ANALYSIS AND INTERPRETATION OF THE RESEARCH MICROSITE PROJECTS IN ALBERTA

Effects of Silvicultural and Environmental Factors on the Post-planting Performance of Crop Trees and Competing Vegetation

1995

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ABSTRACT

The effects of cultural and environmental factors on the survival, growth and development of white spruce and lodgepole pine crop trees, deciduous competing vegetation and herbaceous competing vegetation are reported. The data were collected during the summers of 1992 and 1993 from 28 research microsite projects that had been installed during the 1980's by the Research Branch of the Alberta Forest Service. Controlled factors included type of mechanical site preparation, microsite planting position, planting stock type, and planting date. Response variables include various measures of: crop tree survival, final size and rate of growth; deciduous tree competitors; and shrub, forb and grass competition. Analytical methods include contingency table analyses, multivariate analyses of variance, multiple linear regression analyses, and a variety of exploratory graphical methods. The results indicate that cultural factors, namely, microsite position, stock type and planting season, had direct effects on the performance of both crop trees and competing vegetation. Crop tree survival and growth was negatively affected by high levels of competing vegetation, especially forbs and grasses. Thus, when cultural factors and / or environmental conditions increased the level of vegetative competition, crop tree survival and growth was negatively affected. The province-wide study was not designed to test hypotheses about either methods of mechanical site preparation or ecological conditions. The results show that forb and grass competition must be controlled in white spruce and lodgepole pine plantations for best results. Recommendations regarding the best microsite position, stock type and planting date are less clear although a number of suggestive trends are noted throughout the text.

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1.0 INTRODUCTION

1.1 Background

In Alberta the number of conifer seedlings planted annually increased from approximately 650,000 in 1976 as follows: 18.3 million in 1987, 36 million in 1990, 60 million in 1993, and 70 million in 1994.[a]

Forest land conditions in Alberta's Boreal forests are rarely favourable for regeneration by planting unless sites are treated by site preparation equipment. Mechanical site preparation is intended to modify several elements of the planting site environment including: reduction of slash; alteration of soil temperature, soil moisture, and drainage; increase in the availability of nutrients; exposure of mineral soil; and control of woody and herbaceous competition. The operational objectives of mechanical site preparation include the facilitation of planting operations, improvement of crop tree survival and improvement of post-planting crop tree growth.

Different types of site preparation equipment ameliorate site conditions to varying degrees and create planting microsites of different qualities and properties. Different microsite conditions may in turn affect negatively or positively seedling establishment, survival and growth.

In 1983, the Forest Research Branch of the then Alberta Forest Service initiated a major project to determine optimal planting microsites for several types of site preparation techniques and equipment. Subsequently, 32 research microsite trials were established in several ecoregions of Alberta (Table 1, Fig 1).

Table 1. Overview of the whole project.

Site Preparation Method	Nº. Trials Established	Nº. Seedlings Planted	Nº. Trials Remeasured	Nº. Seedlings Remeasured
Bräcke/Sinkilla Spot	8	12522	8	12522
Bräcke Mounder	9	10160	8	9360
Marttiini Plow	9	14500	7	13440
Modified Blade	1	1200	1	1200
Disk Trencher	1	1800	1	1800
Double Rome Disk	2	3400	2	3400
Rear Ripper Plow	1	1800	0	0

The following types of site preparation equipment were implemented in these trials: Bräcke Spot Scarifier, Sinkilla Spot Scarifier, Bräcke Mounder, Marttiini Plow, Double Rome Disk, Modified Blade, Disk Trencher, and Rear Mounded Ripper Plow.

The establishment and initial assessments of survival and growth of the planted seedlings was reported by Navratil and Harvey (1986), Harvey and Navratil (1987), Fast and Navratil (1988), Konowalyk and Fast (1989).

