

**RESPONSES OF SPRUCE, ASPEN  
AND UNDERSTORY VEGETATION  
TO WILDFIRE AND FIVE SITE  
PREPARATION TREATMENTS**

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**Responses of spruce, aspen and understory vegetation  
to wildfire and five site preparation treatments**

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## ABSTRACT

A study of the effect of wildfire and five site preparation treatments on spruce (*Picea glauca* (Moench) Voss), aspen (*Populus tremuloides* Michx.) and understory vegetation was conducted in 4-9 year old forests in 1993-4 in central Saskatchewan. Treatments included five site preparation techniques, wildfire, and a control (undisturbed forests). Three transects were measured for each treatment.

Trees were tagged and measured in the fall of both years in the following treatments: harvest followed by disk-trenching and drum-chopping, harvest followed by disk-trenching, harvest followed by natural regeneration, and wildfire. Growth rates did not vary among treatments, but spruce growth tended to be greatest in burned transects and aspen growth tended to be greatest in the most intensive site preparation treatments. The number of new trees establishing in 1994 was highest in the fire transects.

For all seven treatments, aspen mass and density was greatest in sites with natural regeneration and lowest in sites subjected to intensive site preparation such as drum-chopping and disk trenching. Understory mass and diversity was lowest in undisturbed forests but did not vary among other treatments.

## ACKNOWLEDGEMENTS

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## INTRODUCTION

A variety of silvicultural methods have been developed in the effort to re-establish productive softwood stands following harvesting (Lanini and Radosevich 1986, Baker 1989, Bassman 1989). In addition to their effect on productivity, silvicultural practices may influence the diversity of a plant community by affecting the dispersal, establishment, growth and mortality of individual plants.

This report describes a two year study on the effects of several silvicultural practices on stand revegetation and diversity. In particular, five site preparation techniques and wild-fire were compared with respect to their potential for regeneration and productivity, and their impact on plant species diversity.

The softwood productivity of a mixedwood stand is influenced to a large extent, by competition from hardwoods (Johnson 1986, Putz 1992, Elliot *et al.* 1993), especially aspen. One of the goals of site preparation, apart from exposing favorable microsites for softwood seedlings, is to reduce competition from hardwoods. Most methods of site preparation involve the removal of aspen stems followed by trenching to sever their roots. However, these methods suppress aspen for a very short time after which suckering occurs. The extent to which aspen will sucker depends, in part, on the extent to which the stand is disturbed (Peterson and Peterson 1992). Thus, it may be that very intensive and extensive site preparation, while reducing competition from aspen in the first year or two, actually increases competition later on due to profuse aspen suckering.

Treatments examined included a control (C), natural regeneration after fire (F), natural regeneration after harvest (N), Bräcke-cultivation (BC), drum-chopping (DC), disk-trenching (DT), and straight-blading (SB; Table 1). These techniques are listed in order of increasing disturbance to soil and vegetation. Controls were undisturbed forests. Fire included areas affected by a wildfire. Natural regeneration involves tree harvest but no site preparation. Bräcke-cultivating makes holes through duff to expose a patch of mineral soil about every 3 m. Disk-trenching involves plowing duff into piles creating trenches of exposed mineral soil separated by about 3 m. Drum-chopping is disk-trenching followed by drum-chopping, during which aspen roots and stems are cut with blades attached to a rotating drum. Straight-blading exposes mineral soil by scraping away duff.

We tested the hypothesis that significant differences exist among treatments in their impact on tree growth and diversity.

**Table 1.**  
**Description of treatments.**

<b>Abbreviation</b>	<b>Wildfire</b>	<b>Harvested</b>	<b>Site preparation</b>	<b>Planted with spruce</b>
C	no	no	no	no
F	yes	no	no	no
N	no	yes	no	no
BC	no	yes	Bräcke-cultivated	yes
DC	no	yes	disk-trenched/drum chopped	yes
DT	no	yes	disk-trenched	yes
SB	no	yes	straight-bladed	yes

## METHODS

Five treatments were examined in October 1993: fire, natural regeneration, Bräcke-cultivating, disk-trenching, and drumchopping (Table 2). Each treatment was represented by three transects except for Bräcke-cultivating, for which only one transect could be located in 1993. Only a subset of all treatments were examined in 1993 because field sites could not be visited until the end of September. Transects were located in young upland forest on morainal (knoll and kettle) topography and gray luvisol on sandy loam, in areas which had been harvested between 1984 and 1990. The fire transects were burned in 1989. The transects were long and narrow in order to accommodate heterogeneity in the plots.

