CFRU Information Report 29

1991 ANNUAL REPORT
OF THE COOPERATIVE FORESTRY
RESEARCH UNIT

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

Miscellaneous Report 365 December, 1991

MAINE AGRICULTURAL EXPERIMENT STATION MISCELLANEOUS REPORT 365

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ADVISORY COMMITTEE CHAIRMAN'S REPORT

At the beginning of 1991, Dr. G. Bruce Wiersma, Dean of the College of Forest Resources, took over as Director of the Cooperative Forestry Research Unit. Dr. Wiersma's interest in CFRU and his extensive knowledge of how to run a research center has been exceptionally helpful to the Unit. He has made a special effort to take tours of cooperators' land and talk with them about what they expect from CFRU. Although Dr. Wiersma has been here only one year, he is making major contributions to the Unit's success.

This year, the CFRU Advisory Committee, in cooperation with the scientists, completed the difficult task of finalizing the research priorities for the next five-year funding period (10/1991 - 9/1996). The CFRU Research Priorities Committee presented final recommendations in January, which included continued research on aspects of Silviculture, Forest Growth and Yield, Site Classification, and increased emphasis on Wood and Sludge Ash Utilization and Wildlife Habitat issues. It was also agreed that the Tree Improvement programs would also receive continued support. The research topics chosen as priority areas were selected only after considerable effort and numerous open discussions were conducted by all involved.

The economic climate has been tough this year for the university and many of the cooperators. The Executive Committee appointed a committee to study the dues structure of CFRU. The committee report, which was accepted by the Advisory Committee, recommended continuing with a dues assessment based on landowner acreage, with a cap for any individual member at 2,000,000 acres. A sum of $400,000 in the current CFRU account will be earmarked as dedicated funding in case the Unit were to close. This sum would meet contractual obligations with the employees and ensure an orderly phase down of projects. This cushion has existed since CFRU started, but the committee recommended making its existence more formal. This does not mean we are planning to close the Unit! Finally, the committee recommended lowering the dues assessment to five cents per acre for the 10/91 - 9/92 fiscal year. The Executive Committee will recommend to the members a dues level for the following year based on the financial status of the Unit.

During 1991, Dr. R. Briggs received a significant grant from the USDA Cooperative States Research Service to conduct additional research work at the Weymouth Point study site. The project, titled "Impacts of Precommercial Thinning and Fertilization on Water Quality", one of only a few accepted for funding by this highly competitive granting source, fits extremely well within the new research priorities for CFRU.

This was a big year for technology transfer. The scientists and staff published over 25 articles and reports. The scientists are also used extensively by cooperators to help with specific questions and problems.

Also this year, significant additional research support was provided by International Paper Co., to conduct studies of effects of papermill sludge ash utilization on black spruce growth. This study, conducted jointly by Dr. R. Shepard and Dr. W. Ostrofsky, expands the research efforts in another of the priority research areas.

Dr. M.L. McCormack has spent most of the year in Europe on sabbatical leave. As you will see in his section of this Annual Report, he took full advantage of his opportunities by interacting with forestry scientists from several European and Scandinavian countries. These experiences were, no doubt, personally rewarding, but should also serve him well in planning his next CFRU research efforts.

Early in 1991, three subcommittees of the Cooperative Forestry Research Unit met to finalize a strategy for moving the CFRU through the next five-year research cycle. The CFRU Executive Committee, the CFRU Research Priorities Committee, and the CFRU Funding Committee worked diligently to assess the status and future needs of the CFRU. One of the recommendations that came from these planning sessions was to reinstitute the position of Leader for CFRU. W. Ostrofsky was appointed to serve a one-year term starting May 1, 1991. In this position, Ostrofsky will assist the Dean with routine administrative functions of CFRU and will represent the CFRU in College and University functions. The position will occupy up to a 25% time commitment, and continuation will be assessed after a one-year trial period.

CFRU remains strong. It is well positioned for the next five-year program of work.

Thomas J. Colgan, Chairman
CFRU Advisory Committee

DEAN'S REPORT

Since starting as Dean of the College of Forest Resources, I have visited with many individuals and personnel of companies supporting the Cooperative Forestry Research Unit and have made several on-site tours. I eventually plan to meet representatives of all our cooperators. Your commitment to forestry research and to the Cooperative Forestry Research Unit is impressive and encouraging.

During this last year there has been *a* slight adjustment in the management of the Cooperative Forestry Research Unit. In order to ensure closer day-to-day supervision of CFRU activities, and also to ensure that the CFRU has a voice equal with all other college departments, I asked Dr. William Ostrofsky, with the concurrence of the Executive Committee and the CFRU Advisory Committee, to assume the leadership of the Cooperative Forestry Research Unit. Dr. Ostrofsky officially took over in May, 1991, and has ably administered and represented the CFRU during the last year.

The Executive and Advisory Committees reviewed the funding for the Cooperative Forestry Research Unit and the contingency fund. Guidelines for the administration of the contingency fund have been formalized.

The Cooperative Forestry Research Unit is a unique organization that is meeting key forestry research needs of the forest industry in Maine. I look forward to continuing this relationship as we work to meet changing research requirements for the future.

G. Bruce Wiersma
Dean, College of Forest Resources
Director, Cooperative Forestry Research Unit

BALANCE SHEET

1990-1991 Period
10/1/90 - 9/30/91

ASSETS:

BALANCE FORWARD SEPTEMBER 30, 1990		$ 640,477.12	
CONTRIBUTIONS 1990 RECEIVED AFTER 9/30/90		20,100.00	
Great Northern Paper Co. and Georgia-Pacific Corp.	$20,000.00		
Hanington Brothers -	100.00		
CONTRIBUTIONS 1991 (01/01/91-9/30/91)		443,949.80	
INVESTMENTS 10/01/90-09/30/91 TOTAL		47,053.70	
ASSETS: 10/01/90-09/30/91			$1,151,580.62

EXPENSES: 10/01/90-09/30/91

VEHICLE REPLACEMENT	0.00	
ADMINISTRATION	38,013.39	
SILVICULTURE - McCORMACK	69,465.30	
SOIL SITE - BRIGGS	111,955.92	
TIMBER QUALITY - OSTROFSKY	68,960.80	
GROWTH & YIELD -- SEYMOUR	7,896.17	
TREE IMPROVEMENT - GREENWOOD	10,000.00	
FERTILIZATION -- SHEPARD	14,540.00	
TREE IMPROVEMENT - CARTER	42,388.86	
MOOSE & HERBICIDES -- SERVELLO	13,574.69	
TOTAL EXPENSES: 10/01/90-09/30/91		- 376,795.13
BALANCE 09/30/91		774,785.49
Less Carry Forward Account		16,425.31
Less Carry Forward Vehicle Account		21,674.95
Balance		736,685.23
Less Dedicated Funds		- 400,000.00
BALANCE ENDING 09/30/91		$ 336,685.23

CFRU LEADER'S REPORT

The Cooperative Forestry Research Unit gained an important new cooperator during the past year, Diamond Occidental Forest, Inc. We welcome them and look forward to working with their staff. Mr. D. Christensen will be serving as their representative on the CFRU Advisory Committee.

Research by the CFRU has continued vigorously. Additional studies have been already initiated in several of the new or expanded research priority areas of the next five-year funding period. Especially noteworthy is a new water quality study being conducted on the Weymouth Point watershed by Dr. R. Briggs. This study will examine the effects of precommercial thinning and fertilization treatments on water quality and nutrient cycling, and will provide important new data on these intensive management practices. Funding for this three-year project has been obtained by Dr. Briggs from a USDA Cooperative States Research Service grant, for which competition is very strong.

Dr. M. McCormack has been on sabbatical leave in Europe since last November and has provided, elsewhere in this report, an indication of the wide variety of forestry practices he encountered. Dr. McCormack is the first CFRU scientist to be granted sabbatical leave. A detailed account of his many experiences is anxiously awaited by CFRU scientists and cooperators alike!

The work on accelerated larch breeding, conducted by Dr. M. Greenwood and others, is progressing well, and the spruce progeny tests of Dr. K. Carter continue to provide important source data. Research was expanded on the effects on tree growth of forest land spreading of papermill sludge ash, with supplemental funding from International Paper Co. This research complements ongoing studies on papermill sludge ash and wood ash utilization being conducted by Dr. R. Shepard.

The first phase of Dr. A. White's work on strip clearcutting has been completed; no new data were collected in 1991. Data from the four-year study have been summarized and will appear in a future publication. The second phase of the research is scheduled to begin in 1992 with herbicide applications in half of the cut strips. Similarly the project conducted by Dr. C. Elliott on use of planned herbicide skips by wildlife has been completed. A final summary report will be forthcoming shortly.

Dr. R. Seymour has been on sabbatical in the Pacific Northwest and British Columbia during the late summer and fall months. His work on timber growth and yield will continue after his return in late 1991.

Several maintenance issues developed during the year. Because of a number of changes in the computing network on campus, a new computer was purchased for E. Heinz, CFRU administrative assistant. This has allowed substantial upgrades in computer hardware for several staff members, by redistributing our existing computers. CFRU is now better prepared to exploit the new University-wide computer services available in the near future.

A scheduled move of the CFRU laboratory in Nutting Hall will be conducted in late December of 1991. This move, precipitated by several other College and University needs, will result in the addition of a much-needed chemical fume hood. No funding for the lab renovation should be required from CFRU.

In conjunction with planning for a new lab, University lab safety guidelines recently have been reinforced. Efforts were spent in equipping and training staff and students on the new chemical lab safety procedures.

In early spring, a new roof cap was installed on the CFRU building, located on the University Forest. This has greatly reduced the persistent water problems.

The continued slow economic situation in the State and the region has been challenging, and it appears it will continue in the coming months, as well. However, the CFRU scientists remain optimistic and aggressive as we plan our research for the coming year and the new five-year funding period.

William D. Ostrofsky, Leader
Cooperative Forestry Research Unit

SILVICULTURE

Dr. Maxwell L. McCormack, Jr.

Introduction

These comments for the CFRU Annual Report are based on a sampling from my journal notes as I approach the final weeks of my sabbatical leave. Freiburg i. Br., site of one of reunified Germany's four faculties of forestry and main city of the Black Forest has been an excellent location for residency. Travelling through eight nations, I have made forestry visits to eight faculties of forestry, 14 research stations, and 40 private or public forest management districts.

Such a program has been dependent on assistance and guidance from many colleagues. Special acknowledgement and thanks are extended to my host Prof. Juergen Huss, Silviculture Institute, Freiburg University; also Dr. Georg Kenk, Baden-Wuerttemberg Forestry Research Institute; Prof. Henri Frochot, National Agricultural Research Institute (I.N.R.A.), Nancy, France; Dr. Achim Dohrenbusch, Institute of Silviculture, Goettingen University; Prof. Pentti Hakkila, The Finnish Forest Research Institute, Helsinki; Dr. Staffan Berg, Skogsarbeten, Kista, Sweden; University of Maine graduate student Morten Moehs who found an apartment in Freiburg where vacant housing is nonexistent; and my special long-time friend Dr. Herbert Hager, Institute of Forest Ecology, University for Bodenkultur, Vienna.

Most of these comments come from experiences in Germany, but include observations from several other European countries. It is stimulating and exciting to observe intensive levels of silviculture carried out over long periods of time. They provide examples beyond our textbook readings. They can be a basis, but not necessarily a model, for advancing our practices by taking advantage of a vast amount of experience already gained by our European colleagues. It is especially gratifying for me to be able to visit districts, stands, and in a few cases individual trees, that I observed 18 years ago.

Comparisons between the forests of northeastern North America and the forests of Europe must be made with caution and qualifications. Comparing forestry practices between the two locations requires even more care. Look at a map of the world. Note, for example, that 60° North latitude runs across the southern tip of Finland, through the wide part of southern Sweden, and through the center of Hudson Bay. Extend the latitude of Maine across to Europe and it runs through northern Italy. Mountain ranges run in different directions and in a different scale of elevations. Ocean currents exert influences. Count important tree species. In European forests there is one beech, one spruce, one pine, one fir.[1] The popular, successful exotics in Europe are Douglas-fir and lodgepole pine from *western* North America.

History, economics, politics, populations, cultures, . . . they are all different . . . and now there is the "New Europe" and the developing European Community. Managed forests go back hundreds of years with data to document them. At the head of the first main staircase in the forestry faculty building in Tharandt, in the former DDR, visitors are greeted by a bust of the school's founder, Heinrich Cotta. In Germany, priorities for forest management, from top to bottom, might run as follows: environmental protection, watersheds, landscape, recreation, wildlife, hunting, timber. As one travels north into Scandinavia, timber works its way up through the list.

The General Situation

After World War II there were concerns about wood supply and, for a period of time, wood shortages were forecast. Now wood production exceeds harvests, and the focus of silviculture is toward quality. A developing emphasis is on individual high-quality trees grown in forests that are always green. Naturalness is a theme. For example, some purists question Douglas-fir culture as being unnatural. Others who recognize the great growth capability of the species in many German forests point out that *Pseudotsuga* was in Europe before the glacial period. There is a strong trend away from single species plantations toward mixtures, and toward developing underplanting techniques for establishing mixtures in existing stands.

Considerations of labor and costs are ever present, though at different scales than in eastern North America. Mechanization has been a means to significantly reduce harvesting costs. Now, silviculture must be carried out more efficiently and mechanization will be necessary to keep operating costs within reason. There is the perpetual forestry debate over numbers of trees per unit of land area. Twenty to 25 years ago the Scandinavians advocated low numbers while German foresters were planting as many as 10,000/ha (4050/ac) of spruce or pine. Today this situation is reversed. Swedish foresters are striving for numbers on the order of 5,000/ha (2025/ac) and German forestry researchers are advocating crop tree densities of 400 to 800/ha (162 to 324/ac).

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[1] beech: *Fagus silvatica* Linne
spruce: *Picea abies* (L.) Karsten
pine: *Pinus silvestris* Linne fir:
Abies alba Miller

The light densities likely would require some pruning, but would minimize, or eliminate intermediate removals of non-merchantable or low-value wood. These opinions are based, in part, on some long-term case histories. For example, I recently visited Norway spruce plantations under study which were planted between 1870 and 1890 with 333 and 1,111 crop trees/ha (135 and 450/ac). Also, I observed a 1908 Douglas-fir planting of 150 trees/ha (61/ac), with some nurse tree understory plantings, which has averaged 20 cu m/ha/yr (approximately 2.2 cords/ac/yr). Figure 1 shows an example of a good Norway spruce crop tree in a thinned plantation in a private forest in Wolfegg, Germany. It is thought that better development could have been achieved through more rigorous control of the original crop tree spacings since this plantation likely had too many trees when it was planted in 1956.

Figure 1. Dr. Winfried Duffner and John Cashwell standing by a Norway spruce plantation crop tree in Wolfegg, Germany. The plantation is 37 years since seeding of the planting stock. The first thinning was at 24 years and the most recent thinning was completed in the past year.

