

CFRU Information Report 22

**1989 ANNUAL REPORT
OF THE COOPERATIVE FORESTRY
RESEARCH UNIT**

**COLLEGE OF FOREST RESOURCES MAINE
AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF MAINE ORONO, MAINE 04469**

COOPERATIVE FORESTRY RESEARCH UNIT

Mission: Research on the Intensive Management
and Utilization of Forest Resources

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ADVISORY COMMITTEE CHAIRMAN'S REPORT

The Cooperative Forestry Research Unit has once again experienced a productive year. We are pleased that both 1989 activities and the considerable research which has been accomplished by the Unit during the past several years will be summarized in this Annual Report. This expanded Annual Report is part of an overall strategy to summarize the numerous achievements of CFRU as we plan for the fourth five-year funding period of the Unit which begins in 1991. In addition to the expanded Annual Report, the Unit also planned a two-day CFRU Forum for March 1990. Both this Annual Report and the planned Forum provide an excellent opportunity to review the outstanding accomplishments of the Cooperative.

A priorities sub-committee was formed to determine and prioritize research topics of current interest to the cooperators. These results will be reported in the March Forum and will be used to plan for the fourth five-year funding period.

Also accomplished during 1989 was a needed overhaul of CFRU's Policies and Procedures. This effort included establishing the first Sabbatical Leave Policy for CFRU, which now brings CFRU into conformance with University Policy. The Sabbatical Leave Policy should benefit CFRU by 1) broadening the participating scientist through close interaction with other leading scientists in that field of work, 2) establishing contacts for future communication and research, 3) broadening the exposure and reputation of CFRU, as well as others.

We are pleased that Dr. Maxwell McCormack, Jr., is taking advantage of this new policy by planning a sabbatical at Freiburg, West Germany. He plans to work on regeneration-phase and herbicide technology oriented research as well as provide visiting lectures and seminars in West Germany and other countries. Dr. McCormack did the preliminary groundwork for this sabbatical while attending a IUFRO meeting on herbicides in France this spring.

The financial position of CFRU is in excellent condition, with some improvement over 1988. This improvement is the result of both the addition of

new members and the increase in dues needed to keep up with inflation.

One of the major efforts of CFRU during 1989 was to develop a new project proposal investigating "high yield plantation management". This project was designed to study the potential biological productivity of various species on good sites having various intensities of silvicultural prescriptions. Because of the complexity of the project and the level of commitment needed by the cooperators, a Technical Advisory Committee was formed made up of technical staff from the cooperators and scientists within the College of Forest Resources. Although it was determined by the Advisory Committee that there were still too many uncertainties for implementation this year, it marked the first time within CFRU for such a co-ordinated effort between the cooperators and scientists in planning a project. As I noted in last year's Annual Report, the synergism resulting from this type of cooperation between the staff of CFRU and the cooperators has provided a research program that is dynamic in its ability to provide timely solutions to the cooperators evolving and ever changing problems and needs.

I wish to thank the other members of the Executive Committee, Tom Colgan and Cliff Swenson for their efforts in keeping CFRU a healthy and vibrant organization. I especially want to thank Dean Fred Knight for his excellent leadership of CFRU and wish the best for him in his upcoming retirement in 1990.

As we look to 1990 and into our fourth five-year planning period there are new opportunities and challenges ahead. We are fully prepared to meet these challenges through a solid commitment of both the cooperators and the CFRU staff and scientists.

Michael S. Coffman, Chairman
CFRU Advisory Committee

DEAN'S REPORT

The Cooperative Forestry Research Unit Advisory Committee, Director and Scientists have devoted a considerable time during the past year in planning for the future. Meanwhile the work on research has continued at a high level of activity. The field season in 1989 was a very active period for the researchers and a large number of temporary summer employees.

This has been a year for self analysis and review of priorities. The cooperators are looking to the future as they make decisions on supporting the CFRU during the five-year period commencing in 1991. We hope that all members will be impressed that the accomplishment of the 15 years ending in 1991 will convince them to continue for another five-year commitment. I doubt that a research group anywhere has accomplished as much in respect to its size and level of support.

Some of these accomplishments have been reported by the scientists in their expanded reports for 1989. However, there are accomplishments by members who are no longer a part of CFRU. Some of the significant accomplishments are in the following one line statements which will remind us of the work of past years.

Exotic larches have been field tested at three sites.

Tree Improvement programs have been reviewed and field studies installed on several species.

Forest fertilization created a positive growth response in red spruce stands of northern Maine.

White pine responds to recommended applications of fertilizers with significant growth improvement.

CFRU scientists were instrumental in obtaining registration for general herbicide products.

Herbicides are effective in reducing raspberry competition on clearcuts in northern Maine.

Aerial applications of herbicides are effective in adjusting spruce-fir stocking densities.

Analyses of nutrient and biomass removals provide basic information on long-term effects of complete-tree harvesting.

Residue management research provides information on nutrient relationships, stream-water quality and long-term forest site productivity.

Mechanical and manual systems have been evaluated for controlling density in spruce-fir in northwestern Maine.

A simple graphical method has been developed to quickly estimate costs and benefits from precommercial thinning in dense young spruce-fir stands.

Timber supply projections were developed for Maine timberlands.

The parasite *Trichogramma minutum* was evaluated as a control for the spruce budworm.

Life tables were developed for the white pine weevil providing a basis for efficient control of high populations.

Damage by reproduction weevils was evaluated on various sites and recommendations developed for reducing losses.

The impact of damage to residual hardwood trees by mechanized whole-tree harvesting is extreme on some sites.

Vigor assessment of red spruce utilizing the Shigometer was proven to be more accurate than traditional methods.

The climatic zones of Maine have been characterized to provide a base for a more accurate site classification system.

These are only a few of the many projects completed during the past 13 years. The overall productivity and contributions to the mission of the CFRU is outstanding. The current full time scientists (Dr. McCormack, Dr. Ostrofsky and Dr. Briggs) and those who were previously a part of the team (Dr. Field, Dr. Houseweart and Dr. Seymour) have all contributed to this record of accomplishment. Additional research completed by associated faculty are included and round out the record. Details on the above accomplishments are available in the published papers of the CFRU and in the past annual reports.

Research is only a part of the story because the responsibility to transfer knowledge to the cooperators is a part of everyone's job. CFRU scientists have given a high priority to this responsibility while continuing their high level of research productivity. During the past year as a part of their public service contribution, they were responsible for putting together the proceedings of the recent (1989) joint meetings of the New England Society

of American Foresters, the Maine Chapter of the Wildlife Society and the Atlantic International Chapter of the American Fisheries Society. This production required many hours of extra effort by the CFRU scientists. These contributions of time and quality work help to raise the appreciation of the work of the CFRU in the eyes of peers throughout the state and region.

The mission of the Cooperative Forestry Research Unit was stated in the planning document published in 1975 in these words - "Cooperative Unit for Research on the Intensive Management and Utilization of Forest Resources". This mission has been sufficient to cover the program during the years that have passed. We have not expanded to the extent envisioned when the cooperative started, and as a direct result work in the utilization area has never been a high priority. That still may occur if the cooperators set utilization as a high

priority. I see no reason to delete utilization from the Mission Statement.

During 1990, we must review what has been accomplished, we must set priorities for the next five years and we must continue research in progress. We need a solid commitment from our cooperators to continue the work into the nineties by agreeing to the five-year program commencing in 1991.

Fred B. Knight
Dean, College of Forest Resources
Director, Cooperative Forestry Research Unit

BALANCE SHEET

1988-1989 Period
10/1/88-9/30/89

ASSETS:

BALANCE FORWARD SEPTEMBER 30, 1988	\$ 519,372.69	
CONTRIBUTIONS 1988 RECEIVED AFTER 9/30/88	19,533.50	
CONTRIBUTIONS 1989 RECEIVED 10/01/88-09/30/89	470,357.00	
INVESTMENTS 10/1/88-09/30/89 TOTAL ASSETS:	48,816.42	
10/01/88-09/30/89		\$1,058,079.61

EXPENSES:

ADMINISTRATION	KNIGHT	57,140.30	
CHAMPION *	WHITE	1,431.75	
HELICOPTER SERVICE	McCORMACK	22,500.00	
GROWTH & YIELD	SEYMOUR	11,397.53	
SILVICULTURE	McCORMACK	139,198.58	
SOIL SITE	BRIGGS	108,293.68	
TIMBER QUALITY	OSTROFSKY	74,959.73	
TREE IMPROVEMENT	GREENWOOD	10,000.00	
** HERBICIDE	McCORMACK	10,000.00	
FERTILIZATION	SHEPARD	8,555.90	
TREE IMPROVEMENT	CARTER	34,238.90	
TOTAL EXPENSES; 10/01/88-09/30/89			477,716.37
Less Account Balance Carried Forward			1,513.26
BALANCE ENDING 09/30/89			\$ 578,849.98

* Helicopter Services - special contributions by Great Northern, International Paper Co., and Boise-Cascade Corp.

Gift from Monsanto specifically for M. McCormack's herbicide research.

SILVICULTURE

Dr. Maxwell L. McCormack, Jr.

History and Accomplishments

The silviculture project commenced in 1976 with initiation of the CFRU and continues in its 14th year. Dr. McCormack has been the principal scientist throughout this period and, additionally, served as CFRU Leader from 1984 through 1986. Since the early years, this project has been responsible for maintenance and supervision of the CFRU Building located on the University Forest and the trailer at Telos Camp. The latter facility, existing through the support of Great Northern Paper, has provided low-cost accommodations at a convenient field location for a variety of research projects.

Over 50 publications have resulted from the general silviculture project work and approximately 30 additional publications and papers have included data from the Weymouth Point Watershed Study. Results and developments from this research have been presented at over 100 formal meetings, seminars and workshops across the northeast from Thunder Bay, Ontario and Urbana, Illinois to Grand Falls, Newfoundland with recent presentations in Vienna, Austria and Nancy, France.

Highlights of project work, which followed the 1976 review of cooperator operations and drafting of a problem analyses, are summarized chronologically.

1977 - McCormack's earlier work on herbicidal suppression of raspberry brambles to benefit spruce-fir regeneration was continued in the Telos Area. Ellis Sprague was employed as the first full-time assistant scientist, the first stages of the long-term spruce-fir thinning study were carried out, and Frank Conlon began his M.S. studies through stem analyses of residual spruce and fir trees.

Working with Al Averill of Northeast Helicopters, the Austin Pond Herbicide Study was established in cooperation with Scott Paper Co. Together with similar treatments carried out through the cooperation of Dick Griffith of St. Regis, this study resulted in the first aerial tests of glyphosate (Roundup^R) and triclopyr (Garlon^R) in eastern North America.

1978 - Evaluations of herbicide technology were intensified and Dr. Michael Newton, Oregon State University, shared part of his sabbatical leave cooperating in the appraisals of herbicide efficacy. The project coordinated the execution of an Experimental Use Permit (USEPA) providing for opera-

tional application of 90 gals of Roundup". Establishment of the long-term spruce-fir thinning study was completed. C. Tattersall Smith, Jr., began evaluations to develop a Ph.D. study of effects of mechanical harvesting on site quality and the CFRU Building was constructed from materials supplied by CFRU cooperators.

1979 - Earlier work was used as a basis for a State of Maine special use label EPA 24(c) for Roundup" as an aerial conifer release treatment. Timing and combinations of glyphosate and triclopyr were studied through cooperative work with International Paper Company at their Northern Experiment Forest. Field trials to study hexazinone (Velpar") were initiated.

Tat Smith's evaluations resulted in establishment of the Weymouth Point Watershed Study (T4R12 WELS) in close cooperation with Great Northern Paper and personnel from the USDA - Forest Service in Durham, NH. Permanent lysimeter plots were established across a pair of watersheds to evaluate nutrient cycling interactions of three harvesting residue management alternatives.

1980 - Detailed background work was carried out at Weymouth Point to document soils, vegetation, and tree biomass conditions. The access road through the treatment watershed was constructed.

Frank Conlon's completed thesis quantified growth responses of released spruces and firs and emphasized that live crown characteristics were most important in selecting crop trees when thinning. Further studies were carried out to refine application rates of glyphosate, triclopyr, and hexazinone. Through coordination of the Paper Industry Information Office and cooperation of Drs. Harvey Holt and Burnell Fischer of Purdue, the first intensive training course on operational herbicide use in forestry was carried out.

1981 - Mechanical harvesting of the clearcut watershed treatment at Weymouth Point was completed. A massive effort was carried out to measure harvested biomass, residues, and soils data.

Further evaluations, including four-year crop tree growth data, were completed at Austin Pond. Working with Northeast Helicopter and Oscar Selin of Georgia-Pacific, the first aerial applications of hexazinone (Velpar") were made. Though these tests were to study brush suppression in conifer plantations, they became a partial basis for development of current hexazinone use in the Maine

blueberry industry.

1982 - Paul Messier assumed the responsibilities as assistant scientist. Post-harvesting soil solution and stream water monitoring was well under way at Weymouth Point and the preharvest grid and reference points were relocated and monumented.

The long-term thinning study plots were heavily infested with spruce budworm. Evaluations of herbicide plots continued and earlier data provided a basis for a State of Maine special use label EPA 24(c) for Garlon^R as an aerial conifer release treatment. The labels available allowed operational treatments totalling 17,580 acres by forest industry landowners. Research and development began on an aerially-applied herbicide technique for mechanically spaced precommercial thinning of overstocked softwood regeneration.

1983 - Tat Smith's Ph.D. dissertation on Weymouth Point was completed, but monitoring of the watershed continued and C. Wayne Martin, USDA - Forest Service, established permanent plots to monitor vegetation regrowth on the treatment watershed. The long-term thinning sites were re-measured for five-year data and six-year post treatment measurements were made at Austin Pond. Evaluations of aerial strip precommercial thinning narrowed the choices of chemical treatments and indicated a need for wider treatment bands.

1984 - Weymouth point monitoring and vegetation surveys as well as evaluations of herbicide treatment efficacy continued. Operational trials of the aerial strip precommercial thinning were carried out on a variety of regeneration conditions. These trials included initial tests of the Thru Valve Boom^R(TVB^R) for controlled spray pattern delivery. Consideration of herbicide treatment interactions with small mammals and songbirds became part of the appraisals of herbicide effects.

1985 - Maintenance of the major studies continued and included intensive survey of Weymouth Point vegetation regrowth. The treatment watershed received an aerial application of triclopyr to provide study of residues, environmental fate, and interactions with the nutrient cycles. Dr. Newton returned to conduct more evaluations of the Austin Pond herbicide plots. This year operational herbicide treatments by industry using Garlon^R and Roundup^R totalled 41,500 acres.

1986 - R. A. Lautenschlager continued his Ph.D. research on raspberry life history and interactions with spruce seedlings. Later in the year he began his responsibilities as the assistant scientist on the silviculture project. Study sites were maintained and additional herbicide testing included imazapyr (Arsenal⁰) metsulfuron (Escort⁰) and sulfome-

turon (Oust^R). Further development work was done with the TVB^R for the aerial strip thinning.

1987 - The eighth year of soil solution and stream sampling at Weymouth Point was completed. The permanent vegetation plots were re-measured. Patrick Strauch initiated his M.S. research on origin and early development of red spruce and fir regeneration. Maine Helicopters cooperated in treating several operational sites with strip thinning tests using the TVB^R and was the applicator for a comprehensive release study located on land of Champion International in Township 34. This latter study included 27 replicated treatments of different herbicides, tank mixes, and surfactant combinations which form a part of G. R. Schaefer's Ph.D. research.

1988 - Intensive evaluations of treatment efficacy were carried out at Township 34. After nine years of monitoring, active on-site work at Weymouth Point was completed, but the grid system and permanent plots are being maintained. Conifer regeneration and vegetation dynamics studies neared completion and ten-year data collection began for the long-term spruce-fir thinning study. Operational guidelines for the aerial strip thinning were defined. Industrial conifer release programs treated 78,300 acres with herbicides during the 1988 season.

Throughout this time period research has been carried out under operational conditions to provide a framework of study sites yielding data over periods of time, rather than short-term studies. Plots and facilities have been maintained to furnish an environment of maximum interaction across a broad spectrum of research and operational personnel. Operational guidelines, prescription development procedures, and growth response data for five- to ten-year periods now can be assimilated. Future work will develop from needs identified in the accumulated data and definitions drawn from the current CFRU research priority surveys.

