*	*	*
Plug -1 No Fertilizer	1.12a	35.76b	49.50a
Plug -1 Fertilizer	*	*	*
Styro 8 No Fertilizer	0.37c	22.11c	3.12b
Styro 8 Fertilizer	0.37c	23.00c	3.22b
Styro 20 No Fertilizer	0.56b	32.30b	10.73b
Styro 20 Fertilizer	0.52b	34.27b	9.73b

SPI Doug-fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	0.96b	35.08b	34.46b
1-1 Fertilizer	*	*	*
Plug -1 No Fertilizer	1.17a	39.70a	63.24a
Plug -1 Fertilizer	*	*	*
Styro 8 No Fertilizer	0.34d	21.86d	2.55c
Styro 8 Fertilizer	0.34d	26.13c	3.12c
Styro 20 No Fertilizer	0.54c	35.54b	11.01c
Styro 20 Fertilizer	0.55c	35.47b	11.28c

* Fertilized at time of planting.

This table shows significant differences between treatments. For land-owners and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 9—Values for caliper, height, and volume of seedlings for the Stock Type/Fertilization Proposal at end of the first growing season, October, 2003.

Boise Pine

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.38d	30.17d	65.85c
1-1 Fertilizer	1.49c	31.45cd	77.08c
Plug -1 No Fertilizer	1.65b	42.87a	125.37b
Plug -1 Fertilizer	1.79a	45.11a	154.52a
Styro 8 No Fertilizer	0.85f	30.11de	24.70ef
Styro 8 Fertilizer	0.83f	27.24e	20.29f
Styro 20 No Fertilizer	1.04e	35.19b	41.49de
Styro 20 Fertilizer	1.07e	33.79bc	44.37d

Boise Fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.06b	44.56a	55.46ab
1-1 Fertilizer	1.10ab	45.96a	60.95a
Plug -1 No Fertilizer	1.07b	35.24cd	46.84b
Plug -1 Fertilizer	1.17a	36.41c	55.17ab
Styro 8 No Fertilizer	0.62d	31.43d	13.39cd
Styro 8 Fertilizer	0.54d	23.66e	7.97d
Styro 20 No Fertilizer	0.76c	41.83ab	26.30c
Styro 20 Fertilizer	0.76c	39.20bc	25.16c

This table shows significant differences between treatments. For land-owners and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 9 contd.

Roseburg Doug-fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.15ab	45.53a	67.33ab
1-1 Fertilizer	1.21a	48.91a	78.44a
Plug -1 No Fertilizer	1.13ab	35.24b	55.21bc
Plug -1 Fertilizer	1.06b	31.02bc	39.92c
Styro 8 No Fertilizer	0.52d	23.64d	7.19d
Styro 8 Fertilizer	0.61cd	27.49cd	11.26d
Styro 20 No Fertilizer	0.69c	34.81b	18.57d
Styro 20 Fertilizer	0.64cd	34.38b	16.00d

SPI Doug-fir

Treatment	Caliper (cm)	Height (cm)	Volume (cm3)
1-1 No Fertilizer	1.02b	40.88ab	47.32b
1-1 Fertilizer	1.07b	39.75b	51.51b
Plug -1 No Fertilizer	1.20a	45.19a	77.01a
Plug -1 Fertilizer	1.28a	43.38ab	78.92a
Styro 8 No Fertilizer	0.58d	26.59d	9.93cd
Styro 8 Fertilizer	0.57d	26.96d	9.76d
Styro 20 No Fertilizer	0.67d	32.59c	16.45cd
Styro 20 Fertilizer	0.79c	39.19b	26.40c

This table shows significant differences between treatments. For land-owners and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 10 - Percent survival, all sites:

		Douglas-fir			Ponderosa Pine
Stock	**Fertilized**	Roseburg	SPI	Boise	Boise
1+1	Yes	74.4	61.6	93	99.2
	No	84.0	62.4	90	100
Plug+1	Yes	24.8	40.8	74	96.8
	No	37.6	44.8	77	97.6
Styro 20	Yes	7.2	49.6	69	93.6
	No	9.6	42.4	59	98.4
Styro 8	Yes	52.0	50.4	51	92.8
	No	16.0	40.0	59	93.6

Table 11a - Raw data means and standard errors for Boise Douglas-fir.

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Stock	**Fertilized**	Mean	SE	Mean	SE	Mean	SE
1+1	Yes	71.9	2.66	18.4	1.23	71.7	9.83
	No	62.7	3.63	16.2	1.10	50.7	10.27
Plug+1	Yes	54.7	5.44	17.2	1.30	51.9	12.71
	No	48.5	2.08	14.9	1.08	33.5	6.36
Styro 20	Yes	52.0	1.32	11.9	0.53	25.0	2.36
	No	52.0	2.20	12.3	0.56	24.0	2.70
Styro 8	Yes	39.2	1.73	10.1	0.76	13.3	2.01
	No	42.8	3.88	9.8	1.03	14.5	3.51

Table 11b - Raw data means and standard errors for SPI Douglas-fir.

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Stock	**Fertilized**	Mean	SE	Mean	SE	Mean	SE
1+1	Yes	63.5	1.56	17.8	0.74	64.2	6.77
	No	64.1	4.80	17.0	1.39	60.0	13.27
Plug+1	Yes	61.8	2.55	18.1	1.27	61.3	11.83
	No	60.9	2.65	17.5	0.78	57.4	7.78
Styro 20	Yes	60.0	3.82	14.2	1.25	37.4	9.57
	No	50.3	3.89	11.7	0.94	26.1	4.69
Styro 8	Yes	46.8	2.09	11.2	0.84	18.5	3.24
	No	47.9	3.75	11.7	0.90	21.5	4.36

Table 11c - Raw data means and standard errors for Roseburg Douglas-fir

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Stock	**Fertilized**	Mean	SE	Mean	SE	Mean	SE
1+1	Yes	54.7	0.56	14.2	0.27	32.8	1.95
	No	54.5	1.92	15.1	0.96	39.1	5.69
Plug+1	Yes	38.4	2.06	11.4	0.95	16.8	3.43
	No	41.6	3.32	12.2	0.91	19.6	4.59
Styro 20	Yes	43.0	2.89	8.1	0.62	7.9	1.81
	No	40.8	0.94	8.9	1.00	10.4	2.83
Styro 8	Yes	31.6	1.51	8.2	0.23	6.7	0.72
	No	27.5	1.92	5.9	0.33	2.8	0.43

Table 11d – Boise Douglas-fir: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	P	F	p
Stock	3,24	20.30	<.0001	22.44	<.0001	23.89	<.0001	22.67	<.0001
Fertilizer	1,24	0.04	.8506	0.53	.4751	1.17	.2902	1.61	.2162
Stock*Fert	3,24	0.99	.4146	2.13	.1231	0.96	.4254	1.09	.3719
Least-Square Means									
1+1		91.9	a	66.8	a	17.1	a	57.3	a
Plug+1		76.1	b	51.6	b	16.1	b	40.0	ab
Styro 20		64.2	c	52.0	bc	12.2	c	24.5	bc
Styro 8		55.4	c	41.6	c	10.1	c	14.0	c

