

SUMMARIES OF POSTERS

Presented at The Silviculture of Temperate and Boreal Broadleaf-conifer Mixtures Workshop held February 28 and March 1, 1995 in Richmond, British Columbia

Control of Spruce Weevil Damage By Introduction of Alternative Commercial Species (FRDA II Project 93-03)

KEN DAY

Abstract

The poster describes an experiment for planting spruce and lodgepole pine in a mixture as a foil for spruce weevils.

Introduction

This trial was established to look at the practicality of establishing spruce plantations with a mixture of other commercial species as a foil for spruce weevils. While research to date has concentrated on stands planted in 1985, which already exhibit significant weevil damage, it seems prudent to examine alternative stand establishment regimes.

Two small blocks will be planted as part of this study. The areas are described as:

- Unit D (6.3 ha); Opening 92A042-361; logged 1970, burned 1971, planted 1973; site preparation 1992, planted 1993.
- Unit E (4.6 ha); Opening 92A042-358; burned 1971, logged 1972; site preparation 1992, planted 1993.

The units will each be divided in half and planted with two treatments. The treatments are described below. The two planting units were site prepared with a brush blade in summer 1992 and contain round piles. Extensive areas of exposed mineral soil and suckering from stumps and roots will result in aggressive colonization by willow and cottonwood, and to a lesser extent by aspen, birch, and alder.

Planting stock for this trial are:

- Lodgepole pine: PSB313B 1+0 Seedlot 8379; grown at PRT, Chilliwack.
- Spruce: PSB313B 1+0 Seedlot 6911; grown at HiGro, Quesnel.

Treatment 1: Mixed-bag Planting

Planting The treatment will be block planting with an intimate mixture of lodgepole pine and spruce, at a density of 1800 stems per hectare. Optimum inter-tree spacing will be 2.5 m and minimum distance will be 1.5 m.

The anticipated benefits of this treatment are:

- spruce will be overtopped by the lodgepole pine, resulting in smaller leader diameters and reduced heat sums on the leader;
- the taller lodgepole pine will hide the shorter spruce trees, rendering them less apparent to the weevils;
- the rapid nutrient uptake and cycling by the pine will benefit the spruce, since these sites are relatively nutrient degraded by burning in 1971/1972 and mechanical site preparation in 1992.

Stand Tending The block plantings will receive the following stand-tending treatments:

Year	Age	Treatment
1996	3	Manual brushing
2008	15	Juvenile spacing
2023	30	Commercial thin to 800 stems per hectare, retaining 30% lodgepole pine
2043	50	Commercial thin to 350 stems per hectare, pure spruce
2073	80	Final harvest, 300 stems per hectare at 50 cm dbh

Treatment 2: Mixed-clump Planting

Planting Trees will be planted in clumps of seven trees, at 300 clumps per hectare. Each clump will consist of four lodgepole pine and three spruce, planted in the arrangements shown at Figure 1. Spacing within the clumps is 1 m between trees, with minimum planting distance set at 0.75 m. Planting densities are based on the following assumptions and calculations:

Basal area capacity = 60 m²/ha

Desired final crop = 50 cm dbh spruce trees at 80 years

Intertree distance (within clumps) = 1 m
Clumps established at final crop density.

Radius of final crop tree: $r = \frac{50 \text{ cm}}{200} = 0.25 \text{ m}$

Basal area of one 50 cm crop tree:
 $BA = \pi r^2 = \pi \times 0.25^2 = 0.1963 \text{ m}^2$

Number of stems per hectare at final crop

spacing: $sph = \frac{60 \text{ m}^2}{0.1963 \text{ m}^2} = 305.65 \text{ per hectare}$

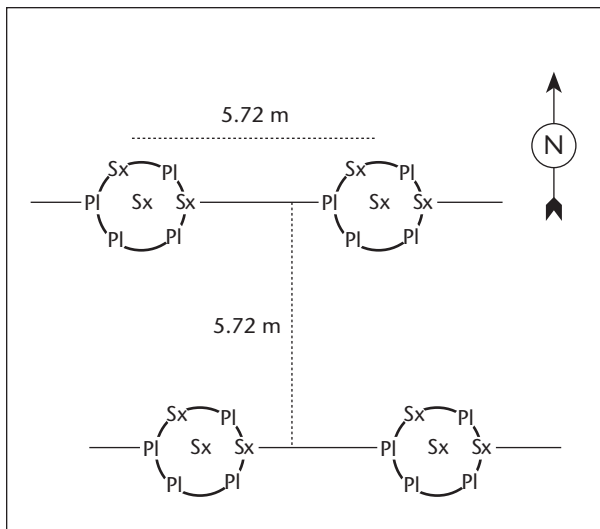


FIGURE 1 Clump layout and planting design.

Distance between clumps:

$$d = \sqrt{\frac{10\,000 \text{ m}^2/\text{ha}}{305.6 \text{ m}^2/\text{ha}}} = 5.7 \text{ m}$$

Clump diameter (assuming intertree distance of 1 m):

$$cd = \frac{\text{Circumference}}{\pi} = \frac{6 \text{ m}}{\pi} = 1.91 \text{ m}$$

The anticipated benefits of this treatment are:

- spruce will be overtopped by the lodgepole pine and adjacent deciduous, resulting in smaller leader diameters and reduced heat sums on the leader;
- the taller lodgepole pine and adjacent deciduous will hide the shorter spruce trees, rendering them less apparent to the weevils;
- the rapid nutrient uptake and cycling by the pine and deciduous will benefit the spruce, since these sites are relatively nutrient degraded by burning in 1971/1972 and mechanical site preparation in 1992;
- brush control need only take place within clumps, and the intervening space will be left in deciduous cover;
- increased component of deciduous will provide biodiversity in forest cover; and
- deciduous trees such as birch, aspen, and cottonwood will be available for harvest in commercial thinnings.

Boreal Mixedwood Understorey Protection Demonstration Trial in Fort Nelson, B.C.

KERRY C. DESCHAMPS AND ROBERT HALL

Abstract

The poster describes a demonstration area that illustrates mixedwood silviculture systems to protect immature spruce understorey while harvesting mature aspen in Fort Nelson, B.C.

Introduction

In northeastern British Columbia, a large portion of the landscape is dominated by mixedwood forests. These are typically characterized by an aspen overstorey and a spruce understorey. It is the presence of white spruce as an understorey component that poses significant operational problems, especially where spruce is greater than 20% by volume or greater than 800 stems per hectare. Particularly challenging is the prescription of harvesting methods to remove the merchantable aspen, while protecting the vulnerable spruce underneath. Research and operations conducted in Alberta and Ontario clearly demonstrate that harvesting operations in mixedwoods can be conducted effectively in a manner that preserves the immature spruce understorey component and promotes healthy future stand development.

In the Fort Nelson Forest District, much interest has been expressed in mixedwood management and the development of prescriptions to protect understorey spruce and promote aspen regeneration. Discussions with Canadian Chopsticks Manufacturing Company Ltd. (CCMC) and Ministry of Forests representatives clearly show the need and their willingness to participate in setting up a demonstration area to showcase exemplary management practices in mixedwood forests.

Objectives

A mixedwood understorey protection demonstration area was set up jointly between CCMC and the Canadian Forest Service (CFS) to meet the following objectives:

- Demonstrate and test different harvesting techniques for protecting understorey spruce and encouraging aspen regeneration.
- Quantify the amount and type of understorey spruce damage (broken tops, bark scrapes, etc.) resulting from the various harvesting techniques.
- Monitor the subsequent development of new aspen regeneration and residual spruce.
- Document the costs and benefits of protecting the understorey by taking into consideration timber and non-timber values.
- Evaluate the feasibility of a two-pass harvesting system, while maintaining visual quality objectives.
- Promote this project through public education and the development of interpretive trials, tour packages, and a video.

Demonstration Area

The demonstration area is located 25 km east of Fort Nelson on the Sierra Yoyo Road within the Boreal White and Black Spruce (BWBSmw2) biogeoclimatic subzone. The 65-ha site was split into four treatment units to accommodate the following four understorey protection treatments:

- Selection logging and random skidding, with a 20 cm dbh limit cut for both aspen and spruce;
- Conventional understorey logging and random skidding: this area will be the control;
- Group retention and random skidding: patches will be identified and left unharvested; and
- Conventional understorey protection logging and designated skidding, with the use of landings and preassigned skid trails.

Before harvesting the following activities took place:

- CCMC staff developed the pre-harvest silviculture prescriptions.
- CCMC staff flagged the boundaries, roads, landings, and retention patches.
- CFS staff established ten 100 m² circular plots in each treatment unit and two 100 m² circular plots in the retention patches (totalling 42 plots in all). Plots were established along survey lines spaced at 80 m apart. A metal pin was driven into the ground at each plot centre and all conifers were tagged, dbh and height measured, and condition noted. All hardwoods were measured for dbh and some were sampled for height.

Harvesting started in late October 1994 and finished in early December 1994. The type of equipment used included a Timberjack 618 Feller Buncher, a Timberjack 480 Grapple Skidder, a Cat EL240C Carrier with DH550 Processing Head, a Cat 322 Carrier with DH550 Processing Head, a Cat 325 Butt'n Top, and D7 and D8K crawlers for roads, deactivation, and piling. During the logging operation, a CCMC supervisor was stationed on-site to monitor the operation and to gather cost and

machine productivity data. Helicopter time was supplied by CCMC for CFS staff to videotape and photograph the demonstration area before and during harvesting operations. After harvesting, CFS staff relocated some of the plots to assess harvesting damage on the residual spruce. Monitoring the subsequent development of new aspen regeneration and residual spruce will be done annually for the next 5 years.