Transect size varied from 1 x 30 to 5 x 60 m depending on tree density. Every spruce and pine (*Pinus banksiana* Lamb.) within the transect was tagged and their diameters were measured. Smaller subplots ranging from 1 x 1 to 2 x 5 m were located equidistantly along one side of the transect. All birch (*Betula papyrifera* Marsh.) and aspen were measured within these subplots.

About 100 other trees (pine, aspen, and spruce) of varying sizes outside the transects were measured, collected, dried and weighed. These trees were used to obtain allometric estimations of tree biomass from diameter (Appendix 1). We used diameter to estimate mass instead of height because height varies with both tree mass and shading.

In July 1994 transects in the remaining three treatments (control, Bräcke-cultivated, and straight-bladed) were located (Table 2), and diversity, biomass, and light penetration were examined. Diversity was measured in five plots (50 x 100 cm) spaced equidistantly along 30 m of each transect. Since the smallest transects were 5 x 30 m in size, the diversity plots were spread out 30 m regardless of transect size. The cover of each species was recorded using Daubenmire's scale. All live above ground understory (e.g. herbs, shrubs, grasses, sedges) in a 10 x 50 cm plot within each diversity plot was collected, dried, and weighed. Total non-spruce mass was calculated as the sum of the understory, aspen, birch, and pine.

Below ground biomass was determined by collecting five root cores, each 10 cm deep, from within each diversity plot. Cores from each plot were combined and roots were washed, dried, and weighed.

Light penetration was determined in each plot during July 1994, using a 40 cm long integrating Licor Photosynthetically Active Radiation Meter. Light intensity measurements were taken both above and below the understory vegetation. Light penetration was calculated for each plot.

In October 1994 diameter measurements were taken of previously tagged trees, and also new trees in the remaining three treatments. Comparisons of 1993 and 1994 data allowed establishment, mortality, and growth to be determined for fire, natural regeneration, Bräcke-cultivated, disk-trenching, and drum-chopping. Only one Bräcke-cultivated transect was measured in both 1993 and 1994. Only two natural regeneration transects were used because one sampled in 1993 could not be relocated in 1994 due to marker removal. Density and mass data were available for all treatments.

For statistical analysis, all proportional data (diversity, light penetration, and growth) were arcsin-square root transformed and other data were log transformed. Data were examined with oneway analysis of variance (ANOVA) across treatments, and means comparisons were performed with Tukey-Kramer honestly significant difference tests.

**Table 2.**  
**Locations of three transects for each of the seven treatments.**  
**See Table 1 for treatment abbreviations and descriptions.**

<b>Treatment</b>	<b>Transect</b>	<b>Map</b>	<b>UTM coordinates</b>
C	1	73-H/12	437484
C	2	73-H/12	419478
C	3	73-H/13	418758
F	1	73-I/4	399115
F	2	73-I/5	374121
F	3	73-I/5	372127
N	1	73-H/12	400462
N	2	73-H/13	422601
N	3	73-H/13	418598
BC	1	73-H/13	407757
BC	2	73-H/13	394592
BC	3	73-H/11	748489
DT	1	73-H/12	438486
DT	2	73-H/12	442488
DT	3	73-H/12	453457
DC	1	73-I/4	371966
DC	2	73-H/12	436486
DC	3	73-H/12	420477
SB	1	73-H/13	376683
SB	2	73-H/13	413751
SB	3	73-H/13	418752

## RESULTS

### *Spruce establishment and mortality*

Spruce establishment did not vary significantly among treatments, although new tree density was highest in two fire transects (Fig. 1). Survivorship from 1993 to 1994 was perfect except for one death in a drum-chopped transect. The Bräcke-cultivated treatment was excluded from the ANOVA because it was represented by only one transect in 1993.

### *Spruce and aspen growth*

Spruce growth varied significantly among treatments and was highest in the fire transects ( $P < 0.05$ ). The Bräcke-cultivated treatment was excluded from the ANOVA because it was represented by only one transect in 1993; natural regeneration was excluded because only one tree was found in this treatment.

Aspen growth rate did not vary significantly among treatments, although the highest values were found in drum-chopped transects (Fig. 2).

### *Mass*

Total spruce mass varied significantly among treatments (Fig. 3), but this result was caused by very high values in the control transects. Spruce mass did not vary significantly among the other treatments.

Total aspen mass varied significantly among the treatments. Mass in the natural regeneration transects was significantly higher than in straight-bladed and drum-chopped transects (Fig. 3).

Understory mass varied significantly among treatments (Fig. 3), primarily because control transects had significantly less understory mass. Understory mass did not vary significantly among the other treatments (Fig. 3).