Over the past decade silviculture project data and information have been utilized in numerous seminars and one-day workshops on herbicide technology. Since the PIIO herbicide course in 1980, formal educational programs of two- to six-days duration have been conducted for over 400 forestry personnel.

Research Effort - 1989

A full summer field season was carried out re-measuring plots and establishing new operational trials. Several summer workers were employed for a total of 385 worker days of which approximately 10 percent was devoted to safety

training and general maintenance. P. Strauch's studies on spruce-fir regeneration were completed. G. R. Schaertl progressed on his Ph.D. program and carried out his second season of vegetation management research. R. A. Lautenschlager continued as full-time assistant scientist in the silviculture program while completing data collection for his dissertation on red raspberry life history and interactions with white spruce seedlings. M. L. McCormack, Jr. wonders how many foresters read the CFRU Annual Report and requests that you let him know your thoughts on its contents.

In addition to the technology transfer activities listed later in this report, Dr. McCormack conducted a three-credit course on forest vegetation management with herbicides. This course met one evening each week during the spring semester with an enrollment of 27. During May, Dr. McCormack attended the IUFRO group meeting on herbicide use in forestry which was held in Nancy, France. He presented two papers on release practices and herbicide research in Maine. As in past years, the silviculture program provided maintenance and supervision of the CFRU trailer at Telos Camp and the CFRU Building in Orono.

This program is going through a transition in its fourteenth year, in part, to adjust to new directions which might result from the current reevaluation of research priorities. Time was devoted to developing a broad CFRU project effort on high yield research through application of intensive silviculture which would integrate much of the information developed by CFRU since its inception. This proposed effort has been tabled, but much of the cooperation thinking which brought it to the forefront is likely to influence future research directions regarding new stand establishment and early growth rates. The aforementioned transition includes completion of the recent studies of spruce-fir regeneration development and nine years of continuous monitoring of soil solutions and stream water at the Weymouth Point Watershed Study. The cessation of winter stream water collection is a happy development, but we look forward to maintaining the plot and grid systems.

Precommercial Thinning

Further trials were conducted in 1988 to develop the aerial strip thinning technique. All applications are being made with a (TVS⁰) due to availability, possible faster aircraft speed, and better understanding of necessary equipment adjustments. In mid-April initial trials of a Del Norte™* electronic navigation system showed potential for

adequate precision for guiding a spray helicopter in applying thinning treatments without the use of ground flagging personnel.

With supplemental support from Dow Chemical to cover costs of the Del Norte™ equipment, operational scale trials were carried out in June in cooperation with Great Northern Paper, International Paper Co., and Boise-Cascade Corp. These trials were done entirely with the electronic guidance system and incorporated tests of modified herbicide treatments and surfactant combinations. Lower total spray volumes were also included in an effort to reduce further the basic costs of treatment.

The summer crew devoted 40 worker days (10% of summer effort) to this project. The navigation equipment appeared to function fairly well with some inconveniences regarding pilot familiarity. Wayne Clark, Maine Helicopters of Augusta, trained for and flew all the applications. Final determination of success, and efficacy of treatments, will be dependent on evaluations during summer 1990 and future observations of subsequent regrowth. Recommended herbicide treatments, spacings, and spray volumes remain as summarized in the 1988 CFRU Annual Report.

Thinning Spruce and Spruce-Fir Stands

Twenty-three worker days were expended during the early part of the season for remeasurements of the Rowell Brook and Lakeville Plantation study sites. This completes the 10-year growth response package for the four principal study sites. Preliminary review of results do not indicate any new information since the summary in the 1988 Annual Report. The data are collected on an individual crop tree basis rather than stand data. Thus, individual tree performances can be evaluated. The future of the plots will be decided after the new evaluations are complete. However, because of its geographical location and extreme stand deterioration, the Lakeville Plantation site likely will not be assessed further.

An indication of comparative growth rates for the ten-year response period is illustrated in Figure 1. Diameter and height growth since thinning at two levels can be seen for the remaining study trees. With reference to Figure 1, age and reduced live crown ratios at time of treatment increase from left (Scott Brook) to right (Lakeville Plantation). The older trees were also more seriously injured by spruce budworm during the years immediately after thinning. A general pattern observed during this study appears to be illustrated in this figure; positive growth responses are more apparent when earlier entries were made (e.g., the Scott Brook stand was age 17 and the Clayton Lake stand was age 34 while the other sites were stocked with

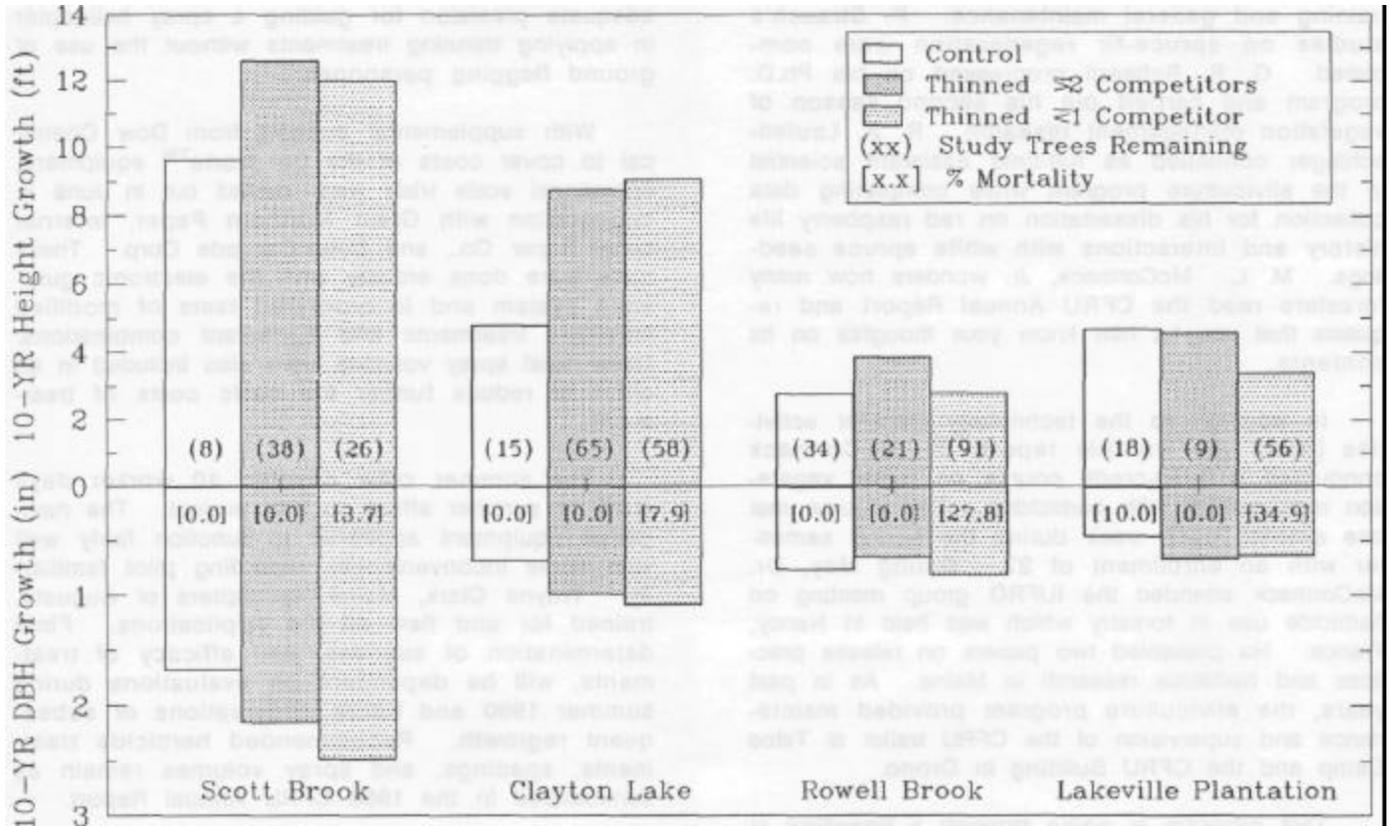


Figure 1. Growth responses for the 10-year period following treatment of the four major long-term spruce-fir thinning study sites. Data for each site are broken down by two levels of competing residuals (0 to 1 and 2 or more competitors) as compared to unthinned (control) study trees. Mortality levels and numbers of remaining study trees are indicated for each category.

trees which were about 70 years or more at time of treatment). Furthermore, the mortality figures indicate greater risks in the older stands especially where the stands were opened up by thinning. Thorough evaluations of the new data are being conducted during this winter.

Management of Undesirable Vegetation with Herbicides

During 1988 three significant publications resulted from CFRU research relating wildlife interactions with herbicide treatments. Two papers by David Santillo and others report on his M.S. thesis studies of small mammals and songbirds on glyphosate-treated cutovers. His work received special support from Great Northern Paper. Data showed that small mammal communities, particularly herbivores and insectivores, may be reduced for at least three years after herbicide treatment. Songbird observations indicated that the reduced structural and floral complexity of vegetation resulted in lower overall songbird abundance during the immediate post-treatment. Trends in vegetational change on older treatments indicated that, by three years post-treatment, areas will have at-

tained some degree of structural complexity due in part to conifer release and partial recovery by herbaceous and woody vegetation. Cover of shrubs, forbs, and grasses tended to increase during the two to three years after treatment. Raspberry brambles recovered by three years after treatment.

Of special interest is the report by Newton *et al.* (1989) on evaluations at the Austin Pond Study Site nine years after a variety of replicated aerial treatments. The treatment-caused reduction of tall hardwoods resulted in a three- to eight-fold increase in available browse. Data indicate that short-term browse reductions are minimal after operational treatments. By nine years after treatment browse availability and quality are improved because of greater light intensity reaching the lower vegetation. Consequently, it is possible to maximize conifer growth and the period of browse availability by early release with herbicides followed by precommercial thinning.

Data collection, one year after treatment, was completed for an efficacy study established in cooperation with Great Northern Paper in T4R11

and T4R12 WELS. Roundup" at rates of 2 lbs ai/ac was mixed with a range of rates of MON-17440 experimental herbicide and several surfactant combinations. This study is part of the continuing effort to perfect operational glyphosate treatments. Data are being processed and plans are being made to evaluate these plots during the second year after treatment. A companion study, located in Rangely Plantation, in cooperation with Boise-Cascade Corp. was measured for two-year post-treatment data. The treatments include glyphosate at 1.5, 2.0, and 2.5 lbs ai/ac with three levels of the formulated surfactant, MON-0818. Results from varying the surfactant are not clear, but lower rates may be adequate. Aggregate stem kill one year after treatment of red maple, birch, pin cherry, and red raspberry show a dose response relationship (Figure 2). These relative levels of

Glyphosate (lb ai/ac) 0 Red Maple

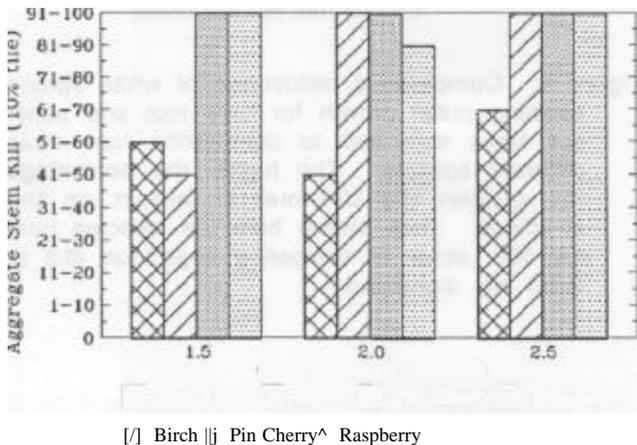


Figure 2. Relative control, one year after treatment, for four common undesirable brush species treated with three different rates of glyphosate.

control are illustrative of effectiveness which will enable managers to develop prescriptions. For example, where predominant brush is composed of pin cherry and raspberry an operational rate of 1.5 lbs ai/ac likely would be adequate. The 2.0 lbs ai/ac treatment incorporate good birch control, but the need for red maple control would suggest the highest rate of 2.5 lbs ai/ac. As the use of various efficacy enhancements are perfected, options to insure desired levels of suppression can be built into prescriptions in the future. Toward this end research attention is being given to surfactants, spray particle sizes, total spray volumes, and subtleties of timing applications.

An example of pursuing this latter need is a new study established in cooperation with Champion International Corp. in Bradley Township. Efficacy of four glyphosate rates (0.0, 1.0, 2.0, and 3.0 lbs ai/ac) across four levels of Entry II™ surfactant are being appraised. Originally, three times of treatment from early August to mid-September were planned. Unfortunately, the early ap-

plication was washed out by rain. The second and third applications were carried out successfully. Thus, with two replications of each treatment, there are 64 plots in place for detailed evaluation over the next two field seasons. Establishment of this study consumed the largest portion of the field season labor resources; 182 worker days (47%).

The Township 34 MD study of 27 replicated herbicide treatments was evaluated for two-year post-treatment results. Treatments and descriptions of this study were included in the 1987 and 1988 Annual Reports. This data collection, requiring 40 worker days for completion, will form a major component of G. R. Schaertl's dissertation. Though the first phase of this study is near completion, selected treatments will be considered for reappraisal during the fifth year after treatment.

R. A. Lautenschlager's dissertation is completely drafted and currently under review. He has assembled data on the life history of raspberry as well as quantification of interactions of white spruce seedlings with raspberry and other competing species. Among the variables studied, his Nelder plots provide a basis to evaluate effects of inter- and intraspecific competition, growing space, shade, and nitrogen supplement (258kg N/ha in the first year, 172kg N/ha in the second year) on growth and biomass production of white spruce and raspberry. Figure 3 illustrates selected data from the plots where general effects of 73% shade and available growing space are apparent.

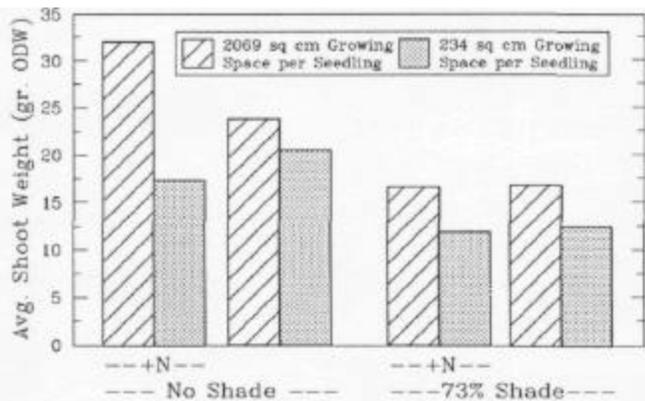


Figure 3. Comparative shoot weights of white spruce seedlings grown in Nelder plots for three seasons, in two different growing space areas, with and without 73 percent shade and nitrogen supplement.

Lautenschlager's field plots in the Telos Area have evaluated bare root and paper pot white spruce seedlings planted in a variety of natural vegetation conditions. There were differences between the planting stock types, and surrounding vegetation exerted a detrimental effect on the spruce seedlings when it gained an overtopping

position. A selected illustration of relative impacts of 50% cover of three types of competing vegetation on the spruce seedling root collar diameter is shown in Figure 4.

Future work will center on refining information on vegetation dynamics, prescription development and efficacy assessment. Quantification of efficacy levels relative to competition effects on growth rates is another topic under consideration.

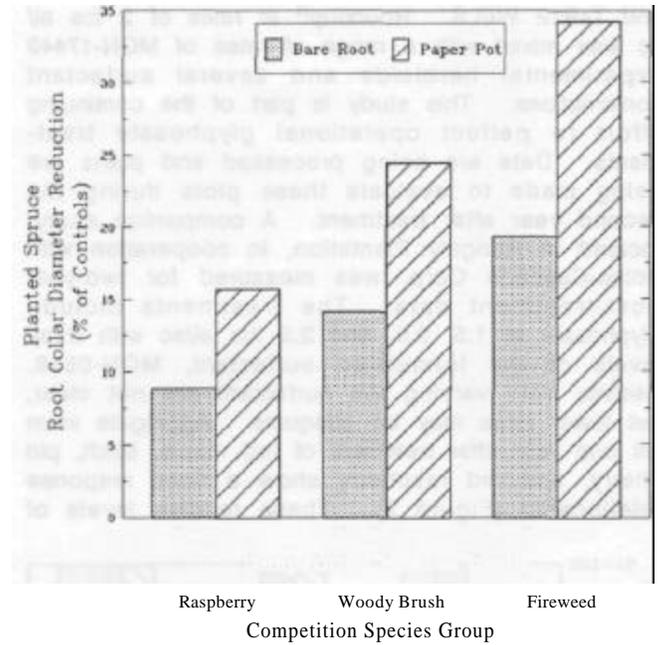


Figure 4. Comparative reductions of white spruce seedling radial growth for bare root and paper pot stock submitted to competition from three different species. The higher the percentage the greater the detrimental impact on the seedlings. Data shown here are selected from the 50% cover of competing vegetation (0.5 to 2.0m ht) condition.