Future work will include remeasurement of plots, and establishment of signs, interpretative trials, videos, and reporting of results.

Acknowledgements

Funding and in-kind support for developing the Mixedwood Understorey Protection Demonstration Area was provided by the following agencies:

- Canadian Chopstick Manufacturing Co. Ltd.
- Natural Resources Canada - Canadian Forest Service
- Green Plan - Forest Practices
- Ministry of Forests - Fort Nelson Forest District
- Canada-B.C. Forest Resource Development Agreement (FRDA).

Effects of Red Alder on Stand Dynamics and Nitrogen Availability (EP-1121)

P.G. COMEAU, G. HARPER, B. BIRING, AND K.D. THOMAS

Abstract

Replacement series and additive experiments were initiated in 1991 to examine both short- and long-term effects of red alder density and proportion on stand dynamics. The results from these experiments will broaden our understanding of nutrient cycling and ecosystem dynamics within these mixedwood stands. The long-term data will provide calibration and verification of canopy light penetration and ecosystem models.

Introduction

Red alder is found throughout the Coastal Western Hemlock biogeoclimatic zone and is the most abundant broadleaf species in coastal British Columbia. Red alder litter influences nutrient cycling in the forest and can also contribute to site nitrogen capital and long-term productivity through the process of symbiotic nitrogen fixation. Juvenile growth of red alder is much more rapid than that of most conifers. Three-year-old red alder can grow 2–3 m/yr in height, and can rapidly overtop neighbouring conifers. This can lead to substantially reduced light availability, which may cause physical damage to crop trees. The degree of light reduction and the amount of damage to conifers depends largely on the density and size of the red alder component of the stand. We initiated studies in 1991 to examine both short- and long-term effects of red alder density and proportion stand dynamics. This study had five major components:

- 1 replacement series field experiments;
- 2 additive field experiments;
- 3 “cluster” experiment;
- 4 modelling light penetration through alder canopies; and
- 5 ecosystem modelling.

Objectives

The objectives of this study are:

- to improve understanding of both the competitive and beneficial effects of red alder when grown with conifers;
- to document and demonstrate the effects of different amounts and spatial arrangements of red alder on the growth and survival of conifers and hardwoods, stand dynamics, crown characteristics, nitrogen availability, nutrient cycling, and long-term productivity.

Field Experiments

Replacement Series Experiment In this study, red alder and Douglas-fir were planted in a series of five proportions (Table 1) at a total density of 742 trees per hectare (3.67 m spacing), following an experimental design protocol prepared by the Oregon State University Hardwood Silviculture Cooperative. One installation was planted at East Wilson Creek in 1992 and another at Holt Creek in 1994 (Table 2). Each installation consists of one replicate of each of the five treatments described in Table 1.

Additive Experiment Additive experiments were established at five locations (Table 2). Douglas-fir and western redcedar were planted in all plots at total densities of 1100 trees per hectare (with the two species planted in equal proportions at alternating planting spots), and one of seven “broadleaf” density treatments (Table 3) was applied. Because of space limitations, treatments were not replicated on individual sites and not all treatments could be applied at all sites. Problems with survival of planted trees due to site conditions, vegetation competition, and browsing were encountered at two locations (Shawnigan Lake and Surrey Nursery).

TABLE 1 *Replacement series experiment treatments*

Treatment	% alder	% Douglas-fir	Trees per hectare	Spacing (m)
1	100	0	742	3.67
2	50	50	742	3.67
3	25	75	742	3.67
4	11	89	742	3.67
5	0	100	742	3.67

TABLE 2 *Field installations*

Study	Site	District	Zone	Moisture regime	Nutrient regime	Treatment	Year
Replacement series	East Wilson Creek	Sunshine Coast	CWHdm	3	c	1–5	1992
	Holt Creek	Duncan	CWHxm	5	d	1–5	1994
Additive	Waterloo Creek	Port Alberni	CWHdm	3	c	1–8	1992
	Gough Creek	Sunshine Coast	CWHdm	3	c	1–8	1992
	Shawnigan Lake	Duncan	CWHxm	mixed	d	1–6	1993
	Surrey Nursery	Chilliwack	CDFdm	6	d	1–8	1993
	Holt Creek	Duncan	CWHdm	5	d	1–8	1994
Cluster	Holt Creek	Duncan	CWHdm	5	d	–	1994

TABLE 3 *Additive experiment treatments*

Treatment	Species	Trees per hectare	Spacing (m)
1	–	0	–
2	Red alder	50	14.2 × 14.1
3	Red alder	100	10.0 × 10.0
4	Red alder	200	7.1 × 7.1
5	Red alder	400	5.0 × 5.0
6	Bigleaf maple	50	14.2 × 14.1
7	Sitka alder	200	7.1 × 7.1

Cluster Experiment Eight patches of red alder were planted at Holt Creek in May 1994, in a 6 ha area that had previously been planted with Douglas-fir in March 1994. Patches of alder, 8 × 8 m, were located at least 50 m apart within the opening and at least 40 m from the edge of the adjoining stand. Two alder densities were each randomly assigned to four patches—25 trees per patch (2500 trees per hectare or 2 m spacing) or 81 trees per patch (10 000 trees per hectare or 1 m spacing).

Measurements

Treatment plots are 70 × 70m (0.49 ha) at East Wilson Creek, Waterloo Creek, and Gough Creek, and 60 × 60m (0.36 ha) at Holt Creek. In each treatment plot, stem diameter and height were measured within a 0.10 ha permanent measurement plot. Soil samples are being collected to document changes in soil nitrogen capital, pH, and organic matter content. A climate station was erected at each installation to provide data on solar radiation, soil and air temperature, soil moisture, and rainfall. Data collection regimes for East Wilson Creek and Holt Creek replacement series

(Figure 1) are the same as for the Gough Creek, Waterloo Creek, and Holt Creek additive (Figures 2 and 3) installations.

Modelling Light Penetration through Red Alder Canopies

The amount of light that penetrates red alder canopies varies as a function of:

- stand characteristics (number, size, spatial arrangement, and crown architecture of red alder);
- season (the locations of the sun and leaf development of the canopy);
- time of day; and
- weather conditions.

Light is one of the major factors involved in interactions between red alder and conifers. A model is currently being developed for estimating the amount of light penetrating red alder canopies. The model will estimate light penetration through alder stands of various sizes and configurations and demonstrate how light penetration varies diurnally and seasonally. Model output will include estimates of hourly averages and of hourly, daily, weekly, and seasonal totals.

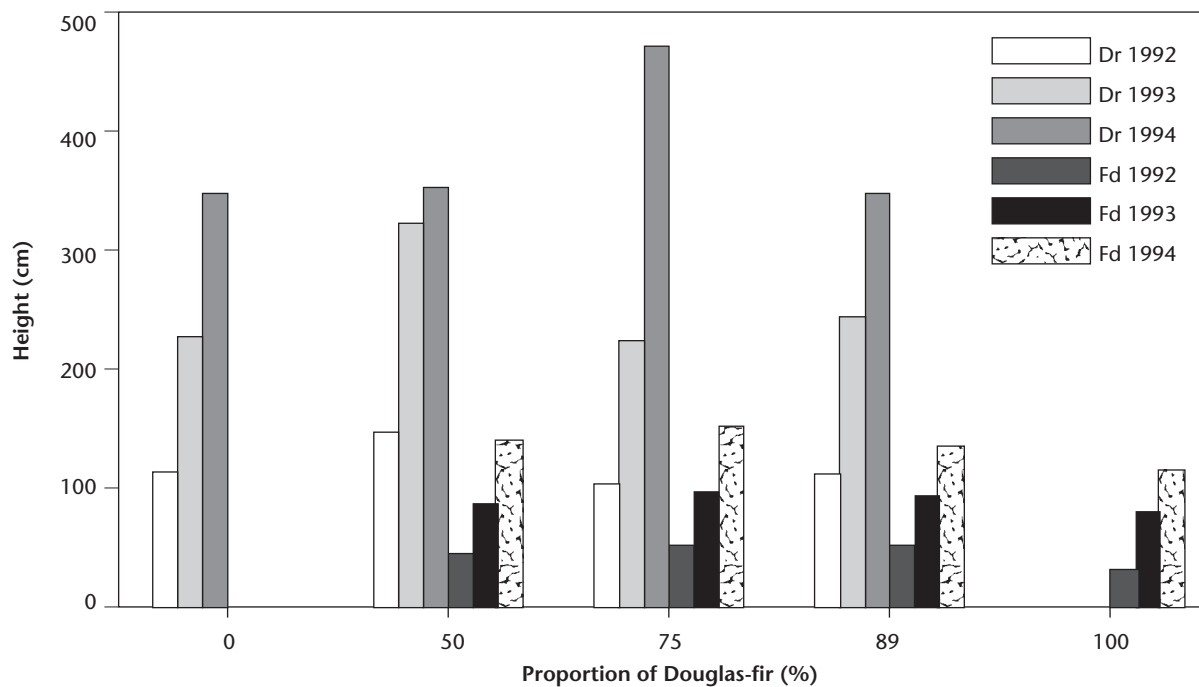


FIGURE 1 East Wilson Creek replacement series: tree heights for 1992, 1993, and 1994 (Fd = Douglas-fir, Dr = red alder).