Problems

Das Waldsterben (forest decline) is not the big problem which it is perceived to be from our vantage point in North America. There are isolated, special instances where it is severe. One such example that I observed was in the Erzgebirge along the border between Czechoslovakia and the former DDR where there is a confluence of industrial emissions. Concerns now seem to center around nutrient cycle interactions and consequent effects on tree growth and development. A more dominant problem is that of wind damage. In Baden-Wuerttemberg, the third largest state of the Federal Republic of Germany, wind damage typically determines 25% to 30% of annual harvest volumes. Consequently, much attention now is directed toward improving stand stability. Species mixtures and wider crop tree spacings are two approaches.

The great importance of animals, for viewing and especially for hunting, causes management conflicts which result in heavy browsing influences on regeneration establishment, species composition, and stem quality. Expensive fencing is often the most workable solution. Competing vegetation, weeds, is more of a problem than is usually admitted. Except for the use of herbicides in France, most treatments are manual or motormanual methods. However, weeds are not as dense and competitive in the European forests as in jbhe forests of northeastern North America, and Norway spruce appears to be an aggressive competitor during stand establishment. Other problems worthy of note are frost, where sheltering tree cover can provide effective protection, and insects. In particular, regeneration weevils *(Hylobius* spp.) can be a serious menace to young plantations as we have observed on occasion in the Northeast.

Included here are some selected examples of field observations to illustrate the array of topics that has been observed. Some of mainly academic interest might stimulate your imaginations, or concerns, about our forests. Others have a direct bearing on practices in our region.

Selected Practices

Spruce Thinnings

Our recent interests in single-grip harvesters is well justified based on experiences in Europe. In thinning Norway spruce, the harvesters operate through marked stands on marked trails which are located at regular intervals. The trails are straight in order to minimize injuries to residual trees, and their placement is determined, in part, by the comfortable reach of the boom. At Wolfegg, a private forest operation in southern Germany, the Managing Director, Dr. Winfried Duffner uses four sizes of machines in order to match machine model with stand conditions and tree sizes. Limbing residues and tops are placed in the trails and form protection for residual tree root systems (Fig. 2). Wood, pulpwood or logs, is grouped adjacent to the trail. The forwarder makes two trips; one for pulpwood, one for logs.

Figure 2. An FMG 170 E single-grip harvester carrying out a commercial thinning in Norway spruce.

Figure 3. John Cashwell standing at the rear of an FMG 0450 during a break in a thinning operation on a difficult, wet site. This shows the width of the machine which is equipped with extra-wide tires.

On a second visit to Wolfegg, joined by John Cashwell, Director of the Maine Forest Service, we observed the smallest machine (FMG 0450, Lillebror) carrying out a first entry commercial thinning in a difficult chance (Fig. 3). The stand was extremely dense and limby on a site that was wet and fragile. The success observed here led us to speculate on the possibility of a "weed wacker" head on the boom for precommercial thinning and mechanical cleaning. This type of equipment, mounted on highway maintenance vehicles is used routinely for roadside brush reduction in Europe.

Later, in Sweden, I learned that Skogsarbeten had reported on use of a cleaning head on three machines (Skogsjan 487, Spindeln; FMG 0450; and Valmet 901). Through the courtesy of Svenska Cellulosa AB, Sundsvall, Sweden, I was able to observe an operational cleaning/thinning with the Skogsjan 487XL (Fig. 4).

Figure 4. A Skogsjan 487XL carrying out an operational cleaning/thinning on land of Svenska Cellulosa AB near Sundsvall, Sweden.

The conditions were very similar to typical Maine sites with soft, wet holes, slopes and numerous boulders. The machine was equipped with the latest version of a cleaning head (Fig. 5). Discussions with the team of three operators, review of company operations data, watching the machine in operation, and riding in the machine during operation were all encouraging.

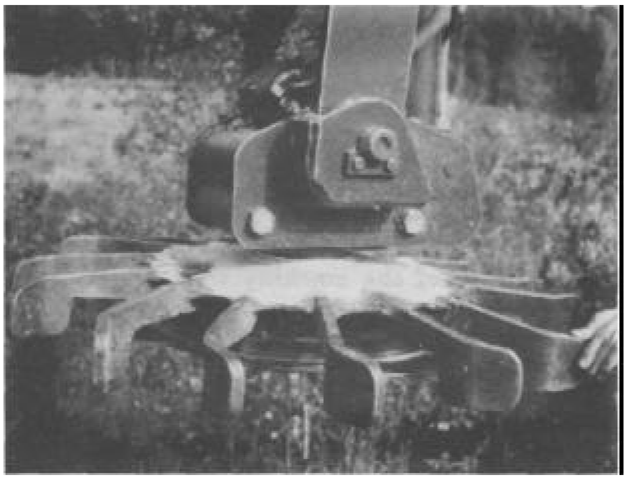


Figure 5. The cleaning head mounted on the boom of the Skogsjan 487XL. The pronged disc rotates freely as it protects the 70-cm cutting disc. The 10-cm prong space assists the operator in judging position of stems to be cut.

Birch as a Nurse Crop for Spruce

In Sweden there is an old saying, "birch is the mother of spruce." This is based on the opinion that some competition helps to develop high quality in Norway spruce. Also, birches *(Betula pendula* Roth and *B. pubescens* Ehrh.) provide important shelter from frost injury to young spruces, suppress some undesirable vegetation, and furnish beneficial litter to the soil. Mixed species generally are considered to be *a* more healthy forest. A retired forester from the Swedish Forest Service, Arne Johanson (Fig. 6), has worked at perfecting this system which can be carried out in three stages (Fig. 7).

After the birches have reached a height of 3 to 4 m, in stage one they are spaced out at intervals of slightly less than 2 m (approximately 3000+ birches/ha). After 5 to 6 years when the birches are 6 to 9 m in height, they are further reduced in stage two. Stage three occurs after another 5 to 6 years when the birches, at heights up to 12 m, provide *a.* modest commercial volume for removal, and the established spruces are in a

Figure 6. Arne Johanson showing a healthy Norway spruce growing under the protection of young, vigorous birches.

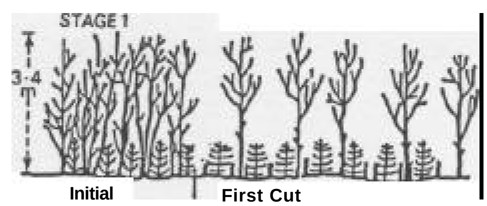
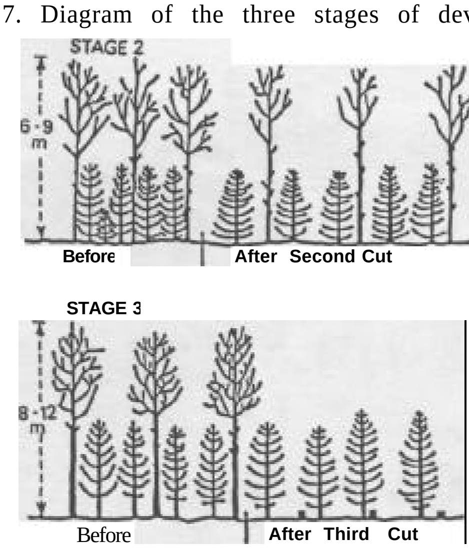


Figure 7. Diagram of the three stages of developing



a young spruce stand under a birch nurse crop (adapted from Malerskog Skogsagarna 1989).

Figure 8. Forester Goran Adelskold in a birch-spruce stand in the later part of stage two and ready for the spruce to begin their full development.

position to develop into a healthy stand (Fig. 8). As many as 100 good quality birches per ha can be retained as larger, potential crop trees. This is an intensive silvicultural technique that results in good stand development in Sweden and Finland and provides the very important protection from frost. This procedure fits well into the no-herbicide silviculture of Sweden.

Spessart **Oak**

No review of European silviculture would be complete without mention of the classic, long rotation (200 to 300 years), high-quality oak *(Quercus petraea* [Mattuschka] Lieblein) production of the Spessart Region in the valley of the Main River. The forestry history of the region dates back to the year 800. The Bishops of Mainz, owners of the Spessart for nearly 900 years, kept the woodlands for hunting. For a period of about 800 years, the main concern was acorn production. The old oaks were retained, and the beech *(Fagus silvatica)* regeneration was removed.

This area is famous for production of large, veneer-quality logs (Fig. 9) which are sold individually at auction. I had the opportunity to revisit the same stands that I visited in 1973. The basic culture remains the same, but with some efforts toward reducing the average rotations closer to 200 years. The oak stands are developed from strips of hand-seeded acorns. The seedings put down 50,000 to 75,000 acorns which develop into 40,000 to 60,000 seedlings/ha (16,200 to 24,300 seedlings/ac) in the first year. Intensive manual cleanings are carried out •within fenced regeneration areas. Beech grows in as an understory nurse crop mixture to help develop clean, straight oak stems. *Carpinus* and *Tilia* trees are also mixed into the stands. Between ages 20 to 25 the fences are removed and a series of thinnings takes place until around age 200 when there are approximately 50 premier crop trees/ha. This is of interest as an example of intensive silviculture over long rotations to produce a high-value, specialty crop.

Figure 9. Forest Director Burger, Forestry District Rohrbrunn, reviews bid prices for the 1991 crop. The log in the center, No. 3438, is 7.1 m long with a diameter of 73 cm. Its volume is 2.97 cu m with a total bid amount of D.M. 11,909.70 ($7000.+).

Figure 10. A group of silviculture students observing a study of beech underplantings in a fenced, thinned Norway spruce stand, Forestry District St. Andreasburg, Harz Mountains.

Beech Renovation and Underplantiiig

Across Germany and much of Central Europe, there is a consistent, strong interest in rebuilding the hardwood forests and introducing mixtures in forests that have become predominately Norway spruce. The most widespread active efforts are being done with European beech. Planting of beech seedlings in small openings from patch harvests or blowdown and underplanting of beech in thinned spruce stands (Fig. 10) are the foci of new prac - tices and research eff orts. There are large areas of spruce-only forests that are vulnerable to se - vere wind damage. One approach to improving stand stability is to establish beech mixtures within the spruce.

In Forestry District Olbernhau in the former East Germany (DDR) near the Czechoslovakia border, new beech forests are being developed where serious forest decline problems existed in past years. Understory site preparation, a com - mon practice in Germany, is done mechanically to support the establishment of seeding and plant ed seedlings produced from local seed sources (Fig. 11). Severe problems from red deer require pro - tection with large, sturdy fencing which costs ap - proximately D.M. 10/m (estimated $9000/mile).

Tall Oak Seedlings

The offices of Forestry District Bebenhau sen are located in a historic old monastery in the Schoenbuch, southwest of Stuttgart. The total forest area is 15,500 ha (38,285 ac) with one public road through the center. Contained therein is a 4,000 ha (9,880 ac) fenced area for red deer. There are 2,000,000 inhabitants within a 35 km (22 mi) radius of Bebenhausen and there are 4,000,000 visits to the forest each year. The District has a

Figure 11. Beech understory site preparation and planted seedlings to rehabilitate a forest decline area in Forestry District Olbernhau, Saxony, near the Czechoslovakia border.

Figure 12. Study group observing large oak seedlings planted at Forestry District Bebenhausen. Individual tree protection is required because of the high deer population maintained on the District.

long history, focused on hunting, dating back to the 14th century. Organized hunts are carried out, and there are special facilities for the public to observe the red deer in their natural habitat. The animals are the first, and very dominant, priority.

A challenge to forest management in this District is to establish productive forests where animal damage and browsing are the normal condition. Site preparation is followed by careful planting of widely spaced, large (1.5 to 3.0 m tall) oak seedlings. Each tree is protected by a large post that supports a tree-encircling wire fence. (Fig. 12). The costs and levels of intensity are akin to investments in high-value seed orchards in North America.

Agro-forestry Hardwood Plantings

In south-central France is a commitment to developing a specialized technique for producing limited numbers of high-quality hardwood stems on agricultural lands. Near Clermont-Ferrand, a cooperative development and research effort is underway on practices to establish high-value hardwood trees in active pasture lands. Thus, the trees must be well protected from grazing animals such as cows and sheep. Interests include *Acer*, *Prunus*, and *Fraxinus*, but the most intensive work observed was with cherry. A typical operational test site involved planting 200 trees/ha (81 trees/ac) at a cost of materials (i.e., not including labor) of FF 10,000/ha ($675+/ac). Each 70-cm seedling is placed within a protective plastic tube supported by one or two wooden posts.

One study area observed contained a number of cherry clones planted, in tall tubes, at different spacings. This is to evaluate any clonal adaptability to the planting technique. Another site (Fig. 13) contained a complex study design to evaluate

Figure 13. Experimental cherry planting in south-central France to evaluate planting method, clonal variation, stock size, and levels of weed control.

Figure 14. Forest Director Hoefle, Bovenden, Lower Saxony, with assistant, marking a stand of mixed hardwoods for a thinning.

Figure 15. Irrigation system in a 17-yr-old maritime pine planation to alleviate precipitation deficits in southwestern France.

planting method, three clones, two tree heights, and three radii of herbicide treatments around each tree.

High-Quality Hardwood Logs

In northern Germany, near Goettingen, is Forestry District Bovenden with a variety of good sites for production of quality mixed hardwoods. Good roads and trails are well established and provide frequent access. Closely monitored stands are thinned at relatively short intervals (Fig. 14). In thinnings, only large trees greater than 50 cm (20 in) and no-longer-needed understory nurse trees are removed. Market values are considered, but attention is always given to species composition, wildlife needs, and landscape values. Future felling of retained crop trees is part of the thinning plan. In marking trees, felling directions are indicated in order to minimize breakage, avoid residual tree damage, and to speed up decisions during felling operations.

Maritime Pine Study by a Forestry Research Cooperative

South of Bordeaux, France, I visited with Henry Chaperon, Director of the Southwest Region of AFOCEL (1'Association Foret-Cellulose). AFOCEL is a private research organization composed of seven regions across France. They employ 120 people of whom half are scientists. Their funding is required by law with compulsory participation by French paper companies. Funding levels are currently set for 5-year periods, and contributions are in the form of a tax on cooperator paper production regardless of where the products are marketed. Most of the forest land is public, or at least not owned by the paper companies. They purchase wood, but also carry out regeneration and silvicultural activities on the lands. Two-thirds of AFOCEL's annual operating budget comes directly from the required contributions. The remaining third is derived from management activities of AFOCEL personnel such as consulting with industry cooperators and operating a quality tree nursery.

In the Southwest Region their research effort works hand in hand with the cooperators and federal researchers to improve production of maritime pine *(Pinus pinaster* Ait.). One example of AFOCEL research is a study coordinated with precipitation deficits; they are currently in a dry period. In a 17-yr-old maritime pine plantation a trickle hose irrigation system has been installed (Fig. 15). Water is drawn from a deep well to alleviate precipitation deficits. Plot measurements have shown a first year volume growth gain from irrigating of 3 to 4 cu m/ha (approximately 0.3 to 0.4 cords/ac).