Total non-spruce above-ground mass did not vary significantly among treatments (Fig. 3).

Root mass varied significantly among treatments (Fig. 4). Root mass was significantly higher in control and Bräcke-cultivated transects than in disk-trenched and drum-chopped transects.

### *Stem density*

Spruce stem density did not vary significantly among treatments (Fig. 5). Aspen density varied significantly among treatments (Fig. 5). Apart from control transects, aspen density was highest in fire and natural regeneration transects, and lowest in drum-chopped and straight-bladed transects.

*Light penetration*

Penetration of light through the canopy varied significantly among treatments and was lowest natural regeneration transects (Fig. 6).

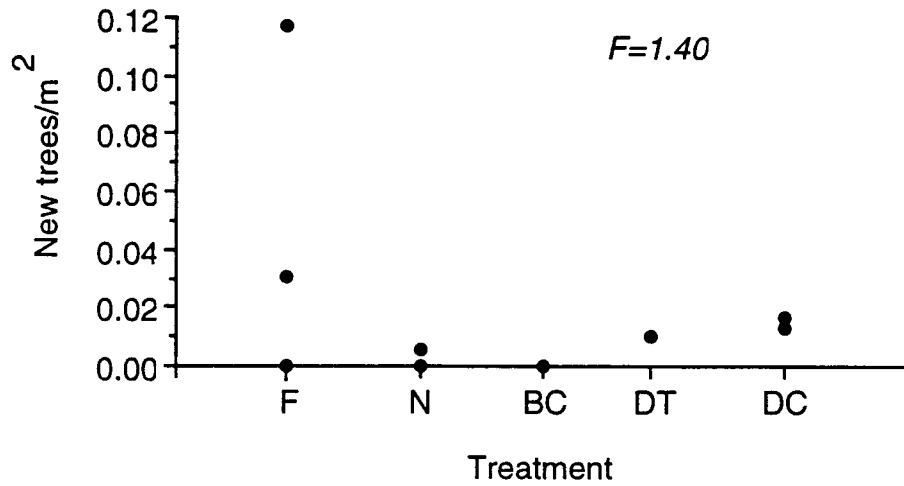
*Diversity and species composition*

Diversity ( $H'$ ) was significantly lower in control transects than any other treatment, but did not vary significantly among other treatments (Fig. 7).

Species composition varied among treatments chiefly in the reduction of aspen in plots with site preparation (Table 3). Further, some species found in control, fire, and natural regeneration transects were less common in transects with site preparation. These included sarsaparilla and colt's foot. Conversely, some species uncommon in less disturbed transects had higher covers in transects with site preparation, e.g. aster and wild rye.

*Relationship between neighbor and spruce mass*

Regression analysis found no significant relationships between total non-spruce mass and spruce mass, or between non-spruce mass and spruce density.



**Fig. 1.**  
**Establishment of spruce trees in five treatments between October 1993 and October 1994.**  
See Table 1 for treatment abbreviations and descriptions.  
The F-value is from analysis of variance comparing the treatments.