Table 11e – Sierra Pacific Douglas-fir: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	P	F	p
Stock	3,32	4.68	.0080	10.11	<.0001	18.82	<.0001	16.00	<.0001
Fertilizer	1,32	0.61	.4399	1.16	.2889	1.20	.2805	0.57	.4545
Stock*Fert	3,32	0.72	.5466	1.17	.3367	0.93	.4362	0.52	.6716
Least-Squared Means									
1+1		62.2	a	63.4	a	17.2	a	58.1	a
Plug+1		42.7	b	61.1	a	17.7	a	56.2	a
Styro 20		45.7	b	54.4	a	12.7	b	28.2	b
Styro 8		45.0	b	47.0	b	11.3	b	18.5	c

Table 11f – Roseburg Douglas-fir: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Stock	3,31[1]	88.21	<.0001	58.47	<.0001	62.20	<.0001	63.33	<.0001
Fertilizer	1,31	0.79	.3816	0.25	.6193	0.37	.5475	0.48	.4957
Stock*Fert	3,31	12.77	<.0001	1.21	.3222	4.48	.0100	4.34	.0115
Least-Square Means									
1+1		79.2	a	54.6	a	14.6	a	34.9	a
Plug+1		31.2	b	40.4	b	11.8	b	17.2	b
Styro 20		8.4	c	42.0	b	8.5	c	8.5	c
Styro 8		34.0	b	29.8	c	7.1	d	4.3	d
1+1	Fert	74.4	a			14.2	a	32.5	ab
	No	84.0	a			15.0	a	37.5	a
Plug+1	Fert	24.8	bc			11.5	abc	16.1	bc
	No	37.6	b			12.2	ab	18.5	bc
Styro 20	Fert	7.2	d			8.2	cde	7.6	cd
	No	9.6	d			8.9	bcde	9.5	c
Styro 8	Fert	52.0	b			8.3	d	6.7	d
	No	16.0	cd			6.0	e	2.8	e

Due to the low survival of container stock at the Roseburg site, data were re-analyzed with only the bareroot stock.

Table 11g – Roseburg Douglas-fir: F and p values from ANOVAs.

		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p
Stock	1,16	45.45	<.0001	10.77	.0047	15.95	.0010
Fertilizer	1,16	0.96	.3410	0.86	.3673	0.78	.3895
Stock*Fert	1,16	0.97	.3390	0.02	.8950	0.01	.8950
Least-Square Means							
1+1		54.7	a	14.7	a	35.3	a
Plug+1		40.5	b	11.9	b	17.7	b

Treatment means in each column followed by the same letter are not significantly different at the 0.05 level.

Table 12a - Raw data means and standard errors for Boise Ponderosa Pine.

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Stock	**Fertilized**	Mean	SE	Mean	SE	Mean	SE
1+1	Yes	77.9	2.23	31.4	0.73	221.2	16.04
	No	72.2	0.76	27.8	1.12	168.8	11.91
Plug+1	Yes	90.9	2.28	36.2	1.72	332.8	37.31
	No	84.0	1.67	34.1	1.50	276.3	29.67
Styro 20	Yes	65.3	1.34	26.1	0.68	135.6	10.58
	No	62.9	1.26	23.5	0.77	102.9	7.51
Styro 8	Yes	56.2	0.56	20.7	0.94	72.1	6.93
	No	54.2	2.26	19.7	1.29	63.3	8.93

Table 12a – Boise Cascade ponderosa pine: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Stock	3,32	4.55	.0092	129.99	<.0001	59.20	<.0001	77.76	<.0001
Fertilizer	1,32	2.22	.1456	10.82	.0025	7.66	.0093	9.11	.0050
Stock*Fert	3,32	0.96	.4242	0.39	.7622	0.32	.8094	0.15	.9262
Least-Square Means									
1+1		100	a	74.9	b	29.5	b	191.0	b
Plug+1		98.7	ab	87.3	a	35.0	a	295.9	a
Styro 20		97.3	ab	64.0	c	24.7	c	116.6	c
Styro 8		95.4	b	55.2	d	20.1	d	65.4	d
Fertilized				71.3	a	27.9	a	160.9	a
No Fert				67.4	b	25.6	b	129.0	b

Treatment means in each column followed by the same letter are not significantly different at the 0.05 level.

Evaluating the Effect of Slow Release Fertilizers Incorporated into Containerized Seedlings in Mediterranean Climates

Ed Fredrickson
Roseburg Forest Products Co.

Objectives:

1. To evaluate the partial contributions of fertilizer type and rate to seedling survival and growth in the field for Douglas fir and ponderosa pine.

2. To determine the influence of site quality and precipitation on seedling response to incorporated slow release fertilization.

Introduction:

Over the last several years, the use of slow release fertilizers incorporated into container seedling media has become increasingly popular. Early results from studies done by the Nursery Technology Cooperative (Oregon State University) and others on Douglas fir response to slow release fertilizers were encouraging and showed strong potential for volume increases at the early stages of seedling growth.

These early results prompted timber companies to experiment with this process in other regions, specifically northern California and southwestern Oregon. The majority of the work done extrapolated the fertilizer data from Oregon to a more Mediterranean climate. Initial results were promising, however, as time went on significant problems with survival and growth were encountered with the fertilizer type and rates used from the Oregon data.

The purpose of this study is to determine appropriate fertilizer ratios and rates for typical conifer species grown in Mediterranean climates and to evaluate survival and growth responses over a range of site qualities and moisture regimes.

Methods:

The experimental design within sites will be a completely randomized 2x2x4 factorial treatment structure split across sites. The treatments will be as follows:

3 sites (20-30" ann. Precip., 30-50" ann. Precip., >50" ann. Precip.)
2 species (Douglas-fir & ponderosa pine, sugar pine on Soper Wheeler Site)
1 stock size per species (ST-8, pine & ST-10, doug-fir)
1 fertilizer blend (Nutra-cote), ratio to be determined
4 rates per species (ST-8 pine = 0, 0.8, 1.6 & 3.2 grams per cell),
(ST-10 doug-fir = 0, 1, 2 & 4 grams per cell)
2 plant timings (fall and spring)

16 total treatments per site x 5 replications = 80 plots per site.

Plots will contain 25 trees per plot spaced 5' x 5'. This will require 2000 total trees per site (1000 p. pine & 1000 d. fir).

Total land area needed will be approximately three acres. Buffer rows of trees should not be necessary since the experiment will be of short duration.

The low precipitation site will be on land managed by W.M. Beaty & Associates, the moderate precipitation site will be on land managed by Silver Butte Timber Co. and the high precipitation site will be on land managed by Soper-Wheeler Company.

Site Prep: All sites will be doubled ripped and site prepped with 4 lbs a.i./ac of atrazine. Follow up foliar treatments will be applied as necessary.
Soil Temperature: Since the release rate of the fertilizer is temperature dependent, soil temperatures will be monitored at two points on each site at a depth of six inches using Hobo data recorders over the entire first growing season. The Co-op will also look into installing a local weather station as an alternative option.

Status: The seed for this study was sent to PRT in Campbell River, B.C. in the fall of 2002 for sowing.

The site located on Silver Butte Timber Co. lands was site prepped and double ripped in the summer of 2002. The site on Soper-Wheeler lands was logged and the slash was piled in the summer of 2003. This site was not double ripped. The site on W.M. Beaty & Associates land was part of the Devil Fire which burned in May of 2001. The site was logged and double ripping was done in the summer of 2002.