Natural Control of an Insect Pest

On a private forest ownership near Salzburg, Austria, air pollution has modified the nutrient cycle which, in turn, has resulted in changes in spruce foliage that have led to problems with a defoliating wasp (in German Fichteplatwaspe: *Pristiphora abietina).* During part of its life cycle, the wasp occurs as a grub in the soil. Forest mound-building ants are one predator feeding on the grubs. Therefore, ants are being cultured as one means of grub control. Birds are encouraged to inhabit the stands since they also feed on the grubs. The defoliating wasps are also a problem in the forests of the Schlagl Monastery near the northern border of Austria. At Schlagl, wild pigs are retained within fenced areas as a means of controlling the grubs.

TIMBER QUALITY IMPROVEMENT AND ASH RESIDUE UTILIZATION

Dr. William D. Ostrofsky

Introduction

As part of the new research priority review by the CFRU Advisory Committee during the past 18 months, the objectives of the Timber Quality program have been expanded to include forest management aspects of ash residue utilization. This new mandate will require some obvious changes in research direction. However, the program also allows for work to be continued on certain timber quality issues. For this part of the program, emphasis will be placed on the evaluation of harvesting systems for damage to residual trees in partially cut stands.

During 1991, two research grants came to termination. The Cooperative Agreement with the USDA Forest Service in Durham, New Hampshire, has ended. This work involved assessing the health of red spruce stands using several different research techniques. Several publications are now in manuscript form, or in review and will become available over the next year or so. Also ending was the grant from the Council of Northeastern Governors (CONEG) thrdugh the Maine Office of Energy Resources. This funding was to conduct research on the effects of biomass harvesting on stand quality. One publication reporting stand damage levels in southern Maine has been completed.

Berhane Manyazawale, a graduate student from Ethiopia, completed her MF degree requirements and is now working with a private company in urban forestry in Washington, DC. Her MF project involved assessing internal decay in red spruce using the Shigometer. The study results have been written as a CFRU Information Report and will be available soon.

During the month of July, Wolfgang Klein, a visiting student from St. Margen, Germany, volunteered to work with the timber quality program. He had attended Colgate Univ. in New York on an international student scholarship during the past school year. His objective was to end his year-long stay in the United States with some summer forestry field experience before returning to forestry school in Germany. His able assistance during his tenura with CFRU was greatly appreciated.

Assisting with all field work during the summer season was Adam Carmichael, an undergraduate student in Natural Resources, and Stuart Gardner, an undergraduate student in Forest Management. Also providing additional part-time assistance was Jian-Hua Jian, a graduate student in Forest Biology. They made an exceptionally careful and hard-working crew.

Shelterwood **Overstory Removal**
Lambert **Lake**

In 1983, a study was initiated to examine the effects of understory herbicide treatments to improve species composition in a hardwood stand dominated by defective and defect-susceptible beech. Damage to beech was the direct result of the beech bark disease. The stand, located in Lambert Lake on land owned by Georgia-Pacific Corp., included mature beech that were growing slowly and were of poor quality. Regenerating beech sprout thickets were occupying a large area of the stand, and were largely of defect-susceptible stock. Herbicides were applied to the mature beech prior to harvesting to prevent additional sprouting and to regenerating beech thickets in the understory prior to a shelterwood harvest. Details and early results of the experiment have been published (Ostrofsky and McCormack 1986).

Red and sugar maples, yellow and white birches, and beech resistant to the beech bark disease were left as overstory trees, to provide regeneration after the 1983 harvest. Regeneration has been assessed yearly, and additional recruitment of regeneration likely to become "established" appears to be over. The regeneration developing after the first cut has developed more slowly than expected, but species composition has greatly improved in the herbicide-treated plots. Additional regeneration will be forthcoming as sprouts from the harvested overstory trees.

The overstory trees were removed as the final shelterwood harvest during January and February of 1991 (Figs. 16 and 17). R. Chandler, Georgia-Pacific Corp., provided assistance by arranging for the harvesting crew, supervising the harvest, and providing harvest volume data. His help with this study has been invaluable.

Regeneration was again assessed during the 1991 growing season, to determine impacts that the harvesting may have had, but the data have not yet been summarized. Further stand development will continue to be monitored for as long as possible. Of particular interest will be the development of sprouts from the beech resistant to the beech bark disease.

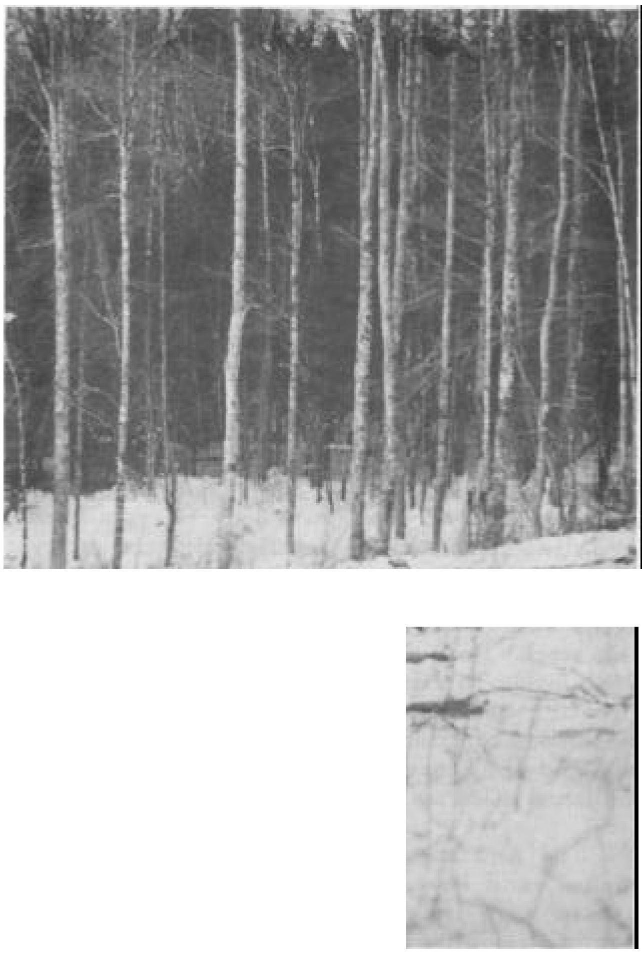


Figure 16. Hardwood regeneration (foreground) eight years after glyphosate treatment and a shelter-wood seed cut and directly after overstory removal. A portion of the remaining overstory can be seen in the background. Most regeneration is birch and maple species.

Figure 17. Beech regeneration eight years after the shelter-wood seed cut and directly after overstory removal in a control (no herbicide treatment) plot.

Ash Utilization

Forest land spreading of papermill sludge ash as well as wood and bark ash residues has been conducted since 1989 (Fig. 18). In addition to the practical problems of application technology, many questions remain as to the effects of such a practice on growth of crop trees and competing vegetation, on nutrient cycling, and on hydrological changes. In response to what appears will become a standard operating procedure for most paper companies in Maine, research on forest effects of ash residue utilization -was identified for expanded emphasis over the next five-year work period.

Dr. R. Shepard has conducted research supported by CFRU on papermill sludge and ash utilization since 1988. Work of this new program will be coordinated closely with his past efforts. Projects will focus on determining the effects of various ash materials on soil and vegetation changes and on other forest management issues as they relate to this new practice.

Two projects were initiated this year. The first is a greenhouse study of the response of black spruce seedlings to various ash application rates. The second is a field study addressing questions similar to those of the greenhouse study. Both studies are supported by a supplemental contribution to CFRU from International Paper Co.

Greenhouse Study

A greenhouse study was conducted to determine the effects of various calcium carbonate ($CaCO_3$) loading rates on growth of black spruce seedlings. Ash was applied at the rates of 0, 1.5,

Figure 18. Application of papermill sludge ash with a Blondin articulated spreader to a harvested and conifer-planted site in western Maine.

3, 6, or 9 tons/acre $CaCO_3$ equivalent to black spruce growing in 15-cm-diameter pots. The spruce were container-grown, one-year-old seedlings transferred to pots containing a homogeneous mineral forest soil and allowed to become established for a period of six months prior to treatment. A total of 9 replicate pots were used for each treatment, with three trees per pot.

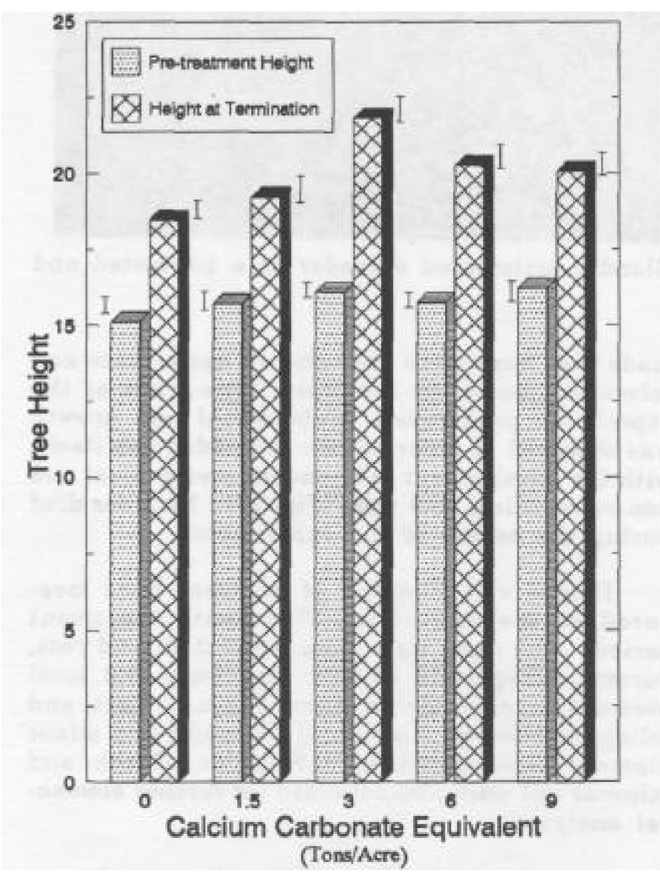
Total tree height and stem diameter were taken of all trees just prior to treatment, at which time the seedlings were just completing bud break. Ash was applied at the appropriate rates, and the trees were watered regularly and uniformly for a period of five months. At this time, height growth had ceased and bud set had occurred.

Trees were visually monitored during the course of the experiment to identify any apparent changes in health or vigor. Most trees appeared slightly chlorotic at the start of the experiment, similar to those planted in landings or skid roads of field operations. A subjective assessment was made that most trees improved in appearance and coloration, becoming a brighter blue-green as the experiment progressed. Substantial root growth was observed to occur within the added ash itself, with the development of abundant mycorrhizal and non-mycorrhizal root tips (Fig. 19). No trees died during the course of the experiment.

Height and diameter of all trees were measured at the end of the five-month treatment period. The trees were then harvested, and root, current foliage, old foliage, stem/twig and total biomass measurements were taken. Root and foliage tissues were analyzed for major and minor element concentrations. Samples of ash and mineral soil were also collected for further elemental analyses.

Black spruce height and diameter growth were significantly improved at $CaCO_3$ equivalent rates of 3 and 6 tons per acre, respectively (Figs. 20 and 21). Overall plant biomass was not significantly affected, but a trend was indicated in which root

Figure 19. Root development that had occurred within the applied papermill sludge ash. Abundant mycorrhizal and non-mycorrhizal root tips were present.



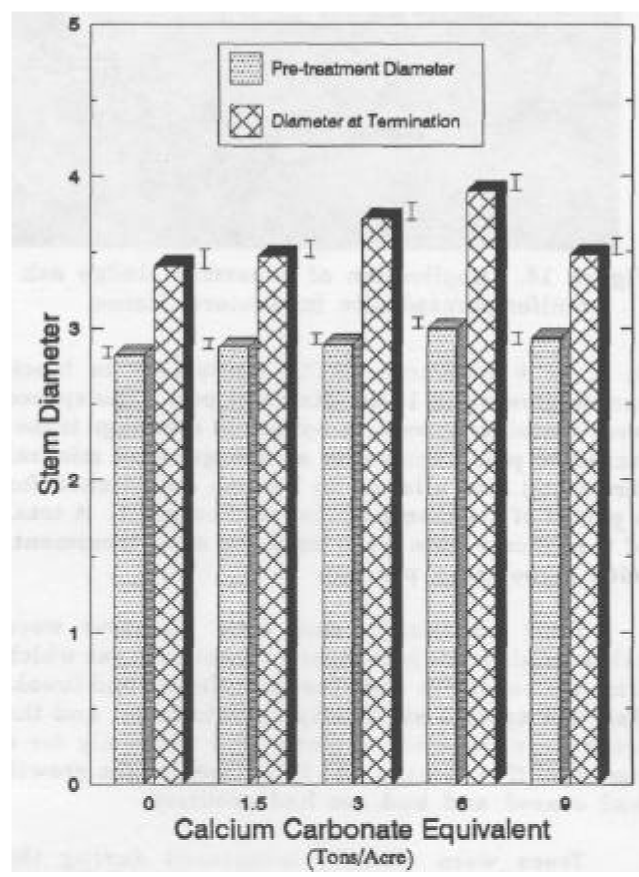


Figure 20. Effect of $CaCO_3$ equivalent rates of papermill sludge ash on height growth of black spruce under greenhouse conditions. Bars represent means of 9 replicates (three trees per replicate), with standard errors indicated.

Table 1. Elemental analysis of black spruce foliage present at the time of the treatment (old), and of foliage developing after treatment (current) as affected by various $CaCO_3$ equivalent rates applied as papermill sludge ash. Values represent means of 9 replicates, with three trees per replicate.

$CaCO_3$ Equiv. (tons/acre)	N	Ca	K	Mg		Al	B	Cu	Fe	Mn	Zn	Mo
						ELEMENT						
						OLD FOLIAGE						
		/G	ury wci£	ut -								
0	.618	1.16	.525		.101	555	39.5	5.33	820	376	74.4	.88
1.5	.630	1.22	.746	.164	.109	518	52.2	5.75	3001	373	55.4	1.05
3	.705	1.18	.696	.176	.097	516	52.7	5.16	630	407	90.4	.98
6	.664	1.30	.686	.174	.102	731	51.4	5.27	461	513	93.5	1.30
9	.684	1.40	.824	.206	.123	1285	56.1	5.82	614	524	99.6	1.84
						CURRENT FOLIAGE						
	- - - -	%	dry weif	?ht -	- -				-ppm			
0	.558	.491	.790	.151	.132	142	21.8	2.60	119	376	35.5	.611
1.5	.607	.597	.855	.155	.127	129	30.4	2.72	113	394	40.3	.750
3	.598	.551	.918	.149	.125	152	31.4	2.70	142	343	47.3	.806
6	.640	.644	.945	.163	.134	165	37.4	3.26	98	464	47.9	.917
9	.717	.708	1.152	.193	.137	213	47.3	3.51	128	573	53.6	1.006

biomass was slightly decreased at rates resulting in most favorable height and diameter growth.

Elemental analyses indicated statistically significant increases for all elements in both old and current foliage, with increasing rates of ash with the exception of P, Cu, and Fe (Table 1). Old foliage also had significantly higher concentrations of elements than current foliage, with the exception of Mn (no significant difference) and K and P (significantly higher in current than in old foliage). Ash and soil elemental analyses are not yet completed.