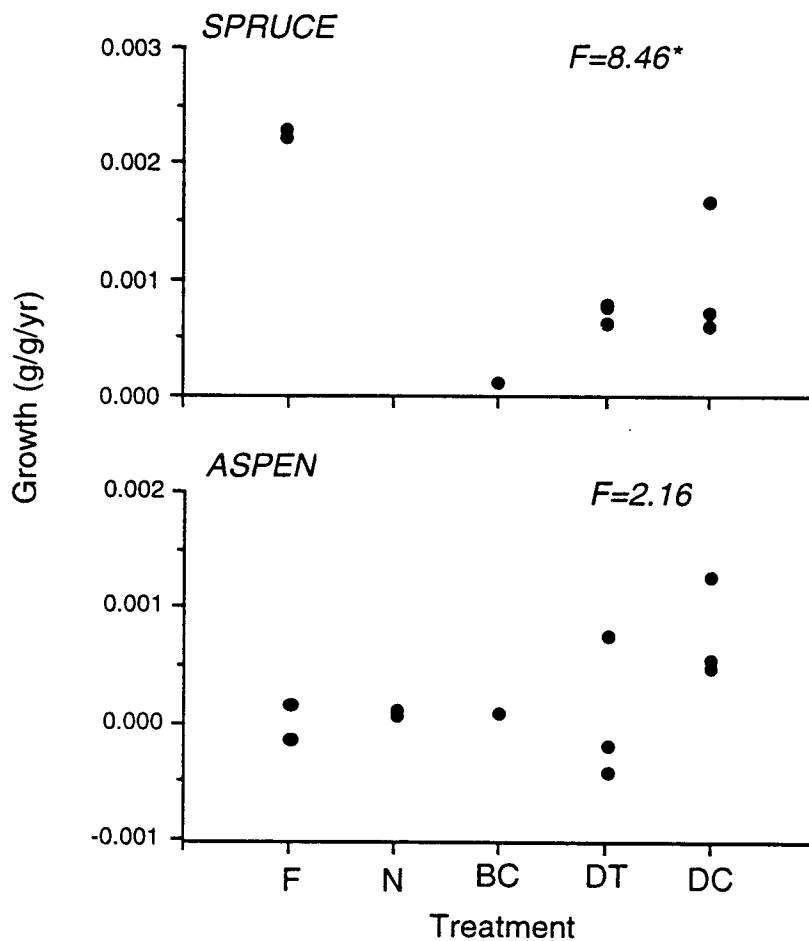


Fig. 2.

Growth rates of spruce (top) and aspen (bottom) between October 1993 and October 1994 in five treatments.  
See Table 1 for treatment abbreviations and descriptions.  