SITE QUALITY

Dr. Russell D. Briggs

Introduction

The primary objective of the site evaluation project, initiated in 1988, is to develop a classification system for assessing the inherent capacity of land to produce spruce and fir. The project is based on the fundamental hypothesis that site quality is a major determinant of forest production. On a regional scale, climate imposes broad constraints on site quality. Within climatic regions, site quality is a function of the quantity and quality of the soil volume available to tree roots.

Development of a site classification system requires several steps: (i) quantitative assessment of the relationship between soil-site variables and productivity; (ii) development of productivity classes on the basis of soil-site variables and subsequent delineation on maps; (iii) field validation and revision where necessary. Currently, the first step is being addressed. Two tasks are in progress: (i) delineation of broad climatic zones within the state of Maine and (ii) empirical development of the relationship between productivity and soil-site variables.

The summer of 1989 marked the second field season for the project. Personnel assisting in the field work included Ronald Lemin, Asst. Scientist, and summer field technicians Richard Dionne, Karen Klavuhn, and John Wentzel. During the 1989 field season, emphasis in location and establishment of plots was shifted from fully-stocked, even-aged, mature spruce-fir stands to vigorously growing, young stands that were precommercially thinned. The change in emphasis was necessary because of the difficulty in locating suitable mature stands on well and moderately well drained soils.

Two factors make the use of precommercially thinned (PCT) stands attractive for this project. First, interstand competition is minimized following precommercial thinning; individual tree growth during the period following treatment theoretically reflects site quality. Second, PCT stands are currently distributed over a wide range of site conditions. Consequently, these stands offer an opportunity to examine thinning response in the context of site quality. The practice of PCT has proceeded on the basis of limited (although impressive) data from a few studies. Estimates are needed of the impacts of PCT on growth and development across a wide range of sites.

A great deal of data was collected during the

field season. Work continues on increment core measurement, laboratory analysis of soil samples, and data entry into the computer. This report will present current status of (i) delineation of climatic regions in Maine and (ii) soil-site relationships for spruce-fir. The latter is subdivided, in accordance with field sampling, into two components: fully-stocked, even-aged mature stands and young, vigorously growing precommercially thinned stands.

Delineation of Climatic Regions in Maine

Monthly and daily data summaries collected from 63 meteorological stations reporting both temperature and precipitation data in Maine during the period 1950-1983 were obtained from the National Oceanic and Atmospheric Administration (NOAA) on magnetic tape. Daily data were used to calculate heat accumulation above a threshold of 40° F (Baskerville and Emin 1969). Monthly summaries were used to derive all other variables used in the analyses (Table 1).

For each station, mean and total values (for temperature and precipitation data, respectively) were calculated for each month during the period of record. Seasonal means (spring, March - May; summer, June - August; fall, September - November; and winter, December - February) were then calculated and used in subsequent analyses (van Groenewoud 1984).

Principal component analysis was performed on the correlation matrix of the climatic variables. Principal component scores were computed as the product of the characteristic vectors (for the first three principal components) and the mean vectors for the climatic data for each of 63 stations. Cluster analysis (Wards minimum variance, SAS 1985) was applied to the resulting principal component scores to define groups of similar weather stations.

Climatic zones were subsequently delineated on a map of the state of Maine. Boundaries among weather station clusters were drawn with the aid of the following information: physiographic provinces (Denny 1982); previously defined climatic regions (Fobes 1946, Lautzenheiser 1972); map of phenological development of balsam fir in Maine (Mingo and Dimond 1979), and the 1:500,000 topographic map for the state. Following the cluster analysis, stepwise discriminant analysis (BMDP 1988) was used to identify those variables that best

Table 1. Variables used in analysis of climatic data obtained from 63 meteorological stations in Maine from 1950-1983.

Description	Season ^a
Heatsum units (40°F base temperature) (Baskerville and Emin 1969).	SP, SU, F W,
Mean monthly temperature	SP, SU, F W,
Mean monthly maximum temperature	SP, SU, F W,
Extreme monthly maximum	SP, SU, F W,
Extreme monthly minimum	SP, SU, F SP,
Number of days temperature > 32°F	SU, F W, SP,
Number of days having \geq 0.1 in precipitation	SU, F W, SP,
Mean monthly precipitation	SU, F F, W,
Total snowfall	SP SP, SU, F
Potential evapotranspiration (Thornthwaite 1948)	

^aEach variable was computed for each station over the observation period by season: W = Winter (Dec. Jan., Feb.); SP = Spring (March, April, May); SU = Summer (June, July, August) and F = Fall (Sept., Oct., Nov.).

differentiated among weather station clusters.

The resulting map, still undergoing assessment, has been included in this report in order to obtain feedback on boundary placement (Figure 5). Currently, a detailed manuscript is being prepared for review and publication. Shown at the scale in Figure 5, the boundaries appear fairly well defined. However, the exercise of drawing the boundaries on the 1:500,000 topographic map for the state is sufficient to point out limitations of the data that arise from sparse distribution of weather stations.

Soil-Site Relationships For Spruce-Fir

Mature Stands

Field work was carried out in the central portion of Somerset County. During the month of June 1989, 13 plots (0.1 ac) were established in fully-stocked, even-aged, mature spruce fir stands using methodology from the previous summer (Briggs 1988). Plot locations are illustrated in Figure 6.

The 1989 data complement those collected from 19 plots in 1988 from the northern half of Piscataquis County (Briggs 1988). In contrast to the 1988 data, in which 12 of 19 plots were located on poorly (PD) and somewhat poorly drained (SPD) soils, 12 of the 13 plots established in 1989 were located on well (WD) and moderately-well drained (MWD) soils. As was the case in 1988, there was no shortage of fully-stocked mature stands on imperfectly drained soils. The major difficulty was locating stands on well and moderately well drained soils; the final plot tally indicates a high degree of success.

Spruce dominated over fir in both basal area and number of stems (Table 2). As was the case for 1988, plots established in 1989 were located in fully-stocked portions of the stands as indicated by their location relative to the modified A- and B-line stocking guidelines for trees in the main canopy (Frank and Bjorkbom 1973) (Figure 7). Stands sampled in 1989 were generally younger than those sampled in 1988 (55-72 and 70-120 years-old, respectively).

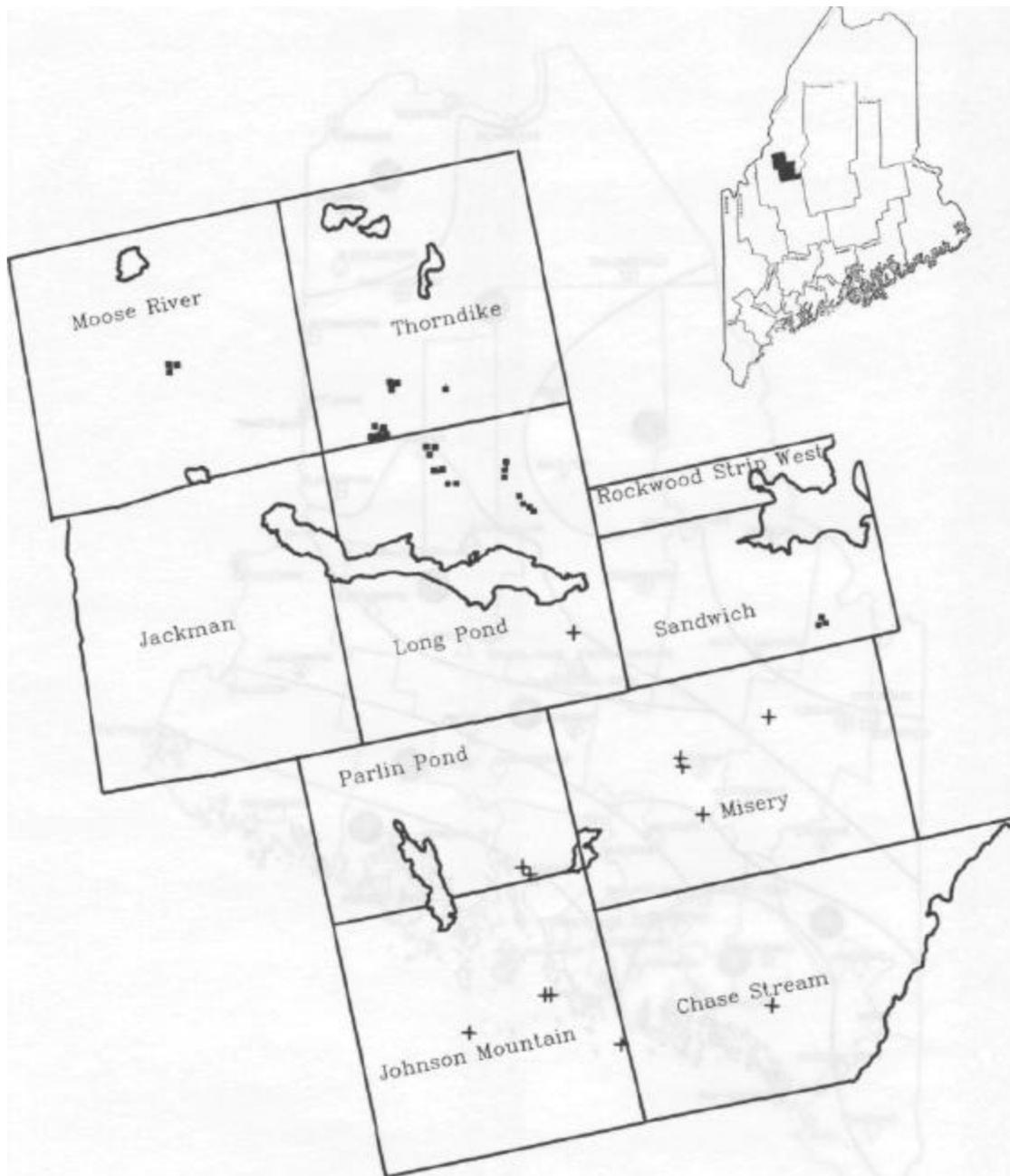


Figure 6. Map of the central portion of Somerset County, Maine, illustrating locations of plots established in mature stands (+) and precommercially thinned stands (•) during the 1989 field season. Insert at upper right shows location in the state.

of the eight subplots, one dominant/codominant tree was selected for detailed stem analysis. Balsam fir was the primary crop tree species. On plots where spruce (red and white) trees suitable for stem analysis occurred, more than 1 tree was selected from some subplots. Total height of each internode was measured in the field. Disks were cut from the stem at 0.5, 4.5, 7.0 ft, and at successive 3 ft increments up the stem. Mean radius (half of the diameter measured by a dtape) was marked on each disk in the field. Bark thickness and ra-

dial increment were measured in the laboratory to the nearest 0.01 mm along the mean radius. An index of competition, the ratio of squared dbh of the sample tree to the average squared dbh of crop trees in the subplot, was computed for each stem analysis tree (Daniels *et al.* 1986).

Understory herbaceous vegetation was sampled (percent cover and average height by species) on four subplots (6.6 ft X 1.6 ft) per plot. In addition, herbaceous vegetation was evaluated

Mensurational summary for the 13 plots established in mature stands during the summer of 1989:

Variable	Mean	Range
Breast Height Age	62	55 - 72
Spruce basal area (ft ² /ac)	194	152 - 222
Fir basal area (ft ² /ac) Total basal area (ft ² /ac)	12	0 - 41
	206	158 - 242
Spruce stems (#/ac)	1254	610 - 1860
Fir stems (#/ac) Total stems (#/ac)	63	0 -740 300
	1317	- 1880
Mean stand diameter (in)	5.2	4.3 - 6.6

*Live trees only

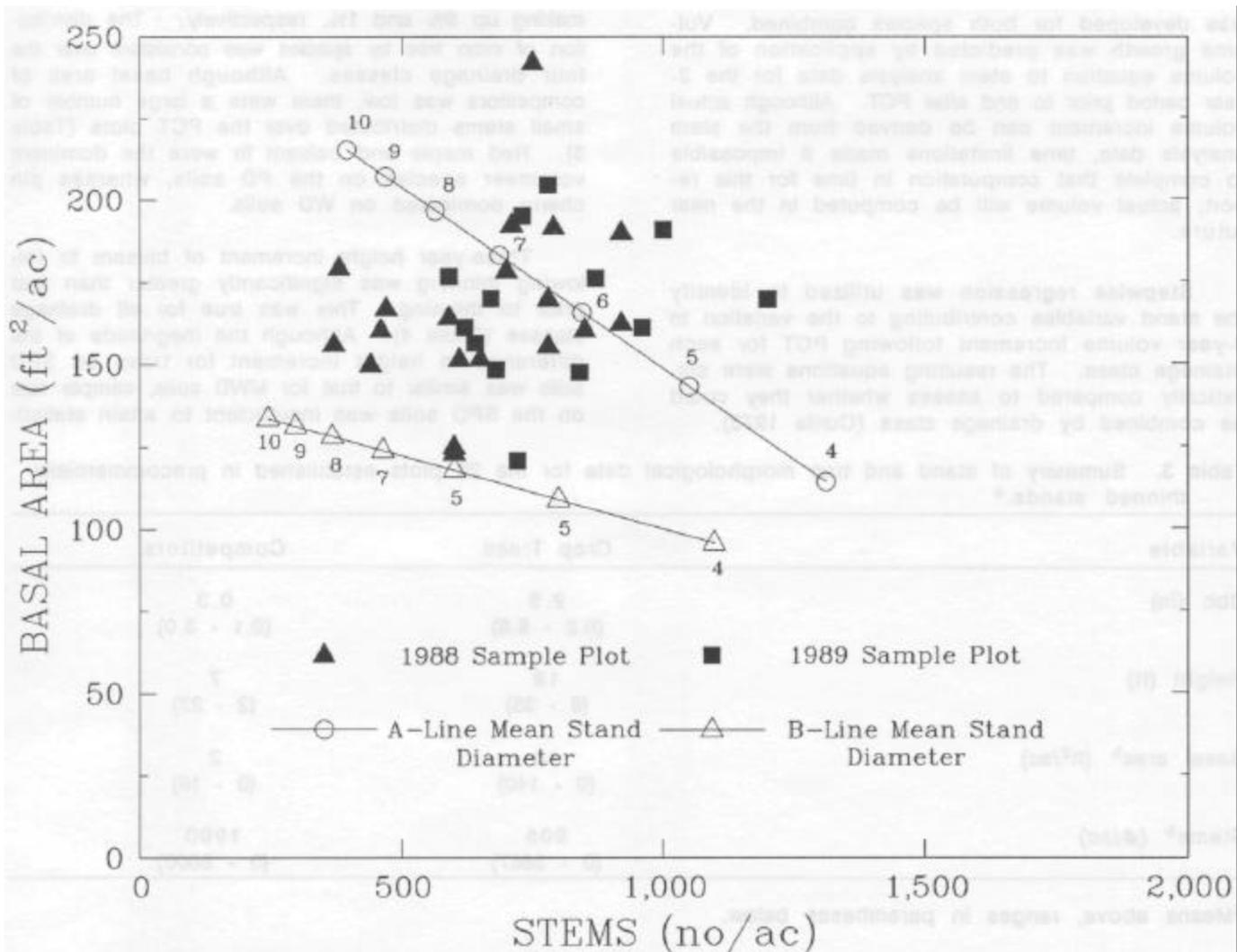


Figure 7. Basal area and number of stems for the sample plots, established in mature stands in 1989 and 1988, in relation to modified A- and B-line stocking guidelines of Frank and Bjorkbom (1973).

over the entire 0.05 ac plot in eight categories of percent cover.

A soil pit was excavated near the center of each plot. Thickness of each horizon, rooting depth, depths to mottling and to root restricting layer were measured along each pit face. The forest floor was sampled for weight and thickness by horizon (O1 and O2) using a 10" X 10" sampling frame at eight systematically located points on each plot. Forest floor and mineral soil samples were returned to the laboratory for physical and chemical analyses.