Results from the greenhouse study indicate that equivalent rates of between 3 and 6 tons/acre $CaCO_3$ optimize above-ground growth of potted black spruce seedlings. These results are encouraging. However, field conditions are considerably different than conditions in a greenhouse. In particular, other competing vegetation and the presence of an organic matter soil horizon are expected to greatly influence effects of ash on crop tree seedling growth.

Field Study - King and Bartlett Township

As a follow-up to the greenhouse study, a field study was installed, with Dr. R. Shepard as co-investigator, to determine the effects of various ash loading rates on growth of black spruce under operational field conditions. The site chosen for the study is located in King and Bartlett Township in western Maine, on lands owned by International Paper Co.

The site was harvested in 1989 and planted in the spring of 1990 with container-grown seedlings of black spruce. In the spring of 1991, 16 square plots measuring 10.67 m (35 ft) on a side were established as two blocks of four replicate treatments per block. The treatments are 0, 3, 6, and 9 tons/acre of $CaCO_3$ equivalent applied as papermill sludge ash. Each plot has a minimum of 15 black spruce seedlings.

Prior to treatment application, soil organic and mineral soil horizon samples were collected from each plot for analysis. Two milacre subplots in each plot were established to sample and characterize the pre-treatment vegetation. Ash was applied at the appropriate rates by hand during early July (Fig. 22). Appearance of the 9 ton/acre $CaCO_3$ equivalent rate treatment is shown in Figure 23.

Samples of pin cherry and red maple foliage were collected 3 and 7 weeks after ash application and submitted for elemental analysis, and in mid-October, black spruce foliage was sampled similarly. In late August, the entire site was treated operationally with the herbicide glyphosate to allow optimum development of the conifer seedlings.

Soil and foliar analyses have not yet been completed, but should be available during the next few months. Soil and foliage samples will be collected again next year, and compared with the pre-treatment information. Also, vegetation growth and regrowth will be monitored by assessing the milacre subplots.

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Figure 22. S. Gardner and J. Jian apply papermill sludge ash to the treatment plots.

Figure 23. Application of the papermill sludge ash at the 9 tons/acre $CaCO_3$ equivalent rate resulted in an ash layer approximately 5 cm in depth.

SITE QUALITY

Dr. Russell D. Briggs

Introduction

The past year has been highly productive for the Site Quality Research Program. Personnel involved with field and laboratory work include Ronald C. Lemin, Jr., Assistant Scientist; Daniel Gilmore and Joseph Pitcheralle, graduate students; Bradford Catling and Anthony Guay, undergraduate students.

The overall program objective, development of a productivity-oriented land classification system for spruce and fir in Maine, is being addressed by three broad projects:

1. Delineation of climatic zones in Maine;

2. Evaluation of relationship between tree growth and soil properties (physical and chemical) for

   a. Unmanaged mature spruce-fir stands,
   b. Intensively managed young spruce-fir stands,
   c. European larch plantations;

3. Precommercial thinning impacts on tree growth and soil solution chemistry as influenced by soil drainage class.

Previous annual reports provided preliminary results for Project 1, as well as details for sampling and location of the field plots established under project 2. Project 3 was established during the past year. This annual report will provide an update of status of the analytical phase of Projects 1 and 2, as well as details about field establishment of Project 3.

Delineation of Climatic Zones in Maine

On a regional scale, climate influences the distribution and composition of vegetation, influencing site productivity. Identification of discrete climate zones is an important initial step for development of a site classification system.

The revised map of climate zones for Maine is provided (Fig. 24). An earlier version was included in the 1989 Annual Report. This map is the product of additional analysis following peer review of a previous manuscript. The revised manuscript (Briggs and Lemin *in press)* has been accepted for publication in the Canadian Journal of Forest Research. The detailed analysis is described in the journal article; reprints will be available in the near future. A brief overview of the analytical procedure used to delineate climate zones follows.

Data were obtained for 63 weather stations reporting both temperature and precipitation in Maine during the period 1954-1983. Monthly means for each of the temperature and precipitation variables were computed over the period and summarized by four 3-month seasons, resulting in 37 individual variables. Principal component analysis (PCA) was used to reduce the dimensionality of the data set. Eighty-two percent of the variation in the original data was accounted for by the first three principal components. Cluster analysis was used to identify homogeneous groups of weather stations based on the scores for the first three principal components for each station.

Results of the PCA were extrapolated across the state of Maine. Stepwise regression was used to define the relationship between scores for the first two components and the location variables of latitude, longitude, and elevation. Using ARCINFO, a grid consisting of the intersection of township lines was superimposed over the state. Elevations for the grid points were obtained from a digital elevation model provided by the Low Level Radioactive Waste Authority. Principal component scores for each grid point were predicted from latitude, longitude, and elevation using the regression equations. The Triangulated Irregular Network module of ARCINFO was used to draw isopleths (climate contours) through the grid, creating a "climagraphic" map. That map, along with the results from cluster analysis and the biophysical regions of Maine (McMahon 1990), was used to delineate climate zones and climate regions. Climate statistics for each of the climate zones will be published in the near future.

The Relationship Between Tree Growth and Soil Properties

Soil-site and tree growth data have been collected in plots established in mature, unmanaged spruce-fir stands; young, precommercially thinned spruce-fir stands; and European larch plantations. Locations and distribution of the field plots were summarized in the 1990 Annual Report. The most important overall accomplishment of the past year has been completion of the laboratory analysis for all soil and forest floor samples that were collected. Joseph Pitcheralle and Daniel Gilmore, M.S. candidates working on spruce-fir and European larch, respectively, did the laboratory analyses.

Analysis of data collected in managed spruce-fir stands during 1989 showed that response of balsam fir to precommercial thinning (PCT) increased as soil drainage class improved from poorly to moderately well drained (Briggs and Lemin

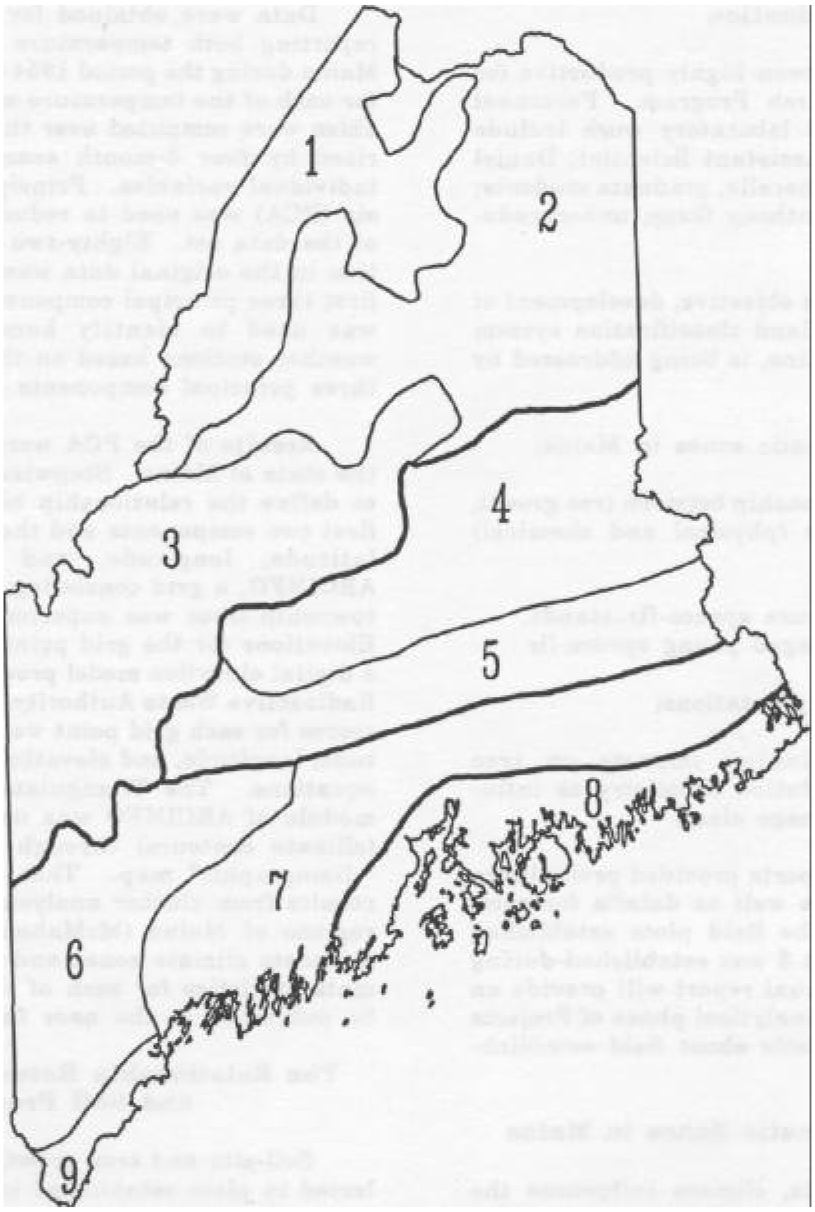

Figure 24. Map of Maine illustrating the location of four broad climatic regions (thicker line) and nine climatic zones (thinner line) within regions.

1991). The data collected in 1990 will strengthen the results of the 1989 data by doubling the sample size and extending the distribution of the plots further across the state. At the present time, analysis of the sample disks that were collected from those trees is almost complete (disks from 10 trees remain). The final data base should facilitate assessment of the impacts of soil fertility, given adequate soil drainage, on productivity.

Foliar Chemistry and Response to Precommercial Thinning

In order to determine if differences in site quality are reflected in levels of foliar nutrients, the plots established in 1989 and 1990 in precommercially thinned stands were revisited during the last week of July, 1991. Foliage samples were collected from three remaining dominant and codominant trees, transported to the laboratory, and dried at 65 C. Samples are currently being processed for chemical analysis and will be analyzed for N, P, K, Ca and Mg. The relationship among foliar nutrients, soil exchangeable cations, and tree growth response will be evaluated.

Precommercial Thinning, Tree Growth, and Water Quality

Two new projects were initiated in 1991: (i) Assessing Impacts of PCT on Tree Growth and Soil Solution Chemistry; and (ii) Development of a Distance Dependent Growth Model for Spruce and Fir in Intensively Managed Stands. Funding for (i), a cooperative project involving CFRU, USDA Forest Service, and University of New Hampshire, has been provided by the USDA Cooperative States Research Service. Funding for the travel required for (ii), a cooperative project involving University of New Brunswick, Canadian Forestry Service, and CFRU (R. Seymour and R. Briggs) has been provided by the Canadian-American Center, University of Maine.

Our work with site quality and PCT has shown the tremendous increase in individual tree growth associated with PCT. Following PCT, volume increment increases as drainage class improves from poorly to moderately well drained. The timing and magnitude of the response of spruce and fir to PCT suggests that available water and nutrients are increased substantially. This increase in resource availability raises several questions: (i) does the increase in soluble nutrients in the rooting zone exceed the uptake capacity of the remaining crop trees; and (ii) how much time is required for plant uptake to equal or exceed the increase in available nutrients? If (i) does not occur, then (iii) can tree growth be increased even more by N fertilization; and (iv) how much N is leached below the rooting zone following fertilization? Finally (v) is there any relationship between ground water deep in the basal till and the water perched on top of the basal till? Stated in another way, do forest management practices have any impacts on deep ground water?

These issues are being addressed at the Weymouth Point Watershed (T4 R12, Maine). The distribution of nutrients in the vegetation, soil solution, and stream water has been intensively monitored since 1979 on paired (uncut and whole-tree harvested) watersheds, under the direction of Dr. Maxwell McCormack. The treatment watershed was whole-tree harvested in 1981, and a conifer release treatment (triclopyr) was applied aerially in 1985. Stream and soil solution chemistry were monitored monthly through 1988. The spruce-fir regeneration has attained the size and density recommended for PCT. The intensive monitoring of the site since the initiation of the new stand was a primary factor in attracting outside funding' to study impacts of PCT.

During the 1991 field season, 27 plots (10 m X 10 m) were located in densely stocked areas of spruce-fir regeneration distributed across three drainage classes: moderately well (MWD), somewhat poorly (SPD), and poorly (PD) drained. Three treatments (control, PCT, and PCT + fertilization) were randomly assigned to each block within drainage classes. Due to the distribution of drainage class and regeneration density, there were 3, 4, and 2 blocks for each of.the PD, SPD, and MWD soils, respectively.

At the end of the growing season, 25-30 crop trees (1.8 m X 1.8 m spacing) were identified on each plot (including controls). Crop trees were numbered, labelled with aluminum tags, and measured for: diameter at the base and at 1.37 m, total height, height to live crown (defined by presence of current year growth), and projection of crown radii. Two 2-m-wide strips were randomly selected and total height, diameters at base and at 1.37 m were measured for each stem above 1.37 m in height.

Three pairs of soil solution samplers were installed at 25- and 50-cm depths below the soil surface on the MWD and SPD plots. Due to the limited soil depth on PD plots, three soil solution samplers were installed only at 25 cm below the surface.

During the first week of August, a bulldozer was used to construct three access roads for well installation. Seven wells were installed at depths ranging from 4.5-8.5 m below the soil surface, deep into the basal till. The equipment used to drill the wells is illustrated in Figures 25 and 26. The initial goal was to drill the wells 6-7.5 m below the surface. Although wells were drilled following a lengthy period of low precipitation, ground water was within 4 m of the surface on the flat portion of the watershed. Once water was encountered, it was impossible to drill any deeper because the well hole collapsed.

Each well was cased using PVC pipe (4 cm id). A 1.5-m slotted pipe section, capped at the bottom, was placed in each hole and connected to an unslotted 3-m section; additional sections were added as necessary until the casing rested in the bottom of the well and protruded approximately 30 cm from the ground surface. Pool filter sand was poured down the hole surrounding the slotted section of well casing. Bentonite pellets were poured over the sand to seal the well from surface water flow. Installation of the well casing is shown in Figure 27. Six of the wells were dug in basal till; one was installed into bedrock underlying 1 m of soil.

Figure *25*. Drilling unit used for excavation of deep wells.

Soil solution, well, and stream water samples were collected in mid-September and again in mid-October. Depth of water from the ground surface in the wells was recorded. Following collection of the October samples, PCT treatments were applied to the plots. Fertilization treatments will be applied in the fall of 1992. Monthly sampling of soil solution, well, and streamwater will be done April-October.

Water samples are being analyzed for nitrate, ammonium, P, K, Ca, Mg, Mn, Al, Cl, sulfate, and pH. The USDA Forest Service Laboratory at Durham, NH, is doing the analysis for Cl and sulfate. The remaining analyses are being conducted by the Analytical and Technical Laboratory at the University of Maine.

In summary, a great deal of data have been collected under the site quality program. The two cooperative projects initiated during the past year will add to our understanding of site quality and

Figure 26. Close up of the drill head.

Figure 27. Installation of PVC well casing.

intensive management. As this report goes to press, we are sitting on the tip of an iceberg of data that will translate into a productivity-oriented site classification system. Analysis of the spruce-fir and larch data will progress rapidly now that the laboratory analyses have been completed. In addition, the analysis of the soil-site data collected by students of Dr. Ralph Griffin since the late 1960s is in the final stages. Jim Steinman, Ph.D. candidate working on those data, expects to defend his dissertation in December.