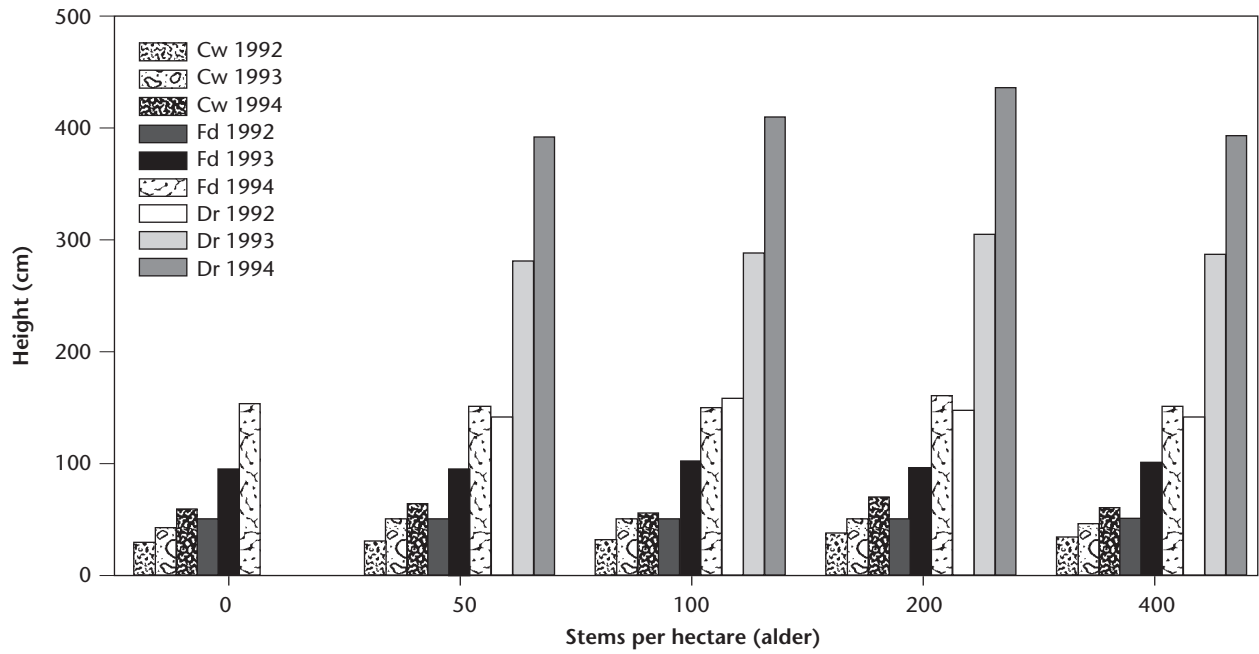


FIGURE 2 Gough Creek additive installation: tree heights for 1992, 1993, and 1994 (Cw = western redcedar; Fd = Douglas-fir; Dr = red alder).

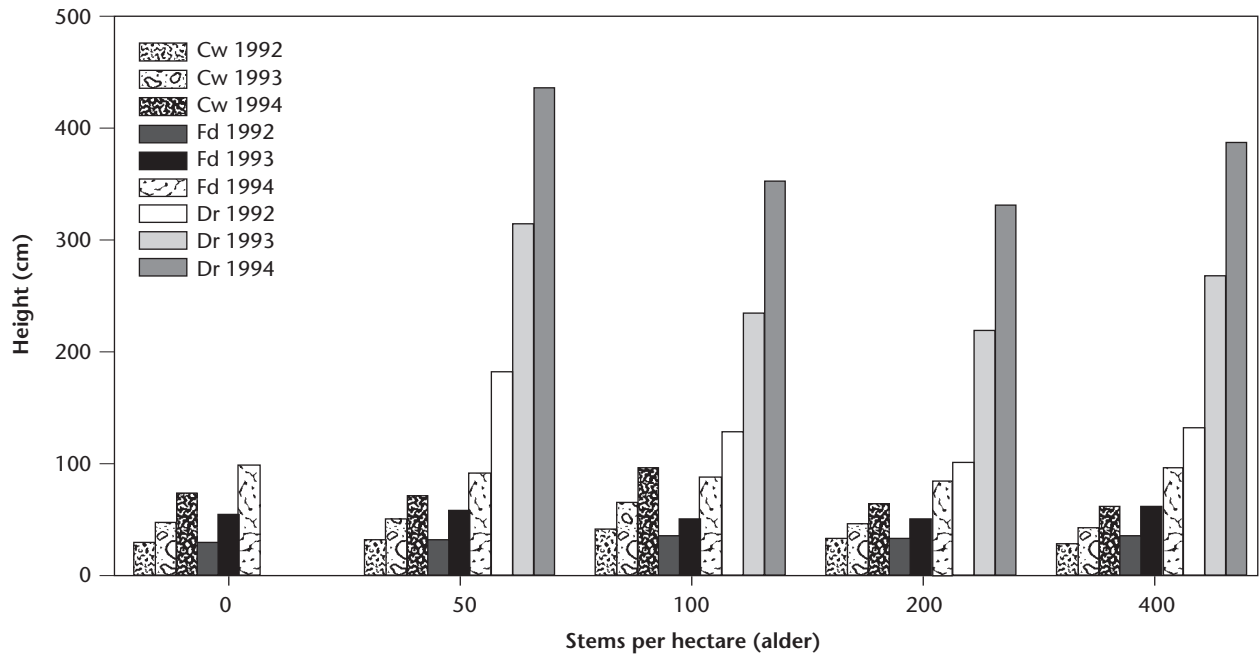


FIGURE 3 Waterloo Creek additive installation: tree heights for 1992, 1993, and 1994 (Cw = western redcedar; Fd = Douglas-fir; Dr = red alder).

Ecosystem Modelling

Ecosystem models are useful tools for exploring the trade-offs between the beneficial and detrimental effects of red alder on stand growth and on long-term site productivity. The FORCYTE-11 ecosystem model has been calibrated for red alder, Douglas-fir, western redcedar, and western hemlock.

Simulations using FORCYTE-11 indicate that between 100 and 200 well-spaced stems of red alder per hectare will increase Douglas-fir yields by up to 13% (Figure 4). However, this study and others indicate that intermixing alder with Douglas-fir will lead to substantial losses in the conifer component unless alder densities are less than 200 trees per hectare. Simulations with mixtures of red alder and western redcedar, or with red alder and western hemlock, provide similar results. However, performance of western redcedar or western hemlock declines when red alder densities exceed 500 trees per hectare.

In simulated replacement series experiments, maximum whole-stand yield was achieved with a stand composed of 60% Douglas-fir and 40% red alder (Figure 5). Douglas-fir yield was highest in the stand with only a 20% red alder component. Simulations suggest that site productivity may decline with successive 80-year rotations of pure

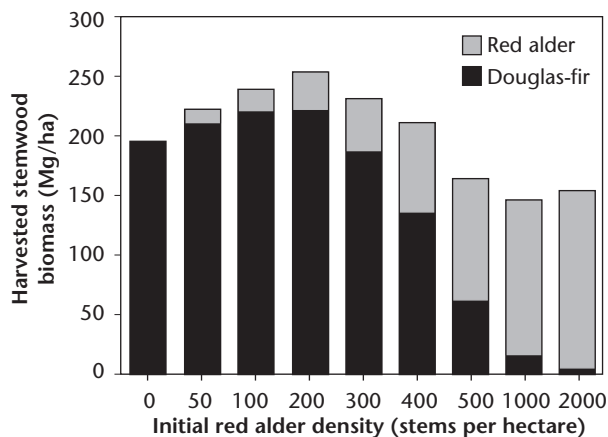


FIGURE 4 Effects of initial red alder density on cumulative stemwood biomass yield of Douglas-fir and red alder for a site index (SI) of 30 m at 50 years and red alder SI of 17 m at 50 years. Results are based on simulations using FORCYTE-11 (Comeau and Sachs 1992).

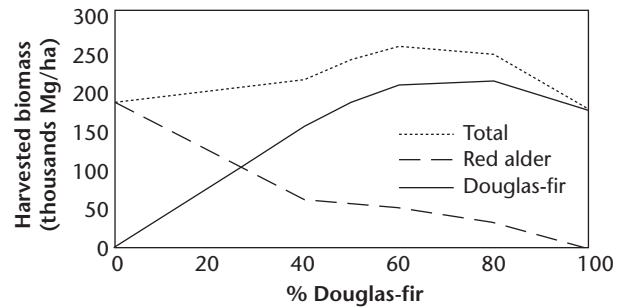


FIGURE 5 Results from a simulated replacement series experiment showing total stemwood biomass yield over 80 years. FORCYTE-11 simulation was done for a medium-quality Douglas-fir site, with 1000 total trees per hectare (planted); red alder were harvested at age 40, and Douglas-fir at age 80 (Comeau and Sachs 1992).

Douglas-fir (where alder is precluded from the stand). However, establishment and retention of 200 red alder per hectare appear to maintain soil nitrogen and site productivity.