Plot layout was done on all three sites in the summer of 2003. The Silver Butte and Beaty sites have 80 plots each; the Soper site has 120.

Weather stations was installed at the Silver Butte and Beaty sites in August. The Soper site received a station in September. The continuous-recording stations measure soil and air temperature, soil moisture, and precipitation. They will be left in place over the winter.

After some rains in the early part of the month, the planting of the fall treatments started on the sites in October. The Silver Butte site was planted on October 24, the Soper site on November 4, and the Beaty site on November 5. The soil was moist at about the six inch depth on the Silver Butte site at the time of planting and the temperature was cool. The soil was dry at the other two sites and it was hot and windy on these sites. The planting was done by early afternoon at all three locations. The seedlings were auger planted on the Soper site to compensate for the lack of ripping. The other two sites were shovel planted. Within a week after planting, all sites had received rain.

There were some changes to the specifications as set forth in the original proposal. All seedlings were grown in Styro-10 containers, the fertilizer was Nutra-Cote 16-10-10, and the fertilization rates were 0, 1, 2, and 3 grams per cell. All the seedlings looked very healthy and each treatment was properly packed and labeled.

At the time of planting, sample seedlings representing all species by land owner were taken back to Redding where measurements of caliper and length were taken on 100 trees per species per land owner (**Table 1**). At the time of measurement, the seedlings were visually examined for fertilizer. None of the seedlings that were treated at the "0" rate (no fertilizer) showed any signs of having been fertilized regardless of species. The ponderosa pines that were supposed to have received one of the three rates of fertilizer (1, 2, or 3 grams/cell) all showed evidence of fertilizer. It was impossible to estimate the rate, but all the seedlings had received some fertilizer. The Doug-fir showed a 13% error in fertilizer application – thirteen percent of the trees that should have been fertilized at one of the 3 rates were in fact not fertilized. The error for the sugar pine was 16%. Trees with as few as one prill per cell were considered fertilized.

The spring planting treatment will be applied in the spring of 2004. Similar measurements/observations like those taken on the fall planted seedlings will be made on seedlings from this planting. Caliper and height will be measured for all seedlings in each treatment at the end of the growing season. Seedling volume will be derived from these measurements. Survival will be noted at the time of measurement. First year results will be reported in the 2004 Annual Report.

2004: The spring-planting treatments for all three sites were installed by early April, 2004. Planting conditions were ideal on all sites at the time of planting. All sites received rain shortly after planting. The seedlings on Silver Butte lands were shovel planted, those on W.M. Beaty lands hodad planted, and the seedlings for Soper-Wheeler were auger planted. All seedlings arrived from the nursery in good condition.

All seedlings for the Silver Butte and Soper-Wheeler sites were labeled properly. The Douglas-fir seedlings for the W.M. Beaty site were labeled properly, but the ponderosa pine seedlings had no indication at all on the label as to how much, if any, fertilizer had been applied. Of the four boxes of pine seedlings designated for this site, only one had been fertilized. We assigned the fertilized box to the 3 gram treatment and planted these seedlings in the plots designated for that treatment. We assigned a treatment to the other three boxes and planted those seedlings just as if they had been labeled correctly. Of course, one of the boxes went into the 0 gram plots, so this treatment was correct as planted.

As had been done with seedlings from the fall-planting treatment, sample seedlings representing all species by land owner/treatment were taken back to Redding where measurements of caliper and length were taken on 100 trees per species per land owner (**Table 2**). At the time of measurement seedlings were visually examined for fertilizer. If a seedling had at least one prill, they were considered fertilized. It was impossible to check for amount of fertilizer ie. 1 gram, 2 grams, etc. There was much variation within a treatment; for example seedlings that were to receive 3 grams of fertilizer might have anywhere from 2 to 30 prills in them.

Consistent with results from the fall planting, many seedlings within a certain fertilizer treatment rate (1 gram, 2 grams, 3 grams) did not have any fertilizer at all. For all three sites between 12-44 percent of the Douglas-fir that were to be fertilized in fact had no fertilizer at all. The ponderosa pine that were incorrectly fertilized ranged from 4 percent to 36 percent. Figures for the sugar pine ranged from 8 to 28 percent. Generally those seedlings that were not to receive any fertilizer (0 gram treatment) were not fertilized. Variations in number of seedlings actually fertilized by species/land owner/fertilization rate are available if interested.

First year growth measurements were taken on all three sites during the fall of 2004. Measurements taken included caliper (at one inch above ground line) and height (ground line to tip of bud). Seedling volume will be calculated from these measurements. Survival was noted at this time as well as pest problems.

Survival for Douglas-fir was greater with the spring planting than with the fall planting on all three sites (**Table 3**). Fertilization had no effect on Douglas-fir survival.

For ponderosa pine, neither planting time nor fertilization affected survival at the Silver Butte site. At the other two sites, survival was greater for spring planting, overall, but this effect varied based on fertilization. At the Soper-Wheeler site, the higher rates of fertilizer resulted in slightly lower survival with the fall-planted seedlings. Fertilization rates did not affect the survival of the spring-planted seedlings. At the Beaty site, survival was greater than 99% for all rates of fertilization with the spring planting. For the fall-planting, the 1 and 2 gram rates had lower survival than the 0 and 3 gram rates.

For the sugar pine on the Soper-Wheeler site, spring planting resulted in significantly greater survival, but survival was greater than 90% for both planting times. There was no fertilization effect.

For all three of the sites, Douglas-fir spring-planted seedlings were significantly taller than fall-planted seedlings (**Tables 4** and **5**). At the Soper-Wheeler and Beaty sites, spring-planted seedlings were also significantly larger in caliper. Only at the Beaty site were the spring-planted seedlings also larger in volume, but only about 3% of the fall-planted seedlings survived.

For Douglas-fir, fertilization effect varied by site. At the Soper-Wheeler site fertilization did not significantly affect seedling size. At the Silver Butte site, seedlings that received the 1 and 2 gram rates of fertilization were significantly larger in caliper and volume than those seedlings that received no fertilization. Although seedlings receiving 3 grams of fertilizer averaged larger caliper and volume than those receiving no fertilizer, the difference was not significant. At the Beaty site, the results varied based upon planting time. Because of the low survival of the fall-planted seedlings, those results are questionable. For the spring-planted seedlings, the only fertilizer effect was a slight but significant decrease in height at the highest rate of fertilization.

For ponderosa pine, there were no significant differences in seedling size resulting from planting time or fertilization at the Beaty site (**Tables 6** and **7**). At the Silver Butte site, spring-planted seedlings were slightly taller than those planted in the fall and there were no significant effects of fertilization. At the Soper-Wheeler site, caliper and volume did not differ significantly with planting time or fertilization, but the unfertilized, spring-planted seedlings were significantly taller than the other seedlings.

For sugar pine, the only significant effect was that fall-planted seedlings were slightly taller than those planted in the spring (**Table 8**).

Second year growth measurements will be taken in the fall of 2005. Survival will be noted at this time. Low survival of the fall-planted Douglas-fir seedlings at the Beaty and possibly the Soper-Wheeler sites may drop these treatments from the study.

Total funded: $27,365; Total Spent as of 12/31/04: $15,060.57.