An equation relating stem volume outside bark to dbh² (inside bark) X total height was developed from the stem analysis data for 240 trees. The ratio of bark thickness to dbh for 1989 was assumed to be constant over time. Statistical analysis revealed no differences in equation coefficients between fir (218) and spruce (22); one equation was developed for both species combined. Volume growth was predicted by application of the volume equation to stem analysis data for the 3-year period prior to and after PCT. Although actual volume increment can be derived from the stem analysis data, time limitations made it impossible to complete that computation in time for this report; actual volume will be computed in the near future.

Stepwise regression was utilized to identify the stand variables contributing to the variation in 3-year volume increment following PCT for each drainage class. The resulting equations were statistically compared to assess whether they could be combined by drainage class (Cunia 1973).

The distribution of sample plots by drainage class (14 WD; 6 MWD; 2 SPD; and 7 PD) shows that most were located on the better drained soils. Many of the WD soils were field classified as Danforth and Masardis series, whereas the PD soils were classified exclusively as Monarda series. Classification into series is subject to change pending laboratory results. The Danforth series was also well represented in those plots located in mature stands. This will facilitate a limited comparison, using stem analysis data, of early growth rates of PCT stands with unmanaged stands on the same soil series.

Precommercial thinning was very effective in reducing competition. Based on data collected in each of eight subplots within the 0.05 ac plots, basal area of crop and competitor trees averaged 48 and 2 sq. ft./ac, respectively (Table 3). Balsam fir accounted for 90% of the crop tree stems over the 29 plots, with red spruce and white spruce making up 9% and 1%, respectively. The distribution of crop tree by species was consistent over the four drainage classes. Although basal area of competitors was low, there were a large number of small stems distributed over the PCT plots (Table 3). Red maple and balsam fir were the dominant volunteer species on the PD soils, whereas pin cherry dominated on WD soils.

Three-year height increment of balsam fir following thinning was significantly greater than that prior to thinning. This was true for all drainage classes (Table 4). Although the magnitude of the difference in height increment for trees on SPD soils was similar to that for MWD soils, sample size on the SPD soils was insufficient to attain statisti-

Table 3. Summary of stand and tree morphological data for the 29 plots established in precommercially thinned stands.³

Variable	Crop Trees	Competitors
Dbh (in)	2.9 (0.2 - 6.6)	0.3 (0.1 - 3.0)
Height (ft)	18 (6 - 35)	7 (2 - 23)
Basal area ^b (ft ² /ac)	48 (0 - 140)	2 (0 - 16)
Stems ^b (#/ac)	905 (0 - 3867)	1900 (0 - 8600)

^aMeans above, ranges in parentheses below.

^bBasal area and number of stems computed for each subplot (8 subplots X 29 plots) = 232 observations.

Table 4. Three-year height increment of balsam fir before and after precommercial thinning.

Drainage Class	Three-year Height Increment			
	Before Thinning	After Thinning	Difference ³	
Well drained	<hr/>			105 48
Moderately well drained	4.03	4.83	0.80**	1642
	4.06	4.42	.36*	
Somewhat poorly drained				
Poorly drained	4.23	4.61	.38	
	3.56	4.42	.85"	

Indicates statistically significant difference at $\alpha = 0.05$; "indicates statistically significant difference at $\alpha = 0.01$.

cal significance. Because there was no comparison with unthinned stands, it is not possible to unequivocally attribute the increase in height increment solely to PCT. Alternatively, these trees may have been sampled during a period of increasing height growth. The effects of PCT on height increment are confounded with age.

Comparison of pre- and post-thinning changes in height increment by drainage class suggests that pretreatment height growth was lower on the PD soils relative to the other 3 drainage classes; PCT may have increased the height growth of trees on PD soils to levels consistent with the other three drainage classes (Table 4). Following thinning, 3-year height increment for trees on PD soils did not differ from those on the other drainage classes.

The effects of PCT on radial increment were visually apparent on each of the trees cut for stem analysis, even those growing on PD soils. Increases in radial increment were more striking on the better drained soils. The magnitude of increase in radial increment following thinning varied with location on the stem. The effects of PCT on stem growth are best illustrated by volume increment, which integrates both radial and height increment over the entire stem.

Stepwise regression of 3-year post-thinning volume increment on a variety of stand and tree variables consistently identified 3-year pre-treatment volume increment and competition index as important predictor variables across drainage classes. F-statistics generated using regression with dummy variables indicated that coefficients

for equations predicting 3-year post-treatment volume increment could be grouped by drainage class (PD and SPD, MWD and WD).

Coefficients for the resulting model illustrate the differential degree of volume increment response by drainage class (Table 5). Volume increment for trees on WD and MWD soils following thinning was 2.0 times that prior to thinning. In contrast, volume increment following thinning on the imperfectly drained soils was 1.6 times that prior to thinning. These results are presented graphically in Figure 8, for a competition index of 1.0. Increasing (or decreasing) the competition index would merely shift the entire family of lines up or down by a constant amount.

These results indicate that early growth response of balsam fir following PCT is sensitive to differences in site quality. The duration of differential thinning response is unknown; most of the PCT stands were treated less than five years ago. There are a few older stands in existence, particularly in eastern Maine. Work in those stands will be necessary to address that issue.

A thorough examination of the data that has been collected for the current project in both mature and PCT stands will be carried out following completion of soil analyses. Those results, coupled with the information forthcoming from analysis of the existing spruce-fir soil-site data base (Steinman *in preparation*), will be important components of the foundation for a site classification system for spruce-fir.

Table 5. Coefficients for the regression of 3-year post-thinning volume increment on pre-thinning volume increment and competition index.³

Drainage Class	B ₁	B ₂	B ₀
Well drained	0.112	1.5857	0.1243
Moderately well drained	0.003	1.5857	0.1243
Somewhat poorly drained	0.046	2.0230	0.1243
Poorly drained	0.014	2.0230	0.1243

^a Model $y = B_0 + B_1 X_1 + B_2 X_2$ where:

y = 3-year post-thinning volume increment (ft³)
 X_1 = 3-year pre-thinning volume increment (ft³)
 X_2 = Dbh² of sample tree/average Dbh² of crop trees in subplot = competition index

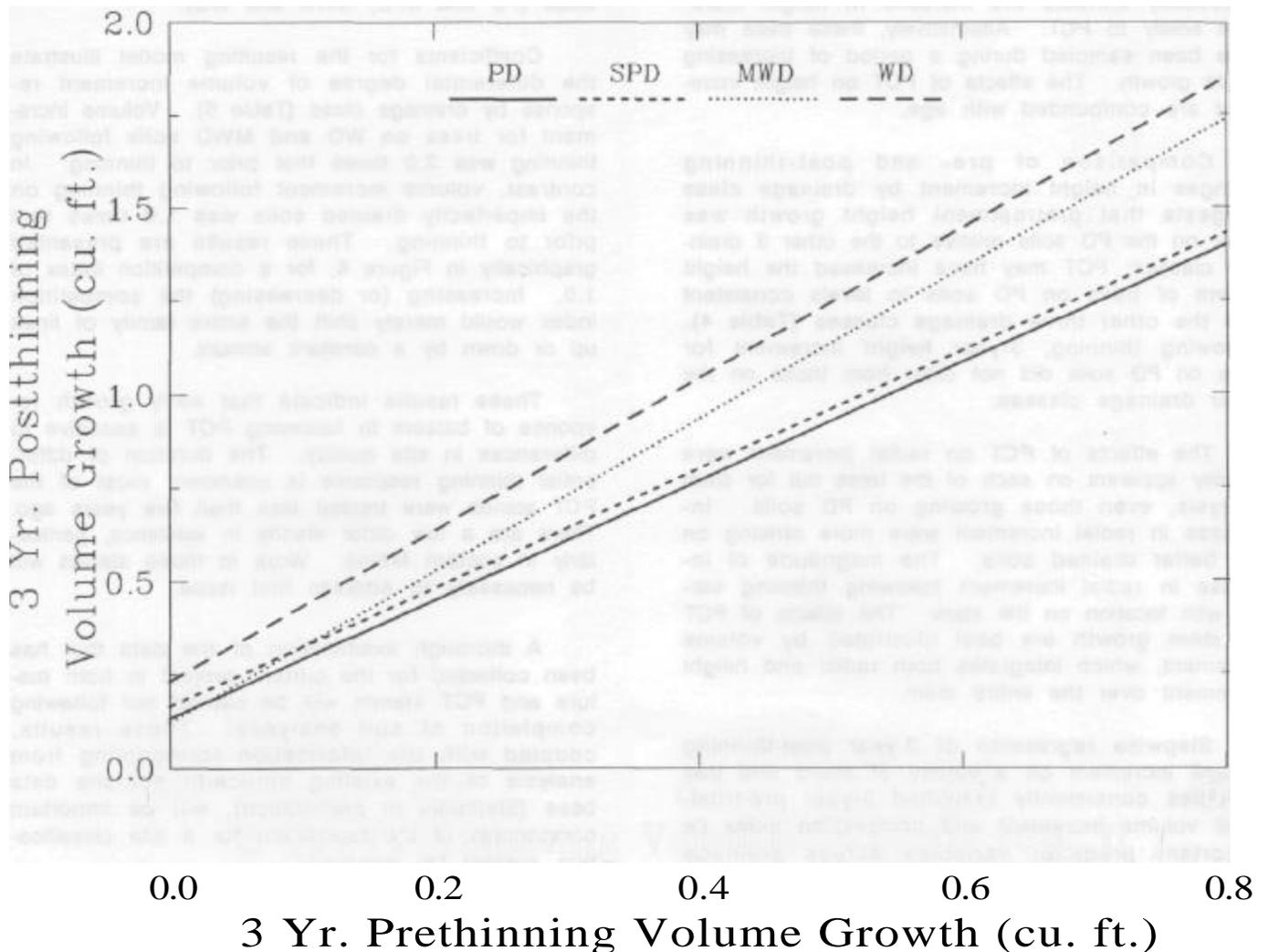


Figure 8. Three year post-thinning volume increment as a function of pre-thinning volume increment and

drainage class.

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SILVICULTURAL TECHNIQUES FOR THE IMPROVEMENT OF TIMBER QUALITY

Dr. William D. Ostrofsky

History and Accomplishments - 1982-1988

The CFRU research program focusing on the hardwood resources of Maine was formally proposed in 1980, as research priorities were outlined for the second (1981-1985) CFRU funding period (CFRU Advisory Committee 1980). At that time, a subcommittee chaired by H. Saunders was formed. The recommendation of the subcommittee was to develop a CFRU program which addressed the application of silvicultural techniques for the intensive management of hardwoods. An effort was made to expand CFRU membership with the addition of several hardwood industries, and in August of 1982 the new research program "Silvicultural Techniques for the Improvement of Hardwood Quality" was initiated.

The first project undertaken focused on the use of herbicides as an understory treatment in hardwood stands severely damaged by the beech bark disease (Ostrofsky and McCormack 1986). Throughout Maine, and especially in central and eastern regions, many acres are occupied by defective beech or disease-susceptible beech sprout thickets. The objective of the study was to explore ways in which the species composition of hardwood stands can be shifted to more desirable timber species and to beech resistant to the disease. Two stand treatment protocols were devised for a shelterwood system which involved either a pre- or a post-harvest herbicide application. Advantages and disadvantages of each protocol have been described, along with regeneration characteristics of the treated stands. Increased awareness of the beech problem by land managers, and of ways to identify resistant beech have resulted. The study is still in progress, with the overstory removal scheduled within the year.

In 1984, a study was conducted of hardwood thinning using biomass (whole-tree) harvesting methods (Ostrofsky et al. 1986). Emphasis was placed on quantifying damage to residual trees, and on harvesting techniques which could reduce damage. "Drive-to-tree" feller-bunchers were used to thin the stands. The study provided documentation of the benefits of proper skid trail layout and spacing, as well as levels of damage which could be expected from similar, whole-tree harvesting operations. Equations were developed to model the probability of an individual tree being injured. These equations represented the first of their kind to be published for northern hardwoods. The equations have been used by other research-

ers in a subsequent study in which a computer simulation of partial harvesting operations was developed. Another result was the development of a standardized system for measuring logging damage in partially cut stands. The system has been used in other research studies, as well as in State surveys of stands harvested for wood biomass.

As research priorities were adjusted in 1986 for the third five-year period of CFRU, the hardwood program was broadened to include research on quality improvement of important softwoods. Thus, the program name was changed to "Silvicultural Techniques for the Improvement of Timber Quality". Studies on the use of the Shigometer for monitoring the health of red spruce was initiated in 1985 and 1986. Preliminary published results have shown that the Shigometer is a simple, rapid, and objective way in which to classify spruce stands on the basis of tree vigor (Ostrofsky 1986). This and other, ongoing studies include monitoring the recovery of red spruce following defoliation by spruce budworm, changes in vigor of red spruce after a low thinning and most recently, the assessment of red spruce health in areas where environmental stress factors (atmospheric pollutants, acidic precipitation, severe weather, and fragile soil/site conditions) are suspected of inducing a forest growth decline.

Another evaluation of harvesting techniques in northern hardwood stands was undertaken in 1987 and 1988. At this time, the program operating budget was substantially increased, which allowed support of a graduate assistant. The project involved assessment of residual stand damage and changes in stand structure resulting from the application of two currently employed harvesting systems for stand thinning. This study provided the first critical evaluation of residual stand damage resulting from a long-reach boom feller-buncher (Hennessey 1989). While resulting damage was below that found in the previous study where drive-to-tree feller-bunchers were used, a further reduction in stand damage is possible by considering skid trail factors and season of harvest. Tree damage probability models were also developed for this long-reach boom system.

The research effort to date has provided valuable information on factors which affect stand quality, and on practical ways by which to maintain or increase quality. These studies have the added dimension of providing fixed, well-documented

areas for future investigations. A more productive forest resource and industry will develop as additional information on timber health and quality becomes available, and as critical evaluations of harvesting and other forest management practices are made.

Research Effort - 1989.

Grade and Vigor Changes in Two Hardwood Stands Five Years After Thinning

In 1984, two hardwood stands were thinned for biomass fuel using whole-tree harvesting techniques. The stands included a paper birch stand in Grafton, Maine on lands owned by Boise-Cascade Corp., and a beech - red oak stand in South Bridgton, Maine on lands owned by S. D. Warren Div., Scott Paper Co. Damage occurring to the residual stands was assessed immediately after the harvest and documented (Ostrofsky et al. 1986). Stand vigor has been monitored yearly with the Shigometer since the harvest, and in 1989 an evaluation was made of tree grade changes occurring as a result of the logging injuries.

Increases in cambial electrical resistance (CER) as measured by the Shigometer indicate a loss of tree vigor. Preliminary analysis indicates that during the five years since thinning, vigor of paper birch has declined in all treatments except the control (unthinned) plots (Table 6). The greatest changes in vigor occurred in treatments 3 (manual felling with winch pre-bunching) and 4 (no pre-harvest trail layout). The vigor of paper birch in the control plots remained constant over the five year period, and maintained a growth rate comparable to trees in other treatments. Changes in CER of red oak over the five year period were of less magnitude than those for paper birch. From 1984 to 1989, a CER increase of only 0.5, 0.3, and 0.6 kohms occurred in the two-chain trial spacing, no

pre-harvest trail layout, and unthinned treatments, respectively. This conforms to the fact that a smaller proportion of trees were wounded, and wounds were less severe at the oak site than at the paper birch site.

Grade changes of all crop trees were measured at both sites during 1989 using a quality classification system for young hardwood trees. Research Assistant J. Steinman, and summer forestry technicians G. Fuller and B. Manyazawale conducted the field work. The tree grading system used was developed by the USDA Forest Service (Sonderman and Brisbin 1978, Sonderman 1979). Logging injuries were classed in the same category as "rot and seams". Three grades were recognized - good, moderate, and poor. Trees were first graded ignoring any logging injuries which may have been present. Trees with logging injuries were then graded a second time, with all logging injuries considered. Significant grade loss occurred as a result of logging injuries to paper and yellow birch (Table 7), where tree grade commonly fell by two categories (from good to poor). Grade losses were also sustained by red oak and beech, but a smaller proportion of trees were affected, and grade was reduced more often by only one category.

Preliminary data were also collected on volume loss in paper birch over the five year period since thinning. Five trees in each of three categories (root wounds only, stem wounds only, and stem and root wounds) were selected for dissection to quantify development of discoloration and decay (Figs. 9 and 10). Tree to tree variability is high in studies of this nature. For this reason, a more comprehensive survey of direct losses is planned.