The F-values are from analyses of variance comparing the treatments (\* P < 0.05).

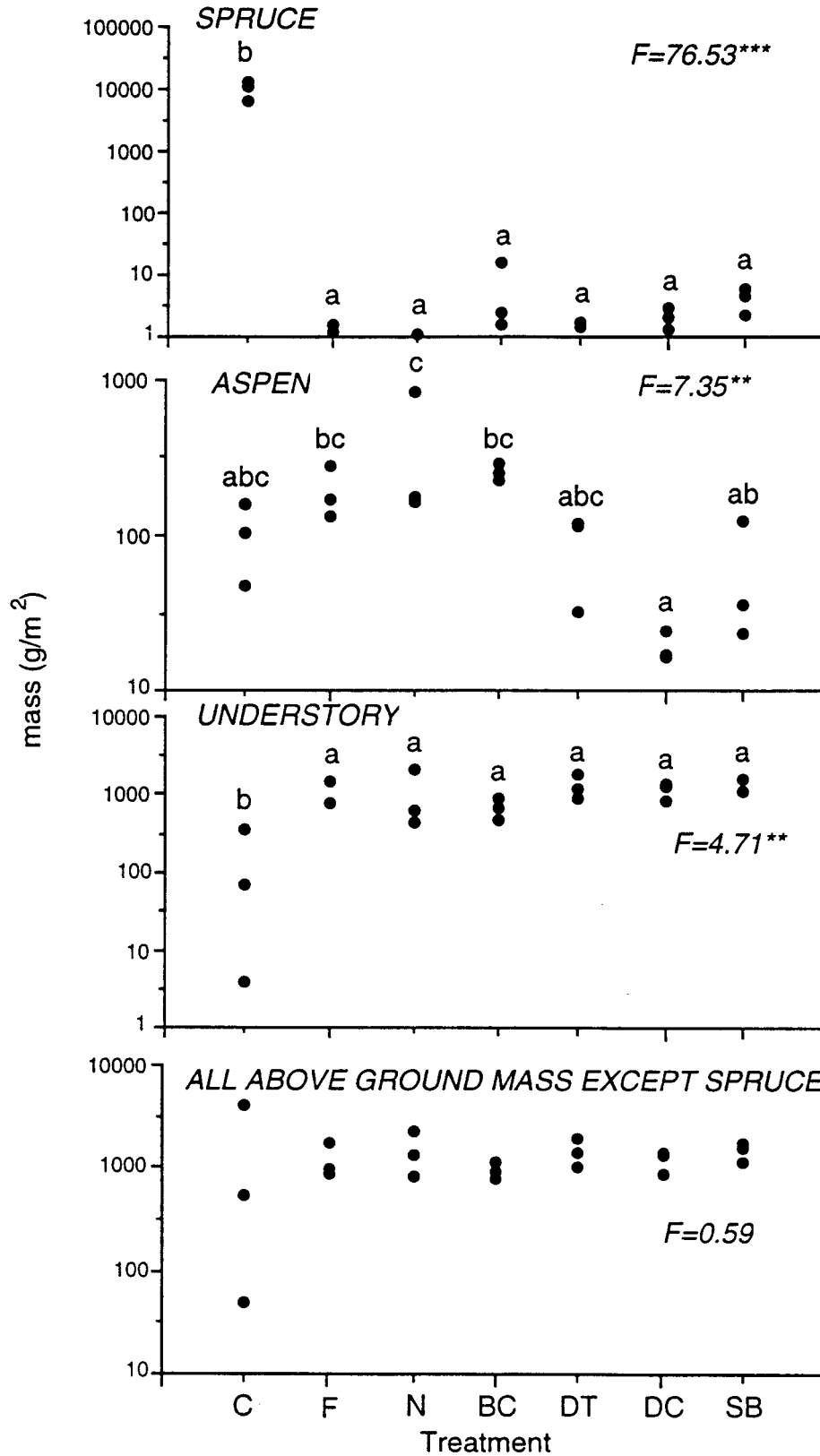
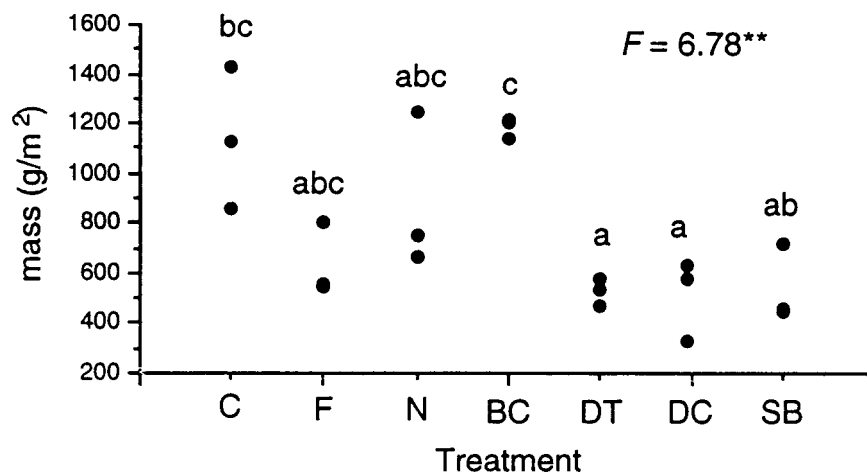