Table 1—Values for caliper, height and volume for seedlings of Slow Release Proposal at time of lifting (fall treatment) fall, 2003.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Soper Wheeler	0.47	22.24	5.17
Silver Butte	0.46	20.21	4.38
Beaty	0.42	17.39	3.18
Douglas-fir			
Soper Wheeler	0.37	27.73	4.00
Silver Butte	0.37	28.69	3.99
Beaty	0.36	23.66	3.12
Sugar Pine			
Soper Wheeler	0.30	16.68	1.55

Table 2—Values for caliper, height and volume for seedlings of Slow Release Proposal at time of lifting (spring treatment) spring, 2004.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Soper Wheeler	0.44	22.25	4.31
Silver Butte	0.45	20.76	4.20
Beaty	0.42	16.72	2.95
Douglas-fir			
Soper Wheeler	0.37	23.16	3.17
Silver Butte	0.38	27.28	3.94
Beaty	0.34	20.24	2.34
Sugar Pine			
Soper Wheeler	0.30	16.42	1.48

Table 3 - Survival for all sites and species

	Fertilizer	**Beaty**		**Silver Butte**		**Soper-Wheeler**		
Timing	Grams	PP	DF	PP	DF	PP	SP	DF
Fall	0	91.2	5.6	91.2	54.4	89.6	89.6	39.2
	1	76.0	2.4	78.4	62.4	93.6	92.0	37.6
	2	75.2	2.4	88.0	48.0	70.4	90.4	40.8
	3	84.0	1.6	86.4	50.4	74.4	95.2	26.4
Spring	0	100	98.4	86.4	91.2	99.2	100	96.0
	1	100	97.6	83.2	89.6	98.4	100	92.8
	2	99.2	95.2	94.4	89.6	96.8	96.8	99.2
	3	99.2	96.8	90.4	84.8	95.2	99.2	93.6

Table 4a - Raw data means and standard errors for Soper-Wheeler Douglas-fir

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	20.7	1.29	4.6	0.15	1.3	0.14
	1	21.3	0.69	4.4	0.27	1.3	0.19
	2	22.5	1.38	4.6	0.40	1.6	0.29
	3	24.2	1.97	4.7	0.88	2.1	0.78
Spring	0	24.6	0.64	4.6	0.47	1.5	0.35
	1	24.4	0.61	4.9	0.39	1.8	0.30
	2	24.6	1.08	5.3	0.41	2.1	0.37
	3	24.4	0.32	5.9	0.37	2.5	0.30

Table 4b - Raw data means and standard errors for Beaty Douglas-fir

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	11.3	2.90	3.7	0.81	0.51	0.30
	1	18.8	4.25	5.2	0.92	1.5	0.69
	2	7.6	0.38	3.1	0.32	0.23	0.01
	3	6.8	0.25	2.6	1.2	0.14	0.10
Spring	0	23.2	0.39	5.4	0.15	1.9	0.13
	1	24.4	0.19	5.6	0.12	2.1	0.10
	2	22.5	0.58	5.4	0.12	1.8	0.12
	3	21.2	0.48	5.4	0.11	1.8	0.11

Table 4c - Raw data means and standard errors for Silver Butte Douglas-fir

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	24.4	2.52	4.8	0.22	1.7	0.20
	1	26.7	1.11	5.8	0.26	2.9	0.41
	2	29.2	1.12	6.2	0.26	3.3	0.36
	3	28.3	2.76	5.8	0.36	2.7	0.30
Spring	0	32.4	1.02	5.3	0.16	2.7	0.21
	1	33.6	0.86	5.4	0.26	2.8	0.34
	2	32.8	0.86	5.7	0.30	3.1	0.36
	3	32.2	1.36	5.4	0.15	2.8	0.22

Table 5a – Soper-Wheeler Douglas-fir: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	183.39	<.0001	15.33	.0004	4.62	.0392	4.10	.0514
Rate	3,32	0.95	.4281	0.26	.8567	0.74	.5347	1.60	.2080
Time*Rate	3,32	0.37	.7726	0.29	.8290	1.11	.3584	0.30	.8228
Least-Square Means									
	Fall	36.0	b	21.8	b	4.44	b		
	Spring	95.4	a	24.5	a	5.06	a		

Table 5b – Beaty Douglas-fir: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,20[1]	2852.02	<.0001	126.58	<.0001	30.47	<.0001	59.03	<.0001
Rate	3,20	0.75	.5314	8.46	.0008	2.52	.0867	4.84	.0108
Time*Rate	3,20	0.34	.7962	5.14	.0085	2.10	.1319	3.66	.0299
linear	1,20			13.68	.0014			8.68	.0080
quadratic	1,20			5.22	.0333			5.40	.0309
cubic	1,20			9.86	.0051			3.39	.0805
Least-Square Means									
	Fall	3.0	b	9.7	b	3.3	b	.31	b
	Spring	94.7	a	22.8	a	5.4	a	1.88	a
	0			15.6	ab			.84	ab
	1			20.3	a			1.56	a
	2			13.0	b			.64	ab
	3			12.0	b			.41	b
Fall	0			10.5	cd			.37	bc
	1			16.9	bc			1.18	b
	2			7.5	d			.23	bc
	3			6.7	d			.09	c
Spring	0			23.2	ab			1.87	a
	1			24.4	a			2.08	a
	2			22.6	ab			1.82	a
	3			21.2	b			1.75	a

[1]Survival DDF is 32.

Treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 5c – Beaty Doug-fir(spring): F and p values from ANOVAs.

		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p
Rate	3,16	8.75	.0011	0.45	.7178	1.49	.2550
linear	1,16	15.83	.0011				
quadratic	1,16	7.87	.0127				
cubic	1,16	2.58	.1280				
Least-Square Means							
	0	23.2	a				
	1	24.4	a				
	2	22.6	ab				
	3	21.2	b				

Table 5d – Silver Butte Douglas-fir: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	63.54	<.0001	25.45	<.0001	0.40	.5306	0.96	.3355
Rate	3,32	0.77	.5218	1.47	.2410	4.38	.0109	4.02	.0156
Time*Rate	3,32	0.47	.7075	1.34	.2794	2.14	.1148	1.78	.1703
linear	1,32					5.29	.0281	5.21	.0293
quadratic	1,32					7.46	.0102	6.51	.0157
cubic	1,32					0.47	.4969	0.33	.5675
Least-Square Means									
	Fall	53.8	b	27.4	b				
	Spring	90.2	a	32.7	a				
	0					5.05	b	2.15	b
	1					5.58	ab	2.77	a
	2					5.93	a	3.17	a
	3					5.51	ab	2.72	ab

Treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 6a - Raw data means and standard errors for Soper-Wheeler Ponderosa Pine

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	27.2	0.55	6.8	0.23	3.8	0.27
	1	25.6	0.63	6.6	0.15	3.1	0.21
	2	27.8	0.70	7.6	0.57	4.8	0.77
	3	26.1	0.54	7.2	0.63	4.2	0.66
Spring	0	31.4	0.56	6.6	0.27	3.9	0.31
	1	24.8	0.61	7.8	0.55	4.6	0.89
	2	27.2	0.96	8.0	0.69	5.1	0.99
	3	26.9	0.77	8.0	0.39	4.9	0.41