Further refinements in the capabilities of this model are under way, including simulation of the effects of different spatial arrangements of red alder. Data from field experiments will be used for calibration and validation of model predictions.

Acknowledgements

This research has been supported by FRDA I, FRDA II, Forest Renewal BC, and the B.C. Ministry of Forests. Support from the Hardwood and Vegetation Management Technical Advisory Committee is gratefully acknowledged.

Reference

Comeau, P. and D. Sachs. 1992. Simulation of the consequences of red alder management on the growth of Douglas-fir using FORCYTE-11. B.C. Min. For. and For. Can., Victoria, B.C. FRDA Rep. No. 187. 45 p.

Response of Hybrid Poplar to Phosphorus Fertilization and Water Supply

R. van den DRIESSCHE

Abstract

The optimal nutrient status for different hybrids being planted on the east side of Vancouver Island is largely unknown. Two experiments were established to examine the response of hybrid poplar to phosphorus and water supply; and to two sources of both phosphorus and nitrogen. Results following one growing period are presented and discussed.

Introduction

Fast growing hybrid poplar plantations are being established in the Fraser Valley and on the east coast of Vancouver Island. Intensive culture of the plantations is necessary to obtain the full growth potential of the poplar hybrids. Besides clean cultivation of the planting sites, fertilization is likely to be required. The optimal nutrient status for different hybrids being planted on the east side of Vancouver Island is largely unknown, and there has been some evidence of phosphorus deficiency. The summer drought of this region may also influence response to mineral nutrition.

Experiment 1

Objectives The purpose of this work was to examine response of hybrid poplar (*Populus trichocarpa* x *P. deltoides*) to phosphorus (P) level and water supply.

Methods Poplar cuttings were grown in 1 m deep containers made from 10 cm diameter water pipe. Each container was filled with peat and vermiculite potting mixture into which triple superphosphate fertilizer had been incorporated to provide one of four levels of P (Table 1). Each container was planted with one of two clones of hybrid poplar, and two moisture regimes were set up by varying the frequency of watering. Nitrogen, potassium, sulphur, copper, and zinc were applied in solution during the experiment. The four factors (Table 1) were fully randomized and the 80 containers were placed in the open at 10 × 15 cm spacing. The experiment started on May 9 and finished on August 2, 1994 after 12 weeks of growth.

Results

Total growth Average dry weight growth by the plants during the 12-week experiment, from lowest to highest P treatment levels, were: 30.7, 46.0, 43.1,

TABLE 1 Treatments in Experiment 1

Factor	Levels				Cumulative number	
Phosphorus (g per container)	0.0	0.5	1.0	4.0	4	
Clones	1		2		8	
Water	dry		wet		16	
Replications	1	2	3	4	5	80

and 24.5 g. Thus the 0.5 g P treatment increased dry matter production by 49.8%.

Shoot and root growth Phosphorus affected shoot and root dry weights similarly. Response to P was much reduced in the dry treatment. Shoot:root dry weight ratio increased at the highest level of P treatment. Root length per plant was initially decreased by P treatment before increasing at the highest P level.

Leaf Area Specific leaf area was strongly increased by increase in P treatment, resulting in greater leaf area per plant at the 0.5 and 1.0 g P treatments.

Photosynthesis Photosynthesis, transpiration, and stomatal conductance were reduced by increase in P level to 1.0 g, but further increase had little effect. The more rapid decrease in transpiration than in photosynthesis with increase in P level indicated that P increases instantaneous water use efficiency. Phosphorus treatment resulted in a steady increase in water potential. Photosynthetic rates per plant, calculated from rate per unit leaf area and total leaf area per plant, showed that the rate per plant did not decline much until 4 g of P were added, and that 0.5 and 1.0 g P increased the rate per plant under wet conditions.

Clones Shoot dry weight and shoot:root ratio of clone 1 was greater than that of clone 2, but otherwise clonal differences were not observed.

Experiment 2

Objectives To examine the response of hybrid poplar to two sources of P and two sources of nitrogen (N).

Methods Raised wooden beds, 0.5 m deep and 1.2 m wide, were divided into forty-eight 2 m long plastic-lined plots. These were filled with building

sand, and dolomitic limestone and P treatments were worked 15 cm into the surface. Nitrogen, potassium, copper, and zinc solutions were applied in solution.

The experiment was designed as a $2 \times 2 \times 4 \times 3 \times 2$ factorial. Factors were fully randomized down to clones, which split each plot. Sand beds were roofed with polyethylene to prevent excessive water accumulation in plastic-lined beds.

Results First-season results indicated that triple superphosphate (TSP) increased shoot dry weight at 250 kg/ha, but 500 kg/ha depressed shoot weight to the control level. Rock phosphate (RP) had no significant effect on shoot weight.

Shoot dry weight of clone 1 was significantly related to percentage of leaf P in RP treatments, where leaf P was generally below 0.2%. Clone 1 shoot dry weight was unrelated to percentage of leaf P in TSP treatments, where leaf P was generally above 0.2%, and presumably adequate. Clone 2 showed a maximum shoot dry weight in the range 0.20–0.25% P regardless of P source.

Discussion

Growth response of hybrid poplar to phosphorus can be large (50%), but is reduced under dry soil conditions. There was no evidence that higher level of P increased response under dry conditions in this experiment. However, treatment with rates between 1.0 and 4.0 g P might have shown such a response in dry soil. Phosphorus level had important effects on specific leaf area and specific root length. The overall effect was to increase photosynthesis per plant under wet conditions and also to increase instantaneous water use efficiency.

TABLE 2 Factors and levels for Experiment 2

Factor	Levels		Cumulative number	
P source	triple superphosphate		rock phosphate	
N source	$(\text{NH}_4)_2\text{SO}_4$		$\text{Ca}(\text{NO}_3)_2$	
P level (kg/ha)	0	125	250	500
Replication	1	2	3	48
Clone	1	2		96

Increases in growth at the 0.5 and 1.0 g P level are not explained fully by the increase in leaf area per plant and could possibly be related to differences in respiration. Differences in dry matter distribution appear to be unlikely causes of the response.

The effect of P treatment in increasing water potential was interesting, since the effect of watering regime on water potential was not significant. The decrease in stomatal conductance with P level presumably accounted for much of this increase, but the large increase in root length

per plant at the 4 g P treatment may have explained the high water potential in this treatment.

The lack of relationship between shoot dry weight and foliar P levels above about 2% in clone 1 suggested that phosphorus requirements of this clone were relatively low, and that it was insensitive to higher levels. Overall results supported the conclusion that optimal concentrations of P in foliage sampled in early July are in the region of 0.20–0.25%.

Simulation of the Growth of Mixed Stands of Douglas-fir and Paper Birch Using the FORECAST Model

D. SACHS

Abstract

The FORECAST ecosystem model was used to simulate the growth of mixed stands of Douglas-fir (*Pseudotsuga menziesii*) and paper birch (*Betula papyrifera*) in the Interior Cedar–Hemlock biogeoclimatic zone (ICH). The model was calibrated using information from current and recent studies in the Kamloops Forest Region, as well as a variety of literature data. A number of 400-year mixed-wood management scenarios were simulated using a replacement series design with a constant density of 1600 stems per hectare and a rotation length of 100 years. Pure stands of birch provided slightly higher yields than pure Douglas-fir stands and dominated the mixtures at birch densities greater than 200 stems per hectare. Mixtures containing less than 200 stems per hectare of birch showed productivity losses in later rotations. These are dependent on the model assumptions and the quality of the input data.

Introduction

Mixed stands of Douglas-fir (*Pseudotsuga menziesii*) and paper birch (*Betula papyrifera*) are common in the Interior Cedar–Hemlock (ICH) biogeoclimatic zone of the southern interior of British Columbia. Recent forest management policy in the southern interior has eradicated birch and created pure conifer stands where possible. However, growing concerns about the role of birch in the long-term productivity of these sites, and the increasing demand for birch logs, has brought this policy into question (Simard and Vyse 1992). This project calibrated the FORECAST ecosystem model to simulate the growth of mixed stands of Douglas-fir and paper birch. Information from a number of current or recent studies in the Kamloops Forest Region along with available

literature data were used. The model was then used to examine the potential effects of different mixed-wood management strategies on the long-term productivity of these sites.

Model Calibration

FORECAST is an ecosystem model that explicitly simulates the effects of nutrient availability and light competition on the growth of trees, shrubs, herbs, and mosses. It is the latest in the FORCYTE series of ecosystem models (Kimmins et al. 1990). The model requires data on height growth, biomass accumulation, nutrient content, light attenuation, and photosynthetic efficiency of each species simulated. Additional data describing decomposition rates for detritus are also required. For this simulation, the calibration for tree stemwood and height growth of both tree species was based on predictions from the B.C. Ministry of Forests VDYP and TIPSYP yield projection models. Data on juvenile height growth of birch and Douglas-fir in the ICH came from Simard and Vyse (1992). Data on the biomass and nutrient content of a chronosequence of birch stands was taken from a study by Wang et al. (1996). Light attenuation and photosynthetic efficiency curves for birch were estimated using data from Wang et al. (1995). In the absence of available data, birch logs were assumed to decompose in 30 years. Additional model calibration data came from the literature (Table 1). Literature data for coastal Douglas-fir were used to estimate decomposition parameters when no interior Douglas-fir data were available.