The Future

As we begin to synthesize all of this material over the next year and develop the site classification system, the emphasis will shift from conifers to hardwoods. Addressing site productivity in hardwood stands will be more difficult, due to the long history of disturbance; we will not have the advantage of large expanses of relatively even-aged, homogeneous spruce-fir stands. Nevertheless, it represents an exciting challenge. Currently, we anticipate evaluating some of Leak's biophysical classification work, assessing how far east that the system can be applied. Beginning in western Maine, we hope to use that classification system as an initial stratification within which the impacts of soil physical and chemical properties on site productivity will be emphasized.

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TREE IMPROVEMENT

Dr. Michael S. Greenwood and Throstur Eysteinsson

Accelerated Larch Breeding Program

1991 was the fifth year of the accelerated breeding and testing program for larch, initiated by Drs. Michael S. Greenwood and Katherine K. Carter in 1987. The objective was to set up a program for demonstration and research in accelerated tree breeding, including research in flower stimulation, pollination, seed production, and progeny testing, and in the process, to create improved (with respect to volume growth, wood properties, straightness) families of tamarack, exotic larches and hybrids (Greenwood and Eysteinsson 1989, 1990).

The program has progressed as follows:

1987. Parental population selected and grafted, 6 clones each of native tamarack, Japanese and European larch (one European larch clone didn't graft well and was discarded).

1987-1989. Accelerated growth in a greenhouse.

1989-1990. Flower stimulation.

1990-1991. Controlled pollination and seed production.

1991-1993. Establishment of progeny tests.

In the near future, approximately 5-10 years from now, it may be possible to select superior families and individuals from among the second generation progeny for continued accelerated breeding to produce a third generation. The option to start mass production of improved larch via rooted cuttings or by establishing seed orchards can be implemented now using putatively improved material (untested but of known parentage) and in as little as 5 years using selections from progeny tests.

Flowering and Seed Production

Flower stimulation using the plant growth regulator gibberellin ($GA_{4/7}$) has been very successful in tamarack (Greenwood and Eysteinsson 1989, 1990; Eysteinsson and Greenwood 1990), and has, in fact, made indoor breeding of tamarack possible. Japanese and European larch have not responded significantly to $GA_{4/7}$ in our experiments as yet. Nevertheless, greenhouse conditions led to sufficient flowering of both species in 1991 (Table 2). One more flower stimulation study, utilizing stem injections of GA^, was initiated on European and Japanese larch in 1991, with results forthcoming in March, 1992.

Seed viability from 1990 crosses was tested in spring, 1991 (Table 3). The seed set obtained from intra-specific crosses and the European x Japanese hybrid cross compared favorably with published reports of seed set from larch seed orchards, natural stands, and controlled crosses (Earner and Christiansen 1960; Hall 1985; Kosinski 1987). Seed viability resulting from controlled crosses varies, but rarely exceeds 70% (Hall 1985), and seed viability from larch seed orchards and natural stands is usually quite low, often 10%-30% (Kosinski 1987; Greenwood and Eysteinsson 1989).

Of the 124 crosses made in the indoor breeding orchard in 1990 and 1991, 20-30 can be expected to yield very poor seed viability due to incompatibility, especially the tamarack x Japanese larch hybrid and to a lesser extent the tamarack x European larch hybrid cross (Table 3). Another 20 or so crosses yielded small families (few cones used and/or little pollen available). These families/individuals can be multiplied via rooted cuttings and tested in clonal field trials in the future if desired. The other 70 or so families are sufficiently large to be included in traditional seedling progeny tests in one or more places.

Table 2. Summary of indoor larch breeding orchard flowering and crosses made in 1990 and 1991.

	Tamarack		Japanese larch		European larch	
	1990	1991	1990	1991	1990	1991
No. clones	6	6	6	6	5	5
No. clones w/females	5	6		3		4
No. clones w/pollen	2	6	2	5	1	5
No. female cones	1207	1781		144		605
No. crosses made	27	41	4	15	1	32

Table 3. Seed viability from crosses made in the indoor larch breeding orchard in 1990. T = tamarack, J = Japanese larch, E = European larch.

Cross	No. Crosses	Seed Viability (%) Mean	Best	Worst
T x T	8	54	68	40
J x J	3	44	49	37
E x J	3	56	61	47
T x E	4	8	14	2
T x J	18	0.8	2.3	0

Progeny Testing

A small progeny test was established in a field at the University of Maine in July, 1991. This test included 12 families produced in the indoor breeding orchard in 1990, 6 European larch seed sources and 1 European x Japanese larch hybrid family (half-sib) provided by S. D. Warren Co., and open-pollinated tamarack from the International Paper Co. seed orchard at Rowland, Maine. This test will compare our breeding orchard progeny to some of the best larch seed sources currently available for this region. It includes 21 individuals per family/seed source, planted at close spacing in a small area, and should yield accurate comparisons of early growth. However, it will need to be thinned in 5 years or so, resulting in less accurate long-term information. A larger, long-term progeny test, including 50 families and 30 individuals per family, is scheduled to be planted in a clearcut in Johnson Mountain Township, Maine, in the spring of 1992.

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TREE IMPROVEMENT

Dr. Katherine K. Carter

Black Spruce Family Tests

Three black spruce plantations consisting of 70 open-pollinated half-sib families collected from 16 different stands located throughout Maine were evaluated after 11 growing seasons. All three plantations were established in May 1981 using "plug+2" seedlings (containerized seedlings transplanted into nursery beds for 2 years). Seedlings averaged 10 in. tall at the time of planting.

All three planting sites were on cut-over forest land that had previously supported conifer or mixedwood stands. The first site is located near Loon Lake in T5R14 on a deep, well-drained silt loam soil. The second site is on a shallow, poorly drained sandy loam in Brassua Township. The third site is located in Rowland, on a moderately well drained to somewhat poorly drained loamy sand. Plantations were treated as needed to control competition. Height of trees at all three field sites was measured at the end of the third, fifth, ninth, and eleventh growing seasons.

Overall growth through age 11 has been excellent at Loon Lake and Rowland, where trees average 13.2 ft and 13.6 ft tall. As would be expected at the poorer site in Brassua, growth is slower but still averaged 11.9 ft. All of these growth rates are superior to those observed for New Brunswick plantations established with 2-2 bareroot stock on a variety of soil types (Fig. 28, van Groenewoud and Ruitenberg 1982). At the best New Brunswick site, on a well-drained silty sand, height growth between ages 6 and 10 averaged 15.7 in. per year, while at Loon Lake the trees grew an average of 17.0 in. per year over the same ages. The New Brunswick data indicates that yearly height growth should increase as the trees move into the 15- to 20-year age class (Table 4).

In all three plantations, there are significant differences among family mean heights. At Rowland, for instance, the tallest family averaged 16.0 ft in height at age 11 and the shortest averaged 10.3 ft. There was no correlation, however, between the growth rate of the parent trees and their half-sib offspring. This finding is in agreement with other studies which indicate that selection of superior trees should be based on the family selection method rather than on plus-tree

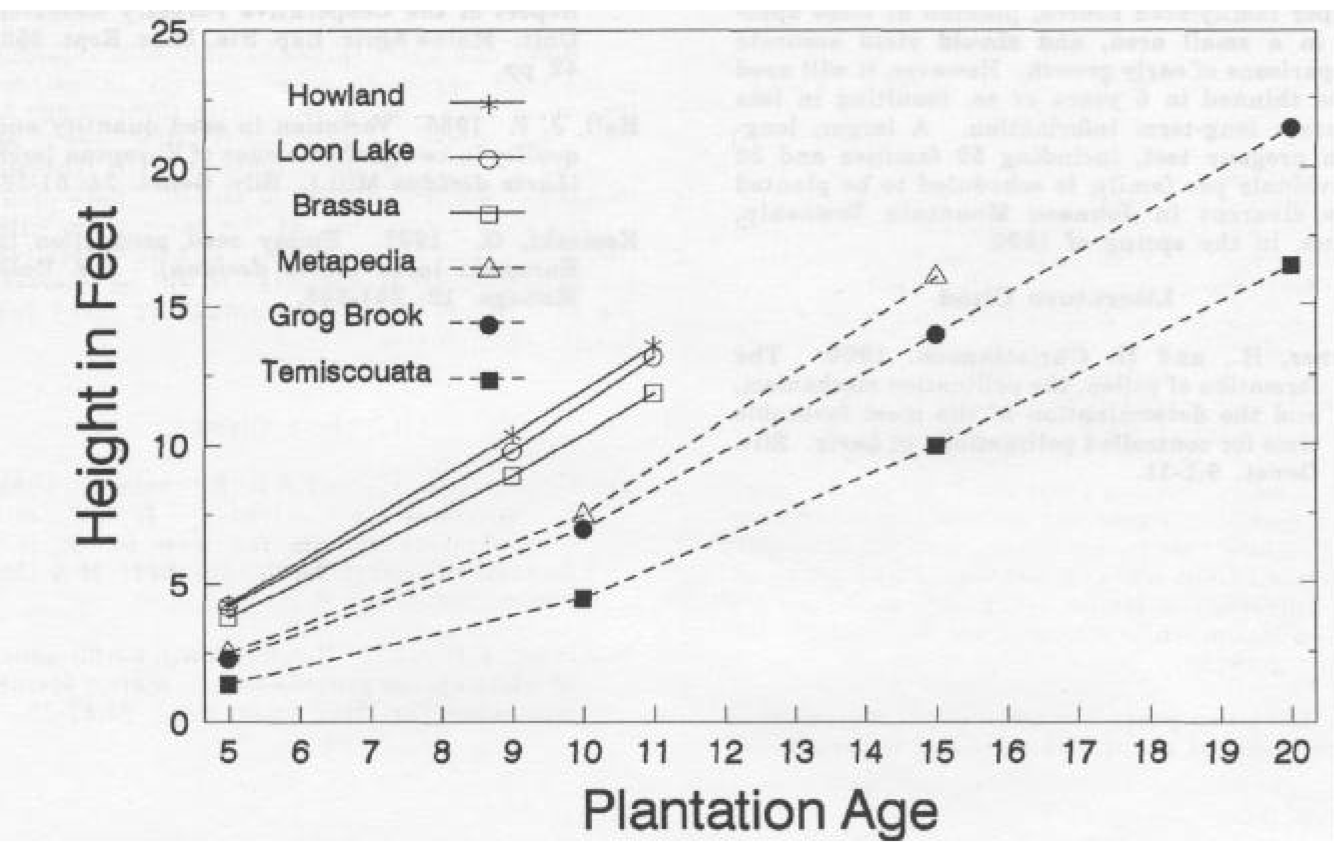

Figure 28. Height growth of black spruce plantations in Maine (—) and New Brunswick (---). New Brunswick data is from van Groenewoud and Ruitenberg, 1982.

Table 4. Mean yearly height growth (inches per year) of black spruce plantations in Maine and New Brunswick[1].

	Maine			New Brunswick		
Ages	Loon Lake	Brassua	Rowland	Matapedia	Grog Brook	Temiscouata
6-10	17.0	15.5	17.7	15.7	14.2	10.2
10-15	20.4	18.0	19.2	18.9	16.2	12.7
15-20	ND[2]	ND	ND	ND	18.5	16.6

[1] Data for New Brunswick adapted from van Groenewoud and Ruitenberg 1982.

[2] No data.

selection in natural stands.

The families in the top third for height in these tests came from eleven different stands located throughout western, central, and northern Maine. Nine of the families tested in these plantations were in the top 30% for height at all three sites. Planting of only these nine families would give an average 11-year height of 14.5 ft at Rowland, 13.4 ft at Brassua, and 14.3 ft at Loon Lake, a gain of about 7% in height over the plantation means. We will continue to analyze growth patterns in these plantations to determine the effects of genetic differences and of site quality on growth rates.

Ottawa River Valley White Spruce Family Tests

A progeny test of 112 families of white spruce from the Ottawa River valley in Canada was also planted in 1981. Previous provenance tests had demonstrated that bulk collections of white spruce seed from the Ottawa River valley produced seedlings with superior growth rates, when grown on a variety of sites ranging from North Dakota to Maine. The superiority of bulked Ottawa River valley provenances has been demonstrated through age 15 in central Maine, where the Ottawa River provenance was 12% taller than white spruce from local seed collections (Wilkinson 1977). In order to further investigate the performance of Ottawa River white spruce, seed was obtained from 112 separate parent trees in that region and grown at the University of Maine, along with seed from six native Maine white spruce trees selected for superior growth.

After two years in the nursery, Maine seedlings averaged about 5 in. tall and Ottawa River seedlings about 6 in. tall (a 19% difference). All seedlings were then established in a plantation near Loon Lake, adjacent to the black spruce family test described earlier. Soil at this site is a deep, well-drained silt loam judged to be favorable for white spruce. These seedlings were remeasured after nine growing seasons, at which time their height averaged 6.9 ft for Maine seedlings and 8.1 ft (or 17% greater) for Ottawa River seedlings. These results confirm that Ottawa River white spruce families maintain their growth advantage over local seedlings through age 9 (age 11 from seed). There is also significant variation among the families; the tallest Ottawa River family averaged 10.1 ft in height.

Since this white spruce plantation is adjacent to the black spruce described above, it is instructive to compare their growth rates through age 9. The black spruce averaged 9.8 ft tall at age 9, as opposed to white spruce heights of 8.1 ft (Ottawa River) and 6.9 ft (Maine seed source). Both plantations were established at the same time, with similar types of planting stock, and have received the same cultural treatments. It will be interesting to contrast the future growth of these two species on this site.

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van Groenewoud, H., and A.A. Ruitenberg. 1982. A productivity oriented forest site classification system for New Brunswick. Canadian Forestry Service Inf. Rept. M-X-136. Fredericton, NB. 9 p.

Wilkinson, R.C. 1977. Height growth performance of white spruce provenances in central Maine. Northeast For. Tree Impr. Conf. 25:87-93.

SLUDGE AND ASH

Dr. Robert K. Shepard, Jr.

Introduction

During the past year, growth measurements were made at the five locations where ascertaining the effect of sludge or ash on tree growth is one of the objectives. Foliage samples for determination of nutrient concentrations were taken at all locations. Soil samples were also taken at all locations. Analyses of foliar nutrient concentrations were completed. Analyses of soil samples are still in progress. This report emphasizes tree growth, foliar nutrient concentrations and growth of competing vegetation. Results are presented by location.

Location 1

Treated plots received a combination of primary (80%) and secondary (20%) papermill sludge in early October, 1989, at a rate of approximately 40 dry tons per acre. Diameter growth of the planted red pine was significantly increased by the sludge in 1991, being 0.19 in. greater than growth of trees in the control plots (Fig. 29). Two-year diameter growth was also significantly greater (1.20 in. vs. 0.97 in.). Diameters were measured at 3 ft above ground on all trees, because when the plots were established, some trees were less than 4.5 ft tall.