The 1989 work on both whole-tree harvested

Table 6. Vigor of paper birch before and five years after thinning.⁶

Treatment	Number of Sample Trees	Pre-harvest(1984)		Post-harvest(1989)	
		CER (kohms)	DBH (in)	CER (kohms)	DBH (in)
One-chain	36	15.4	6.27	17.3	6.72
Two-chain	60	15.2	6.90	15.6	7.20
Winch	88	13.9	5.94	16.9	6.71
No Trail	113	16.2	6.33	18.7	6.79
Unthinned	49	16.6	5.86	16.5	6.28

treatments are one-chain trail spacing with mechanical harvest; two-chain trail spacing with mechanical harvest; manual harvest with chainsaw and winch prebunching; no preharvest trail layout; and unthinned control.

Table 7. Summary of grade changes in northern hardwood crop trees from logging injuries.

Treatment ^b	Location	Species	Total	Grade Without Logging Damage			Grade With Logging Damage			
				Good	Moderate	Poor	Good	Moderate	Poor	
2	Grafton									
		Paper Birch	61	57	4	-	No. of Trees	39	7	15
		Yellow Birch	35	22	5	0	8	15	5	15
4	Grafton	Paper Birch	111	107	2	2		56	5	50
		Yellow Birch	33	25	7	1		7	7	19
2	Bridgton	Red Oak	71	54	1	0		49	0	22
		Beech	27	1	5	11		8	3	16
4	Bridgton	Red Oak	51	35	9	7		34	7	10
		Beech	32	17	5	10		13	6	13

^bTreatment 2 = two-chain trail spacing, mechanical harvest Treatment 4 = no pre-designated trails before harvest (operator judgement)



Figure 9. Typical logging injury to roots of paper birch.

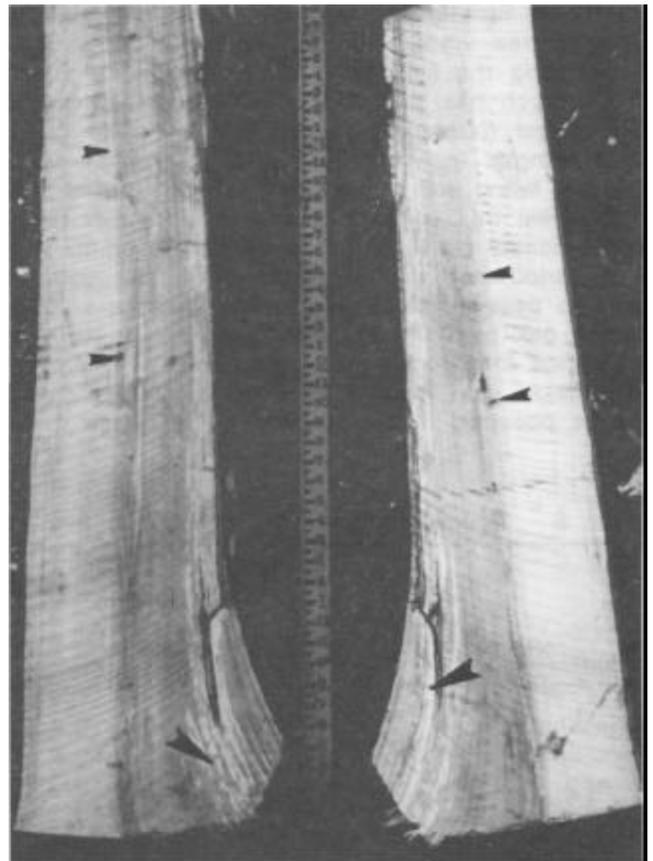


Figure 10. Dissection of tree shown in Fig. 9. Advanced decay (large arrows) and extensive discoloration (small arrows) have developed five years after injury.

Table 8. Total foliar biomass of paper birch as related to Shigometer-determined tree vigor classes, Grafton, Maine.³

DBH Class(in)	CER Class ^b		
	High Vigor (12-14 kohms)	Moderate Vigor (16-18 kohms)	Low Vigor (20-22 kohms)
	Leaf Dry Weight(g)		
4.0 - 5.9	3055a	1947b	1286b
6.0 - 7.9	4244a	2228ab	1757b

^aAverage total leaf dry weight based on 4 replicate trees. Row numbers followed by the same letter are not statistically different (p=0.05)

^bCER = Cambial electrical resistance.

sites was supported in part by a grant from CONEG through the Maine Office of Energy Resources. The grant has not been expended; the remainder will be used in the 1989-90 budget year for project completion.

Relationship of Paper Birch Foliage Biomass to Tree Vigor

The relationship between cambial electrical resistance (CER) and vigor of paper birch was explored by quantifying differences in foliar biomass of trees rated as high vigor, moderate vigor, and low vigor by the Shigometer. Vigor categories were determined on the basis of pre-harvest CER measurements on 1,091 paper birch at the Grafton site. Four trees each of high vigor (CER = 12-14 kohms), moderate vigor (CER = 16-18 kohms), and low vigor (CER = 20-22 kohms) were selected in each of two size classes (4.0-5.9 in dbh and 6.0-

7.9 in dbh). Trees were felled, branch and tree characteristics were measured and labelled, and foliage was removed and processed with the able assistance of J. Steinman, G. Fuller, and B. Manyazawale (Fig. 11).

A consistent relationship was found between CER class and foliage biomass in both diameter classes tested (Table 8). A statistically significant difference in foliage biomass was found between high vigor trees, and moderate and low vigor trees. These findings support the biological basis of measuring tree vigor using this electrical resistance method, and will prove useful in quantifying changes in tree health resulting from forest management practices.

Mechanical Harvesting in Northern Hardwoods

A residual stand damage evaluation was completed of a mechanical harvesting system used to thin stands of northern hardwoods. The project formed the basis of an M.S. program completed by M. T. Hennessey.

A swing-to-bunch feller-buncher with a long-reach (20 ft) boom was used to thin a sugar maple - beech - yellow birch stand on lands owned by Georgia-Pacific Corp. in Orient Township, Maine. Damage to residual trees from the mechanical harvest was compared with that caused by a conventional chainsaw cable skidder operation in the same stand. The proportion of stems wounded was less (20% - 31%) in the area mechanically harvested than in the area conventionally harvested (22% - 44%). Harvesting to a planned residual basal area of 40 ft²/A resulted in the lower proportion of damaged trees, while harvesting to a planned residual basal area of 60 ft²/A resulted in the higher proportion for both harvesting systems. A greater proportion of stems was wounded during the summer (35%) than during the winter (18%) in the mechanical operation. A model was developed which relates harvesting system, planned residual



Figure 11. J. Steinman and B. Manyazawale process a paper birch for foliage biomass measurement.

basal area, species, distance of a stem from a skid trail or access corridor, and initial stand basal area to the probability of injuring an individual stem (Fig. 12).

Red Spruce Vigor Assessment

In 1989, a USDA Forest Service Cooperative Agreement was established between the CFRU timber quality program and the Northeastern Forest Experiment Station Laboratory at Durham, New Hampshire. This research is part of a more comprehensive study to test the hypothesis of an aluminum-induced calcium deficiency syndrome in declining red spruce, coordinated by Dr. W. Shortle, USDA Forest Service (Shortle and Smith 1985). The Cooperative Agreement will focus on the research objective of determining patterns of tissue electrical resistance that indicate loss of cambial activity and living stem tissue in mature spruce trees. Assistance with other phases of the study, including collection and processing of fine root tips for determination of metal ion composition is also required.

Fine root samples have been collected from red spruce at Mt. Mitchell NC, Whiteface Mtn. NY, Mt. Washington NH, Howland, ME, and Isle Au Haut, ME. These samples are currently being

analyzed for metal ion composition. Additional fine root samples were collected from these, and several other sites during early fall of 1989, and will be processed over the next several months.

In addition, stand CER (two 50-tree replications) and IER (internal electrical resistance, two 15-tree replications) of red spruce were measured at eight sites. Two sites each were used from Whiteface Mtn. NY, and Mt. Washington NH, and one site from Mt. Abraham VT, Crawford Notch NH, Isle Au Haut ME, and Howland ME. Highest stand CER was measured at Isle Au Haut ($x = 15$ kohms), where stand decline is considered serious. Lowest stand CER was measured at Crawford Notch ($x = 8.7$ kohms). IER measurements indicated 27% of the trees at Whiteface Mtn., and 23% at Mt. Abraham had some internal decay. The remaining sites had between 10% and 17% with internal decay.

Summer forestry technician B. Manyazawale assisted with the collection of the fine root samples, and with the Shigometer measurements. She will continue working with the USDA Forest Service Cooperative Agreement project over the next year as a Master of Forestry student.

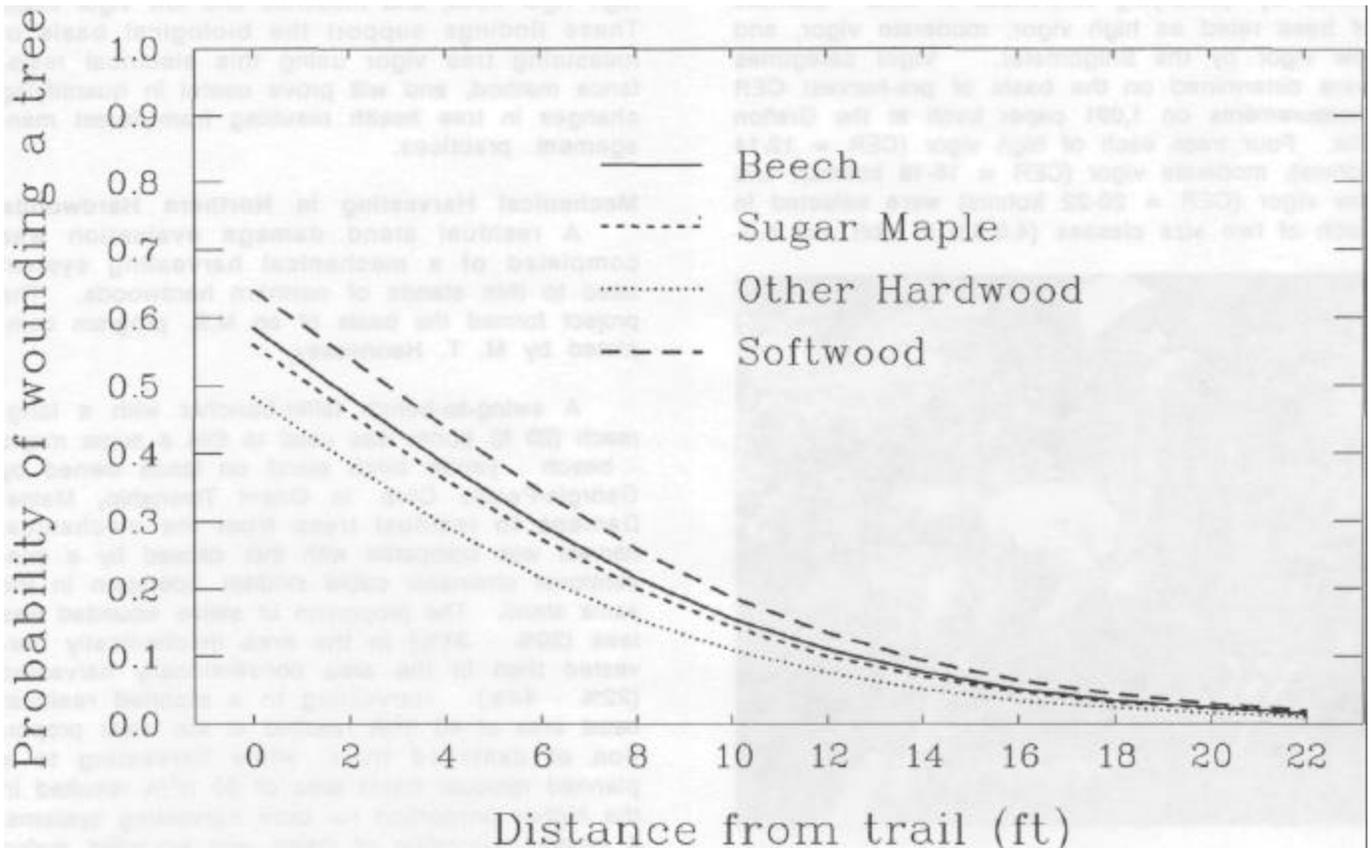


Figure 12. Probability of wounding a stem during a mechanical harvest to 40 ft²/A residual basal area.

Red Spruce Vigor - Recovery Five Years After a Spruce Budworm Epidemic

The objective of this study is to determine the rate of stand recovery and/or decline resulting from different levels of damage to red spruce from spruce budworm defoliation. Final stand CER measurements were taken in 1989 from the twelve study stands (six sites). The data have not yet been analyzed. Measurements of sample tree growth rates, important supporting data for tree vigor evaluations, is continuing.

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TREE IMPROVEMENT

Dr. Michael S. Greenwood and Throstur Eysteinnsson

Larch Breeding Program

A rapid generation breeding and testing program for larch was initiated by Drs. Michael S. Greenwood and Katherine K. Carter in 1987. The objective was to set up a joint University of Maine and industry program to compare the gains (in volume growth, cold tolerance, wood properties) that can be achieved from selection and breeding of tamarack and exotic larches using accelerated breeding and testing techniques. If successful, this program could result in establishment of larch plantations which could be harvestable during the peak of the predicted spruce-fir shortage. Improved species and/or hybrid families could be mass produced by vegetative propagation. Methods developed can also be applied to other important conifer species. Fast-growing plantations near paper mills could relieve pressure to harvest land with higher recreational value.

A 3-stage program was proposed:

I. Stimulate flowering on grafts of select trees, followed by controlled pollination to generate full-sib progeny.

II. Clonally propagate these progeny for the establishment of field and greenhouse tests, to compare performance of the species and hybrids and variability among families.

III. Select superior individuals from among the second generation progeny for continued accelerated breeding to produce a third generation, and to estimate gains. The option to start mass production of improved trees can be implemented any time after the first crosses are made.

With the help of Scott Paper Company and International Paper Company, a total of 18 plus trees, representing selected native tamarack, Japanese larch and European larch, were grafted into a potted breeding orchard. This breeding population is now in the forestry greenhouse at the University of Maine and flower stimulation treatments were carried out in the summer of 1989. The first controlled crosses in this orchard will be made in spring, 1990.

As part of the accelerated larch breeding program, the results of two flower induction experiments, carried out in a prototype indoor tamarack orchard, were tabulated in early 1989. The first controlled crosses made in this orchard, as well as several hybrid crosses attempted outdoors, also yielded results in early 1989 (presented below). A

new pollination study was started and a hedge orchard for vegetative propagation studies was set up during the spring and summer of 1989. Results of these studies, as well as the flower stimulation treatments carried out in the indoor breeding orchard, will be forthcoming in 1990.

Flower Induction

The larger of the 1988 flower induction experiments was carried out in an indoor, potted tamarack orchard composed of 12 grafted scions of mature trees and 12 seedling progeny of the same trees grafted onto rootstock at age 1. The grafts' growth was accelerated by greenhouse conditions. When the experiment started, the trees were 3 years old (from grafting) and 2.5 - 3 m tall.

Each of the 24 grafts was randomly assigned to one of three groups. In the first group, 3 entire first-order lateral branches per treatment per tree were randomly chosen to receive 5, 7 or 9 biweekly applications of the plant growth regulator gibberellin ($GA_{4/7}$). These treatments commenced May 11, at the start of long-shoot elongation. In the second group, 3 branches per tree received 5 biweekly $GA_{4/7}$ applications starting May 11, and another 3 branches per tree starting June 6. The third group received no $GA_{4/7}$ treatments. The $GA_{4/7}$ was applied as an aqueous foliar spray in 5% ethanol. Control branches, 3 per tree in each group, were sprayed with ethanol solution minus the $GA_{4/7}$. Half the trees were root pruned in early June. Root pruning is known to enhance the promotive effect of $GA_{4/7}$ on flowering in some conifer species.

Two of the $GA_{4/7}$ treatments were replicated on field grown grafts that were somewhat smaller but of the same origin as the indoor population. Two randomly chosen branches on each graft received 5 biweekly $GA_{4/7}$ foliar spray applications starting June 6 (at the start of shoot elongation) and 2 additional branches per tree starting June 20. Buds were counted in 1989 when seed cone-, pollen cone- and vegetative buds could easily be distinguished; February, for the indoor orchard and late April outdoors.