Fig. 3.  
 Masses of spruce, aspen, understory, and total above ground mass except spruce, in seven treatments.  
 (See complete Caption on next page.)

**Fig. 3.**

**Masses of spruce, aspen, understory, and total above ground mass except spruce, in seven treatments. See Table 1 for treatment abbreviations and descriptions. Note log scales. The F-values are from analyses of variance comparing the treatments (\*\*\*:  $P < 0.001$ , \*\*:  $P < 0.01$ ). Common lower case letters represent means not significantly different from one another.**



**Fig. 4.**

**Root mass in seven treatments.**

**See Table 1 for treatment abbreviations and descriptions. \*\*: P < 0.01.**

**Common lower case letters represent means not significantly different from one another.**

**The F-value is from analysis of variance comparing the treatments (\*\*: P < 0.01).**

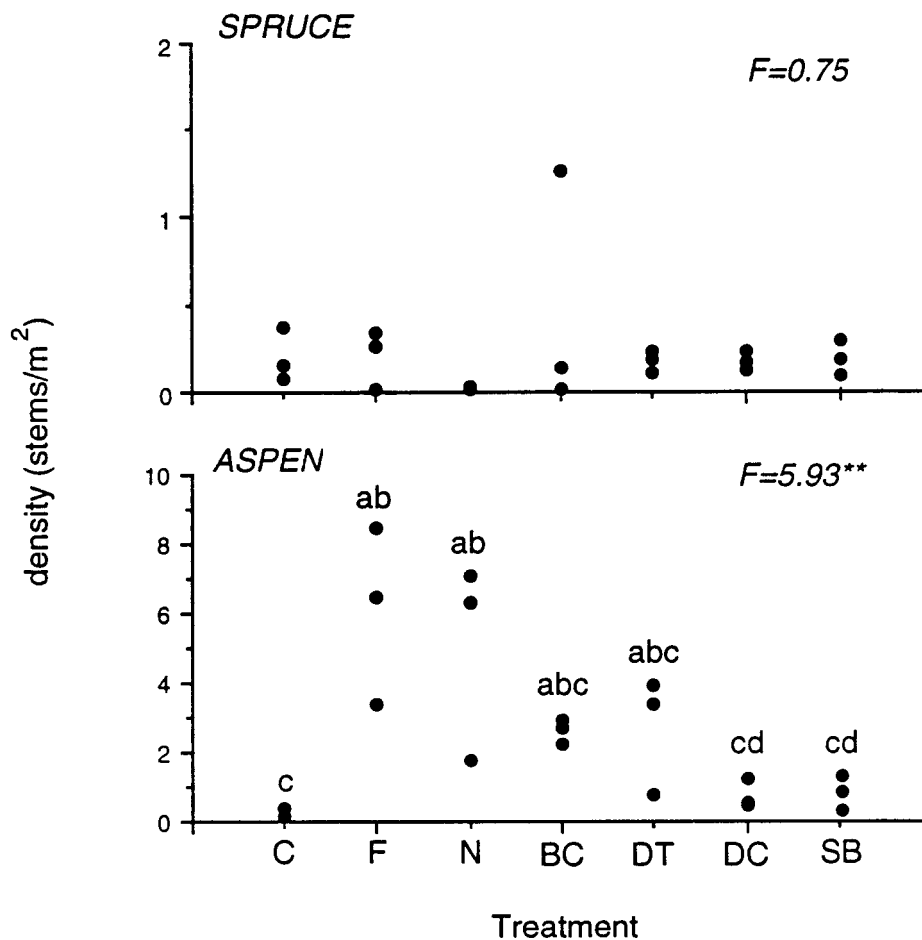


Fig. 5.

Stem density of spruce (top) and aspen (bottom) in seven treatments. See Table 1 for treatment abbreviations and descriptions. The F-values are from analyses of variance comparing the treatments (\*\*:  $P < 0.01$ ). Common lower case letters represent means not significantly different from one another.

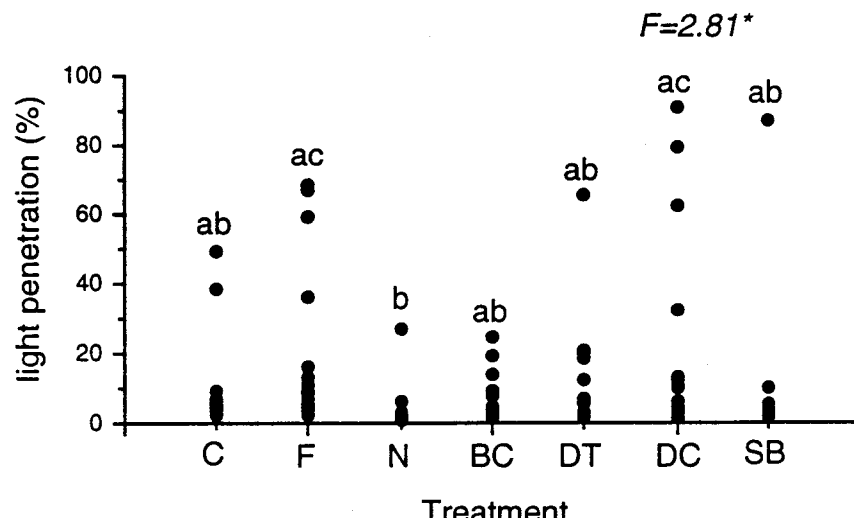
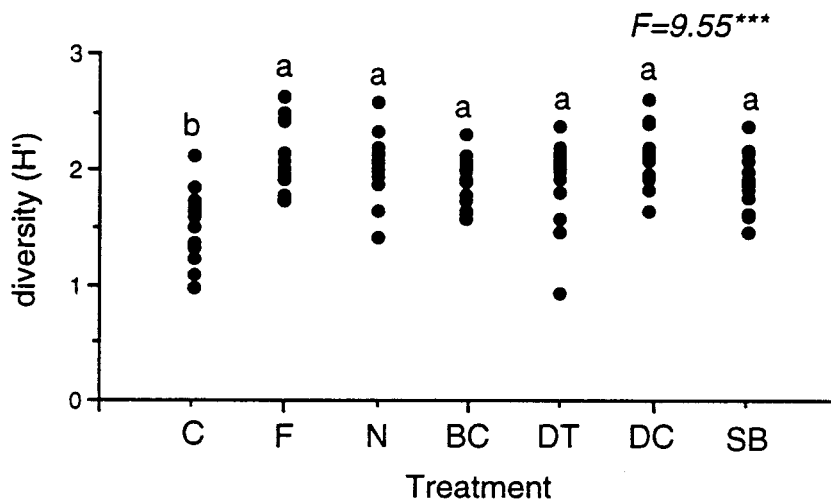


Fig. 6.

Light penetration to the soil surface in seven treatments.

See Table 1 for treatment abbreviations and descriptions. The F-value is from analysis of variance comparing the treatments (\*:  $P < 0.05$ ). Common lower case letters represent means not significantly different from one another.



**Fig. 7.**

**Species diversity in seven treatments.**

**See Table 1 for treatment abbreviations and descriptions. The F-value is from analysis of variance comparing the treatments (\*\*\*: P < 0.001). Common lower case letters represent means not significantly different from one another.**

**Table 3.**  
**Cover (%) of common species (> 5% in at least one treatment) found in seven treatments.**

See Table 1 for treatment abbreviations and descriptions.