Diameter growth increased in spite of a large increase in the amount of competing vegetation, which was primarily raspberry and goldenrod. Samples of vegetation taken from all plots revealed that the weight of that vegetation was approximately 2.5 times greater in the sludge-treated plots than in the control plots. The red pine were generally at least 2 to 3 ft taller than the competing vegetation at the end of the 1990 growing season. They were apparently large enough to withstand the increased competition from the raspberry and goldenrod and simultaneously to benefit from the sludge application.

The reason for both the increase in the amount of competing vegetation and the improved red pine diameter growth is evident in the nutrient concentrations of foliage samples taken from both the raspberry (September, 1990) and red pine (October, 1990) (Table 5). Concentrations of nitrogen, potassium, and phosphorus in raspberry foliage from the treated plots were significantly greater than foliage from the control plots. The difference in nitrogen concentrations was especially large, being 0.65% (2.52% vs. 1.87%). Improved nutrient conditions undoubtedly caused the additional raspberry growth. In addition, the palatability of the raspberry was apparently increased, as evidenced by the heavy browsing of the raspberry by deer and moose along the game trails. An increase in nitrogen and some other elements should enhance the protein content of the vegetation, improving its nutritive value.

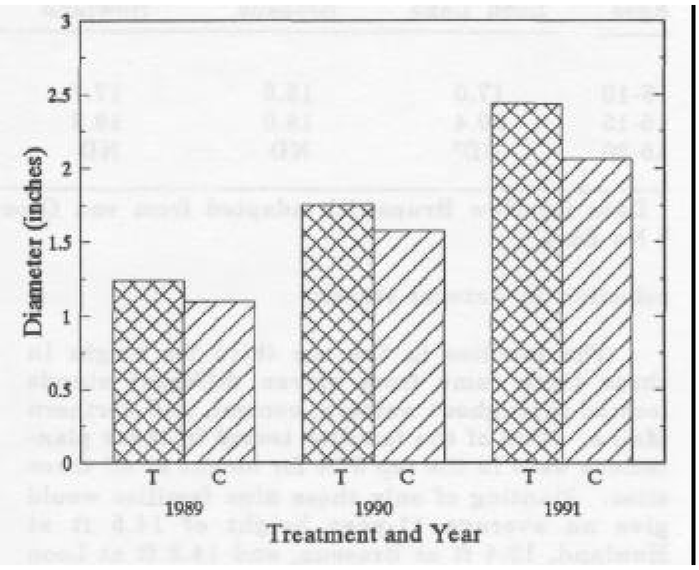

Figure 29. Stem diameter of red pine in plots treated with a mixture of primary and secondary papermill sludge (T) at a rate of 40 dry tons per acre and in control plots (C). Sludge was applied in early October, 1989.

Foliar concentrations of aluminum, boron, manganese, and iron were significantly less in the treated plots. Lower concentrations of these elements would be expected in view of the higher soil pH in the treated plots, which tends to reduce the availability of these elements. Large reductions of iron and boron might negatively affect growth of the competing vegetation through the creation of deficiencies of these elements.

Nitrogen concentrations in red pine foliage from treated plots were significantly greater than in foliage from the control plots. Potassium and phosphorus concentrations were also somewhat higher, but not significantly so. The higher nitrogen concentrations are especially important, because concentrations of that element in foliage from the control trees indicate that insufficient nitrogen may be limiting growth on this site. Hence, any improvement in the nitrogen status of the red pine should enhance growth.

Table 5. Concentrations of elements in red pine foliage from plots treated with a combination of primary and secondary papermill sludge at a rate of 40 dry tons per acre and from control plots. Samples were taken after the first growing season following treatment.

Element	-Treated-		- Control-	
	R[1]	RP	R	RP
		Of A 4-		
Nitrogen	2.52	1.30	1.87	1.09
Calcium	0.891	0.122	0.904	0.112
Potassium	1.33	0.519	1.11	0.461
Magnesium	0.296	0.073	0.298	0.071
Phosphorus	0.278	0.121	0.164	0.108
Aluminum	24.5	166	48.9	176
Boron	26.4	11.8	37.8	12.4
Iron	59.2	35.6	73.5	32.4
Manganese	642	439	1250	371
Zinc	32.4	27.2	35.4	25.8
Copper	6.17	2.84	5.43	2.45

R = raspberry, RP = red pine

It is worth noting that concentrations of aluminum, manganese, boron, and iron were not significantly lower in red pine foliage from treated plots, and that in general the red pine was less sensitive to the nutrients added by the sludge than was the raspberry. This is probably due to the lower nutrient requirements of the red pine and the larger root systems that occupy a greater volume of soil than the more shallow root systems of the raspberry. Because the red pine root systems occupy a larger soil volume than the raspberry root systems, pH effects will be slower to occur and may be less pronounced and have a smaller effect on foliar nutrient concentrations. It is possible that red pine foliage nutrient concentrations taken after the 1991 growing season will exhibit more of an effect of the sludge.

Location 2

Plots at this location received a mixture of primary (80%) and secondary (20%) sludge applied at a rate of approximately 20 dry tons per acre in mid-June, 1989. Diameter growth of planted red pine, measured 1 ft above ground, was not increased significantly by the sludge application during any year, although during 1990, growth of the treated trees was 0.09 in. greater than growth of the control trees (Fig. 30). As at Location 1, growth of the red pine was good, averaging about 0.5 in. per year.

Examination of foliar nutrient concentrations provides at least part of the reason as to why there was no diameter growth response (Table 6). There were no significant differences in concentrations of any nutrients in foliage produced during either 1989 or 1990. As with Location 1, this area appears to be nitrogen deficient, but nitrogen levels in the foliage were not increased by the sludge application.

Competing vegetation, which consisted primarily of grasses and sedges, was not stimulated by the sludge application. Samples of this vegetation, taken from all plots, showed no difference in dry weight between treated and control plots. Raspberry was absent from this area.

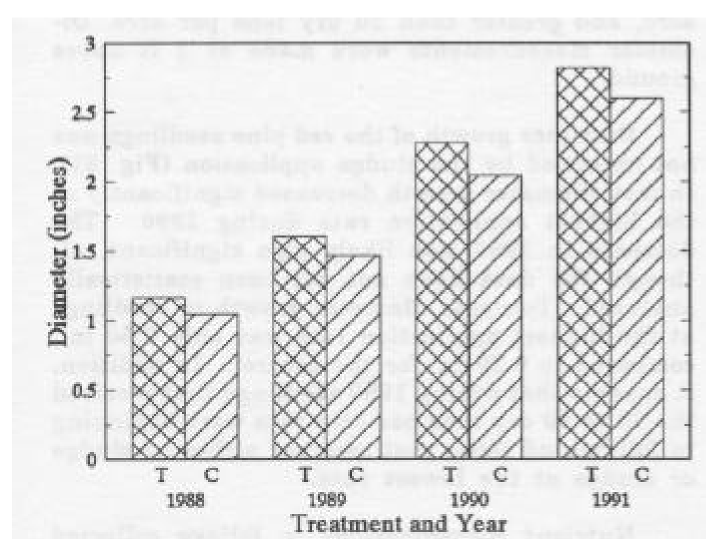

Figure 30. Stem diameter of red pine in plots treated with a mixture of primary and secondary papermill sludge (T) at a rate of 20 dry tons per acre and in control plots (C). Sludge was applied in mid-June, 1989.

Table 6. Concentrations of elements in red pine foliage from plots treated with a combination of primary and secondary sludge at a rate of 20 dry tons per acre and from control plots. Samples were taken after the first and second growing seasons following treatment.

Element	•1989-		•1990-	
	Treated	Control	Treated	Control
		V d t		
Nitrogen	1.11	1.05	1.28	1.23
Calcium	0.162	0.138	0.141	0.135
Potassium	0.594	0.695	0.557	0.671
Magnesium	0.086	0.080	0.099	0.094
Phosphorus	0.139	0.146	0.133	0.140
		[illegible]		
Aluminum	217	206	190	223
Boron	10.4	9.7	11.1	12.7
Iron	34.1	33.3	32.9	32.1
Manganese	100	104	69	90
Zinc	28.8	26.9	30.4	30.7
Copper	2.92	2.74	2.63	2.49

Location 3

This site was treated with a mixture of primary (80%) and secondary (20%) sludge in September, 1989. The application rate was highly variable, ranging from as low as 5 to 10 dry tons per acre to in excess of 60 dry tons per acre. Some areas were left untreated. After the sludge was applied, red pine seedlings were selected for growth measurements and foliar nutrient concentration determinations. The seedlings ranged in height from about 1.5 ft to 3 ft. Four broad sludge application rates were chosen: 0 dry tons per acre, 5 to 15 dry tons per acre, 15 to 30 dry tons per acre, and greater than 30 dry tons per acre. Diameter measurements were made at 1 ft above ground.

Diameter growth of the red pine seedlings was not improved by the sludge application (Fig. 31). In fact, diameter growth decreased significantly at the highest application rate during 1990. The decrease in 1991 was likely also significant, although the data have not yet been statistically analyzed. Two-year diameter growth of seedlings at the highest application rate was only 0.50 in., compared to 0.70 in. for the control. In addition, it appears that during 1990 seedlings that received the 15 to 30 dry tons per acre rate were beginning to fall behind those that received either no sludge or sludge at the lowest rate.

Nutrient concentrations in foliage collected after the 1990 growing season offer no explanations for the reduced growth at the highest application rate (Table 7). There was a significant increase in magnesium at all of the non-zero treatments. Magnesium concentrations in the foliage of the control seedlings are low, indicating a deficiency. An increase in foliar magnesium would be expected to improve growth, because the element is essential to chlorophyll production. Differences in nitrogen concentrations among treatments were not significant, although there is a suggestion of some increase in nitrogen concentrations in foliage from the seedlings that received the highest sludge rate.

Aluminum, manganese, and boron all decreased as application rate increased, presumably the result of successively higher soil pH and reduced availability of those elements for root uptake. These seedlings were considerably smaller

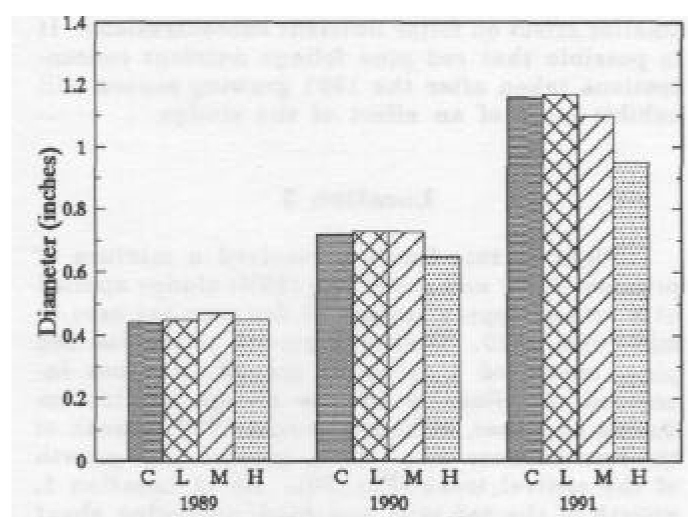

Figure 31. Stem diameter of red pine in plots treated with a mixture of primary and secondary papermill sludge at four rates (C = 0, L = 5 to 15, M = 15 to 30, H = 30+ dry tons per acre). Sludge was applied in September, 1989.

Table 7. Concentrations of elements in red pine foliage from plots treated with a combination of papermill sludge at four rates (Control = 0, Low = 5 to 15, Medium = 15 to 30, High = 30+ dry tons per acre). Samples were taken after the first growing season following treatment.

Element	Treatment			
	Control	Low	Medium	High
	Of A			
Nitrogen	1.18	1.14	1.21	1.28
Calcium	0.217	0.227	0.236	0.215
Potassium	0.380	0.400	0.373	0.360
Magnesium	0.055	0.073	0.080	0.078
Phosphorus	0.098	0.101	0.101	0.106
	----- mg/kg -----			
Aluminum	230	243	214	178
Boron	13.2	11.2	10.8	8.1
Iron	38.3	30.9	28.1	30.4
Manganese	842	746	686	632
Zinc	35.3	34.8	38.8	37.2
Copper	4.02	4.31	4.73	4.46

than the trees at the two previous locations, with smaller, shallower root systems. They thus responded faster to the changes in soil pH. It should be stressed that reductions in foliar aluminum and manganese are not necessarily detrimental. Plants have no known requirement for aluminum, and both aluminum and manganese may be toxic in high concentrations, which may occur on highly acidic soils.

Competition from raspberry developed rapidly in this area during 1990. Although differences in the amount of raspberry among treatments were not quantified, differences were evident. The amount of raspberry increased as sludge application rate increased. Based on raspberry foliar nutrient concentrations from Location 1, there seems little doubt that raspberry at Location 3 benefitted substantially from the sludge and that competition from the raspberry caused the reduced diameter growth of red pine seedlings at the highest application rate.

Three additional points should be noted. First, the red pine at Location 3 were considerably smaller than at Location 1. Many seedlings that received the highest rate were overtopped by the raspberry and subjected to severe competition. The crowns of many of the seedlings should begin to extend above the raspberries during 1992 and once that occurs, seedlings should show less of an effect from the competition. Second, although diameter growth decreased, presumably due to the increased competition, the competition was not severe enough to increase mortality. Third, there was a difference of only 0.03 in. among the mean pretreatment diameters of seedlings in each of the four treatments. This means that the significantly slower diameter growth at the highest sludge application rate did not happen because those seedlings were substantially smaller than the remaining seedlings when the sludge was applied.

Location 4

Plots in this area were treated with wood ash at a variety of rates ranging from 0 to 15 tons of calcium carbonate equivalent per acre in early November, 1989. Trafficability was poor when the plots were treated, and the spreader did not disperse the ash properly, thus leading to a range of application rates. Therefore, results are presented here for the control plots and for all treated plots combined.

Growth of the planted red pine did not increase significantly during the 2 years following treatment with the wood ash (Fig. 32). Growth of trees from both treated and nontreated plots was virtually identical for each of the two years following treatment, and for the two years combined it was 1.23 in. for trees from the control plots and 1.20 in. for trees from the treated plots.

Growth of raspberry, the primary species of competing vegetation, was stimulated by the wood ash application. Overall, dry weight of raspberry averaged 50 percent greater on the treated plots, but on some treated plots it was more than twice the mean dry weight of raspberry on the control plots. The reason for the absence of a tree growth response and the increase in density of raspberries can be seen in the foliar nutrient concentrations. There were no differences in any red pine foliar nutrient concentrations between treated and control plots (Table 8). Based on this, there was no reason to expect a tree growth response. On most sites, nitrogen is the element most important to increased tree growth. The wood ash contains virtually no nitrogen, and thus, the element most essential to increased tree growth was not added to the site. In contrast, the raspberry foliage showed increases in potassium, magnesium, and especially in phosphorus. Requirements of hardwoods and herbaceous vegetation for a variety of nutrients are generally greater than requirements of conifers, and it appears that nutrients contained in the ash increased raspberry growth.