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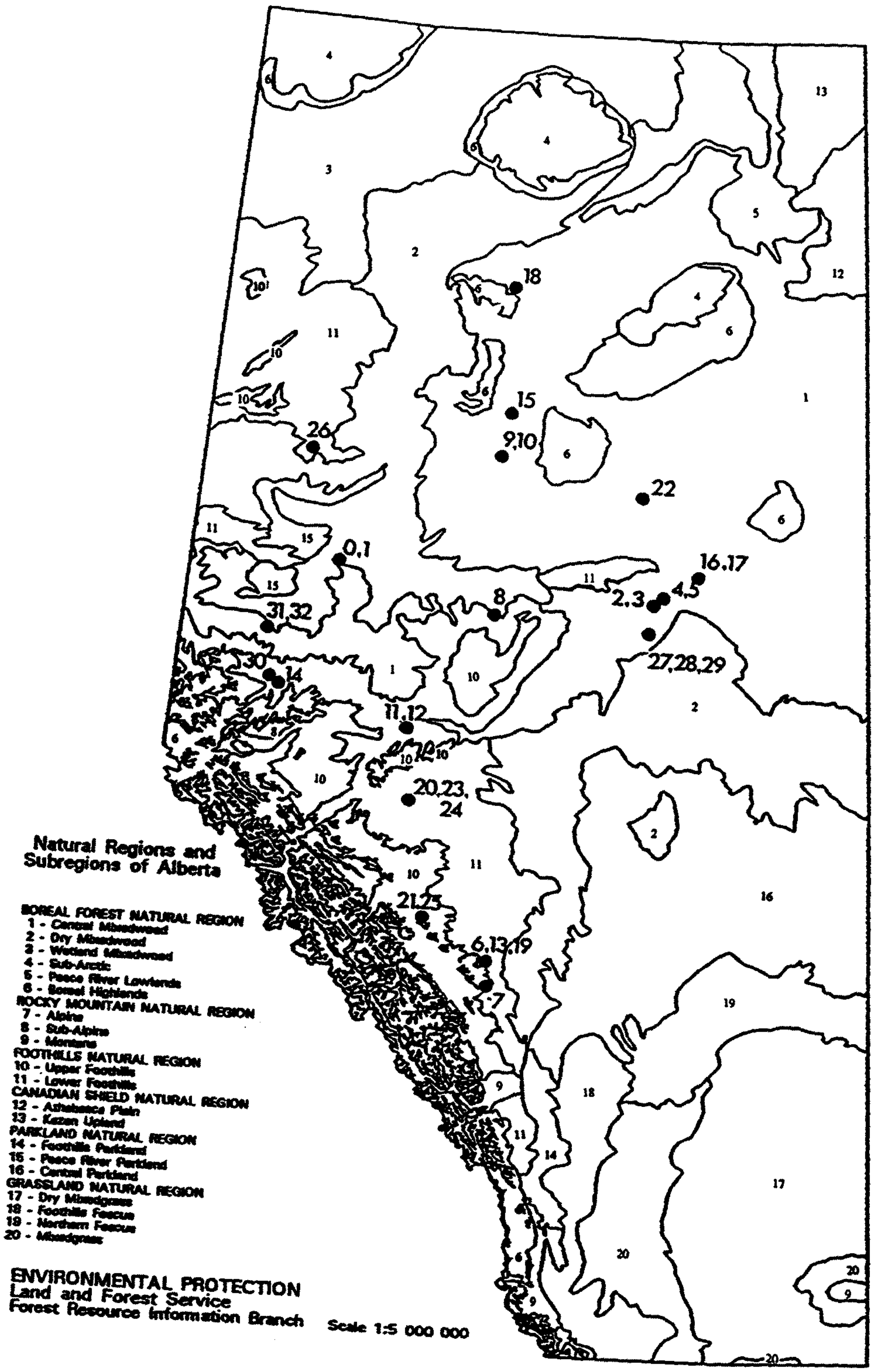


Figure 1. Map of microsite trial locations.
Dots and large numbers represent trials, eg. 23 is the trial 4-23.

The importance and long-term measurement to the proper interpretation of microsite and other treatment effects on these trials beyond the initial assessments was recognized by the silviculture staff of Alberta Forest Service and Canadian Forest Service. Consequently a project to assess survival and growth 8 to 10 years after planting was initiated with the funding from the 1990 – 95 Canada – Alberta Partnership Agreement in Forestry.

Thirteen trials were remeasured in 1992 and 14 more in 1993. Extensive statistical analyses of these data were completed for each trial by Dr. Kenneth M. Brown, Lakehead University and reported in the 1993 and 1994 progress reports (Brown 1993a, 1993b, 1993c, 1993d; Brown 1994a, 1994b, 1994c, 1994d).

The present report assembles the statistical summaries from the single trial analyses and presents the major trends and relationships observed within three site preparation methods: Spot Scarification (Table 4), Mounding (Table 29), and Marttiini Plow (Table 45).

Exploratory data analysis procedures were used to examine a pooled summary of results from all trials for evidence of patterns that may indicate the effects of ecosite variables and generic microsite positions on crop tree response.

The report is formatted into chapters that are designed to answer the questions asked at the design and subsequent analysis stages of the project.

1.2 Project design

The major questions that were incorporated into the project design and analysis were as follows:

A. Do microsite positions affect seedling survival, seedling condition such as multileadering, and seedling growth?

B. Do microsite positions affect the levels of competing vegetation?

C. Do competition levels affect seedling survival, seedling condition and seedling growth?

D. Do the various components of the competing vegetation plant community interact with one another? For example, does aspen density affect the degree of herbaceous plant cover?

2.0 SPOT SCARIFIERS

2.1 Overview of the group

The Spot Scarifier Group of trials includes 8 Bräcke Spot trials and 1 Sinkilla trial (Table 2). One trial (4 - 6 at Prairie Creek) suffered such high mortality that it was dropped from the analysis. Of the remaining 8 trials, 6 were planted to white spruce and 2 were planted to lodgepole pine. At the time of measurement, the Spot Scarifier trials were between 6 and 10 years old. On all trials 3 microsite positions were planted: top of overturn, hinge of overturn, and bottom of scalp microsite positions. Six of these trials also included unscarified controls.

2.2 Effects of microsite position on seedling condition

2.2.1 Introduction

At the time of measurement, the condition of each seedling was recorded by means of a list of Crop tree Condition Codes (abbreviated Ccc here). The Ccc's are defined in Table 3.

The total number of dead trees was assumed to be the total of the recorded dead trees (Ccc = 7) and the missing trees. Generally speaking, trees rated as Ccc = 2, 3, 4, 5, or 6 represented a negligible component of the total crop.

2.2.2 Summary of results

Table 4 presents the number of trees in the "single-stemmed and healthy" condition class (Ccc = 0) by species, microsite position and trial. To allow a fair comparison between trials, the results are also presented as the abundance of Ccc = 0 trees as a percent of the total number of trees planted in the category in question. For example, in the case of Trial 4 - 0, a total of 540 trees were planted; 180 trees on each of the 3 microsite positions. Of the 180 trees planted on the top of overturn position, 55 were recorded as "single-stemmed and healthy" or Ccc = 0 (Table 4). The arithmetic is illustrated in Eq 1.

$$\boxed{\begin{array}{l}\text{Percentage of trees planted on}\\ \text{the top of overturn microsite that}\\ \text{were classified as Ccc = 0}\end{array}} = \frac{55}{180} \times 100 = 30.5\% \qquad \text{Eq 1}$$

Table 4 shows that there was considerable variation across trials in the proportion of Ccc = 0 trees. Specifically, Trial 4 - 4 had a relatively low proportion of Ccc = 0 trees while Trials 4 - 20 Sw, 4 - 20 Pl and 4 - 23 all had relatively high proportions of Ccc = 0 trees.