Female flowering was significantly increased (over control) by all $GA_{4/7}$ treatments commencing at the start of shoot elongation in both the indoor and outdoor populations. Results of the 3 treatment durations did not differ significantly however. $GA_{4/7}$ applications commencing later (4 weeks later in the greenhouse, 2 weeks later outdoors) were ineffective in promoting flowering.

In the greenhouse, female flowering was almost tripled by root pruning (RP), increased 16-fold by GA (mean of the 3 treatment durations starting at shoot elongation) and 26-fold by RP + GA over control. The increases due to GA and RP + GA were both statistically significant, but not the response to RP alone. Both juvenile and mature grafts responded significantly to the GA treatments with similar increases in female flowering (Fig. 13). The mature grafts responded to the combined RP + GA treatment with a much greater increase than the juvenile grafts however. Thus, RP enhanced the promotive effect of GA on female flowering, but only in mature grafts.

In the field population, the early GA treatment resulted in a 7-fold increase in female flowering over control. Here, the age class difference was not significant.

Male flowering was not significantly increased by GA treatments or root pruning.

These experiments showed, for the first time, that GA_{4/7} can promote flowering in tamarack, also that early application of GA is important, the effect is enhanced by root pruning and female flowering

is preferentially promoted. This outcome is consistent with results of studies on other conifer species involving flower stimulation by GA_{4/7}. Also indicated here is a maturation related difference in the ability to respond to GA_{4/7} and root pruning.

Seed Production

The production of sufficient seed quantities is very important in a tree breeding program. Seed-set is notoriously low in Japanese and European larch seed orchards, usually less than 30%, and tamarack apparently has the same problem. This problem is being studied in the hope that seed viability can be improved.

Several controlled crosses were made in the greenhouse and outdoors in spring, 1988. These included both intra-species and hybrid crosses between tamarack, Japanese larch and the European x Japanese or "Dunkeld" hybrid. Open pollinated seed was also collected from several trees on the Univ. of Maine Orono campus, the IP seed orchard near Howland, ME, a Japanese larch plantation near Dover-Foxcroft, ME and a wild tamarack population in Alton Bog north of Old Town, ME.

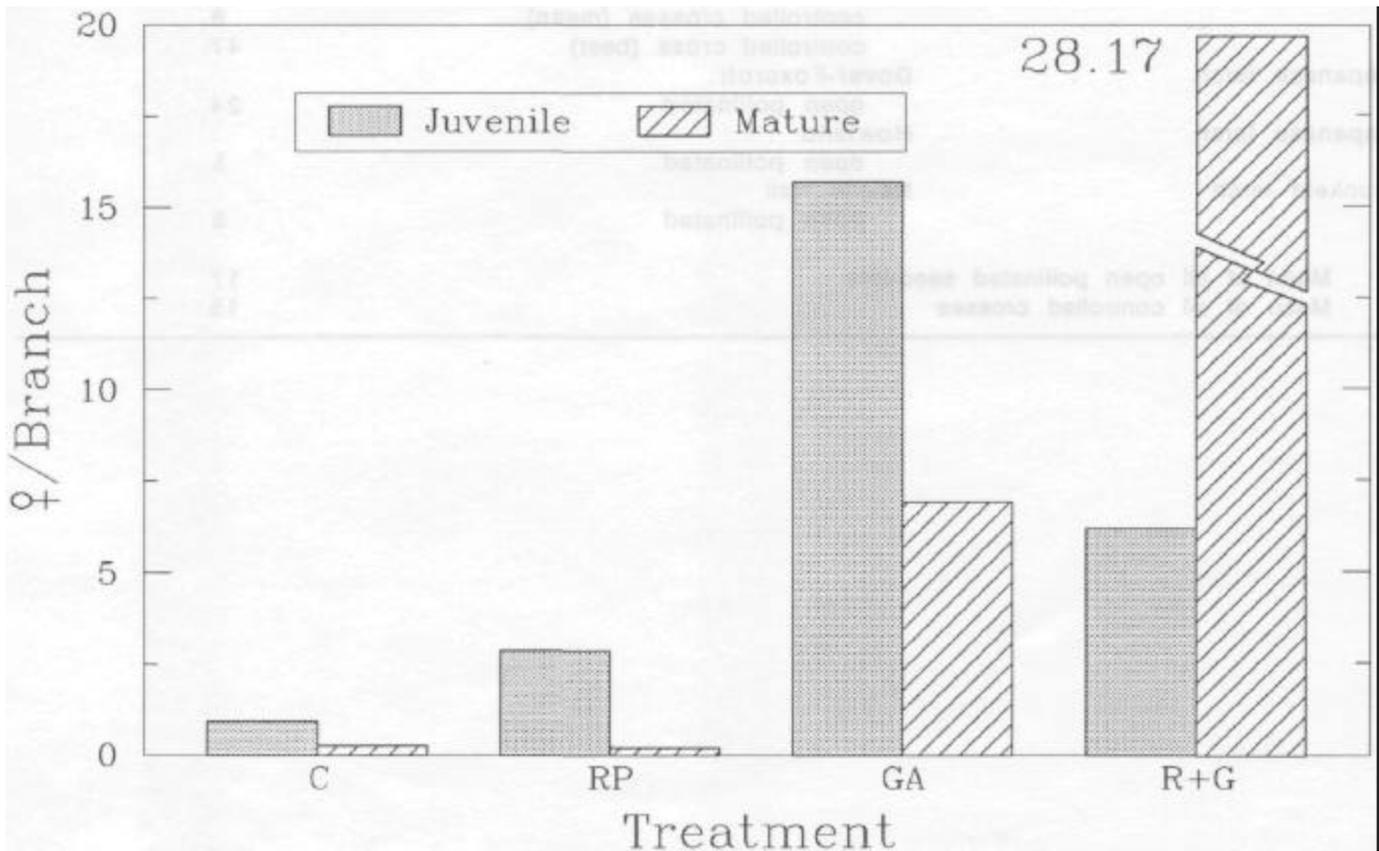


Figure 13. Response of juvenile and mature tamarack grafts to root pruning (RP), gibberellin (GA) and the two treatments combined (R+G), C = control.

A portion (usually half) of each seed-lot was stratified for roughly 1 month and then placed in petri dishes in an environmental chamber for germination. The results of the germ tests are summarized in Table 9. After over a month in the environmental chamber, several hundred seeds that had not germinated were dissected. They were empty without exception, indicating that all the viable seeds had germinated.

Results indicate that seed viability from controlled crosses in the greenhouse can be as good or better than that of open pollinated seed. The low

mean seed viability from indoor crosses indicates that pollen handling and pollination techniques need to be refined. To this end, a more involved pollination experiment was carried out in the spring of 1989.

The implications of the results presented here for an accelerated larch breeding program based on indoor orchards are generally positive, i.e. that flowering can be stimulated in young potted grafts and that viable seed can be expected from controlled crosses.

Table 9. Germination of several 1988 larch seed-lots by location and mode of pollination.

<u>Species</u>	<u>Location/Type</u>	<u>Percent Germination</u>
Tamarack	Alton Bog open pollinated Nutting Hall	35
Tamarack	open pollinated	46
Tamarack	controlled cross x Dunkeld	18
	controlled cross x Japanese larch Howland	46
	open pollinated	4
	controlled crosses (mean) Greenhouse	4
Tamarack	controlled crosses (mean)	11
	controlled cross (best) Dover-Foxcroft	1
	open pollinated Howland	1
Tamarack	open pollinated Neville Hall	8
	open pollinated	8
Japanese larch	Mean of all open pollinated	47
	seed-lots Mean of all	24
Japanese larch	controlled crosses	24
Dunkeld larch		5
		8
		1
		7
		15

TREE IMPROVEMENT

Dr. Katherine Carter

Research Summary 1976-1988

When the Cooperative Forestry Research Unit was initiated in 1976, it incorporated the tree improvement research cooperative which had been started under the leadership of Dr. David Canavera in 1974-75. This early tree improvement cooperative included 14 industrial landowners and had a budget of \$17,500. From the beginning, this tree improvement research project worked with a variety of softwood and hardwood species. From 1974 through 1979, the objectives of the program were to conduct research on methods to increase the productivity of Maine forest lands through the application of genetic and cultural improvement techniques, to provide a mechanism for the transfer of genetic research results into practical use, and to encourage cooperation among the various participating organizations (Canavera 1975). These general objectives are still the guiding principles of the tree improvement program in CFRU.

During 1974-79, research focused on the identification of optimum greenhouse growing techniques and containers, plantation trials of exotic species, and provenance tests of North American species. Forty-eight test plantations of 14 different species were established during this period. Since 1980, research has emphasized tree improvement of black spruce, white spruce, and larch species, while continuing to maintain the earlier plantations and derive useful results from them. A few of the major results from the last 14 years are presented in the following paragraphs.

Hardwoods were a major interest of the early tree improvement cooperators. Species trials and provenance tests of paper birch, exotic white birches, European black alder, green ash, and black walnut were established. For each species, the most useful provenances for use in Maine plantations have been identified. Results of early growth in each of these species have been published in the papers listed at the end of this section.

Black spruce and white spruce are major plantation species in the state and have been the subject of much research over the past 15 years. Early rangewide provenance tests identified superior seed sources for black spruce in the Great Lakes region (Bihun and Carter 1983), and for white spruce in the Ottawa River Valley (Tebbetts 1981). Plus-tree selection methods were evaluated in black spruce and in white spruce, and heritability estimates were calculated (Carter 1987). The tree improvement research staff has worked in coop-

eration with CFRU landowners to establish seed production areas and seed orchards for these species.

Native and exotic larches have also been a major focus of CFRU tree improvement activities. Species and provenance trials of exotic larch species were established early in the project. After 12 years in the field, our earliest plantation of Japanese, European, and hybrid larch provenances have DBH ranging from 4.7 to 7.8 inches. Larch research projects have also resulted in recommendations for propagation using rooted cuttings (Carter 1984) and a general summary of recommendations for larch plantations has been published (Carter and Selin 1987).

In addition to the species mentioned above, research has been conducted on several other species including balsam fir, jack pine, Douglas-fir, Norway spruce, and western white pine. As a result of tree improvement research over the past 15 years, landowners are able to identify the most desirable seed sources for plantation establishment. For several major species, they can predict expected gains from tree improvement activity. As the concern over forest productivity increases in the future, application of genetic information such as this will become even more important to enable our forests to produce wood as efficiently as possible.

Research Effort - 1989**Japanese Larch Root Regeneration**

Initial root establishment after planting is important to seedling survival and growth. In order to determine whether "fresh" (non-dormant) and dormant, overwintered seedlings differ in root growth capacity, we compared growth of 13 families of container-grown Japanese larch seedlings. "Overwintered" seedlings of all families were grown in a greenhouse from January to May, and were then placed in an outdoor shadehouse where they were maintained for the next 12 months. "Fresh" seedlings of the same seedlots were grown in the greenhouse from January to May of the following year. Both types of seedling stock were then removed from their containers and planted in an outdoor nursery bed on May 13th. At the time of transplanting, both types of seedlings had coherent root plugs. The overwintered seedlings were just beginning to break bud; this is typical of the condition of overwintered larch planting stock under operational conditions. Seedling height averaged 30.2 cm (12 inches) for the overwintered stock and 12.8 cm (5 inches) for the fresh

Height and number of new roots, for fresh and overwintered stock of 13 Japanese larch families.

<u>Treatment</u>	<u>Height (cm)</u>		<u>Number of Roots</u>	
	<u>Average</u>	<u>Range of Means</u>	<u>Average</u>	<u>Range of Means</u>
Overwintered	30.2	23 - 35	32.0	8 - 45
Fresh	12.8	9 - 15	96.2	61 - 145

stock.

After four weeks in the transplant beds, seedlings were carefully excavated and the number of new roots which had formed on each seedling were counted. Although fresh seedlings were only half as tall as overwintered seedlings, on the average they produced three times as many roots (Table 10). Roots of the fresh seedlings were extending from all portions of the root plug, whereas roots of the overwintered seedlings tended to extend from the lower portion of the root plug. Although on average the seedlings in both classes probably had sufficient root growth to become well established, some individual overwintered seedlings had very low numbers of new roots. Within each treatment class, there were significant differences among the

families in height, but not in number of roots. There was no correlation between seedling height and number of new roots. Survival was 100% for both stock types.

Exotic Larch Provenance Tests

A provenance test of Japanese, European, Siberian, and Japanese-European hybrid larches established in Orneville, Maine, in 1977 were measured for DBH after 12 seasons of growth (Table 11). Height of these trees was not measured at this time, but most heights were estimated to be greater than 30 feet. Differences in DBH among the provenances are significant, with Japanese-European hybrids being the largest and pure Japanese larch generally smallest in DBH. DBH is correlated ($r=0.73$) with 6th-year height measurements.

Table 11. Average DBH (age 12) and height (age 6) for exotic larch provenances in the Orneville test.

<u>Species</u>	Provenance	Ht.(ft) aqe 6	DBH(in) age 12
*			
E	400	17.5	6.0
E	407	17.4	5.5
E	408	20.4	6.6
E	409	19.6	6.2
E	410	19.7	6.6
E	41 1	17.8	5.7
E	635	17.9	6.0
E	636	17.1	5.8
E	637	18.0	6.4
E	641	20.6	6.0
E	647	17.6	6.3
H	638	19.5	7.8
H	640	19.9	7.2
H	643	19.8	7.5
H	645	22.4	7.3
H	646	20.0	6.6
S	634	18.5	6.1
J	401	17.5	6.3
J	402	15.3	5.7
J	403	16.9	6.1
J	404	15.8	5.0
J	405	15.1	5.5
J	406	16.1	6.0
J	413	16.6	6.0
J	414	15.0	4.7
J	415	16.5	6.5
J	416	15.2	5.5
J	417	15.6	5.9
J	418	15.9	5.4
J	419	17.0	6.4
J	420	16.7	6.0
J	421	16.7	6.8
J	422	15.0	5.6
J	423	18.3	6.8
J	639	15.5	5.8
J	642	16.2	6.2
J	644	16.2	5.5

E = European larch

J = Japanese larch

S = Siberian larch

H = Japanese x European hybrid larch

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GROWTH AND YIELD PROGRAM

Dr. Robert S. Seymour

Timber Management and Harvesting Research - 1981-1987

When Dr. Field left CFRU, program emphasis changed from forest economics and utilization to applied studies in timber management and harvesting. The first study undertaken in 1982 compared experimental cable yarding (Smith Timbermaster skyline yarder) and winch prebunching (Radio Horse 9) to conventional skidder-based logging systems for commercial thinning in small-diameter spruce-fir stands (Seymour and Gadzik 1985a). Cable yarding proved to be unsuitable for thinning due to high operating costs and excessive losses of residual trees for access corridors. Winch prebunching followed by skidder yarding compared favorably to a conventional skidder operation (without prebunching), but was labor intensive. Although commercial thinning using any logging system has not become a widespread operational practice, the concept of prebunching to controlled access trails serves as a model for future studies of mechanized Scandinavian thinning systems, in which several cooperators show a growing interest.

In 1983, a large-scale study of precommercial thinning technology compared motormanual (brush saw) production in stands of varying densities and ages with and without prior treatment by a large mechanical swath cutter (Seymour *et al.* 1984). Brush-saw production was strongly related to stand density (stems per acre), but was unaffected by prior mechanical treatment. A nomogram was developed and published (Seymour and Gadzik 1985b) that predicts motormanual precommercial thinning costs for varying stand density, prior mechanical treatment, and labor costs. The combined mechanical-motormanual treatment was more economical only in very dense stands (over 20,000 stems per acre), and has since been halted by two cooperators where it had formerly been widely used.

Other important accomplishments include cooperation with Dr. Ostrofsky on a large-scale evaluation of whole-tree chipping systems (using drive-to-tree feller-bunchers) for commercial thinning pole-sized northern hardwood stands. Major review articles were published on the growth and yield of spruce-fir stands (Seymour 1985), silvicultural practice in the Northeast (Seymour *et al.* 1986), and the interaction of whole-tree harvesting systems with stand development (Seymour 1986). The Green Woods model was adapted for use in the

spruce-fir supply-demand study (Sewall Co. 1983) and a users manual published through the USDA Forest Service (Seymour *et al.* 1985).