Location 5

Treatment at this location consisted of a combination of wood ash and secondary papermill sludge applied to plots at four different rates: 0, 2.4, 4.8, and 9.6 dry tons per acre; three different times during the spreading season, late May, late July, and early October; and for one, two, or three years in succession. The area had been planted to black spruce two years before the study began. Root collar diameters were measured before the 1988 growing season, the first year during which treatments were applied, and after the 1988, 1989, and 1990 growing seasons. Foliage samples were taken after the 1988, 1989, and 1990 growing seasons. Analyses of all of the data are not complete, and this report presents general trends in diameter growth and foliar nutrient concentrations from plots that received the highest application rate for one, two, or three years in succession. Data have been averaged for the three application times in each year.

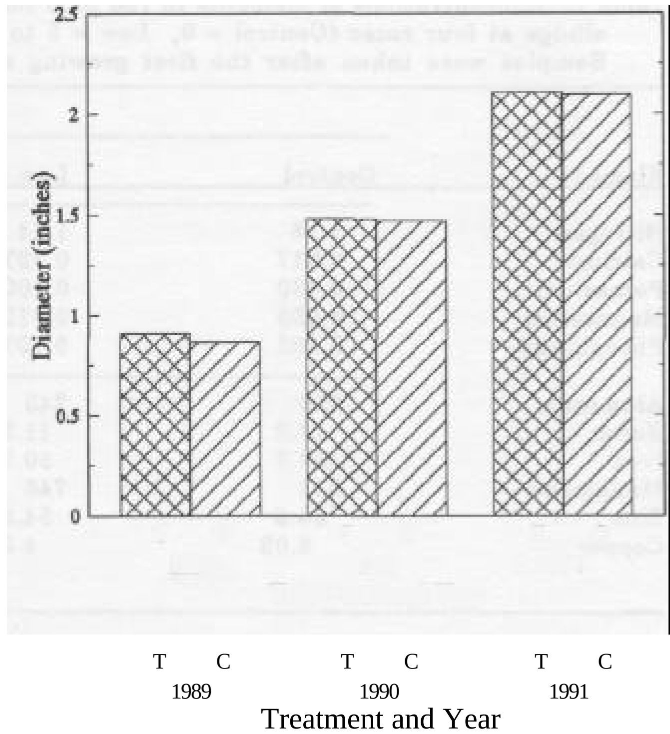

Figure 32. Stem diameter of red pine in plots treated with wood ash at rates ranging from 3 to 15 tons of calcium carbonate equivalent per acre (T) and in control plots (C). Ash was applied in early November, 1989.

Pretreatment (1987) root collar diameters were essentially the same in all treatments. However, with time the mean root collar diameter of seedlings in the control plots has increased by 1.13 in., whereas the mean root collar diameters of seedlings in the 4.8 and 9.6 tons per acre treatments increased by 0.92 in. and 0.93 in., respectively (Fig. 33).

Table 8. Concentrations of elements in raspberry and red pine foliage from plots treated with wood ash at rates from 3 to 15 tons of calcium carbonate equivalent per acre and from control plots. Samples were taken after the first growing season following treatment.

Element	-Treated-		-Control-	
	R[1]	RP	R	RP
Nitrogen	1.83	1.27	1.88	1.35
Calcium	0.642	0.130	0.781	0.145
Potassium	1.35	0.56	1.06	0.49
Magnesium	0.480	0.091	0.383	0.090
Phosphorus	0.363	0.130	0.198	0.116
Aluminum	15.1	180	29.7	190
Boron	41.3	13.3	28.5	11.5
Iron	39.9	32.7	42.5	32.2
Manganese	367	242	848	277
Zinc	24.1	31.2	27.3	37.0
Copper	5.25	2.80	5.78	3.25

[1] R = raspberry, RP = red pine

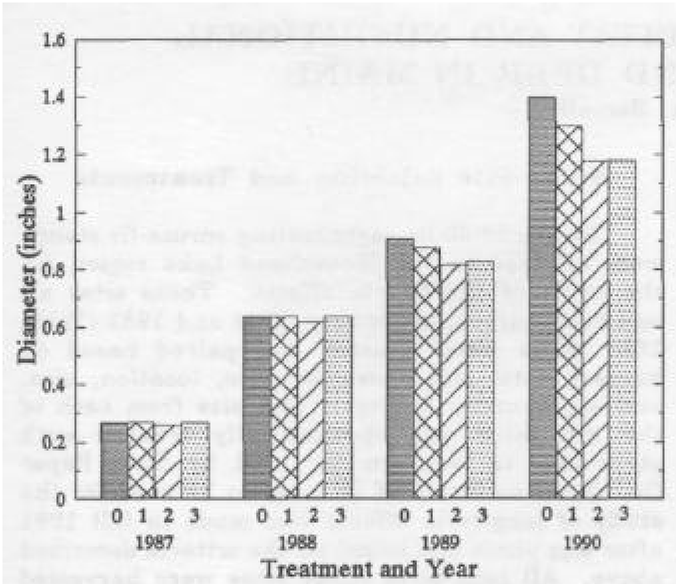

Figure 33. Root collar diameter of black spruce seedlings treated with a combination of secondary papermill sludge and wood ash at four different rates (0 = 0, 1 = 2.4, 2 = 4.8, 3 = 9.6 dry tons per acre) for 1, 2, and 3 years in succession. The first treatments were applied in May, 1988.

Foliar nutrient concentrations in trees from the control plots, with the possible exception of magnesium, were high enough so as to be not limiting to growth. Concentrations of several nutrients, including potassium, magnesium and boron appear to have increased following treatment, but there is little difference in concentrations in seedlings treated for one, two, or three years in succession (Table 9). Apparently only small amounts of the additional nutrients provided by the second and third applications were taken up by the seedlings.

Aluminum and manganese were somewhat lower in foliage from treated trees, possibly because of reduced availability caused by a rise in soil pH. Both of these elements decreased successively as application rate increased, probably because of successive increases in soil pH. Concentrations of copper also seem to be lower in foliage from the treated trees.

Reductions in root collar diameter growth were likely due to increases in competition from herbaceous vegetation of a variety of species, primarily fireweed; raspberry was absent from this site. This competition became intense in 1989 and has persisted through 1991. To a degree, the area has a checkerboard appearance due to stimulation of the competing vegetation. The perimeters of many plots were clearly delineated by this vegetation, which was denser in plots that received the higher application rates.

Additional Work

Six-year measurements were made in the white pine nitrogen fertilization plots, and eight-year measurements were made in the red spruce fertilization plots. This completes the measurements for these two studies.

Table 9. Concentrations of elements in black spruce foliage from plots treated with a combination of secondary papermill sludge and wood ash at a rate of 9.6 dry tons per acre. Plots were treated for 1, 2, or 3 years in succession, with the first application in 1988. Foliage samples were taken after the 1990 growing season.

Element	Number of Applications			
Nitrogen	2.06	1.97	1.86	1.93
Calcium	0.503	0.510	0.487	0.446
Potassium	0.500	0.556	0.560	0.581
Magnesium	0.074	0.091	0.087	0.100
Phosphorus	0.215	0.214	0.205	0.203
		met l\r rt g/Kg		
Aluminum	90.3	81.6	74.4	66.8
Boron	24.0	29.2	28.2	30.6
Iron	63.7	64.2	61.1	61.8
Manganese	1593	1237	1041	990
Zinc	59.4	58.5	58.8	48.0
Copper	4.18	3.90	3.58	3.64

HERBICIDE EFFECTS ON HABITAT AND NUTRITIONAL ECOLOGY OF MOOSE AND DEER IN MAINE

Dr. Frederick A. Servello

Introduction

The purpose of this project is to determine the effects of glyphosate application in regenerating spruce-fir stands on moose nutrition and habitat use and on deer nutrition. This study focuses on the winter season for moose and the summer for deer because it is during these periods that there is the greatest potential for herbicide effects. We also are examining both short-term (1-2 years post-spray) and long-term (7-10 years post-spray) effects of glyphosate application.

The research is being conducted by two M.S. graduate students (Kevin Raymond, Bill Eschholz) and an undergraduate honors student (Justin Vreeland). Dr. Brad Griffith, a co-principal investigator on the project, has left the University of Maine; however, he continues to provide input on the project. Dr. William Krohn, the Leader of the Maine Cooperative Fish and Wildlife Research Unit, has agreed to serve as the co-advisor for Bill Eschholz in place of Dr. Griffith.

Funding for the first year of this project was provided by the Cooperative Forestry Research Unit, the Maine Cooperative Fish and Wildlife Research Unit (USFWS), and Monsanto Agricultural Products Company.

The specific objectives of the project are:

1. to determine the effects of glyphosate on winter browse availability and digestible energy and protein availability for moose, 1-2 and 7-10 years post-treatment;

2. to determine the effects of glyphosate on winter browse utilization and diet quality for moose, 1-2 and 7-10 years post-treatment;

3. to determine if intensity of stand use by moose differs between glyphosate-treated and untreated stands, 1-2 and 7-10 years post-treatment;

4. to determine the effects of landscape-scale habitat characteristics on moose use of glyphosate-treated and untreated stands;

5. to determine the effects of browse availability and stand characteristics on moose use of glyphosate-treated and untreated stands; and

6. to determine effects of glyphosate on food availability for deer in summer, 1-2 and 7-10 years post-treatment.

Study Site Selection and Treatments

Twelve 20-80 ha regenerating spruce-fir stands were selected in the Moosehead Lake region for the study of short-term effects. These sites all had been harvested between 1983 and 1987 (Table 10). Sites were selected and paired based on harvest date, site characteristics, location, size, and surrounding habitat. One site from each of the six pairs was operationally treated with glyphosate in late summer 1991 by Scott Paper Co. Final selection of 28 sites to be used for the study of long-term effects was made in fall 1991 after site visits and based on the criteria described above. All long-term study sites were harvested between 1963 and 1973. Seventeen of these sites were treated with glyphosate between 1982 and 1985. Eleven other sites received no herbicide treatment. No sites have been thinned, except for two sites where thinning occurred on less than 10% of the acreage. Site locations are shown in Figure 34.

Field and Laboratory Accomplishments

Moose habitat use, browse availability, browse utilization, and stand vegetation characteristics were measured on each of the 12 short-term sites in January-March 1991 (prior to treatment of the 6 treatment sites). Browse availability and utilization were measured on 24 sample plots per site. Samples of up to 11 browse species were collected from each site for nutritional analyses (lab chemistry) and for determining twig diameter-weight regressions to compute browse availability and utilization on a biomass basis.

Six aerial surveys were flown on all short-term sites to document moose use, and 3 aerial surveys were flown on 6 long-term sites to test aerial methods. Ground surveys of track counts were performed on the day following each aerial survey to evaluate the accuracy of aerial surveys. The number of aerial surveys in 1991 was limited by low snowfall.

Based on preliminary data analysis, the short-term treatment and control sites had similar levels of moose activity and similar vegetation structure prior to treatment as expected. Data analysis is in progress.

On the short-term sites, aerial surveys found 95% of the track sets observed on the ground surveys; however, aerial surveys were ineffective on the older long-term sites because of the advance regeneration. Our experience with ground

Table 10. Location, harvest date, and glyposate treatment date for study sites used in the moose/herbicide study.

Site type	Township	Treatment Date	Harvest Date
Short-term study			
Treated	Shawtown	1991	1985-86
Control	Shawtown	.	1985-86
Control	Shawtown	-	1985
Treated	Shawtown	1991	1985
Control	Shawtown	.	1986
Treated	Shawtown	1991	1986
Control	Moose River	1991	1987
Treated	Jackman	.	1983
Treated	Johnson Mt.	1991	1986
Control	Johnson Mt.	-	1987
Treated	West Forks	1991	1986
Control	Johnson Mt.	-	1987
Long-term study			
Treated	Brassua	1985	1974-75
	Brassua	1984	1976-77
	Brassua	1985	1977-78
	Long Pond	1982	1973-74
	Long Pond	1982	1973-74
	Long Pond	1985	1973-74
	Smithtown	1984	1974-75
	Smithtown	1984	1974-75
	Smithtown	1984	1978-79
	T5R11	1983	1976
	T4R12	1983	1980
	T4R12	1983	1980
	T4R12	1983	1976
	T4R12	1983	1980
	T4R12	1985	1974
	T4R12	1985	1980
	T4R12	1983	1980
Control	Smithtown		1975-76
	Shawtown		1968
	Shawtown		1965-66
	Shawtown		1971-72
	Shawtown		1970-71
	Long Pond		1969-70
	Long Pond		1973-74
	Thorndike		1966-67
	Parlin Pond		1983
	Sandwich		1966-67
	Sapling		1963-64

surveys in 1991 demonstrated that ground surveys are feasible for a large number of sites, and they allow more surveys per site because weather conditions are less limiting than for aerial methods. Therefore, all moose habitat surveys will be conducted using ground surveys in 1992 and 1993.

Future Plans

Ground surveys of moose habitat use will be conducted on all 40 study sites in winter 1992. Short-term and long-term sites will be surveyed 10 and 6 times each, respectively. Browse surveys and sample collections will be conducted on all short-term sites and one-half the long-term sites in winter 1992. Nutritional quality analyses will be repeated as in 1991. Data analyses will be accelerated in 1992. Planning and preparation for the deer work, which will occur in summer 1992, are in progress.