Table 4 also suggests that microsite position had little effect on the proportion of Ccc = 0 trees. In 5 of the trials (4 - 0, 4 - 7, 4 - 20 Sw, 4 - 20 Pl, and 4 - 23) the proportion of Ccc = 0 trees is relatively even across microsite positions. In case of the 2 trials that deviate from this pattern, the top of overturn has the *highest* proportion of Ccc = 0 trees in Trial 4 - 1 and the *lowest* proportion of Ccc = 0 trees in Trial 4 - 4.

Overall, the 2 lodgepole pine trials had higher proportion of Ccc = 0 trees than did the 5 white spruce trials, but the sample of lodgepole trials is too small to suggest much confidence in this result.

Table 2. Overview of the Bräcke Spot / Sinkilla Patch trials.[a]

Trial Nº. / Location	Species[a] / Date planted	Date measured / Age	Nº. trees planted	Nº. trees surviving	Nº. trees in Ccc=0[b]	Microsites planted[c]	Other treatments
4 – 0 Martin Hills	S_w 4 Aug '83	1992 9 years	540	304	158	Bräcke T, H, S	burned prior to scarification
4 – 1 Martin Hills	S_w 2, 3 June '83	1992 9 years	678	527	234	Bräcke T, H, S	none
4 – 4 Calling Lk.	S_w 27 July '83	1992 9 years	784	642	129	Bräcke T, H, S, C	burned prior to scarification
4 – 6 [d] Prairie Ck.	P_l 19 Aug '83	1993 10 years	600	112	84	Bräcke T, H, S	none
4 – 7 Swan Lake	S_w 23 June '83	1993 10 years	800	609	409	Bräcke T, H, S, C	none
4 – 20 S_w Edson	S_w 3 Sept '86	1993 7 years	2400	1621	1412	Bräcke T, H, S, C	none
4 – 20 P_l Edson	P_l 3 Sept '86	1993 7 years	2400	1526	1375	Bräcke T, H, S, C	none
4 – 23 Edson	P_l 4 June '86	1993 7 years	1920	1404	1280	Bräcke T, H, S, C	3 fertilizer treatments
4-30 Musreau Lk	S_w June '87	1993 6 years	2400	1754	1754 [e]	Sinkilla T,H,S,C	none

[a] S_w = white spruce; P_l = lodgepole pine.

[b] Crop tree condition code (Ccc) is zero when the reference tree is single-stemmed and healthy.

[c] T = top of overturn; H = hinge; S = bottom of scalp; C = unscarified control

[d] Trial 4-6 was dropped from further analysis due to the extremely high mortality.

[e] All trees on Trial 4-30 were coded Ccc=0.

Table 3. Crop tree condition code (Ccc) definitions.

Crop tree Condition Code (Ccc)	Descriptive definition
0	single-stemmed and healthy
1	multi-topped
2	chlorotic
3	brown needles
4	some loss of needles
5	die back
6	dead terminal
7	dead tree
(blank)	missing tree

Table 4: Percentage of crop trees assessed as "single-stemmed and healthy" (Ccc = 0): by species, trial, and microsite position.

Bräcke Spot/Sinkilla Patch Group of trials

White spruce Trials

Microsite position	4-0 40 cc Aug 83	4-1 3+0 bare June 83	4-4 40 cc June 83	4-7 40 cc June 83	4-20Sw 40/65/90 Sept 86	4-30 40/65/90 June 87	*Sw Pos means*
top of overturn	30.5	42.9	8.1	47.5	62.3	([a])	*38.3*
hinge of overturn	32.7	30.9	19.4	52	60.5	([a])	*39.1*
bottom of scalp	24.4	29.6	26.5	54.5	52.3	([a])	*37.5*
control	•	•	(11.7)	(50.00)	(60.10)	([a])	•
Trial means[b]	*29.2*	*34.5*	*18.0*	*51.3*	*58.4*	([a])	*38.3*

Lodgepole pine Trials

Microsite position	4-20Pl 40/65/90 Sept 86	4-23 40 cc June 87	*Pl Pos. means*
top of overturn	56.1	67.1	*61.6*
hinge of overturn	58.3	68.5	*63.4*
bottom of scalp	60	71.4	*65.7*
control	54.6	59.6	*57.1*
Trial means	*57.2*	*66.6*	*62.0*

[a] Condition codes are not available for Trial 4-30.
[b] Spruce trial means do not include control postion.

2.3 Effects of microsite positions on seedling growth

2.3.1 Introduction

The growth response of individual crop trees to treatment was measured by means of the 4 variables defined in Table 5.

Table 5. Crop tree growth response variable definitions.

Abbreviated name	Description of measured variable
Ci92	1992 annual height increment
AveCi	average annual height increment (last 3 years)
Crc	root collar diameter
Cth	total height

The results for each variable are reported as *expected means.* The expected means are the means predicted by the analysis of covariance linear model after adjusting for the apparent effect of the covariate(s).

To understand why *expected means* are preferable to *measured means* for comparison purposes, consider the case where crop tree response is negatively affected by, say, the intensity of forb and grass competition. Suppose further that we are interested in comparing, say, the top of overturn with the bottom of scalp microsite positions. In such a case, it would be unfair to compare the measured means if the 2 microsites positions differed in the level of forb and grass competition. Otherwise, an apparent difference between microsite positions in crop tree response may simply reflect the effects of different levels of forb and grass competition on crop tree response. In order to achieve a more fair comparison, we include the level of forb and grass competition as a covariate in the ANOVA linear model. Then we compute the average response for each microsite position after adjusting to a common (trial-wide average) level of forb and grass competition. Finally, we compare these adjusted or "expected means."