Growth, Yield and Wood Supply Modelling and Analysis - 1987-1988

In 1987, I left the full-time CFRU staff to join the teaching faculty, and revised my research program in response to the 1986 priorities review. This period included accomplishments in four general areas:

1. With funding from the Maine Dept. Conservation Forests for the Future Program, the FORMAINE wood supply simulation model was created and used to forecast future wood supplies for all commercial species in Maine.
2. A simple PC-based computer model known by the acronym SISTIM (Simulating Silvicultural Treatments In Maine) was developed to predict yields and future wood costs for any natural or intensively managed spruce-fir stand.
3. A new formulation for the widely used stocking guides was developed and applied to eastern white pine (Seymour and Smith 1987).
4. A regional workshop on growth and yield was organized (Seymour and Leak 1987) and a regional committee formed (NEC-71) to establish a formal regional growth-and-yield data and modelling cooperative.

Two Ph.D. students also began studies of stand development during this period: Xiandong Meng completed field work in a comparison of growth and biomass yields between well drained and poorly drained soils in young (age 10-12) stands with a history of herbicide release treatment. Mary Ann Fajvan completed a two-year assessment of several hundred permanent growth plots to compare site index and empirical yields of spruce-fir among three soil-based site classes.

Research Effort - 1989

Wood Supply Modelling

In response to many requests from users, the FORMAINE model used in the 1987-88 analysis of Maine's wood supplies was extensively reprogrammed. Changes include: a more user-friendly interactive input routine; the ability to produce formatted output files that permit linkages with spread-

sheet or other data analysis packages; and most importantly, the ability to simulate realistically management strategies that include partial cutting. A 50-page users manual describing the modal and these changes was drafted and is currently in review.

Growth and Yield Cooperative - NEC-71

Approval for establishing a regional cooperative was secured at the regional level, but the project was deferred at the national level pending minor revision of the proposal. Approval is expected during 1990.

Stand Development

Forest stands of red spruce and eastern hemlock frequently have a white pine component. Since hemlock and spruce are very shade tolerant, they can occur beneath or within the main forest canopy in mixture with white pine. If the presence of white pine is not detrimental to growth of these species, then these multi-storied stands may have greater volume production than stands containing only spruce and hemlock.

The purpose of this study is to examine the age structure and forest stand development patterns of mature white pine-hemlock-red spruce stands to determine:

1. If the mean age of the white pine is significantly different from the mean age of hemlock and the mean age of spruce.
2. If there is a difference in volume production when white pine is present in mixture with spruce and hemlock.

During the summer of 1989, five stands were selected on Champion International Corporation's land in Townships 36 and 42. A total of 389 1/20 acre plots was established. Since white pine was the least abundant of the three species in each stand, the diameter and crown class of all white pine was measured. An average of 34 pines per acre was noted (range 27-43 per acre).

A subsample of 50 plots (10 per stand) was randomly selected for more intensive measurements. Half the plots in each stand were selected from those plots that were originally identified as containing at least one dominant or codominant pine. The other five plots contained at least one dominant or codominant red spruce and/or hemlock. The diameter and crown class of all trees on each of the 50 plots was recorded. Breast-height age cores and tree heights were taken from a subsample of representative diameter/crown classes by species.

Preliminary examination of the overall mean difference between the basal area of plots containing pine versus those that did not show slightly higher basal areas in the pine plots (168 ft²/A versus 148 ft²/A). Analysis of variance of pine versus non-pine plots for the five stands showed no significant difference in mean basal area ($\alpha=.05$).

Initial examination of the age structure of each stand shows the presence of two or three age classes. The influences of partial harvests during the late 1800's and early 1900's, in addition to spruce budworm effects, probably have been major contributors.

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FERTILIZATION PROJECT

Dr. Robert K. Shepard, Jr.

History and Accomplishments

The Forest Fertilization Project was initiated with the primary objective of determining the response of red spruce to fertilization, with the emphasis on nitrogen. The project was expanded to include white pine, because of its high value and accumulated evidence that suggested a nitrogen deficiency in many white pine stands. Since 1987, the major emphasis has been on the effects of applying sludge and ash to forest lands.

Early work showed that growth of most spruce-fir stands is limited by insufficient nitrogen, with insufficient phosphorus also limiting growth on some sites, but to a lesser degree than nitrogen. Subsequent emphasis was placed on ascertaining the effect of soil drainage class on response to nitrogen, response to different application rates, and the effect of thinning, with and without fertilization, on growth. Results of this work indicated no difference in response among drainage classes, even though foliar analyses showed nitrogen concentrations to be lower in foliage of trees on poorly drained soils than on better drained soils. Five-year growth increased as nitrogen application rate increased from 100 pounds per acre to 300 pounds per acre. Five-year growth due to thinning alone was equal to growth due to fertilization alone. Fertilization plus thinning produced better growth than thinning alone.

Results of the white pine fertilization work indicate that four-year volume growth in many stands may be increased by 1,000 bd ft per acre or more. For high value stands with some pruned crop trees, this means a four-year value increase of more than \$100 per acre. This has implications for benefits that may accrue to the landowner from applying a high nitrogen secondary municipal or papermill sludge.

The sludge-ash research has not been in progress long enough to draw definitive conclusions, but early results do suggest that soil pH will be altered little or not at all by applying ash at the maximum rate presently allowed, and conifer seedlings planted on sites previously occupied by hardwoods may exhibit a negligible early growth response to sludge and ash application.

Research Effort - 1989

This report is divided into two parts, one describing the sludge and ash research and the other describing the nitrogen fertilization research, with emphasis on the former. The sludge

and ash research is presented for each study individually.

Sludge and Ash Research

Study 1

The major objectives of this study are to determine the effects of a combination of woodash and papermill secondary sludge applied at different rates, different times within the spreading season and for different numbers of years in succession on black spruce seedling growth and soil properties. The first treatments were applied in 1988. In 1989, treatments were applied to those plots scheduled to be treated either in two or three successive years. Second-year seedling root collar diameters and heights were measured in all plots. Chemical analyses of samples of the upper four inches of the B horizon were completed for all plots. Analyses of 1988 sludge-ash samples were completed. Samples for 1989 are presently being analyzed. Analyses of foliage and forest floor samples are in progress. The data presently available are in various stages of summarization and analysis and consequently, only general trends are presented here.

Sludge-Ash Characterization

Some of the more important parameters of the sludge-ash combinations for each of the three treatment times are presented in Table 12. Differences among the combinations for individual parameters are apparent from one time to another. Important characteristics overall are the relatively high pH and calcium carbonate equivalents, the high concentration of base cations, especially calcium, and the relatively low concentration of nitrogen. Ash constituted approximately 75 percent of the total dry weight of each treatment.

Root Collar Growth

Root collar growth appears to have been affected little or not at all by treatment (Table 13), with the possible exception of the 4.8 dry tons per acre treatment applied in late May, 1988. All data must be subjected to an analysis of covariance using pretreatment root collar diameter as the covariate. Such an analysis may reveal significant differences among some treatments.

Foliar Nutrient Concentrations

Concentrations of nitrogen, phosphorus, potassium, calcium and magnesium in 1988 foliage were all quite high and not noticeably affected by treatment (Table 14). The high nitrogen concentration, approximately 1.9 percent for all treatments, is especially notable, because nitrogen is the ele-

Table 12. Important parameters of the sludge-ash mixtures.

Parameter	Application Time			
	Early October	Late May	Late July	
PH		8.96	8.88	11.00
CaCO ₃ -Eq (%)		26.5	20.6	31.4
Ca (mg/kg)		122000	85000	123000
Fe (mg/kg)		7300	10400	9300
K (mg/kg)		27000	19000	29000
Mg (mg/kg)		11000	8400	11000
Na (mg/kg)		2200	4200	2200
P (mg/kg)		6100	4100	6500
Pb (mg/kg)		67	36	28
Cd (mg/kg)		5.4	5.0	5.1
N (%)		0.79	0.65	0.62

Table 13. Root collar diameters of black spruce seedlings treated at one of three different times for one year only or for two successive years.

Treatment Time	Measurement Time	Sludge-Ash Application Rate (dry tons per acre)							
		n		2 4		4 8		9 6	
		1 ^a	2	1	2	1	2	1	2
May	Pretreatment	0.25	0.27	0.25	0.26	0.26	0.26	0.25	0.26
	First Growing Season	0.59	0.63	0.59	0.61	0.72	0.63	0.59	0.63
	Second Growing Season	0.82	0.91	0.81	0.85	0.98	0.84	0.80	0.83
July	Pretreatment	0.28	0.27	0.25	0.26	0.26	0.26	0.27	0.26
	First Growing Season	0.66	0.64	0.59	0.64	0.65	0.58	0.66	0.60
	Second Growing Season	0.91	0.89	0.82	0.85	0.88	0.79	0.86	0.80
October	Pretreatment	0.26	0.29	0.28	0.28	0.27	0.26	0.23	0.28
	First Growing Season	0.64	0.63	0.67	0.64	0.63	0.61	0.59	0.68
	Second Growing Season	0.91	0.91	0.92	0.87	0.87	0.83	0.76	0.89

^a 1 = treated one year only
 2 = treated two years

Table 14. Nutrient concentrations in 1988 foliage of black spruce seedlings treated with a sludge-ash mixture in late May, 1988.

Sludge-Ash Application Rate (dry tons/ac)	Nutrient				
	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
0 0	1 .92	0.18	0.36	0.48	0.06
2 4	1 .90	0.18	0.36	0.50	0.06
4 8	1 .92	0.18	0.36	0.43	0.06
9 6	1 .92	0.18	0.36	0.42	0.06

Table 15. pH and base cations in the upper four inches of the B horizon.

Sludge-Ash Application Rate(dry tons per acre)	Parameter				
	PH	Ca		Mg	Na
				meq/100g	
0	4.91	0.365	0.120	0.091	0.027
2.4	4.92	0.354	0.156	0.104	0.030
4.8	4.96	0.386	0.197	0.106	0.031
9.6	4.92	0.436	0.305	0.135	0.040

ment that most commonly limits the growth of spruce and fir. Nitrogen concentrations in foliage of trees in natural spruce stands approaching maturity would likely range from about 0.9 to 1.1 percent on most sites. The high foliar nutrient concentrations are not totally unexpected given that the site was formerly occupied by a hardwood stand. Had the previous stand been spruce-fir, nitrogen concentrations may have been substantially lower.

Based on pot studies with red spruce and white spruce seedlings, only magnesium was present in concentrations less than optimum for good to very good growth. However, there is question as to the extent to which results from pot studies conducted in a greenhouse are transferable to field conditions. Also, black spruce may be less nutrient demanding than red and white spruce.

Soil Properties

Concentrations of base cations tended to increase with increasing application rate (Table 15). Although these data have not yet been analyzed statistically, many of what appear to be differences among treatments are probably real, because each of the values in Table 14 is the mean of 27 plots. Potassium displayed the most pronounced increase in concentration with increasing application rate, with the amount at 9.4 dry tons per acre being approximately 2.5 times that of the control plots.

Interestingly, soil pH has not been affected by the treatments. The absence of a pH change is important, because current DEP guidelines for ash application incorporate both soil pH and calcium carbonate equivalents of the ash. The maximum allowable calcium carbonate equivalent is three tons per acre with the pH of the soil not to exceed 7 following application. The calcium carbonate equivalent of the 9.4 tons per acre treatment ranged from about 2.5 to 3 tons per acre. Thus, it seems that a considerably higher calcium carbonate equivalent could be applied with little effect on PH.

Lead and cadmium were included only in the analyses of plots (nine) to be treated at the maximum rate for three successive years and for the corresponding control plots (nine). Values for the treated plots were 12.6 mg per kg and 0.20 mg per kg for lead and cadmium, respectively. Values for the control plots were 10.6 mg per kg and 0.17 mg per kg for lead and cadmium, respectively. Differences were not statistically significant.

Study 2

The main purpose of this study is to assess the effect of different rates of woodash on properties of the forest floor and mineral soil under different levels of site disturbance. Thirty-six plots were established in three disturbance conditions created by a 1988 strip harvest in a predominantly northern hardwood stand. The disturbance conditions are skid trails in the cut strips from which the forest floor had been removed but with no rutting, undisturbed forest floor in cut strips, and no disturbance (uncut strips). Three adjacent strip pairs (one cut strip, one uncut strip) were selected, and four plots were established in each of the three disturbance conditions represented in each strip pair. Woodash was applied by hand in late July, 1989, to each group of four plots at rates of 0, 3, 6, and 9 tons of calcium carbonate equivalent per acre. Samples of the forest floor (where present) and of the upper four inches of the B horizon were taken in all plots in October. These samples are presently being analyzed.

Within two to three weeks after treatment, differences in color and density of herbaceous vegetation between treated plots and control plots in the skid trails were evident. Vegetation in treated plots was greener and denser than vegetation in control plots. Also, there were numerous spruce and fir seedlings in the trails, presumably due to the favorable seedbed provided by the exposed mineral soil. In 1990, plots in the skid trails will be sampled to determine possible effects of different ash application rates on herbaceous

vegetation and tree seedlings.

Study 3

The purpose of this study is to assess the effect of different rates of ash application on the growth of planted red pine and properties of the forest floor, and to determine the effect of operational ash spreading on streamwater quality.

Fifteen plots were established in a young red pine plantation. Woodash treatment rates of 0, 3, 6, 12, and 24 tons of calcium carbonate equivalent per acre were chosen. A Blondin forwarder with a mounted spreader was used to treat the plots. The original intent was to treat 12 plots, thus providing three replications of each treatment. However, it was not possible to treat the plots until early November, 1989, by which time trafficability was severely reduced due to the combination of heavy rain and fine textured soils. As a result, it was only possible to treat eight plots, providing two replications per treatment.

Samples of the forest floor and upper 4 inches of the mineral soil will be taken from all plots in 1990, and dbh and height measurements will be made on all trees. Foliage samples will also be collected from the red pine and analyzed for nutrient concentrations. Drainage patterns in two nearby clearcuts approved for spreading were mapped in preparation for a study to ascertain possible effects of ash, applied operationally, on streamwater quality. This study will begin in 1990 and will also include soil sampling.

Study 4

The purpose of this work is to determine the effect of papermill sludge application on growth of planted red pine and on soil properties and streamwater chemistry. Plots for the tree growth portion of the study were established in two clearcuts designated for sludge spreading. Five plots in one clearcut were treated in mid-June, 1989, with approximately 20 dry tons of sludge per acre with five plots to serve as controls. Five plots in the other clearcut were treated with approximately 50 dry tons per acre in mid-October. Foliage samples were collected in October from trees in plots treated in mid-June and from control plots. Forest floor and mineral soil samples were taken from those plots in late September. Pre- and post-growing season diameters at one foot above ground were measured on all trees in the same plots.

Eight plots were established in the third clearcut and two in the nearby uncut forest. Tension lysimeters were placed in all plots. Soil samples, lysimeter water samples, and water samples from streams flowing along both sides of

the area of the clearcut to be treated were collected periodically throughout the summer. Four plots in the clearcut were treated in early September, with four serving as controls. The two plots in the undisturbed forest were not treated. Trees will be selected in treated and non-treated portions of the clearcut and measured to determine a possible growth response.

The diameter measurements made in the plots treated in mid-June indicated no effect of sludge application on 1989 growth. The mean increase in diameter growth of trees in treated plots was 0.44 inch, whereas for trees in control plots the mean increase was 0.41 inch. Because of the late application time in the clearcut containing the intensively monitored plots, results of analyses of samples collected following treatment are not yet available.

Analyses of streamwater samples collected prior to spreading indicated that the effects of clearcutting on streamwater chemistry were still evident six years after cutting, with ion concentrations increasing with distance along the stream from the point of entry into the clearcut. The most notable increases were in $\text{NO}_3 - \text{N}$ and base cations that were still leaching from the clearcut.

Although not one of the original objectives, sampling of a large stockpile of sludge was conducted in January. Analyses of the samples revealed considerable variability in both total and extractable elements within the pile, a result of both mill process changes and on-site weathering of the pile. This means that the combination of stockpile variability and variability in actual loading rates applied by spreading equipment makes the quantification of actual application rate on a site very difficult.

Nitrogen Fertilization Research

Eastern White Pine

Fourth-year measurements were made in plots in 16 stands. This completes the fourth-year measurements in the 28 stands in which plots were treated with nitrogen at rates of 0, 75, 125, and 175 pounds per acre. The data have not yet been subjected to statistical analysis, but a summarization suggests some trends:

1. Response appears to be greater on the till soils than on outwash soils (Fig. 14), and
2. The difference between the two soil groups is perhaps most important for sawlog stands, with those on till soils apparently responding more to lower rates than those on outwash soils (Fig. 15).