Table 6b - Raw data means and standard errors for Beaty Ponderosa Pine

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	22.0	0.42	8.0	0.11	3.9	0.11
	1	21.5	0.30	7.4	0.41	3.3	0.38
	2	20.4	0.38	7.8	0.29	3.6	0.32
	3	20.7	0.58	8.5	0.30	4.1	0.27
Spring	0	21.5	0.78	8.2	0.31	4.1	0.42
	1	20.6	0.39	7.6	0.13	3.3	0.07
	2	20.3	0.81	7.7	0.18	3.4	0.23
	3	20.7	0.51	7.6	0.33	3.3	0.34

Table 6c - Raw data means and standard errors for Silver Butte Ponderosa Pine

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	23.7	0.76	7.1	0.50	3.5	0.59
	1	24.7	0.90	7.9	0.28	4.4	0.31
	2	24.9	0.45	7.3	0.37	3.8	0.40
	3	24.8	0.74	7.3	0.15	3.8	0.23
Spring	0	26.4	0.76	7.4	0.33	4.2	0.32
	1	27.1	1.07	7.4	0.30	4.2	0.49
	2	28.6	0.39	7.2	0.36	4.3	0.55
	3	26.1	0.54	7.0	0.31	3.6	0.37

Table 7a – Soper-Wheeler ponderosa pine: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	41.46	<.0001	3.00	.0927	3.01	.0925	2.53	.1218
Rate	3,32	7.17	.0008	12.85	<.0001	1.99	.1350	1.54	.2232
Time*Rate	3,32	4.31	.0116	5.46	.0038	1.22	.3167	0.66	.5852
linear	1,32	14.84	.0005	6.80	.0137				
quadratic	1,32	0.01	.9339	9.98	.0034				
cubic	1,32	6.66	.0147	20.26	<.0001				
Least-Square Means									
	Fall	82.0	b						
	Spring	97.4	a						
	0	94.4	a	29.2	a				
	1	96.0	a	25.1	c				
	2	83.6	b	27.4	ab				
	3	84.8	b	26.4	bc				
Fall	0	89.6	a	27.1	b				
	1	93.6	a	25.5	b				
	2	70.4	b	27.7	b				
	3	74.4	b	26.1	b				
Spring	0	99.2	a	31.4	a				
	1	98.4	a	24.7	b				
	2	96.8	a	27.2	b				
	3	95.2	a	26.8	b				

Treatment means in the each column followed by the same letter do not differ significantly at the 0.05 level.

Table 7b – Beaty ponderosa pine: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	81.82	<.0001	1.14	.2936	0.35	.5584	0.99	.3262
Rate	3,32	3.73	.0209	2.54	.0742	2.24	.1029	2.53	.0746
Time*Rate	3,32	3.46	.0276	0.25	.8586	2.07	.1235	1.14	.3479
linear	1,32	2.07	.1601						
quadratic	1,32	9.09	.0050						
cubic	1,32	0.03	.8585						
Least-Square Means									
	Fall	81.6	b						
	Spring	99.6	a						
	0	95.6	a						
	1	88.0	ab						
	2	87.2	b						
	3	91.6	ab						
Fall	0	91.2	ab						
	1	76.0	c						
	2	75.2	c						
	3	84.0	a						
Spring	0	100	a						
	1	100	a						
	2	99.2	a						
	3	99.2	a						

Table 7c – Silver Butte ponderosa pine: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	0.83	.3701	22.80	<.0001	0.46	.5037	0.28	.6016
Rate	3,32	2.48	.0787	1.74	.1795	0.68	.5732	0.54	.6603
Time*Rate	3,32	0.77	.5170	0.83	.4858	0.47	.7070	0.68	.5731
Least-Square Means									
	Fall			24.5	b				
	Spring			27.0	a				

Treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 8a - Raw data means and standard errors for Soper-Wheeler Sugar Pine

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	19.0	1.20	4.3	0.18	1.1	0.17
	1	20.2	0.50	4.3	0.15	1.2	0.13
	2	20.8	1.57	4.9	0.29	1.5	0.24
	3	20.1	1.00	4.6	0.21	1.3	0.16
Spring	0	15.5	0.82	4.6	0.22	1.1	0.16
	1	19.3	2.15	4.7	0.33	1.3	0.32
	2	17.4	0.65	4.4	0.14	1.0	0.09
	3	18.6	1.39	5.1	0.28	1.4	0.10

Table 8b –Soper-Wheeler sugar pine: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	18.92	.0001	7.63	.0094	0.85	.3645	0.37	.5469
Rate	3,32	0.88	.4638	1.54	.2230	1.06	.3802	1.11	.3605
Time*Rate	3,32	0.66	.5816	0.46	.7112	1.62	.2039	1.27	.3005
Least-Square Means									
	Fall	91.8	b	19.9	a				
	Spring	99.0	a	17.4	b				

Treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

AN EXPERIMENT TO EVALUATE THE COMPETITIVE AND ECOLOGICAL EFFECTS OF UNDERSTORY VEGETATION ON THE PRODUCTIVE POTENTIAL OF YOUNG DOUGLAS-FIR PLANTATIONS

Robert F. Powers
Senior Scientist, PSW Research Station

Background

In 1994 the American Forestry and Paper Association (AF&PA) formed a partnership with the U.S. Department of Energy (DOE) to begin a competitive grants program called "Agenda 2020." The purpose was to focus research on industrial priorities for increasing productivity and energy efficiency. One of the priorities was "Sustainable Forestry." This Agenda 2020 priority centers on four research pathways: Biotechnology and Tree Improvement, Basic Physiology of Forest Productivity, Sustainable Forest Productivity, and Remote Sensing to Improve Forest Inventory and Stand Management. The goal is to substantially improve the productivity of our forests which provide the raw material for the industry. Forest Service Research joined the partnership in support of Sustainable Forestry in 1998. The Forest Service and DOE provide funds and technical support. AF&PA provides oversight and establishes priorities through various working groups. The National Council of the Paper Industry for Air and Stream Improvement (NCASI) provides technical expertise.

A national call for Forest Service Research proposals went out in 2002. Proposals were reviewed and ranked by AF&PA foresters for geographic regions of the U.S. R.F. Powers submitted a proposal titled "Treatments to Enhance Forest Productivity." The proposal was based on priorities raised at the February 2002 session of the Sierra-Cascade Intensive Forest Research Cooperative (SCIFMRC) in Mt. Shasta. A top priority was to determine the limits of plantation productivity for Douglas-fir and other species under various silvicultural alternatives. Powers' proposal received high marks by AF&PA, and in July 2002 he was awarded a 3-year grant of $56 thousand per year. He notified the SCIFMRC Executive Team that he'd like to use the funds to enhance the Co-op's efforts. He then asked Brian Schlaefli, Chair of Working Group 2, to convene a meeting of SCIFMRC individuals to hone this research proposal. The original proposal was a modified"Garden of Eden" study expanded to Douglas-fir and other geographic regions. With this as a talking point, a half-day discussion was held December 3 in Mt. Shasta. A consensus was reached to initiate the study described below.

The Study

Problem statement. Early productivity of pine plantations declines as understory competition increases. Growth drops as ground cover of woody shrubs approaches 20 to 30%, with the effect persisting well after trees have overtopped the brush. Consequently, managers have tried to keep understory cover well-below the 20 to 30% threshold. However, the role of N-fixing shrubs is controversial. Some ecologists argue that the long-term value of N-fixing species exceeds their early competitive effect. Arguments such as these largely are speculative, because critical experiments have not been designed to test the concept. Further, with the exception of work by Newton and colleagues in Oregon, few findings have surfaced on the competitive effect of woody and herbaceous species on the development of Douglas-fir plantations in drier climates characterizing the interior sites managed by SCIFMRC members.