Initial State and Model Testing

Before using the FORECAST model for management simulations, an initial-state file describing the forest floor detrital materials and soil nutrient

TABLE 1 Additional sources of data for the calibration of the FORECAST model for these simulations.

Information	Source
Douglas-fir biomass equations	Gower et al. 1987, Brown 1978
Douglas-fir N content	Clayton and Kennedy 1985
Douglas-fir needle decomposition	Edmonds 1987, Harmon et al. 1990
Douglas-fir branch and bark decomposition	Fogel and Cromack 1977
Douglas-fir log decomposition	Sollins et al. 1987, Harmon et al. 1986
Douglas-fir fine root decomposition	Sollins et al. 1980
Douglas-fir root biomass and turnover	Fogel 1983, Santantonio and Hermann 1985, Vogt et al. 1986
Birch photosynthetic efficiency	Jurik et al. 1988
Birch leaf decomposition	Prescott (in progress), Bockheim et al. 1991, Berg and Staaf 1987, Berg and Wessen 1984, Van Cleve and Noonan 1975
Birch root biomass and turnover	Safford 1974, Vogt et al. 1986

capital must be created. This was done by running the model with nutrient limitation to growth disabled for a 400-year simulation consisting of two rotations. The initial rotation started with a mixture of Douglas-fir and birch that was grown for 250 years, and then destroyed by a fire. This was followed by another mixed stand that was clearcut harvested after 150 years. The resulting forest floor was used as the starting point for all subsequent simulations.

Initial test simulations indicated that birch was much more sensitive to site nitrogen availability than was Douglas-fir. This is not surprising since the nitrogen content of birch tissue is significantly higher than that of Douglas-fir. Simulated pure stands of birch demanded as much as $70 \text{ kg N} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$, whereas Douglas-fir demand rarely exceeded $50 \text{ kg N} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$. Birch needed an annual nitrogen input of at least 6 kg/ha to maintain productivity in the simulations. For an initial test, the model was used to simulate a mixed stand containing 1200 Douglas-fir and 400 birch seedlings per hectare at planting with an annual nitrogen input of 5 kg/ha from non-symbiotic N_2 fixation (Figure 1a). However, this level of nitrogen input far exceeded the demands of a pure Douglas-fir stand, and its site productivity quickly increased

to the highest level in the model, which resulted in Douglas-fir outcompeting birch in later rotations. To lower nitrogen input when birch was not present, the constant annual nitrogen input due to non-symbiotic N_2 fixation was lowered to a more reasonable 1.5 kg/ha. In addition, symbiotic N_2 fixation of approximately $5 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$ was simulated for birch, based on initial laboratory data from Simard et al. (in progress). In the FORECAST model, symbiotic N_2 fixation is dependent on the total leaf biomass of the N_2 -fixing species. Thus stands of Douglas-fir do not receive excessive nitrogen inputs when birch is present at low levels or absent entirely. As the amount of birch in a stand increases, the annual nitrogen input increases. As a result, the simulated mixture grows more consistently in later rotations (Figure 1b). This nitrogen input scenario was used in the subsequent management simulations.

Management Simulations

A series of pure stands and mixtures of different initial planting densities of Douglas-fir and birch were simulated. Each simulation consisted of four consecutive 100-year rotations. Each rotation ended with a clearcut harvest and replanting of the

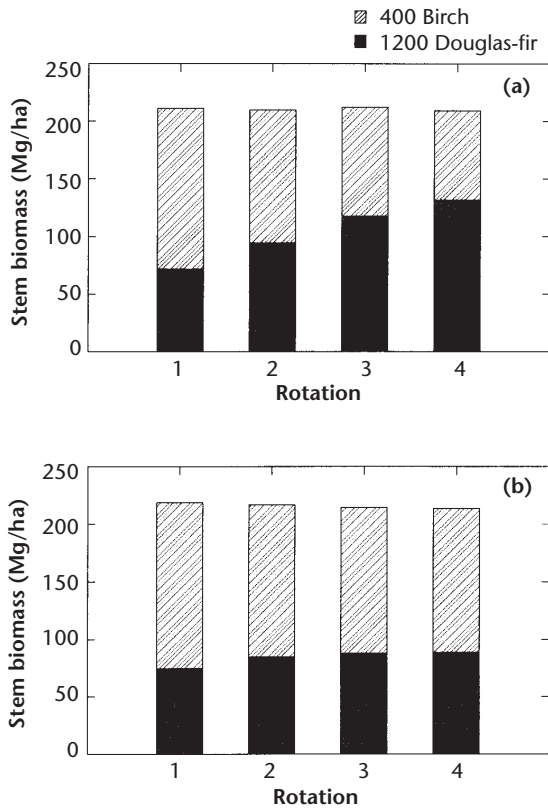


FIGURE 1 Replacement series showing predicted stemwood biomass accumulation of birch and Douglas-fir when planted in pure stands and mixtures at a constant density of 1600 stems per hectare over four consecutive 100-year rotations.

mixture. The first two scenarios simulated pure stands of birch and Douglas-fir (Figure 2). Birch showed a very slight decline in predicted yield in the last two rotations. Douglas-fir showed a greater decline in yield over four rotations. Birch dominated the mixed stands in all but the 200 birch:1400 Douglas-fir simulation (Figure 3). Total cumulative yield for the four rotations was approximately equal for all combinations containing birch (Figure 4). The pure Douglas-fir stands had the lowest predicted yield (Figure 4). The 400 birch:1200 Douglas-fir mixture was extended for an additional 400 years to examine extreme long-term trends (Figure 5). Douglas-fir yields increased slightly each rotation and appeared to plateau in rotations 7 and 8. Total yield remained stable for 800 years.

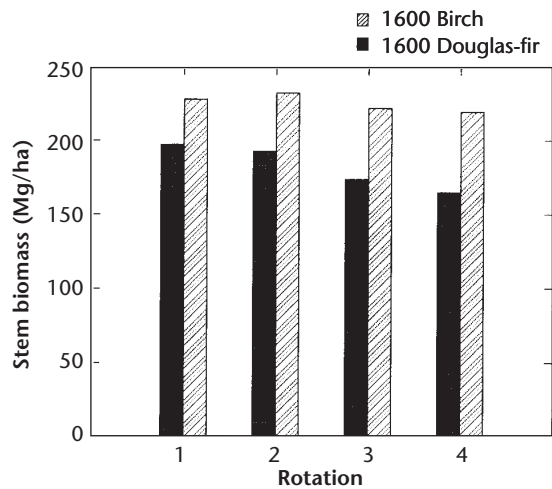


FIGURE 2 Predicted stemwood biomass produced growing each species separately over four consecutive 100-year rotations.

Additional initial planting densities were simulated to further examine predicted competition between Douglas-fir and birch in a replacement series design (de Wit 1960; Radosevich and Holt 1984) (Figure 6). In the first rotation, birch was a better competitor than Douglas-fir, providing a higher proportion of total yield in the mixed stands than would be expected if the two species were equally competitive (as indicated by the thin dashed straight line connecting the endpoints of the birch yield curve in Figure 6a). Douglas-fir provided less than the expected yield. Total yield remained constant for most mixtures, but dropped off slightly at high Douglas-fir densities. Results in the fourth rotation (Figure 6b) were similar, but yields of both species declined when fewer than 200 birch trees per hectare were present in the stand.

Discussion

The current calibration of FORECAST has some problems, but does indicate that birch may be important in maintaining the long-term productivity of these sites. FORECAST was designed to evaluate long-term trends, and not for quantitative yield prediction. Also, every model is imperfect, and all results are a function of the assumptions implicit in the model's design or the

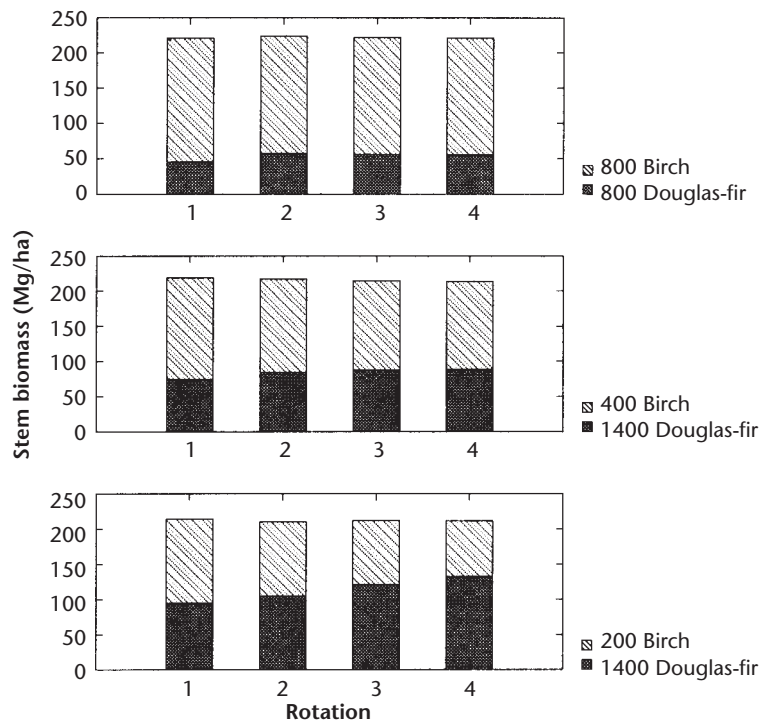


FIGURE 3 Stemwood biomass produced growing each species in combination over four consecutive 100-year rotations.