2.3.2 Summary of results

The expected means by microsite position and trial are presented in the tables below for response variables Ci92 (Table 6), AveCi (Table 7), Crc (Table 8) and Cth (Table 9). Within the same trial, the top of overturn position consistently produced larger trees than did the bottom of scalp position. Trees on the hinge position tended to be of intermediate size. It is unwise to make comparisons between trials since the trials differ widely in age, site quality, and so on. It seems obvious, however, that the lodgepole pine trees are substantially larger than the white spruce trees. For example, compare the response of 4 - 20 Pl with that of 4 - 20 Sw.

Table 6: Expected Ci92 means from the MANOVA: by species, trial, and microsite position.

Bräcke Spot/Sinkilla Patch Group of trials

White spruce Trials

Microsite position	4-0 40 cc Aug 83	4-1 3+0 bare June 83	4-4 40 cc June 83	4-7 40 cc June 83	4-20Sw 40/65/90 Sept 86	4-30 40/65/90 June 87	*Sw Pos means*
top of overturn	7.8 a	13.2 a	20.2 a	12.4 a	13.5 a	9.4 a	*12.8*
hinge of overturn	6.9 a	10.6 a	19.8 a	12.6 a	12.1 b	8.1 b	*11.7*
bottom of scalp	6.4 a	10.8 a	18.7 a	11.4 b	13.0 ab	7.4 c	*11.3*
control	•	•	(22.0 a)	(12.4 a)	(12.2 b)	(8.3 b)	•
Trial means[a]	*7.0*	*11.5*	*19.6*	*12.1*	*12.9*	*8.3*	*11.9*

Lodgepole pine Trials

Microsite position	4-20Pl 40/65/90 Sept 86	4-23 40 cc June 87	*Pl Pos. means*
top of overturn	23.3 a	29.9 a	*26.6*
hinge of overturn	22.4 ab	28.2 b	*25.3*
bottom of scalp	21.0 b	23.5 c	*22.2*
control	22.4 ab	24.4 c	*23.4*
Trial means	*22.3*	*26.5*	*24.4*

[a] Spruce trial means do not include control postion.

Table 7: Expected AveCi means from the MANOVA: by species, trial, and microsite position.

Bräcke Spot/Sinkilla Patch Group of trials

Microsite position	White spruce Trials: 4-0 40 cc Aug 83	4-1 3+0 bare June 83	4-4 40 cc June 83	4-7 40 cc June 83	4-20Sw 40/65/90 Sept 86	4-30 40/65/90 June 87	*Sw Pos means*	Lodgepole pine Trials: 4-20Pl 40/65/90 Sept 86	4-23 40 cc June 87	*Pl Pos. means*
top of overturn	7.4 a	12.6 a	14.6 a	14.0 a	14.9 a	12.7 a	*12.7*	23.6 a	28.1 a	*25.9*
hinge of overturn	7.2 a	10.3 a	12.6 ab	14.0 a	12.7 b	10.3 b	*11.2*	21.7 b	26.2 b	*24.0*
bottom of scalp	6.8 a	11.1 a	12.0 b	12.7 a	12.9 b	8.4 c	*10.6*	20.1 c	21.6 c	*20.9*
control	•	•	(14.5 a)	(13.7 b)	(13.0 b)	(10.3 b)	•	22.1 ab	22.8 c	*22.5*
Trial means[a]	*7.1*	*11.3*	*13.1*	*13.6*	*13.5*	*10.5*	*11.5*	*21.9*	*24.7*	*23.3*

[a] Spruce trial means do not include control postion.

Table 8: Expected Crc means from the MANOVA: by species, trial, and microsite position.

Bräcke Spot/Sinkilla Patch Group of trials

Microsite position	White spruce Trials: 4-0 40 cc Aug 83	4-1 3+0 bare June 83	4-4 40 cc June 83	4-7 40 cc June 83	4-20Sw 40/65/90 Sept 86	4-30 40/65/90 June 87	*Sw Pos means*	Lodgepole pine Trials: 4-20Pl 40/65/90 Sept 86	4-23 40 cc June 87	*Pl Pos. means*
top of overturn	9.6 a	15.1 a	20.6 a	23.6 a	13.2 a	13.1 a	*15.9*	20.9 a	25.8 a	*23.4*
hinge of overturn	8.2 b	12.5 b	15.4 c	19.8 b	10.9 b	12.2 b	*13.2*	18.1 bc	22.6 b	*20.4*
bottom of scalp	8.5 b	12.2 b	14.4 c	18.6 b	10.7 b	11.9 b	*12.7*	17.2 c	19.0 c	*18.1*
control	•	•	(17.5 b)	(20.6 b)	(11.0 b)	(12.0 b)	•	18.9 b	12.0 c	*19.4*
Trial means[a]	*8.8*	*13.2*	*16.8*	*20.6*	*11.6*	*12.4*	*13.9*	*18.8*	*21.9*	*20.3*

[a] Spruce trial means do not include control postion.

Table 9: Expected Cth means from the MANOVA: by species, trial, and microsite position.