Species	Common Name	TREATMENT						
		C	F	N	BC	DT	DC	SB
<b>Trees</b>								
<u>Betula papyrifera</u>	paper birch	5	2	<1	<1	4	1	1
<u>Picea glauca</u>	white spruce	61	0	0	<1	<1	<1	3
<u>Populus balsamifera</u>	balsam poplar	0	0	18	6	0	0	5
<u>Populus tremuloides</u>	trembling aspen	31	36	57	60	26	9	28
<b>Erect shrubs</b>								
<u>Rosa acicularis</u>	prickly rose	3	10	13	17	8	2	3
<u>Rubus strigosus</u>	wild red raspberry	<1	25	13	12	15	24	10
<u>Viburnum edule</u>	lowbush cranberry	2	7	5	6	1	2	4
<u>Salix spp.</u>	willow	0	2	<1	<1	1	0	11
<u>Shepherdia canadensis</u>	Canada buffaloberry	0	0	0	5	0	0	0
<u>Alnus crispa</u>	green alder	0	0	23	5	4	0	24
<u>Rosa woodsii</u>	woods rose	0	0	0	1	0	4	21
<b>Herbaceous</b>								
<u>Bryophytes</u>	mosses	32	18	2	4	15	14	1
<u>Linnaea borealis</u>	twinline	8	11	<1	2	<1	0	0
<u>Cornus canadensis</u>	bunchberry	3	15	5	2	2	1	2
<u>Aralia nudicaulis</u>	wild sarsparilla	3	6	10	6	1	1	3
<u>Petasites palmatus</u>	palmate-leaved colt's foot	2	6	8	8	0	<1	2
<u>Aster ciliolatus</u>	Lindley's aster	<1	1	<1	2	5	4	2
<u>Aster puniceus</u>	purple-stemmed aster	0	0	5	<1	0	0	<1
<u>Elymus innovatus</u>	hairy wild rye	0	<1	0	0	7	<1	0
<u>Equisetum sylvestris</u>	horsetail	<1	4	0	0	1	0	5
<u>Maianthemum canadense</u>	two-leaved Solomon's seal	3	1	2	4	<1	<1	2
<u>Mertensia paniculata</u>	tall lungwort	<1	7	8	6	2	3	4
<u>Lathyrus ochroleucus</u>	wild peavine	<1	2	2	2	6	0	<1
<u>Fragaria virginiana</u>	strawberry	<1	<1	12	7	4	14	6
<u>Sonchus arvensis</u>	perennial sow-thistle	0	<1	<1	0	3	6	0
<u>Epilobium angustifolium</u>	fireweed	0	15	9	24	12	19	17

## DISCUSSION

### *Aspen and spruce*

Site preparation techniques were successful at suppressing aspen mass and stem density (Fig. 3 and 5). This was countered, however, by relatively high growth rates of aspen in transects with site preparation (Fig. 2). Site preparation may give spruce seedlings a window of opportunity to grow initially, but eventual regrowth of aspen at high rates might indicate that the benefits of preparation are greatest in early stages.

Spruce density did not vary significantly among treatments (Fig. 5). This was surprising in light of the fact that spruce was planted in all site preparation treatments (Table 1). This result was caused partly by seedling densities in two fire transects equalling those in planted transects (Fig. 5). Only one seedling was found in the three natural regeneration transects. Similar results were found for spruce mass (Fig. 3), which did not vary among treatments apart from the control transects.

Natural spruce establishment (Fig. 1) and the growth of established seedlings (Fig. 2) was highest in two fire transects, suggesting that fire and site preparation differ in their ability to promote natural establishment and growth.

Root mass varied considerably among treatments (Fig. 4) and was lowest in transects with the most intensive site preparation. In contrast, transects with natural regeneration and Bräcke-cultivating had values for root mass close to those in control plots (Fig. 4). Because nutrient leaching results from the removal of early successional vegetation (Likens and Bormann 1974), natural regeneration and Bräcke-cultivating are probably the treatments most effective at conserving nutrients and enhancing sustainable forest productivity.

Light penetration to the soil surface differed little among treatments (Fig. 6) but was lowest in natural regeneration plots which supported the highest mass of aspen (Fig. 3).