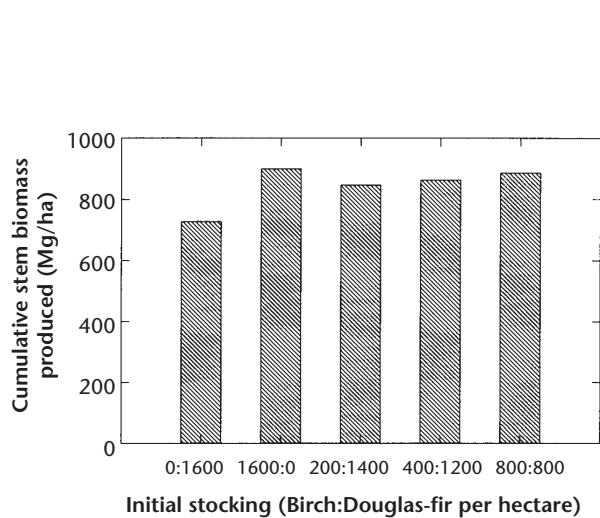


FIGURE 4 Predicted cumulative yield for four consecutive 100-year rotations of pure and mixed stands of birch and Douglas-fir.

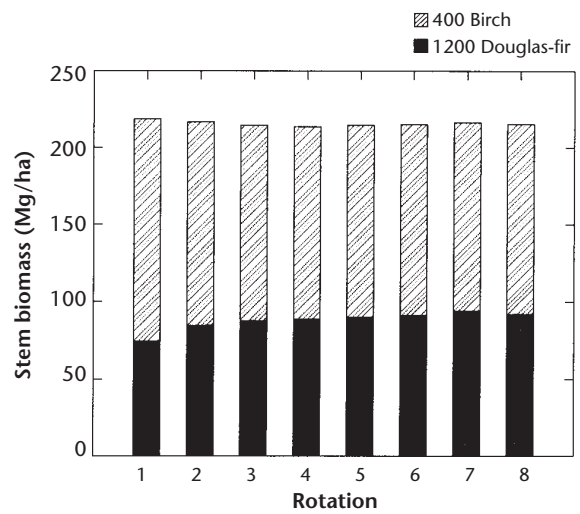


FIGURE 5 Predicted stemwood biomass produced growing the species in combination for eight 100-year rotations.

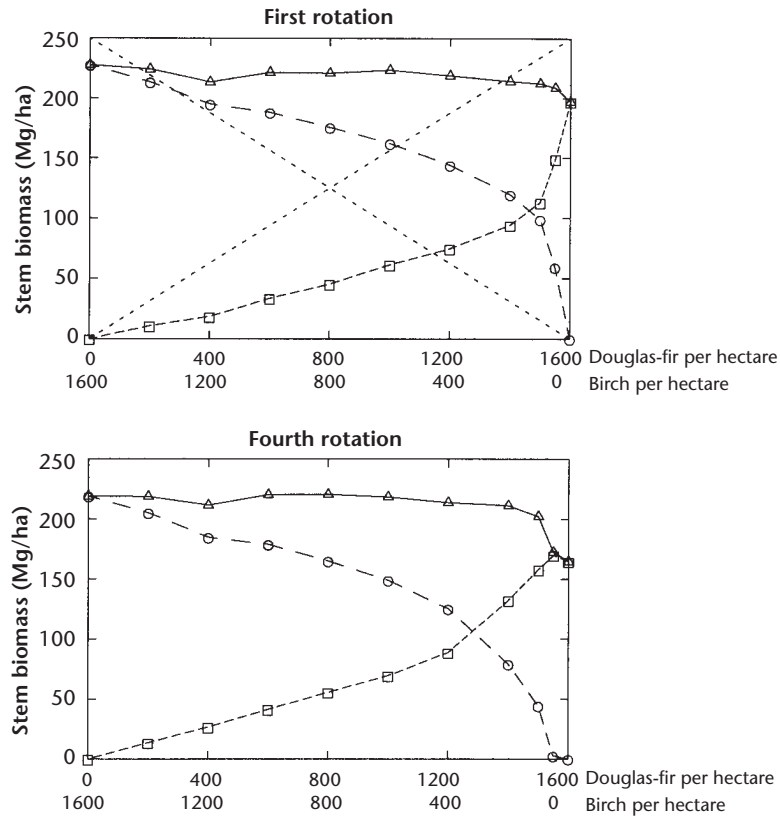


FIGURE 6 Replacement series showing predicted stemwood biomass accumulation of birch and Douglas-fir when planted in pure stands and mixtures at a constant density of 1600 stems per hectare (Δ total stemwood biomass; \circ birch stemwood biomass; \square Douglas-fir stemwood biomass).

quality of the input data. However, modelling efforts are useful for integrating data from a wide variety of studies to make projections, and for indicating future research priorities.

The model indicates that birch stands require an average annual nitrogen input of at least 6–7 kg/ha to maintain productivity. This is not unreasonable given preliminary laboratory evidence that the rhizospheres of birch seedlings support a high level of associative N_2 -fixing bacteria. Given that birch was assumed to provide a great deal of the nitrogen input in this model run, it is not surprising that simulations of management scenarios with minimal birch content predicted lower yields in later rotations because of nitrogen limitation (Figure 6b).

FORECAST appears to overpredict birch yield in both pure and mixed stands. In reality, a 100-year-old stand of pure Douglas-fir would probably contain more sound stemwood biomass than a 100-

year-old pure birch stand. However, FORECAST does not simulate heart rot or the general decline of individual trees. The recommended rotation age for birch in the ICH is 40–50 years, with merchantable volume actually declining in older stands because of the high incidence of decay (Simard and Vyse 1992). However, the birch yield model used to generate the input data for these simulations clearly overestimates the volume in older stands. The birch stemwood biomass accumulation data used as model input reaches its asymptote at about 100 years. Hence, FORECAST is overestimating the yield of pure birch stands because of poor input data. The input data for Douglas-fir stands shows continued stemwood biomass accumulation beyond 200 years. Therefore, for any simulated rotation length greater than 120 years, a pure Douglas-fir stand will produce more stemwood biomass than a pure birch stand.

FORECAST may also overestimate birch yield in

mixtures because of the lack of simulation of individual tree canopies. This could cause an overestimate of the competitive effect of birch on Douglas-fir. In FORECAST, the foliage of a species is simulated as an opaque blanket covering a hypothetical hectare so that the competitive effect of just a few trees is spread equally over the entire area. The opaque blankets of each tree species interact to compete for light. Therefore, as few as 100 birch trees per hectare significantly interfere with Douglas-fir growth. In reality, so few birch would not suppress Douglas-fir growth as greatly as predicted, partly because trees grow in patches. This is especially true in the ICH where root disease is common. To more accurately simulate the growth of these mixed stands, there must be some spatial representation of individual tree canopies, or at least patches of trees.

Aside from the simulation of light competition, the other main problem with this version of FORECAST is that nitrogen is considered to be the only other factor limiting tree growth. In reality, soil moisture is important, with birch being a much stronger competitor on the moist ICH sites (Simard and Vyse 1992). Other nutrients may also be limiting, as evidenced by the high cation levels in birch foliage. The model is capable of simulating three limiting nutrients concurrently, but sufficient data for any nutrient other than nitrogen do not exist at this time.

Despite these shortcomings, the FORECAST model provides some evidence that growing mixed stands of birch and Douglas-fir should be feasible and may offer higher long-term yields of fibre than pure stands of Douglas-fir. Under the current model assumptions, maintaining 200 birch trees per hectare could sustain long-term productivity on these sites. These simulations should be repeated when revised yield curves for birch in the ICH and field estimates of nitrogen-fixation rates in birch rhizospheres are available.

Acknowledgements

Funding for this project was provided by the Kamloops Forest Region and Research Branch, British Columbia Ministry of Forests. A copy of the FORECAST model was graciously provided by Hamish Kimmins and Kim Scoullar, the model developers. FORECAST was based on the FORCYTE series of models

developed by Dr. Hamish Kimmins and Kim Scoullar with funding from the ENFOR program of Forestry Canada.