Bräcke Spot/Sinkilla Patch Group of trials

Microsite position	White spruce Trials: 4-0 40 cc Aug 83	4-1 3+0 bare June 83	4-4 40 cc June 83	4-7 40 cc June 83	4-20Sw 40/65/90 Sept 86	4-30 40/65/90 June 87	*Sw Pos means*	Lodgepole pine Trials: 4-20Pl 40/65/90 Sept 86	4-23 40 cc June 87	*Pl Pos. means*
top of overturn	55.4 a	100.9 a	97.3 a	73.9 ab	71.2 a	66.4 a	*77.5*	103.4 a	131.3 a	*117.4*
hinge of overturn	51.9 a	81.8 b	85.5 a	77.2 a	63.8 b	65.3 ab	*70.9*	96.6 b	123.1 b	*109.9*
bottom of scalp	50.3 a	79.2 b	86.1 a	71.4 b	63.6 b	56.8 c	*67.9*	90.3 b	105.0 c	*97.6*
control	•	•	(75.9 a)	(75.8 ab)	(63.8 b)	(62.5 b)	•	96.1 b	106.8 c	*101.4*
Trial means [a]	*52.5*	*87.3*	*89.6*	*74.2*	*66.2*	*62.8*	*72.1*	*96.6*	*116.6*	*106.6*

[a] Spruce trial means do not include control postion.

2.4 Effects of microsite positions on competing vegetation

2.4.1 Introduction

Several measures of competing vegetation, all defined in Table 10, were recorded on a 10 m^2 (1.8 m radius) circular competition plot centered on each crop tree.

Table 10. Definitions of measures of competing vegetation.

Abbreviated name	Description of measured variable	Measurement scale
Tot.ns	Total number of deciduous trees counted on the 10 m^2 competition plot	count
Tot.ns class	Tot.ns partitioned into 4 categories. Class limits were taken to be the low quartile, median, and high quartile.	ordinal
Dth	Total height of the tallest deciduous tree on the 10 m^2 competition plot	ratio
Dth class	Dth partitioned into 4 categories. Class limits were taken to be the low quartile, median, and high quartile.	ordinal
Scp	Level of shrub competition on the 10 m^2 competition plot	ordinal
Fcp	Level of forb and grass competition on the 10 m^2 competition plot	ordinal

Within a single trial, the relationships between microsite position and several measures of vegetative competition were studied by means of contingency tables. For example, Table 11 reports the number of competition plots in each cell of the microsite position by level of forb and grass competition (Fcp) contingency table for Trial 4 - 0. The chi-square statistic associated with Table 11, 81.2, indicates that Fcp and microsite position are not independent on this trial.

Each trial in the Spot Scarifier Group has its own series of contingency tables. In order to summarize these results, we proceeded in 2 stages. First, we tabulated the chi-square statistics for each category of trial number and vegetative competition variable (Table 12). This allowed us to identify those measures of competing vegetation that showed a lack of independence with microsite position. For example, in the case at hand, it is clear from Table 12 that Tot.ns class and Dth.class varied independently of microsite position but Scp and Fcp often failed to be independent of microsite position.

Second, for each measure of vegetative competition that showed a relationship with microsite position, we prepared a table of statistical summaries of the standardized residuals. Table 13 illustrates such a summary of the Scp x microsite position contingency tables. Table 14 does the same thing for the Fcp x microsite position contingency tables. The summary statistics used in these tables are the median and the quartiles of the standardized residuals.

Table 11. Observed number of plots (o), expected number of plots (e), and standardized residual (r) for Trial 4 - 0: by microsite position and density of forbs and grasses (Fcp). The probability of the associated chi-square statistic of 81.2 with 4 degrees of freedom is less than 0.0001. [a]

Density of forbs and grasses	Microsite Position			total
	top	hinge	scalp	
none	(o) 31 (e) 12.07 (r) 5.45	6 14.28 – 2.19	2 12.65 – 2.99	39
moderate	39 22.60 3.45	15 26.72 – 2.27	19 23.68 – 0.96	73
heavy	56 91.33 – 3.70	128 108.00 1.92	111 95.68 1.57	295
total	126	149	132	407

[a] Computing formulas for expected values and standardized residuals are presented in the box below.

$$\text{expected values} = \frac{\text{row total x column total}}{\text{grand total}}$$

$$\text{standardized residuals} = \frac{\text{observed count} - \text{expected value}}{\sqrt{\text{expected value}}}$$

2.4.2 Summary of results

The cross-trial summary of chi-square statistics associated contingency tables of microsite position by various measures of vegetative competition is given in Table 12. The rational behind this summary was explained above.

Table 12 shows that a relationship exists between microsite position and the degree of shrub competition (Scp) on all trials in the Spot Scarifier Group. Table 13 is presented to investigate the general pattern of that relationship. The table shows that the top of overturn position is more likely than expected to be shrub-free and less likely than expected to support shrub competition at levels 2 (moderate) or 3 (heavy). Conversely, the bottom of scalp position is less likely than expected to be shrub free and more likely than expected to support shrub competition at levels 2 (moderate) or 3 (heavy).

Table 12 also shows that a relationship exists between microsite position and the degree of forb and grass competition (Fcp) on all but 2 of the trials in the Spot Scarifier Group. Table 14 reveals the general pattern of that relationship. The table shows that the top of overturn position is more likely than expected to be forb/grass-free and less likely than expected to support forb/grass competition at levels 2 (moderate) or 3 (heavy). Conversely, the bottom of scalp position is less likely than expected to be forb/grass free and more likely than expected to support forb/grass competition at levels 2 (moderate) or 3 (heavy).