Critical questions. Our group defined a series of major questions for research:

- How are interior Douglas-fir plantations affected by understory species?
- Are there understory density thresholds?
- Is there a competitive difference between herbaceous plants and woody shrubs?
- Is there a difference between N-fixing and non N-fixing shrubs?
- Do effects vary by site?
- Does fertilization make a difference?
- How do treatments affect the time to reach a target tree size?

Approach. The experiment will center on freshly prepared sites within the natural range of Douglas-fir in southern Oregon and Northern California. The treated area will encompass 15 acres, bordered by a cleared buffer with a minimum width of 100 feet. Sites will be wing-subsoiled in two directions before planting to minimize any legacy of skid trails or landings. Sites will be planted at a 12-ft spacing with superior quality Douglas-fir and a second species, such as ponderosa pine. Tree spacing and size of treatment plots (1/4 acre) are appropriate to maintain stand-like conditions until trees reach a DBH of 8 inches. Six main effect treatments applied randomly to each of four replicate plots are:

- No vegetation control (4 plots)
- Complete vegetation control using appropriate herbicides (4 plots)
- Herbaceous competition, only (no herb control vs 1st-year only = 8 plots)
- Woody shrubs, only (non N-fixing = 16 plots)
- Woody N-fixing shrubs, only (16 plots)
- Fertilization with a nutrient complete mix at lower levels of competition (12 plots)

Herbaceous competition will be at two levels: no initial treatment of herbs, and 1st-year only. For the woody shrub treatments, manzanita and ceanothus seedlings appropriate for the site will be produced in a nursery and planted with tree seedlings to achieve, by 5 years, ground covers of 5, 15, 30, and 50 percent. Planting densities will be based on assumed rates of mortality and estimated diameters of shrub crowns at 5 years. Each ground cover density will be maintained by spot treating individual plants when a ground coverage treatment has increased to one-third of the target level of the next highest cover treatment

Treatments with a target ground cover of 15% will be fertilized with mixtures of macro and micro nutrients at two intervals: (1) at 3 to 5 years when trees are well established; (2) when tree crowns have reached about two-thirds ground cover (the rapid stage of crown building).

Measurements. Soil profiles will be characterized according to the national standards of the Natural Resource Conservation Service. Meteorological data (plus soil moisture and temperature) will be recorded continuously using data loggers. Tree survival, height, crown length and width, and ground cover will be measured at growth years 1, 3, 5, 7, and 10. Foliar samples will be taken from current and 1-year foliage for nutrient analysis at each measurement interval. Samples also will be analyzed for cumulative water stress as indexed by ^{13}C and ^{12}C isotopic ratios. Soil samples will be analyzed for microbial abundance and diversity (functional and numerical).

Costs per installation through the 3-year life of the grant

Activity	**Year 1**	**Year 2**	**Year 3**
Site identification and preparation (20 acres)	5,000		
Slash abatement	1,300		
Tree seedlings	4,000		
Brush seedlings	12,000		
Plot layout	1,700		
Meteorological station		6,000	
Plant trees		2,500	
Plant brush		4,500	
Herbicide treatment		3,000	
Tree and brush measurements		5,000	
Brush density adjustments			2,500
Chemical analyses			12,500
Soil sampling			5,000
Microbial analysis			8,000
Data analysis			6,500
Total by year	**24,000**	**21,000**	**34,500**

Approximately $168 thousand are available over three years for this study. The estimated total of $79,500 per site covers 47 percent of PSW's available funds. This means that we can fund two installations and must decide on where they will be.

Demands on SCIFMRC

Powers takes overall funding and research responsibility. SCIFMRC will propose candidate sites. While 15 acres are needed for the 60 treatment plots, total cleared area probably will approach 30 acres. The first site is projected for Boise land in southern Oregon in the western Cascades. A second site should be established the following year in the eastside Cascades (on the most productive land), or in the northwestern Sierras or Cascades on very productive ground. Which way to go is the prerogative of the Co-op. Harvesting/clearing the site is the responsibility of the SCIFMRC partner, as is protection from other uses. If approved as a SCIFMRC project, Gary Fiddler will oversee the first three years of work to establish the experiment and SCIFMRC will assist by underwriting his time through membership dues. We will seek new grants to fund further work and to encourage piggybacking of other studies, such as forage production and wildlife use.

Status: As a follow-up to the January 13, 2003 Co-op meeting at which the Agenda 2020 proposal was accepted as a Co-op project, the membership was contacted in order to get suggestions on possible sites for the study (originally the first site was going to be located on Boise Cascade lands but the site nominated was not selected). In response to this request, two companies, Roseburg Resources (Ed Fredrickson) and Sierra Pacific Industries (Mark Gray) offered possible sites.

The Roseburg site consisted of two clearcut blocks located east of Redding near Big Bend. The stands had been harvested in the summer of 2003 and the additional site preparation required for implementation could be done in the fall. The stands harvested were high-site mixed conifer and the topography was almost flat. There were no restrictions on either of the blocks that would hinder the installation of the study. After two confirmation visits the Roseburg blocks were selected as the first Agenda 2020 site.

The SPI site was located northeast of Burney near the intersection of Highway 89 and the Dana Cutoff road. This site consisted of a single block that was scheduled for harvest in the fall of 2003. The stand was mixed conifer growing on a good site. Topography was flat. As with the Roseburg site, there were no restrictions on this stand that would hinder installation of the Agenda 2020 study. This block was chosen as the second site for the study.

As of December, the Roseburg site has been harvested and site preparation has been completed. The SPI site has been harvested with site preparation to follow in 2004. The goal is to install the Agenda 2020 study on both sites during the same time period. Plot layout is scheduled for the summer of 2004 with planting to be done in the spring of 2005.

Tom Jopson (Cal Forest Nurseries) has started the collection of manzanita cuttings in order to raise the seedlings (rooted cuttings) of this species that will be needed for the study. The ceanothus seedlings will be raised from seed that Tom has ordered from the Lawyer Nursery. Both shrubs will be raised by Cal Forest at their Etna, CA location.

2004: Site preparation was completed on the Sierra Pacific Industries site during the summer of 2004. Plot layout on both sites was completed by September. Some changes were made to the original proposal prior to plot installation. Conifer spacing was changed from 12x12 to 8x8 feet resulting in 168 trees per plot. Of these 168 trees, 80 are measure trees. There will be a total of 8736 seedlings (4368 pine and 4368 Doug-fir) planted per site. There are thirteen treatments replicated four times per site. This makes a total of 52 plots per site. Contracts for marking the planting spots at both sites were let during November. The conifer seedlings for this study are being raised at Cal Forest Nursery. Ceanothus seedlings are growing at Cal Forest nursery, also. Nursery crews collected plant material in November from the sites in order to start raising the manzanita plants required by the study. The treatments will be installed in the spring of 2005 as originally planned.