References

- Berg, B. and H. Staaf 1987. Release of nutrients from decomposing white birch leaves and Scots pine needle litter. *Pedobiologia* 30:55–63.
- Berg, B. and B. Wessen. 1984. Changes in organic-chemical components and ingrowth of fungal mycelium in decomposing birch leaf litter as compared to pine needles. *Pedobiologia* 26:285–298.
- Bockheim, J.G., E.A. Jepsen, and D.M. Heisey. 1991. Nutrient dynamics in decomposing leaf litter of four tree species on a sandy soils in northwestern Wisconsin. *Can. J. For. Res.* 21:803–812.
- Brown, J.K. 1978. Weight and density of crowns of Rocky Mountain conifers. U.S. Dep. Agric. For. Serv. Intermtn. For. Range Exp. Sta., Ogden, Utah. Res. Pap. INT-197. 56 p.
- Clayton, J.L. and D.A. Kennedy. A comparison of the nutrient content of Rocky Mountain Douglas-fir and ponderosa pine trees, 1980. U.S. Dep. Agric. For. Serv. Intermtn. For. Range Exp. Sta., Ogden, Utah. Res. Pap. INT-281. 13 p.
- deWit, C.T. 1960. On competition. *Versl. Lanbouwk. Onderz.* 66:1–82.
- Edmonds, R.L. 1987. Decomposition rates and nutrient dynamics in small-diameter woody litter in four forest ecosystems in Washington, U.S.A. *Can. J. For. Res.* 17:499–509.
- Fogel, R. 1983. Root turnover and productivity of coniferous forest. *Plant and Soil* 71:75–85.
- Fogel, R. and K. Cromack, Jr. 1977. Effect of habitat and substrate quality on Douglas-fir litter decomposition in western Oregon. *Can. J. Bot.* 55:1632–1640.
- Gower, S.T., C.C. Grier, D.J. Vogt, and K.A. Vogt. 1987. Allometric relations of deciduous (*Larix occidentalis*) and evergreen conifers (*Pinus contorta* and *Pseudotsuga menziesii*) of the Cascade Mountains in central Washington. *Can. J. For. Res.* 17:630–634.
- Harmon, M.E., G.A. Baker, G. Spycher, and S.E. Greene. 1990. Leaf-litter decomposition in the *Picea / Tsuga* forests of Olympic National Park, Washington, U.S.A. *For. Ecol. Manage.* 31:55–66.

- Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, S.W. Lienkaemper, K. Cromack Jr., and K.W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. *Adv. Ecol. Res.* 15:133–302.
- Jurik, T.W., J.A. Weber, and D.M. Gates. 1988. Effects of temperature and light on photosynthesis of dominant species of a northern hardwood forest. *Bot. Gaz.* 149(2):203–208.
- Kimmins, J.P., K.A. Scoullar, and M.J. Apps 1990. FORCYTE-11 user's manual for the benchmark version. *For. Can. North. For. Cent.*, Edmonton, Alta. ENFOR Proj. P-370. 294 p.
- Prescott, C.E., R. Kabzems, S. Simard, C. Staley, L. Zabek, and P.G. Comeau. 1996. Mixedwood forests: implications for litter decomposition. These proceedings.
- Radosevich, S.R. and J.S. Holt. 1984. *Weed ecology*. John Wiley and Sons, New York, N.Y. 265 p.
- Safford, L.O. 1974. Effect of fertilization on biomass and nutrient content of fine roots in a beech-birch-maple stand. *Plant and Soil* 40:349–363.
- Santantonio, D. and R.K. Hermann. 1985. Standing crop, production, and turnover of fine roots on dry, moderate, and wet sites of mature Douglas-fir in western Oregon. *Ann. Sci. For.* 42(2):113–142.
- Simard, S., C.Y. Li, and D.A. Perry. [n.d.]. Associative nitrogen fixation by paper birch and Douglas-fir seedlings grown in mixture in soils collected from the southern interior of British Columbia. In preparation.
- Simard, S. and A. Vyse. 1992. Ecology and management of paper birch and black cottonwood in southern British Columbia. B.C. Min. For. Res. Branch, Victoria, B.C. Land Manage. Rep. No. 75.
- Sollins, P., S.P. Cline, T. Verhoeven, D. Sachs, and G. Spycher. 1987. Patterns of log decay in old-growth Douglas-fir forests. *Can. J. For. Res.* 17:1585–1595.
- Sollins, P., C. Grier, F.M. McCorison, K. Cromack, Jr., R. Fogel, and R.L. Frederiksen. 1980. The internal element cycles of an old-growth Douglas-fir ecosystem in western Oregon. *Ecol. Monogr.* 50:261–285.
- Van Cleve, K. and L.L. Noonan. 1975. Litter fall and nutrient cycling in the forest floor of birch and aspen stands in Interior Alaska. *Can. J. For. Res.* 5:626–639.
- Vogt, K.A., C.C. Grier, and D.J. Vogt. 1986. Production, turnover, and nutrient dynamics of above- and belowground detritus of world forests. *Adv. Ecol. Res.* 15:303–377.
- Wang, J.R., S. Simard, and J.P. Kimmins. 1995. Physiological responses to thinning in paper birch stands in the ICH zone of British Columbia. *For. Ecol. Manage.* 73:177–184.
- . [1996]. Above-ground biomass production and nutrient accumulation in an age sequence of paper birch in the Interior Cedar–Hemlock Zone in British Columbia. *For. Ecol. Manage.* In press.

Mixedwood Forests: Implications for Litter Decomposition

C.E. PRESCOTT, R. KABZEMS, S. SIMARD, C. STALEY, L. ZABEK, AND P.G. COMEAU

Abstract

A network of ongoing experiments in British Columbia is described, experiments that explore the implications of mixedwood management for rates of litter decomposition in forests. The influence of tree species composition is being assessed by comparing rates of decay of foliar litter of different species and relating this to the chemical “quality” of each litter. The influence of the forest floor is being compared by measuring rates of decomposition of a single litter type on different types of forest floors. Finally, the influence of mixed forests is being assessed by comparing rates of decomposition of pure and mixed-species litter in pure and mixed stands. The results will be used to predict rates of decomposition under different management scenarios, such as mixedwoods.

Introduction

Recent interest in management of mixedwood forests in British Columbia, including boreal spruce and aspen, interior Douglas-fir and birch, and coastal Douglas-fir and alder, has highlighted our limited understanding of the interactions among species in mixed forests, particularly as they influence below-ground processes. Studies in other forests have demonstrated that seral stages or interplanting with other species, particularly hardwoods, can significantly improve growth of regenerating conifers, partly through improved nutrition of trees in mixed forests. In the United Kingdom, Sitka spruce in mixtures with larch or pine grow significantly faster than those in single species plantations, and this has been linked to greater availability of nitrogen in the forest floor of mixed plantations (Carlyle and Malcolm 1986). Williams and Alexander (1991) suggested that the improved nitrogen availability in mixed plantations was at least partly due to more complex fungal-

faunal interactions in mixed plantations, which increased the rates of decomposition and nitrogen release from litter. Development of hardwood clumps after clearcutting white spruce in the boreal forest contributes to acceleration of nutrient cycling because of higher concentrations of nitrogen and phosphorus in foliar litter of aspen and poplar and subsequent faster decomposition (Paré and Van Cleve 1993). Conifer litter often decomposes more rapidly when mixed with hardwood leaf litter (Taylor et al. 1989), suggesting that decomposition of conifer litter may be faster in mixed plots. The influence of mixed litters of either hardwood or conifer have been less consistent (Blair et al. 1990). The forest floor that develops under mixed stands may also influence the rate of decomposition and nutrient release from litter. McClaugherty et al. (1985) noted a slight tendency for litter to decompose more rapidly in forests of its own species than does transplanted litter, but it has also been suggested that litter will decompose more rapidly on N-rich sites, regardless of species. Most of these observations are from studies of different forest types, in which not only the species, but site factors such as fertility and climate, also vary. Testing the pure effect of species on decomposition requires plantations of different species on a single site.

The following questions are being addressed in a network of ongoing studies in British Columbia:

- Are there consistent differences in decay rates of litter of different tree species in British Columbia, and are these predictable from measures of the “quality” of the litter?
- Does litter decompose fastest on its own forest floor, or on N-rich forest floors?
- Does litter decompose more rapidly in mixed or pure forests?
- Does mixing litter of different species influence decomposition rates?

Methods

Freshly fallen foliar litter of each species was collected in autumn at each site. Fibreglass mesh bags, 10–15 cm on a side with pore size 1.5 or 0.5 mm, containing 2.0 g of foliar litter, were used in all experiments. At yearly intervals for 5 years, 10 bags of each type are removed from each plot, and the dry weight of material remaining in each bag is measured. Mass remaining at each time and decomposition constant will be determined for each litter type in each plot and compared among plots (to determine the influence of forest floor in pure and mixed forests), among litter types (to determine the influence of litter quality), and in mixed and pure bags (to determine the influence of mixing litters).

Experiment 1: Decomposition Rates of Litter of 14 Tree Species in British Columbia

Question: Influence of litter quality.

Sites Boreal spruce forest in the BWBS zone near Dawson Creek; coastal mixed conifer forest in the CWH zone near Maple Ridge.

Litter Types Lodgepole pine (Pl), white pine (Pw), ponderosa pine (Py), western hemlock (Hw), western redcedar (Cw), western larch (Lw), Engel-

mann spruce (Se), subalpine fir (Fs), amabilis fir (Fa), Douglas-fir (fd), trembling aspen (At), cottonwood poplar (Act), vine maple (Mv), and red alder (Dr).

Duration 1993–1998

Results to Date During the first year, less of the original 2 g of litter remained at the coastal site, but the relative ranking of species at the two sites was similar (Table 1).

Experiment 2: Decomposition Rates of Litter of Seven Tree Species in ICH Forests

Questions Influence of litter quality, forest type, and opening.

Sites Forests and adjacent cutovers in the ICH zone near Hidden Lake, Malakwa, and Adams Lake.

Litter Types Trembling aspen, western larch, Douglas-fir, paper birch, white pine, lodgepole pine, and western redcedar

Duration 1992–1997

Results to Date After 2 years, there was some variation in relative rates of decomposition of litter types (Table 2). Decomposition was usually more rapid in cutovers than in adjacent forests.