### *Understory vegetation and diversity*

Understory mass was significantly lower in control transects than in any other (Fig. 3), but mass did not vary significantly among site preparation treatments or differ between them and fire. Understory plant diversity showed the same response (Fig. 7). Understory species composition behaved in a similar manner: there were great differences between control plots and all others for early-successional species such as lungwort, peavine and strawberry, but no large differences between wildfire transects and site preparation treatments (Table 3). Thus, the understory was affected by any form of disturbance, whether wildfire or site preparation, but the forms of disturbance differed little in their effects on mass or diversity.

## **CONCLUSIONS**

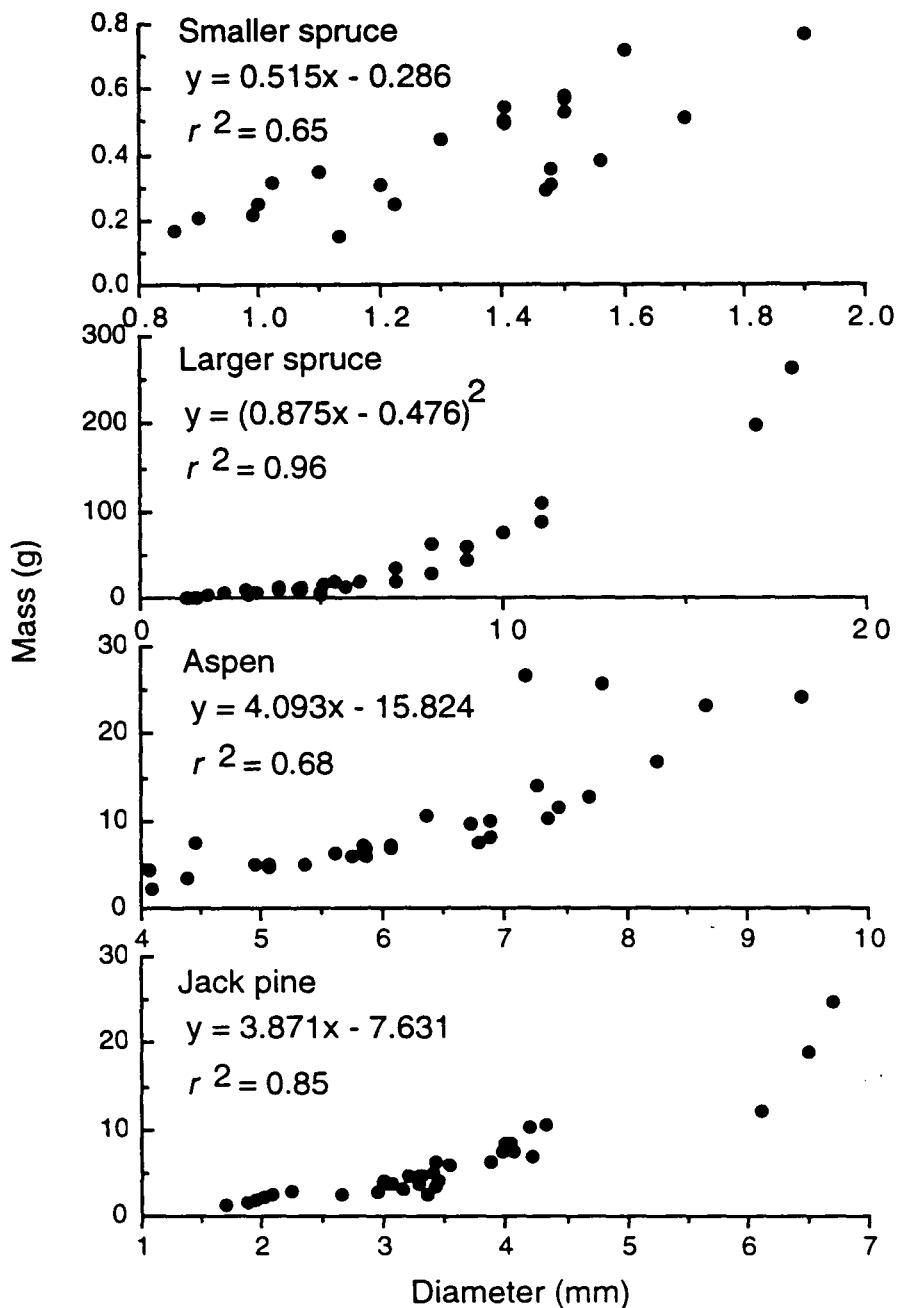
Site preparation was effective at suppressing aspen, but natural spruce establishment and growth were generally higher in fire transects. Total spruce mass did not vary significantly among treatments.

Wildfire and site preparation were similar in their effects on understory mass and diversity.

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### APPENDIX 1



**Fig. 8.**  
**Data and results of regression analyses for determining mass (y) from diameter (x).**