Red Spruce

A summary of five-year data indicates two important points. First, growth of dominant and codominant trees increased with successive increases in nitrogen application rate from 0 to 300 pounds per acre (Fig. 16). Basal area growth was 47 percent greater at 300 pounds per acre than at

0 pounds per acre. Second, increases in basal area per acre were substantially greater for both thinning-no fertilization and thinning-fertilization (200 pounds of nitrogen per acre) than for no thinning-no fertilization and thinning-no fertilization (Fig. 17). The data are presently being statistically analyzed.

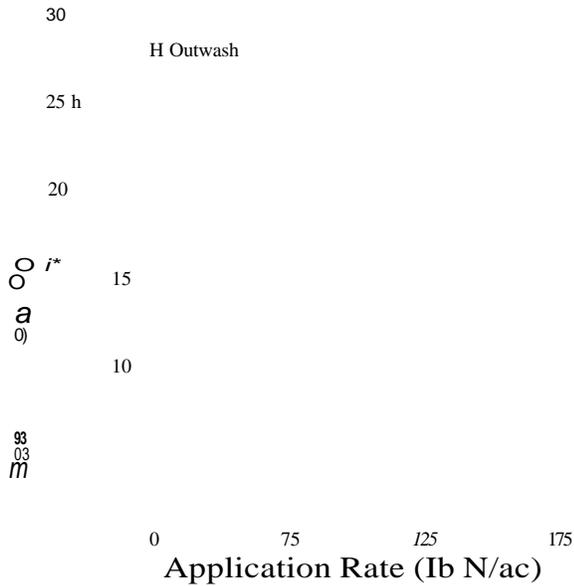


Figure 14. Four-year basal area growth of white pine stands on till and outwash soils fertilized with different rates of nitrogen.

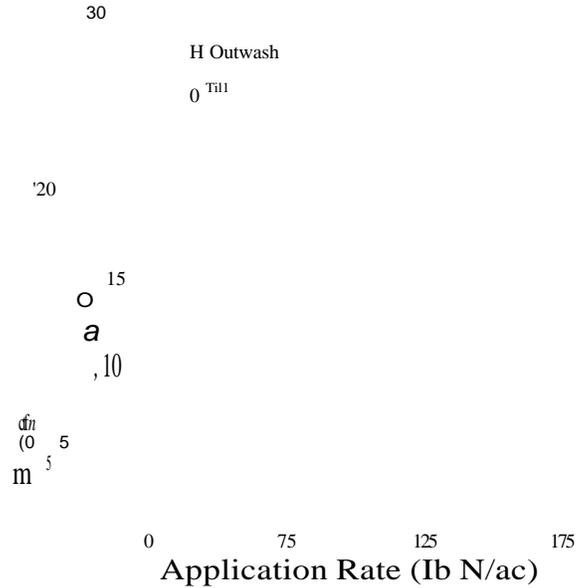


Figure 15. Four-year basal area growth of white pine sawtimber stands on till and outwash soils fertilized with different rates of nitrogen.

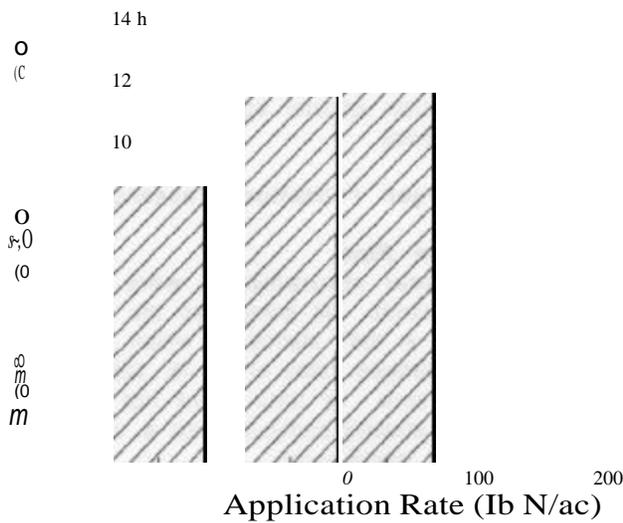


Figure 16. Five-year basal area growth for dominant and codominant red spruce fertilized with different rates of nitrogen - poorly and somewhat poorly drained soils combined.

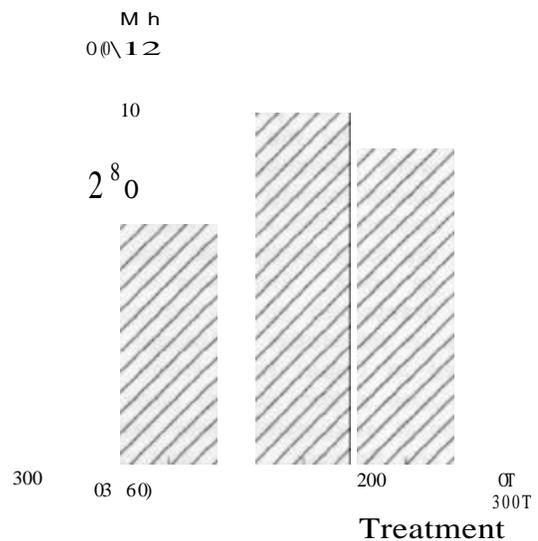


Figure 17. Five-year basal area growth for dominant and codominant red spruce subjected to thinning and fertilization treatments -- poorly and somewhat poorly drained soils combined. (0 = 0 lb of N per acre, 200 = 200 lb of N per acre, T = thinned)

THE EFFECT OF PROGRESSIVE STRIP CLEARCUTTING ON THE SUCCESSFUL ESTABLISHMENT OF SPRUCE AND BALSAM FIR REGENERATION

Dr. Alan S. White

Introduction

The purpose of this project is to determine the effects of narrow (30 ft and 60 ft) strip clearcuts on conifer and hardwood regeneration as well as on windthrow in residual strips. This fall marked the fourth year of data collection on permanent plots in cut and residual strips at two different locations. Although some trends seem to be emerging, the data are variable both among plots and among years. The first three years of data have been subjected to preliminary analyses whereas data from the fall of 1989 are still being summarized.

Preliminary Results

On both sites, spruce, fir, and their combination tended to vary significantly among plot locations. Hemlock showed the same pattern on one site, but was not abundant enough to be analyzed on the other. These three species all tended to have their greatest densities in the uncut strips although the exact pair(s) of plot locations showing the significant differences varied. White pine, the only other major conifer on these sites, occasionally showed significant differences, but the patterns were not as strong as for spruce, fir, and hemlock.

In contrast to the conifers, paper birch tended to be much higher in the cut strips. Red maple on Site 1 had higher densities of small stems (< 3.5 in) in the uncut strips, but the reverse for larger stems. Such a result could be the product of sprouts or better growing conditions in the cut strips. High variability made it impossible to find any significant results for red maple on Site 2.

Trends in stocking of spruce, fir, their combination, and hemlock followed those of densities, i.e., stocking was lower in the cut areas. In general, white birch was higher in the cut strips whereas red maple was quite common everywhere. No significance tests have been computed for stocking.

In interpreting these preliminary results, it is very important to look at the influence of size class. Most of the significant differences for conifers occur in the smaller (<6.6 in) size classes, an effect which also strongly affects the results for total seedlings of each species. The lower numbers and high variability in larger (> 6.6 in) size classes result in relatively few significant differences among plot locations in these size classes. Furthermore, stocking is very low for these larger seedlings, regardless of whether one looks at cut or uncut plots. Consequently, the definition of an established seedling will play an important role in interpreting these results. It is also obvious that the time frame during which regeneration is evaluated is critical because the number of seedlings seems to be varying over time, a trend which will be evaluated at the conclusion of this study.

Windthrow did not seem to be a problem during the first three years, but no statistical analyses have been done as yet. Several trees were blown down during the time between 1988 and 1989 surveys, but whether or not enough came down to be significant remains to be seen.

Conclusions

During the early years following narrow strip clearcutting, there seems to be a trend toward higher density and stocking of spruce, fir, and, to a certain extent, hemlock in the residual strips. In contrast, white birch has much higher densities and stocking in the cut strips. However, there is very high plot-to-plot and year-to-year variation in the data for all species. Most differences between cut and uncut strips occur in the smallest size classes, thus making the decision of minimum seedling size for successful establishment critical to interpretation of results. Furthermore, changes from year to year are large and may strongly influence the conclusions drawn from regeneration surveys done at different times. Data from this year and next may modify some of these preliminary findings.

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**ADDITIONAL TECHNOLOGY TRANSFER ACTIVITIES
BY CFRU PERSONNEL**

- Briggs, R.D. Site Evaluation Project Update. Invited presentation, Boise-Cascade Corp., Rumford, ME. April 26, 1989.
- Site Evaluation in Maine. Scott Paper Company Soils Workshop. July 25-28, 1989.
- ____Biomass and nutrient removals resulting from whole-tree and tree-length harvesting of a northern hardwood stand. Northeastern Forest Soils Conference. Burlington, VT. July 31-Aug. 1, 1989.
- CFRU Site Evaluation and Classification Project. Field presentation, Champion International Corp., Osborn Twp., ME. Sept. 19, 1989.
- Lautenschlager, R.A. Browse production for big game use following herbicide treatments. MONSANTO'S Forest Vegetation Management Seminar, Carrabassett Valley, ME. March 7, 1989.
- ____Effects of forest management on moose and deer populations. Moose and Deer Research Conference, New Hampshire Dept. of Fish and Game, Concord, NH. March 21, 1989.
- Herbicides benefit forests. Portland Press Herald, Sept. 25, 1989.
- McCormack, M.L., Jr. CFRU research programs. Western Maine Forest Forum, Lewiston, Maine. November 28, 1988.
- Commencement address. Maritime Forest Ranger School, Fredericton, NB. Dec. 16, 1988.
- Biological interactions from biomass harvesting of spruce-fir forests. Northern Forest Forum, Caribou, ME. March 13, 1989.
- Forest vegetation management with herbicides. Silviculture Class, Orono, ME. March 28 & 29, 1989.
- Industrial forestry practices in northern Maine. Bangor Rotary Club, Bangor, ME. April 4, 1989.
- Forestry herbicides roundtable discussion for operational forests. Maritime Forest Ranger School, Fredericton, NB. April 18 & 19, 1989.
- CFRU silviculture research review. Boise-Cascade, Rumford, ME. April 26, 1989.
- ____Industrial forestry practices in northeastern North America. Seminar. Hochschule fur Bodenkultur, Vienna, Austria. May 18, 1989.
- Silvicultural use of herbicides in northeastern North America. IUFRO Meeting, P 13-00 Herbicides in Forestry, Nancy, France. May 23, 1989.
- ____Aerial strip thinning with herbicides. IUFRO Meeting, P 13-00 Herbicides in Forestry, Nancy, France. May 23, 1989.
- ____Developing forestry herbicide prescriptions. Dow Chemical, Forestry Workshop, Bangor, ME. July 11, 1989.
- ____Field tour. Results of operational uses of herbicides. Dow Chemical Forestry Workshop, Bangor, ME. July 12, 1989.
- CFRU silviculture research with herbicides. Field presentation, Champion International Corp. Osborn Twp., ME. Sept. 19, 1989.
- Ostrofsky, W.D. Harvesting alternatives for stands damaged by the beech bark disease. Invited presentation, Nat. SAF Conv., Rochester, N.Y. Oct. 19, 1988.
- ____Periderms in trees. Seminar presentation, Botany 556. Orono, ME. Nov. 8, 1988.
- Timber Quality - Project Update. Invited presentation, SWOAM. Dover-Foxcroft, ME. Feb. 21, 1989.
- Management of beech bark disease. Seminar presentation, Botany 456. Orono, ME. Feb. 21, 1989.
- ____Pest problems associated with conifer plantation establishment on hardwood cutover sites. Technical Session Moderator, Northeastern Forest Pest Council Annual Meeting. Portland, ME. March 14, 1989.
- .Harvesting - Project Update. Invited presentation, Boise-Cascade Corp., Rumford, ME. April 26, 1989.

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Ostrofsky, W.D. An overview of timber management practices in Maine. UNH Forestry Technician Field Tour. Twp. 34 MD, ME. May 4, 1989.

-----Think like a tree - How trees respond to injury. Invited presentation, SWOAM. Woodstock, ME. June 10, 1989.

-----Ecological factors that affect stand quality. Invited presentation, Silviculture Education for Loggers Conf., Craftsbury Common and Rochester, VT. June 27 and 28, 1989.

-----An evaluation of residual stand impacts from harvesting using a long-reach boom feller-buncher; Tree and stand vigor assessments using the Shigometer. Field presentation, Champion International Corp., Osborn Twp., ME. Sept. 19, 1989.

Seymour, R.S. Timber Supply Projections for Maine. Seminar presentation, ARE Seminar Series, Dept. Agr. Res. Econ., Orono, ME. Feb. 13, 1989.

-----Forest Practices: Facts, Issues and Controversies. Seminar presentation, 30th Annual Pulp and Paper Foundation Summer Institute. Orono, ME. June 19, 1989.

Seymour, R.S., and M. Fajvan. Review of soil-site index-yield study. Field presentation, Champion International Corp. Osborn Twp., ME. Sept. 19, 1989.

Seymour, R.S. Member, Maine Bureau of Public Lands Silvicultural Advisory Committee.

-----Member, Baxter Park Scientific Forest Management Area Advisory Committee.

-----Member and Chair, Maine Board of Licensure for Professional Foresters.

Shepard, R.K. Provided written statement to LURC on the potential benefits of landspreading papermill sludge. Feb., 1989.

-----MAES Technical Bulletin manuscript review. Feb., 1989.

-----Two poster presentations, NESAF winter meeting. Portland, ME. March, 1989.

-----Provided technical assistance to the Houlton Water District for a small-scale municipal wastewater spray program on forest lands. April, 1989.

COOPERATIVE FORESTRY RESEARCH UNIT ADVISORY COMMITTEE
1989 Membership

The CFRU Advisory Committee sets priorities and reviews proposals for the Cooperative Forestry Research Unit. Members active during all, or part, of 1989 were:

Michael Coffman, Manager, Planning, Champion International Corporation (Chairman)
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Richard Sirken, Georgia-Pacific Corporation
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Robert V. Withrow, Boise-Cascade Corp.
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CFRU STAFF
(September 30, 1989)
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APPENDIX
Terminology

SCIENTIFIC NAME	COMMON NAME
<i>Abies balsamea</i> (L.) Mill.	Balsam fir
<i>Abies</i> spp.	Fir
<i>Acer rubrum</i> L.	Red maple
<i>Acer saccharum</i> Marsh.	Sugar maple
<i>Alnus glutinosa</i> (L.) Gaertn.	European black alder
<i>Betula alleghaniensis</i> Britt.	Yellow birch
<i>Betula papyrifera</i> Marsh.	Paper birch
<i>Fagus grandifolia</i> Ehrh.	American beech
<i>Fraxinus pennsylvanica</i> Marsh.	Green ash
<i>Juglans nigra</i> L.	Black walnut
<i>Larix decidua</i> Mill.	European larch
<i>Larix laricina</i> (DuRoi) K. Koch	Tamarack (Eastern larch)
<i>Larix leptolepsis</i> (Sieb. & Zucc.) Gord.	Japanese larch
<i>Larix siberica</i> Ledeb.	Siberian larch
<i>Larix</i> spp.	Larch
<i>Picea abies</i> (L.) Karst.	Norway spruce
<i>Picea glauca</i> (Moench) Voss	White spruce
<i>Picea mariana</i> (Mill.) B.S.P.	Black spruce
<i>Picea rubens</i> Sarg.	Red spruce
<i>Picea</i> spp.	Spruce
<i>Pinus banksiana</i> Lamb.	Jack pine
<i>Pinus monticola</i> Dougl.	Western white pine
<i>Pinus resinosa</i> Ait.	Red pine
<i>Pinus strobus</i> L.	Eastern white pine
<i>Prunus pensylvanica</i> L.	Pin cherry
<i>Pseudotsuga menziesii</i> (Mirb.) Franco	Douglas-fir
<i>Quercus rubra</i> L.	Red oak
<i>Rubus idaeus</i> L.	Common red raspberry
<i>Tsuga canadensis</i> (L.) Carr.	Hemlock