TABLE 1 *Dry weight of foliar litter of 14 tree species remaining after incubating for 1 year in coastal and boreal forest sites in British Columbia*

Species	Coastal		Boreal		Broadleaved (coastal)		
	Weight (g)	Rank	Weight (g)	Rank	Species	Weight (g)	Rank
Py	1.26	1.0	1.54	1.0	Mv	0.49	1.0
Pw	1.27	2.0	1.70	7.0	Dr	1.12	2.5
Lw	1.28	3.0	1.62	2.0	At	1.12	2.5
Fd	1.31	4.0	1.64	4.0	Act	1.35	4.0
Pl	1.34	5.5	1.67	5.5			
Se	1.34	5.5	1.67	5.5			
Fs	1.37	7.0	1.63	3.0			
Hw	1.51	8.5	1.77	8.0			
Fa	1.51	8.5	1.85	9.0			
Cw	1.62	10.0	1.90	10.0			

TABLE 2 Dry weight of foliar litter of seven tree species remaining after incubating for 2 years in three ICH forests in interior British Columbia. Weight remaining of original 2 g and rank are shown.

Species	Hidden Lake		Malakwa		Adams Lake	
	Forest	Cutover	Forest	Cutover	Forest	Cutover
At	1.07 (1)	0.92 (1)	1.01 (1)	1.03 (1)	1.19 (5)	1.04 (1)
Lw	1.09 (2)	1.18 (3)	1.05 (3)	1.29 (3)	0.97 (1)	1.29(6)
Fd	1.11 (3)	1.14 (2)	1.15 (4)	–	1.00 (2)	1.10 (3)
Ep	1.34 (6)	1.20 (4)	1.02 (2)	1.37 (5)	1.20 (6)	1.08 (2)
Pw	1.25 (5)	1.28 (5)	1.25 (6)	1.25 (2)	1.02 (3)	1.22 (5)
Pl	1.18 (4)	1.35 (6)	1.16 (5)	1.33 (4)	1.04 (4)	1.16 (4)
Cw	1.36 (7)	1.56 (7)	1.36 (7)	1.61 (6)	1.37 (7)	1.39 (7)

Experiment 3: Decomposition of Birch Leaf Litter in Forest Floors of Three Species

Question Influence of forest floor.

Sites Microcosm experiment, all at 20°C, 70% moisture.

Litter Types Paper birch leaf litter in forest floors of lodgepole pine, Douglas-fir, and red alder.

Duration 70 weeks

Results to Date Birch leaves lost weight fastest in alder forest floors and slowest in pine forest floors (Figure 1). This was not related to N availability, which was highest in Douglas-fir forest floors by the end of the experiment (Figure 2). Weight loss was related to the amount of frass in the bags, indicative of soil faunal activity, which was greatest in alder and least in pine.

Experiment 4: Decomposition of Cedar, Hemlock, and Douglas-fir in Forests of Each Species

Questions Influence of litter quality and forest floor.

Sites Four 30-year-old plantations of western redcedar, western hemlock, and Douglas-fir in the CWH zone near Port Renfrew and Lake Cowichan.

Litter Types Cedar, hemlock, and Douglas-fir are collected from 35-year-old plantations near Maple Ridge.

Duration 1995–2000

Results to Date Established in April 1995.

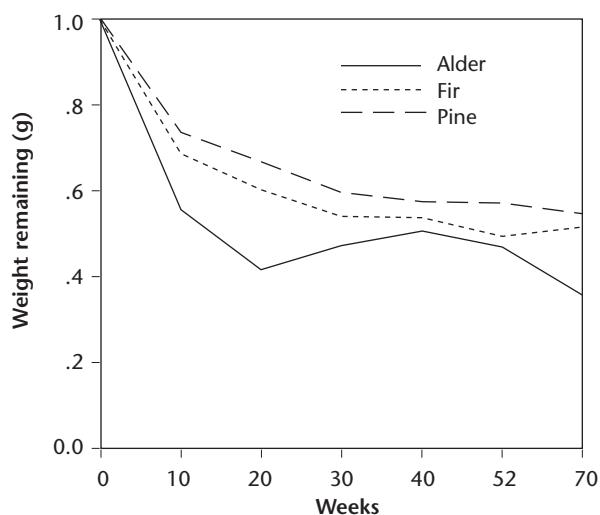


FIGURE 1 Dry weight of paper birch leaf litter remaining during incubation in forest floors of lodgepole pine, Douglas-fir, and red alder in laboratory microcosms.

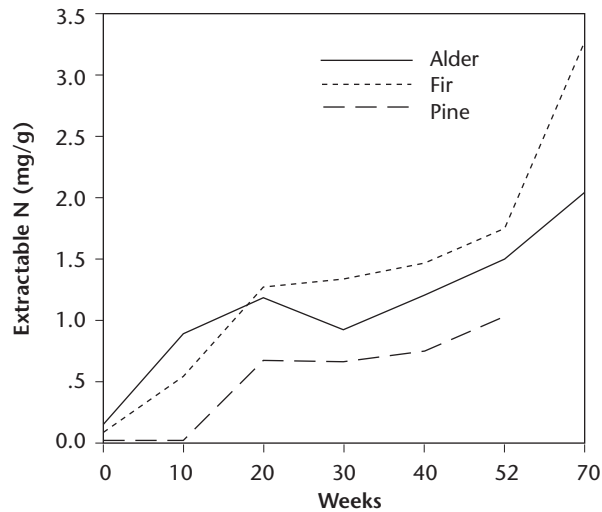


FIGURE 2 Concentrations of KCl-extractable N in forest floors of lodgepole pine, Douglas-fir, and red alder in laboratory microcosms.

Experiment 5: Decomposition of Pure and Mixed Litter of Spruce and Aspen in Pure and Mixed Forests

Questions Influence of forest type, mixing litter, and mixed forest.

Sites One trembling aspen, one interior spruce, one mixed spruce-aspen forest in the BWBS zone near Dawson Creek.

Litter Types Aspen, spruce, mixed.

Duration 1993–1998

Results to Date During the first year, mixed litter of both species decomposed more slowly than pure litter. There was not a consistent effect of forest type (Table 3).

Experiment 6: Decomposition of Pure and Mixed Litter of Pine, Douglas-fir, and Birch in Forests of Each Species

Questions Influence of forest floor and mixing litter.

Sites 25-year-old plantations of lodgepole pine, Douglas-fir, and paper birch in the Skimikin stump trial in the ICH zone near Salmon Arm.

Litter Types Pine, fir, birch, mixed pine–fir, pine–birch, fir–birch.

Duration 1995–2000

Results to Date Established in May 1995.

Experiment 7: Decomposition of Pure and Mixed Litter of Douglas-fir and Red Alder

Questions Influence of forest floor, mixing litter, and N-fixing species.

Sites Three pure 20-year-old stands of Douglas-fir and red alder in the CWH zone near Maple Ridge.

Litter Types Douglas-fir, alder, mixed.

Duration 1995–2000

Results to Date Established in April 1995.

TABLE 3 Dry weight of foliar litter of aspen and spruce remaining after incubating for 1 year in pure and mixed stands of aspen and spruce in northern British Columbia. Weight remaining of original 2 g and rank are shown.

Site	Aspen		Spruce		Mean	
	Alone	Mixed	Alone	Mixed	Alone	Mixed
Aspen	0.70 (4)	0.68 (1)	1.39 (3)	1.3 (1)	1.04 (3)	1.02 (1)
Spruce	0.68 (3)	0.74 (3)	1.33 (1)	1.38 (2)	1.01 (2)	1.06 (2)
Mixed	0.60 (1)	0.76 (4)	1.37 (2)	1.46 (3)	0.99 (1)	1.10 (3)
Cutover	0.65 (2)	0.70 (2)	1.51 (4)	1.56 (4)	1.08 (4)	1.13 (4)

Summary

A network of experiments has been established to determine the influence of litter quality, forest floor, and mixing litter on rates of decomposition. Results of these experiments and others addressing the effects of climate, litter quality, opening size, and fertilization will improve our ability to predict rates of litter decomposition and nutrient recycling in British Columbia forests under different management scenarios.

References

- Blair, J.M., W. Parmalee, and M.H. Baere. 1990. Decay rates, nitrogen fluxes, and decomposer communities of single- and mixed-species foliar litter. *Ecology* 71:1976–1985.
- Carlyle, J.L. and D.C. Malcolm. 1986. Nitrogen availability beneath pure and mixed larch and spruce stands growing on a deep peat. *Plant Soil* 93:95–113.
- McClaugherty, C.A., J. Pastor, J.D. Aber, and J.M. Melillo. 1985. Forest litter decomposition in relation to soil nitrogen dynamics and litter quality. *Ecology* 66:266–275.
- Paré, D. and K. Van Cleve. 1993. Soil nutrient availability and relationships with aboveground biomass production on postharvested upland white spruce sites in interior Alaska. *Can. J. For. Res.* 23:1223–1232.
- Taylor, B.R., W.F.J. Parsons, and D. Parkinson. 1989. Decomposition of *Populus tremuloides* leaf litter accelerated by addition of *Alnus crispa* litter. *Can. J. For. Res.* 19:674–679.
- Williams, B.L. and C.E. Alexander. 1991. Interactions on mixing litters from beneath Sitka spruce and Scots pine and the effects on microbial activity and N-mineralization. *Soil Bio. Biochem.* 23(1):71–75.