Table 12. Chi-square statistics associated with microsite position-by-vegetative competition contingency tables: by crop species, trial number and measure of vegetative competition.[a]

Bräcke Spot / Sinkilla Patch Group of trials

Crop species Trial number	Vegetative competition variable			
	Tot.ns	**Dth**	**Scp**	**Fcp**
White spruce 4-0	$\chi^2 = 10.25$ n.s.	$\chi^2 = 9.51$ n.s.	$\chi^2 = 28.2$ ***	$\chi^2 = 81.2$ ***
4-1	$\chi^2 = 3.1$ n.s.	$\chi^2 = 0.7$ n.s.	$\chi^2 = 40.96$ ***	$\chi^2 = 183.0$ ***
4-4	$\chi^2 = 1.26$ n.s.	$\chi^2 = 5.58$ n.s.	$\chi^2 = 1.26$ n.s.	$\chi^2 = 1.12$ n.s.
4-7	$\chi^2 = 4.6$ n.s.	$\chi^2 = 3.8$ n.s.	$\chi^2 = 55.1$ ***	$\chi^2 = 3.35$ n.s.
4-20 Sw	$\chi^2 = 3.55$ n.s.	$\chi^2 = 2.33$ n.s.	$\chi^2 = 127.1$ ***	$\chi^2 = 111.4$ ***
4-30 Sinkilla	$\chi^2 = 30.61$ **	$\chi^2 = 8.98$ n.s.	$\chi^2 = 49.19$ ***	$\chi^2 = 68.59$ ***
Lodgepole pine 4-20 Pl	$\chi^2 = 2.51$ n.s.	$\chi^2 = 3.23$ n.s.	$\chi^2 = 71.71$ ***	$\chi^2 = 28.19$ ***
4-23	$\chi^2 = 9.10$ n.s.	$\chi^2 = 10.31$ n.s.	$\chi^2 = 49.4$ ***	$\chi^2 = 56.75$ ***

[a] n.s. = $Pr(\chi^2) > 0.05$ (accept that the classification variables operate independently)
* = $0.01 \le Pr(\chi^2) \le 0.05$
** = $0.001 \le Pr(\chi^2) \le 0.01$
*** = $0.0001 \le Pr(\chi^2) \le 0.001$

Table 13. Median and quartile summaries of standardized residuals from 8 microsite by Scp contingency tables.

Bräcke Spot / Sinkilla Patch Group of trials

Degree of shrub comp.	Microsite position		
	top of overturn	hinge	scalp
Scp = 1 (shrub–free)	M = +2.84 Q's = +1.82, +3.49	M = –0.41 Q's = –1.26, +0.23	M = –1.93 Q's = –2.88, –1.28
Scp = 2 (moderate shrubs)	M = –3.78 Q's = –4.20, –2.00	M = –0.16 Q's = –0.60, +0.78	M = +2.86 Q's = +1.22, +4.44
Scp = 3 (heavy shrubs)	M = –1.77 Q's = –2.52, –0.69	M = +0.22 Q's = –0.82, +1.00	M = +0.92 Q's = +0.51, +2.43

Table 14. Median and quartile summaries of standardized residuals from 8 microsite by Fcp contingency tables.

Bräcke Spot / Sinkilla Patch Group of trials

Degree of forb and grass comp.	Microsite position		
	Top	Hinge	Scalp
Fcp = 1 (forb & grass–free)	M = +3.70 Q's = +1.06, +5.66	M = –1.00 Q's = –2.15, +0.21	M = –2.89 Q's = –3.76, –1.08
Fcp = 2 (moderate f & g)	M = –1.44 Q's = –3.30, +0.29	M = +0.27 Q's = –0.24, +0.74	M = +1.21 Q's = –0.22, +2.58
Fcp = 3 (heavy f & g)	M = –2.48 Q's = –3.92, –0.31	M = –0.05 Q's = –0.64, +1.18	M = +2.28 Q's = +1.04, +3.30

Tables 13 and 14 are an attempt to summarize a series of contingency tables that share a common pair of classification variables. In the case of Table 13, the classification variables are microsite position and Scp; in the case of Table 14, microsite position and Fcp. So far as we know, such summaries have not been published before. We present the following further explanation to help interested readers interpret the tables for themselves.

As a rule of thumb, so long as the standardized residuals are less than or equal to 1.0 in absolute value, we can be sure that the Chi-square statistic will not exceed the 5 percent critical value. For example, a 3 x 3 contingency table has 4 degrees of freedom and a Chi-square critical value of 9.49. Working backwards, if each cell contributes no more than

$$\sqrt{\frac{9.49}{9}} = 1.02$$

in absolute value, then the Chi-square statistic will not exceed the critical value.

This being the case, when we look at summaries like Tables 13 and 14, we should begin by looking for cells wherein the *median* of the standardized residuals exceeds 1.0 in absolute value. Whenever we see a cell wherein both the *median* and the *quartiles* are all of the same sign (all pluses or all minuses) and all exceed 1.0 in absolute value, then we know that the lack of independence in that cell is particularly strong. In Table 14, for example, we find this to be the case in all 4 corner cells.

2.5 Effects of competing vegetation on seedling growth

2.5.1 Introduction

The evidence used to detect a causal relationship depends in each case upon the nature of the vegetative competition variable in question and the crop tree response variable. The various possibilities are elaborated below in Table 15. Tables 16, 17, and 18 summarize the degree to which 3 measures of vegetative competition are related to 5 crop tree response variables. The 3 measures of vegetative competition are Tot.ns (Table 16), Scp (Table 17), and Fcp (Table 18). The 5 crop tree response variables are Ccc, Ci92, AveCi, Crc, and Cth.

Table 15. Crop tree response variables and the nature of evidence used to detect causal relationships by categories of vegetative competition variables.