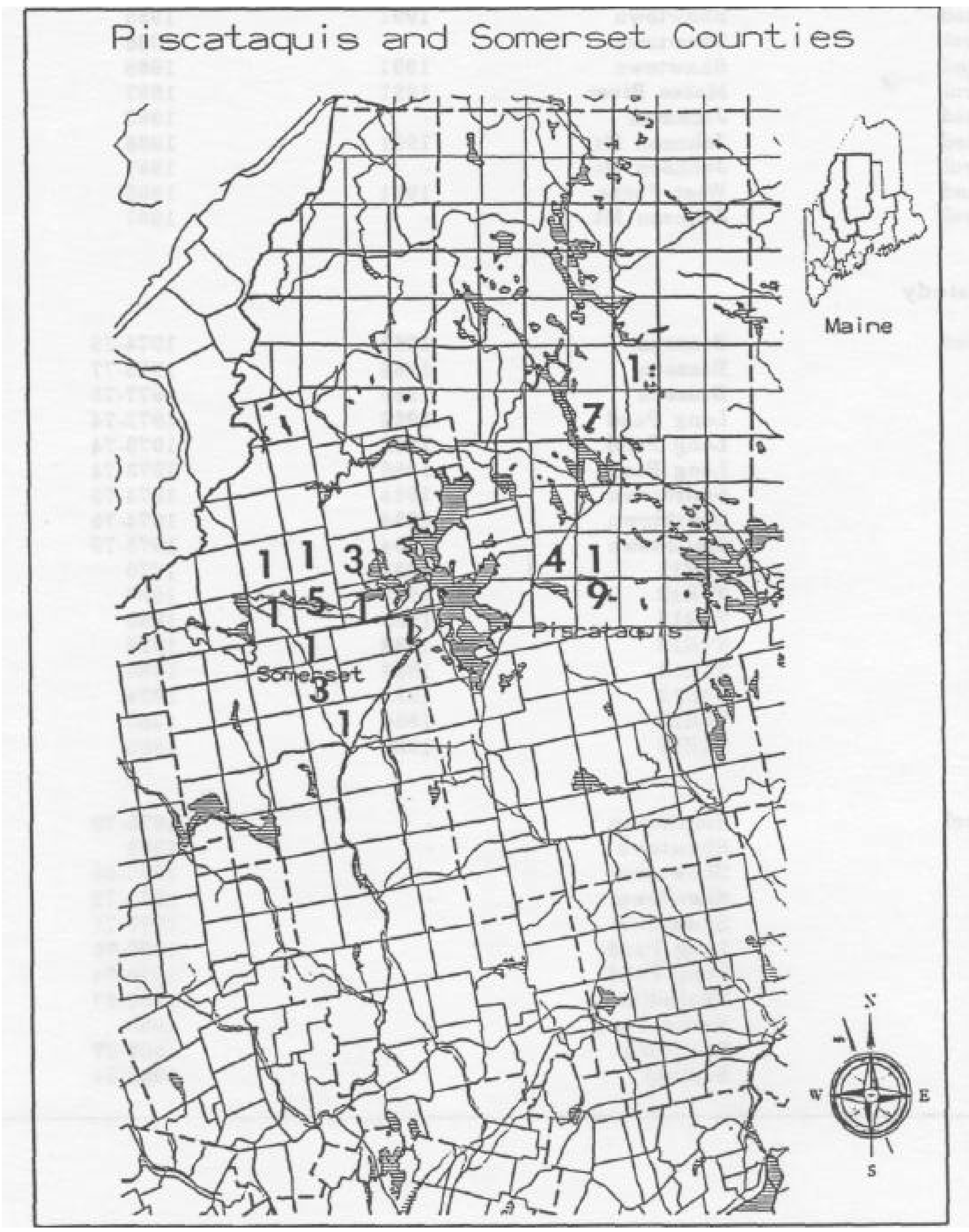

Figure 34. Location of study sites for the moose/herbicide project. Numbers indicate the number of sites in each township.

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Briggs, R.D., and R.C. Lemin, Jr. 1991. Early response of balsam fir to precommercial thinning in the context of site quality, pp. 201-211. *in:* C.M. Simpson, ed., Proceedings of the Conference on Natural Regeneration Management, Fredericton, NB. 261 pp.

Briggs, R.D. 1991. Soil - a dynamic resource. SWOAM Newsletter, May 1991 16(5):5-6.

Carter, K.K. 1991. An examination of the effects of climate on tree growth in multi-location provenance tests, p. 41. *in:* Emerging Issues in Northern Hardwood Management: Air Pollution, Climate Change, and Biodiversity. Ford Forestry Center Misc. Pub. 91-1, 75 pp. (Abstract).

Carter, K.K., and A.G. Snow, Jr. 1990. Virginia pine. pp. 513-519 *in:* R.M. Burns and B.H. Honkala, eds., Silvics of North America, Vol. 1: Conifers. Washington, DC. 675 pp.

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Carter, K., and D. Maass. 1991. A forester's guide to larch in eastern North America. Maine Agric. Exp. Sta. Misc. Rept. 359. 47 pp.

Lautenschlager, R.A. 1990. Response of wildlife to forest herbicide application in the Northeastern United States and Atlantic Canada. *in:* C.W. Murdoch, ed., Proc. For. Veg. Mgmt. Workshop, Col. For. Res., Univ. of Maine. Rept. #90-08:19.

Lautenschlager, R.A. 1991. Red raspberry ecology and the effect of raspberry and other forest brush on white spruce growth. Maine Agric. Exp. Sta. Misc. Rept. 360. 7 pp.

Lautenschlager, R.A. 1991. Response of wildlife in northern ecosystems to conifer release with herbicides. Maine Agric. Exp. Sta. Misc. Rept. 362. 12 pp.

Lautenschlager, R.A., and G.R. Schaertl. 1991. Electrical conductivity of five concentrations of two glyphosate-containing herbicides. S. J. Appl. For. 15:85-88.

Lautenschlager, R.A., and G.R. Schaertl. 1991. Electrical conductivity of two glyphosate-containing herbicides at five concentrations. Proc. Northeastern Weed Science Society 45:65. (Abstract).

Manyazawale, B. 1991. Relationship between the Shigometer reading and the actual state of decay in red spruce *(Picea rubens* Sarg.) M.F. Project Rept. 31 pp.

McCormack, M.L., Jr. 1990. Overview, pp. 8-34. *in:* Proceedings of the Conference on the Impacts of Intensive Harvesting, Fredericton, NB. 105 pp.

McCormack, M.L., Jr. 1991. Herbicide technology for securing naturally regenerating stands. pp. 193-200. *in:* C.M. Simpson, ed., Proceedings of the Conference on Natural Regeneration Management, Fredericton, NB. 261 pp.

McCormack, M.L., Jr., D.B. Field, R.M. Frank, Jr., and R.S. Seymour. Compilers. 1990. Forestry Practices, Goals and Standards for the Improvement, Maintenance, and Protection of the Forest Resources of Maine. Maine Division, New England Society of American Foresters. 24 pp. plus Appendix.

Ostrofsky, W.D., and J.A. Dirkman. 1991. A survey of logging damage to residual stands harvested for wood biomass in southern Maine. Maine Agric. Exp. Sta. Misc. Rept. 363. 8 pp.

Ostrofsky, W.D., and W.C. Shortle. *in press.* Current and potential uses of the Shigometer for forest tree health evaluations. IUFRO.

Schaertl, G.R. *in press.* Glyphosate and imazapyr interact to reduce competition but may injure conifers in Maine. Proc. Northeastern Weed Science Society 45: (Suppl.).

Seymour, R.S., and R.C. Lemin, Jr. 1991. Empirical yields of commercial tree species in Maine. Maine Agric. Exp. Sta. Misc. Rept. 361. 112 pp.

Shepard, J.P., C.A. Nowak, D.C. LeBlanc, R.D. Briggs, and R.B. Downard, Jr. 1990. Influences of acidic deposition and forest development on conifers at Pack Forest, NY. pp. 274-289. in: S.P. Gessel, D.S. Lacate, G.F. Weetman and R.F. Powers, eds., Productivity of Forest Soils. Proceedings of the 7th North American Forest Soils Conference, University of British Columbia, Faculty of Forestry Publication, Vancouver, BC. 525 pp.

Shepard, R.K., Jr., G.A. Reams, and R.C. Lemin, Jr. 1991. Response of eastern white pine to nitrogen fertilization. North. J. of Appl. For. 8(2):83-85

Strauch, P. 1991. The establishment and early growth of red spruce and balsam fir regeneration, pp. 147-155. *in:* C.M. Simpson, ed., Proceedings of the Conference on Natural Regeneration Management, Fredericton, NB. 261 pp.

White, A.S. 1991. The effects of strip clearcutting on regeneration and windthrow in an eastern Maine mixed conifer forest. Final report to Champion International Corp.

ADDITIONAL TECHNOLOGY TRANSFER ACTIVITIES BY CFRU PERSONNEL

Briggs, R.D. Effects of four coniferous species on soil properties. Forestry Seminar. Orono, ME. November 30, 1990.

__________ Forest site classification in Maine. Faculty of Forestry Seminar, SUNY College of Environmental Science and Forestry, Syracuse, NY. February 1, 1991.

___________ The Weymouth Point Watershed - Long-term study of forest management impacts on a spruce-fir ecosystem. CFRU Advisory Committee Field Meeting, Weymouth Point, ME. July 30, 1991.

Briggs, R.D., C.A. Nowak, and E.H. White. Effects of four conifer species on soil properties. Poster presentation. Winter Meeting, New England SAF, Burlington, VT. March 13-15, 1991.

Briggs, R.D., and K.K. Carter. Matching tree species to planting site characteristics. Invited presentation and field tour to Boise-Cascade Corp., Rangeley, ME. June 19, 1991.

Carter, K.K., and Yu-guo Huang. Performance of larch species and hybrids at two locations in Maine. Paper presented to the Northern Forest Genetics Conference, Burlington, VT. July 23-25, 1991.

Carter, K.K., G.W. Adams, and M.S. Greenwood. Early family selection in black spruce. Paper presented to the Northern Forest Genetics Conference, Burlington, VT. July 23-25, 1991.

Carter, K.K. Provenance tests as indicators of tree growth response to climate change. Poster presented to the Canadian Tree Improvement Association, Ottawa, Canada. August 19-22, 1991.

_________ Forestry as a Career. Presentation to high school students in the Expanding Your Horizons program, Univ. of Maine, Orono. ME. March 5, 1991.

________ Provenance tests as indicators of tree growth response to climate change. Presentation to the Forestry seminar, Univ. of Maine, Orono, ME. April 5, 1991.

_________ Exotic larches for fast-growing fiber. Invited presentation to Diamond Occidental Forest, Inc., Old Town, ME. August 15, 1991.

Eysteinsson, T., and M.S. Greenwood. Controlled mating without pollination bags in indoor breeding of larch. Paper presented at the first Northern Forest Genetics Association Conference, Burlington, VT. July 23-25, 1991.

Manyazawale, B., and W.D. Ostrofsky. An assessment of internal decay of red spruce using the Shigometer. Poster presentation. Winter Meeting, New England SAF, Burlington, VT. March 13-15, 1991.

McCormack, M.L., Jr. Long-term sustainability of plantation forestry. Seminar. Forest Ecology Institute, University for Bodenkultur. Vienna, Austria. April 16, 1991.

___________ Forestry use of herbicides in the northeastern U.S.A. Seminar. Faculty of Forestry. Sopron, Hungary. April 19, 1991.

_________ Industrial forestry practices and the use of herbicides in northeastern North America. Seminar. Silviculture Institute, Faculty of Forestry. Goettingen, Germany. May 6, 1991.

McCormack, M.L., Jr. Forestry practices and silvicultural problems in northeastern North America. Seminar. Silviculture Institute, Faculty of Forestry. Freiburg i. Br., Germany. June 17, 1991.

Ostrofsky, W.D. Interactions between mechanical wounding of trees and forest stress. Presentation, FTY 556, Orono, ME. October 9, 1990.

A new method for estimation of paper birch foliar biomass. Presentation, 48th Ann. Meeting of the Maine Hardwood Association, Houlton, ME. October 18, 1990.

Forest health issues - Logging injuries to residual trees. Presentation and field tour, Boise-Cascade Corp., Newry, ME. October 25, 1990.

__________ The Cooperative Forestry Research Unit. Newspaper and Radio Interview for UM Press Release. August 2, 1991.

Ostrofsky, W.D., and K.T. Smith. Cochairs, 32nd Northeastern Forest Pathology Workshop. Bethel, ME. May 28-30, 1991.

Schaertl, G.R. Is plant development in forests different among herbicide-induced and other forms of secondary succession? Northeastern Weed Science Society, Baltimore, MD. January 8-10, 1991.

__________ Glyphosate and imazapyr interact to reduce competition but may injure conifers in Maine. Forest Vegetation Management Workshop, Bangor, ME. April 30-May 1, 1991.

Shepard, R.K. Landspreading of sludge and ash in Maine. Discussion with Savannah Equipment Company, Savannah, GA. 1991.

Feasibility of applying fish processing waste to clearcuts. Discussion with Connors Aquaculture, Eastport, ME. 1991.

__________ Sludge landspreading in Maine. Discussion with a representative of the Dept. of Chemistry and Biochemistry, Univ. of Moncton, Moncton, NB. 1991.

Foliage sampling for nutrient determinations. Advice provided to International Paper Co., Clayton Lake, ME, 1991.

White, A.S. 1990. Effects of strip clearcutting on regeneration and windthrow. Invited seminar at the University of Maine Forestry Seminar Series. Orono, ME. 1990.

COOPERATIVE FORESTRY RESEARCH UNIT ADVISORY COMMITTEE 1991 Membership

The CFRU Advisory Committee sets priorities and reviews proposals for the Cooperative Forestry Research Unit. Members active during all, or part, of 1991 were:

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CFRU STAFF (September 30, 1991)

Program Leaders

William D. Ostrofsky, Associate Research Professor of Forest Resources (CFRU Leader)
Maxwell L. McCormack, Jr., Research Professor of Forest Resources Russell D. Briggs, Assistant Research Professor of Forest Resources

Professional Staff

Ronald C. Lemin, Jr., Assistant Scientist (Site Quality)
Peter Caron, Research Associate (Tree Improvement)
Eleanor G. Heinz, Administrative Assistant

Cooperating Professors

Michael S. Greenwood, Professor of Forest Resources Katherine K. Carter, Associate Professor of Forest Resources Robert S. Seymour, Associate Professor of Forest Resources Robert K. Shepard, Jr., Associate Professor of Forest Resources Alan S. White, Associate Professor of Forest Resources William B. Krohn, Professor of Wildlife (CFWRU Leader) Fred Servello, Assistant Professor of Wildlife Catherine A. Elliott, Extension Wildlife Specialist

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OTHER ORGANIZATIONS PROVIDING SUPPORT FOR CFRU PROJECTS

DowElanco
Maine Agricultural Experiment Station
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Monsanto Agricultural Products Company
USDA Northeastern Forest Experiment Station
USDA State & Private Forestry

APPENDIX

Terminology

SCIENTIFIC NAME	COMMON NAME
Abies alba Miller	Silver fir
Abies balsamea (L.) Mill.	Balsam fir
Abies spp.	Fir
Acer rubrum L.	Red maple
Acer saccharum Marsh.	Sugar maple
Acer spp.	Maple
Betula alleghaniensis Britton	Yellow birch
Betula papyrifera Marsh.	Paper birch
Betula pendula Roth	European white birch
Betula pubescens Ehrh.	Downy birch
Carpinus spp.	Hornbeam
Epilobium spp.	Fireweed
Fagus grandifolia Ehrh.	American beech
Fagus silvatica Linne	European beech
Fraxinus spp.	Ash
Larix decidua Mill.	European larch
Larix laricina (DuRoi) K. Koch	Tamarack (Eastern larch)
Larix leptolepis (Sieb. & Zucc.) Gord.	Japanese larch
Picea abies (L.) Karst.	Norway Spruce
Picea glauca (Moench) Voss	White spruce
Picea mariana (Mill.) B.S.P.	Black spruce
Picea rubens Sarg.	Red spruce
Picea spp.	Spruce
Pinus contorta Dougl.	Lodgepole pine
Pinus pinaster Ait.	Maritime pine
Pinus resinosa Ait.	Red pine
Pinus strobus L.	Eastern white pine
Pinus silvestris Linne	Scotch pine
Pinus taeda L.	Loblolly pine
Pristiphora abietina Christ.	Spruce sawfly
Prunus pensylvanica L.	Pin cherry
Prunus spp.	Cherry
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir
Quercus rubra L.	Red oak
Quercus petraea (Mattuschka) Lieblein	Sessile oak
Rubus idaeus L.	Common red raspberry
Solidago spp.	Goldenrod
Tilia spp.	Basswood
Tsuga canadensis (L.) Carr.	Hemlock