Interrelationship of Seedling Dormancy Status and Media Temperature in Determining New Root Growth Capacity of Northern California Conifer Species

Douglas F. Jacobs, Principal Investigator

Objectives: This study was designed to examine how potential for new seedling root growth (i.e., extension of current roots and formation of new roots) is affected by both media temperature and changes in seedling phenology as seedlings transition through the dormancy cycle. Though it has been established that root growth of many conifer species is maximized around 20°C, few studies have examined how media temperature may interact with changes in seedling dormancy status during the period from dormancy induction in fall through dormancy release in spring. Additionally, no studies have examined either of these trends specific to seed sources in northern California. This information will be useful to help match seedling physiological status with site environmental conditions to optimize new root growth immediately following planting.

Procedures: Seedling shipments were received from Cal Forest Nursery (Etna, CA) on 8-14-2004, 9-17-2004, and 11-12-2004. Species included Douglas-fir (single seed source from 1676 m elevation, but with or without nursery blackout treatment), ponderosa pine (seed sources from elevation of 1067 and 1524 m), and California red fir (single seed source, 1676 m elevation). On each date, seedlings of each species/source (5 treatments, 600 seedlings total) were measured for initial root volume, height, and root collar diameter. A subsample of seedlings was evaluated for numbers of new white roots. After initial measurements, seedlings were placed into a hydroponic growing system (Figure 1) to evaluate growth potential over a four-week period. The system is set up as a randomized complete block design with three blocks serving as replications. Each block contains four growing tanks (45.7 cm x 45.7 cm x 30.5 cm), with each tank corresponding to a controlled root zone temperature (10, 15, 20, and 25 °C). Each tank in a block supports ten seedlings per species/source. Water in each tank is pumped through a thermoelectric chiller/heater with set points at each of the four temperatures. Pumping of water from the tank and through the chiller/heater is achieved through the use of small magnetic drive centrifugal pumps connected to polyethylene tubing. Preliminary measurements indicated that water temperature throughout the initial four-week period was within ± 2 °C of each set point. To avoid potential for experimental confounding, supplemental nutrition was not added to the water. The system is set up in a controlled environment growth room, with a 16-hour photoperiod, a constant air temperature of 23.3 °C, and light intensity of 120 μmol/m^2/sec. Also on each date, dormancy status and cold hardiness for each seed source/treatment were determined by the electrolyte leakage method. Thirty-six seedlings from each seed source/treatment, not used for the growth trial, were used for this procedure. For each treatment, approximately five needles were removed from each seedling and cut into segments 1 cm in length. These were divided into four equal groups. Segments from each group were placed in nine vials containing de-ionized water, with ten segments per vial. The nine vials corresponded to nine test temperatures [2 (control), -3, -7, -11, -15, -19, -24, -29, -34, and -40 °C]. Measurements of conductivity in each vial were made after freezing and autoclaving, allowing calculation of an index of injury at each temperature. Preliminary data from August 2004 showed how the species, seed sources, and blackout treatments differed in dormancy status (Figure 2). This data suggests that 1) high elevation ponderosa pine was more cold hardy than low elevation ponderosa pine, 2) nursery black out treatments increased cold hardiness of Douglas-fir, and 3) California red-fir was slightly more cold hardy than Douglas-fir without blackout.

Obstacles: The exploratory nature and complexity of the experimental procedure presented some problems initially. Foliage of seedlings placed in the system on 8-14-2004 and 9-17-2004 began to turn brown within 3-10 days. Root systems also exhibited high mortality. Seedlings in high root zone temperatures (20, 25 °C) exhibited symptoms faster than those in colder temperatures (10, 15 °C), leading us to hypothesize that aeration was insufficient. Supplemental aeration had not been added for two reasons: 1) water in the tanks was under constant flow through the pumps and thermoelectric system, and 2) fresh water had to be added periodically to keep levels in the tank high. This was apparently inadequate, as indicated by supplemental measurements of dissolved oxygen in non-aerated tanks compared to those in aerated tanks. Dissolved oxygen in non-aerated low temperatures was also higher than non-aerated high temperatures. For seedlings placed in tanks on 11-12-2004, we added a supplemental aeration system consisting of six dual-valve aquarium/hydroponic air pumps connected to the tanks (one line per tank). At the end of each pump line is an aquarium air stone. The air stones release small bubbles of air into the water. This not only brings bottom water to the surface, but releases oxygen directly into the water. Three weeks into the current sampling, we have determined that this modification was successful for both California red fir and ponderosa pine, which appear healthy. However, some of the Douglas-fir seedlings again exhibited foliar symptoms within several days of transplant, and about 60-80 % have been removed from the sampling. Remaining seedlings of all species are exhibiting new root formation and elongation, particularly at higher root zone temperatures. There is also noticeable new root production at lower root zone temperatures, although there has been little root elongation. Growth parameters from this sample will be quantified at the end of the four-week period.

Future Plans: Despite the successes of the most recent round of measurements, adjustments to the current system are being considered. Although California red fir and ponderosa pine do not seem to be negatively affected with our current system, Douglas-fir seedlings still show high mortality, even with supplemental aeration. As noted previously, this occurred fastest in the warmer root zones, indicating a possible deficiency in dissolved oxygen. Plans are underway to mitigate any limitations associated with aeration deficiency. One proposed method is potting seedlings into sealed cylindrical tubes and suspending the tubes in the temperature-controlled water. Root zone temperature would be controlled and oxygen levels consistent across all treatments. However, irrigation presents a logistical obstacle to this method. An individual irrigation regime may need to be developed for each seed source in each root zone temperature to ensure a consistent moisture level in the media. Another option is to use a modified version of our current system to increase aeration. This can possibly be accomplished by using one dual-valve air pump, containing two air stones, in each tank to increase the amount of dissolved oxygen and decreasing the number of seedlings placed in each tank. Alternatively, it may prove most logistical to maintain our current system, which has proven effective for California red fir and ponderosa pine, and emphasize these two species for the remainder of the current experiment. As our system is further refined, we will proceed with original proposal objectives, including 1) making final morphological measurements at the end of each four-week test period, 2) assessment of new root and shoot biomass production, 3) evaluation of dormancy status using the electrolyte leakage procedure and monitoring days to budbreak, and 4) examining photosynthetic efficiency (e.g., rate of photosynthesis and chlorophyll fluorescence) throughout the growing cycle.

Total Funded: $30,000; Total Obligated as of 12/31/04: $30,000.