<table>
<tr><th>Vegetative competition variable</th><th>Crop tree response variable</th><th>Evidence of a causal relationship</th></tr>
<tr><td>Tot.ns class
(ordinal scale)</td><td>Ccc
(nominal scale)</td><td>magnitude of the chi-square statistic associated with the Tot.ns class x Ccc contingency table
(See the Ccc column in Table 16)</td></tr>
<tr><td>Tot.ns
(count)</td><td>Ci92, AveCi, Crc, Cth
(ratio scales)</td><td>level of significance of the regression coefficient associated with Tot.ns when Tot.ns is included in the ANCOVA linear models for Ci92, AveCi, Crc, and Cth.
(See appropriate column in Table 16)</td></tr>
<tr><td>Scp and Fcp
(ordinal scale)</td><td>Ccc
(nominal scale)</td><td>magnitude of the chi-square statistic associated with the Tot.ns class x Ccc contingency table
(See the Ccc column in Table 17 for Scp and in Table 18 for Fcp)</td></tr>
<tr><td>Scp and Fcp
(coded as dummy variables)
In the case of Scp, 2 dummy variables, Scp.2 and Scp.3, are defined as follows:
<table><tr><th>Scp</th><th>Scp..2</th><th>Scp..3</th></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>2</td><td>1</td><td>0</td></tr><tr><td>3</td><td>0</td><td>1</td></tr></table>Fcp is coded in an analogous manner.</td><td>Ci92, AveCi, Crc, Cth
(ratio scales)</td><td>level of significance of the regression coefficient associated with the dummy variable, e.g., Scp.2, when that dummy variable is included in the ANCOVA linear model
(See appropriate column in Table 17 for Scp and Table 18 for Fcp)</td></tr>
</table>

Table 16. Effect of total number of deciduous stems (Tot.ns) on crop tree response variables. Values under Ccc are Chi-square statistics from the Tot.ns Class-by-Ccc Class contingency table. Values under Ci92, AveCi, Crc, and Cth are the regression coefficients associated with Tot.ns when Tot.ns is included as a MANOVA covariate.[a]

Bräcke Spot / Sinkilla Patch Group of trials

Species Trial	Crop tree response variables				
	Ccc	Ci92	AveCi	Crc	Cth
White spruce 4-0	$\chi^2 = (5.6)$ $p = 0.46$	n.s.	n.s.	n.s.	n.s.
4-1	$\chi^2 = (1.0)$ $p = 0.98$	n.s.	n.s.	n.s.	n.s.
4-4	$\chi^2 = 24.2$ $p = 0.0005$	-0.36	-0.18	-0.17	-0.76
4-7	$\chi^2 = 20.3$ $p = 0.0024$	n.s.	n.s.	n.s.	n.s.
4-20 Sw	$\chi^2 = 36.2$ $p \leq 0.0001$	-0.09	-0.09	-0.09	-0.19
4-30	all trees coded Ccc = 0	n.s.	n.s.	-0.07	n.s.
Lodgepole pine 4-20 Pl	$\chi^2 = 36.5$ $p \leq 0.0001$	-0.22	-0.23	-0.27	-0.83
4-23	$\chi^2 = 12.3$ $p = 0.05$	-0.25	-0.23	-0.22	-0.81

[a] Values in parentheses are not significantly different from zero.

Table 17. Effect of abundance of shrubs (Scp) on crop tree response variables. Values under Ccc are Chi-square statistics from the Scp-by-Ccc Class contingency table. Values under Ci92, AveCi, Crc, and Cth are the regression coefficients associated with dummy variables Scp.2 (coefficient β_2) and Scp.3 (coefficient β_3) when these variables are included as MANOVA covariates.[a]

Bräcke Spot / Sinkilla Patch Group of trials

Species Trial	Crop tree response variables				
	Ccc	**Ci92**	**AveCi**	**Crc**	**Cth**
White spruce 4-0	$\chi^2 = (8.1)$ $p = 0.08$	n.s.	n.s.	n.s.	n.s.
4-1	$\chi^2 = (4.8)$ $p = 0.30$	n.s.	$\mu = 16.4$ $\beta_2 = -1.8$ $\beta_3 = -2.0$	$\mu = 17.6$ $\beta_2 = -1.8$ $\beta_3 = -2.4$	n.s.
4-4	$\chi^2 = 18.6$ $p = 0.0009$	$\mu = 29.7$ $\beta_2 = (3.2)$ $\beta_3 = -7.6$	$\mu = 18.1$ $\beta_2 =$ n.s. $\beta_3 = -4.3$	$\mu = 21.8$ $\beta_2 = (-1.6)$ $\beta_3 = -4.3$	$\mu = 113.2$ $\beta_2 =$ n.s. $\beta_3 = -23.8$
4-7	$\chi^2 = 13.2$ $p = 0.01$	$\mu = 13.6$ $\beta_2 = (1.0)$ $\beta_3 = (-1.1)$	$\mu = 15.1$ $\beta_2 = (0.4)$ $\beta_3 = (-1.7)$	$\mu = 22.9$ $\beta_2 = (-1.4)$ $\beta_3 = -6.3$	$\mu = 82.5$ $\beta_2 = (2.3)$ $\beta_3 = (-4.7)$
4-20 Sw	$\chi^2 = (4.5)$ $p = 0.33$	$\mu = 16.7$ $\beta_2 = -0.53$ $\beta_3 = -2.4$	$\mu = 17.0$ $\beta_2 = -0.38$ $\beta_3 = -1.7$	$\mu = 14.6$ $\beta_2 = -0.41$ $\beta_3 = -2.1$	$\mu = 76.8$ $\beta_2 = -1.5$ $\beta_3 = -5.4$
4-30	all trees coded Ccc=0	$\mu = 14.2$ n.s.	$\mu = 17.3$ n.s.	$\mu = 18.5$ n.s.	$\mu = 91.6$ $\beta_2 = -5.1$ $\beta_3 = -9.8$
Lodgepole pine 4-20 Pl	$\chi^2 = (7.1)$ $p = 0.12$	$\mu = 29.2$ $\beta_2 = -2.7$ $\beta_3 = -10.3$	$\mu = 28.9$ $\beta_2 = -2.8$ $\beta_3 = -8.8$	$\mu = 26.2$ $\beta_2 = -2.9$ $\beta_3 = -6.6$	$\mu = 122.8$ $\beta_2 = -11.4$ $\beta_3 = -33.9$
4-23	$\chi^2 = (1.7)$ $p = 0.78$	$\mu = 35.4$ $\beta_2 = -3.2$ $\beta_3 = -9.5$	$\mu = 32.87$ $\beta_2 = -3.0$ $\beta_3 = -8.2$	$\mu = 29.3$ $\beta_2 = -2.7$ $\beta_3 = -7.4$	$\mu = 147.4$ $\beta_2 = -13.1$ $\beta_3 = -27.7$

[a] Values in parentheses are not significantly different from zero.