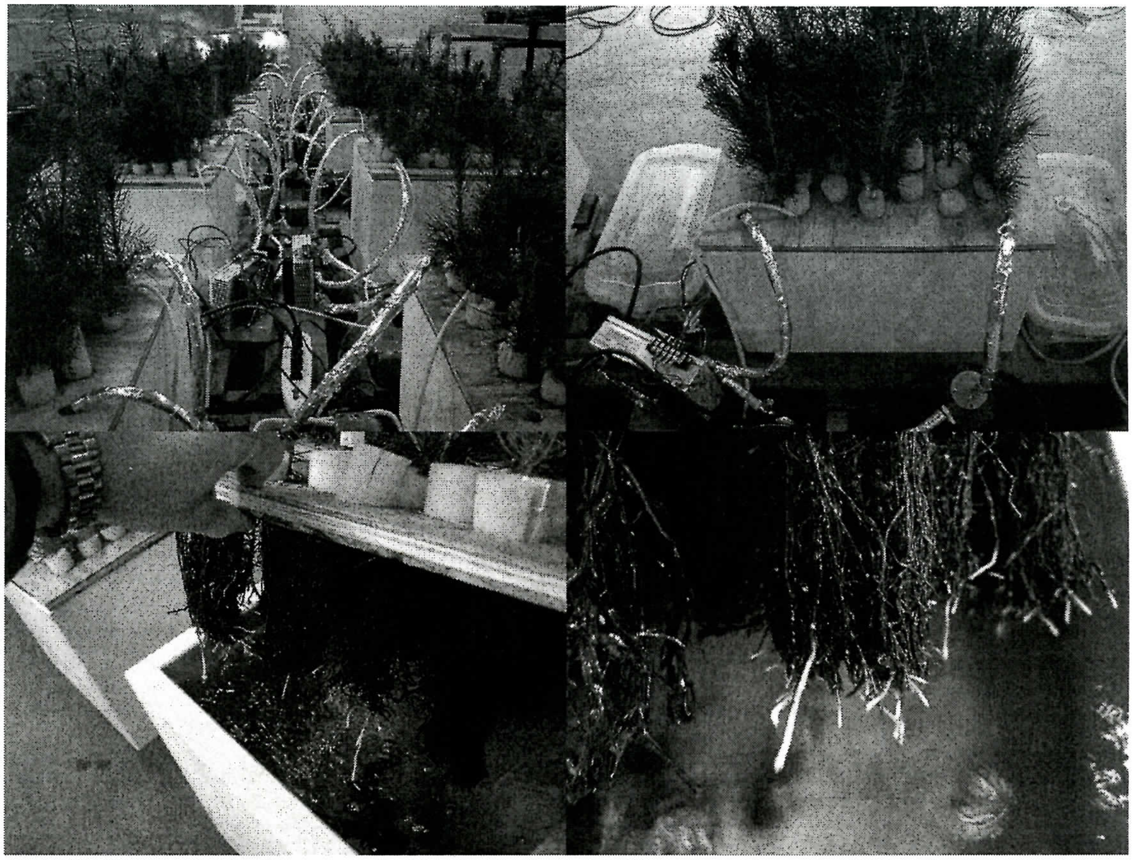


Figure 1. Experimental setup to examine capacity for new seedling root growth as affected by media temperature.

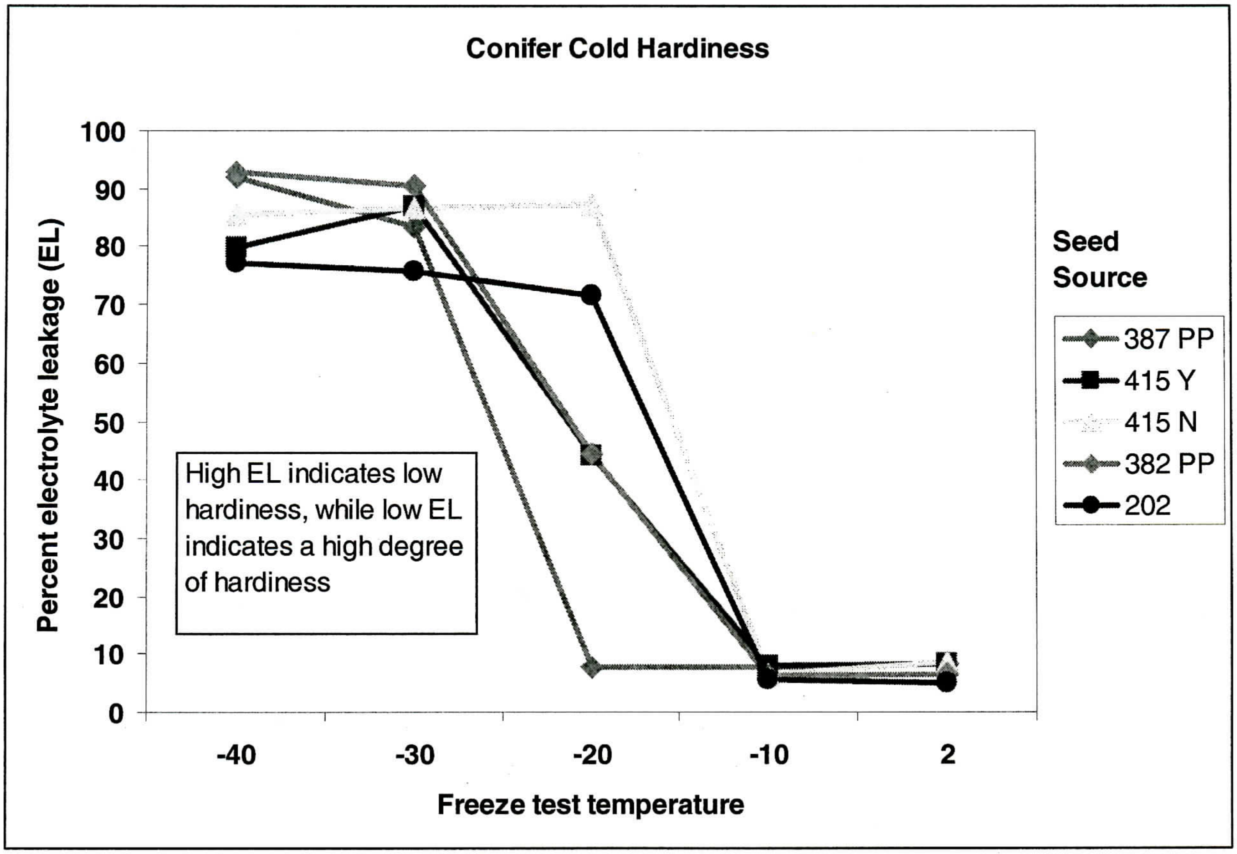


Figure 2. Variation in electrolyte leakage (EL) by species and seed sources as sampled in August 2004. Seed source designations are 387 PP – 1524 m elevation, 382 PP – 1067 m elevation, 415 Y – Douglas-fir (1067 m elevation) with blackout, 415 N – Douglas-fir (1067 m elevation) without blackout, and 202 – Red fir (1676 m. elevation).

Sierra Cascade Intensive Forest Management Research Cooperative
Income/Expense Statement
Calendar Year Report for the Period Jan. 1 to Dec. 31, 2004

Beginning Balance on January 1, 2004		**$ 67,108.98**
Total Income (Membership Dues)		**$72,000.00**
Expenses:		
Plot Lay-out Supplies	21.45	
Plot Measurement/Lay-Out Contracts	13,269.12	
Plot Measurement/Lay-Out PSW Per Diem	696.03	
Release Spray	9,197.78	
Weather Stations	82.00	
New/Old Proposals, Funding	44,438.40	
Co-op Manager Expenses	49,303.97	
Total Expenses		**$117,008.75**
Year End Balance as of December 31, 2004		**$22,100.23**

Co-op Manager's Time Breakdown

Annual Report	15%
Annual Business Meeting	5%
Proposal Work	59%
Field Trip	5%
Billings, Invoices, etc.	16%

WORKING GROUP MEMBERSHIP

Working Group I
Seed to Establishment

Tom Jopson, Chair
Ed Fredrickson
Jerry Gallagher
Mark Gray
Stuart Gray
Ron Hague
Tom Harvie
Lewis Howe
Duane Nelson
Glenn Novak
Tom Young

Working Group II
Out-planting Through Precommercial Thinning

Brian Schlaefli, Chair
Ed Fredrickson
Mark Gray
Stuart Gray
Jason Warshawer
Duane Nelson
Bob Powers
Tom Young
Lewis Howe