Table 18. Effect of abundance of forbs and grasses (Fcp) on crop tree response variables. Values under Ccc are Chi-square statistics from the Fcp-by-Ccc Class contingency table. Values under Ci92, AveCi, Crc, and Cth are the regression coefficients associated with dummy variables Fcp.2 (coefficient γ_2) and Fcp.3 (coefficient γ_3) when these variables are included as MANOVA covariates.[a]

Bräcke Spot / Sinkilla Patch Group of trials

Species **Trial**	**Crop tree response variables**				
	Ccc	**Ci92**	**AveCi**	**Crc**	**Cth**
White spruce 4-0	$\chi^2 = 66.5$ $p \leq 0.0001$	$\mu = 16.6$ $\gamma_2 = -8.4$ $\gamma_3 = -13.2$	$\mu = 15.9$ $\gamma_2 = -7.2$ $\gamma_3 = -11.8$	$\mu = 14.8$ $\gamma_2 = -4.5$ $\gamma_3 = -7.9$	$\mu = 100.9$ $\gamma_2 = -42.3$ $\gamma_3 = -68.0$
4-1	$\chi^2 = 166.5$ $p \leq 0.0001$	$\mu = 18.0$ $\gamma_2 = -8.2$ $\gamma_3 = -11.1$	$\mu = 16.4$ $\gamma_2 = -7.1$ $\gamma_3 = -9.7$	$\mu = 17.6$ $\gamma_2 = -5.2$ $\gamma_3 = -7.2$	$\mu = 115.0$ $\gamma_2 = -44.3$ $\gamma_3 = -63.3$
4-4	$\chi^2 = 36.0$ $p \leq 0.0001$	$\mu = 29.7$ $\gamma_2 = -7.9$ $\gamma_3 = -13.2$	$\mu = 18.1$ $\gamma_2 = -4.2$ $\gamma_3 = -5.8$	$\mu = 21.8$ $\gamma_2 = -4.4$ $\gamma_3 = -7.0$	$\mu = 113.2$ $\gamma_2 = -21.0$ $\gamma_3 = -30.0$
4-7	$\chi^2 = 233.7$ $p \leq 0.0001$	$\mu = 13.6$ $\gamma_2 = -6.3$ $\gamma_3 = -8.3$	$\mu = 15.1$ $\gamma_2 = -6.4$ $\gamma_3 = -9.1$	$\mu = 22.9$ $\gamma_2 = -7.3$ $\gamma_3 = -10.5$	$\mu = 82.5$ $\gamma_2 = -32.6$ $\gamma_3 = -50.6$
4-20 Sw	$\chi^2 = 114.7$ $p \leq 0.0001$	$\mu = 16.7$ $\gamma_2 = -3.3$ $\gamma_3 = -7.5$	$\mu = 17.0$ $\gamma_2 = -2.9$ $\gamma_3 = -6.7$	$\mu = 14.6$ $\gamma_2 = -2.1$ $\gamma_3 = -4.4$	$\mu = 76.8$ $\gamma_2 = -11.8$ $\gamma_3 = -28.1$
4-30	all trees coded Ccc=0	$\mu = 14.2$ $\gamma_2 = -3.8$ $\gamma_3 = -7.9$	$\mu = 17.3$ $\gamma_2 = -4.5$ $\gamma_3 = -8.9$	$\mu = 18.5$ $\gamma_2 = -3.7$ $\gamma_3 = -7.8$	$\mu = 91.6$ $\gamma_2 = -18.3$ $\gamma_3 = -37.9$
Lodgepole pine 4-20 Pl	$\chi^2 = 302.4$ $p \leq 0.0001$	$\mu = 29.2$ $\gamma_2 = -10.0$ $\gamma_3 = -15.3$	$\mu = 28.9$ $\gamma_2 = -9.3$ $\gamma_3 = -14.6$	$\mu = 26.2$ $\gamma_2 = -7.1$ $\gamma_3 = -12.7$	$\mu = 122.8$ $\gamma_2 = -35.9$ $\gamma_3 = -57.9$
4-23	$\chi^2 = 446.1$ $p \leq 0.0001$	$\mu = 35.4$ $\gamma_2 = -9.8$ $\gamma_3 = -13.3$	$\mu = 32.8$ $\gamma_2 = -8.8$ $\gamma_3 = -12.2$	$\mu = 29.3$ $\gamma_2 = -5.7$ $\gamma_3 = -9.0$	$\mu = 147.4$ $\gamma_2 = -39.0$ $\gamma_3 = -54.5$

[a] Values in parentheses are not significantly different from zero.

2.5.2 Effects of Tot.ns (and Tot.ns class) on crop tree responses

In each trial, the relationship between Tot.ns Class and Crop tree Condition Code (Ccc) was examined by means of contingency table analysis. The column labeled Ccc in Table 16 reports the chi-squared statistics associated with these analyses. Generally speaking, the results indicate at most a weak relationship between Tot.ns and Ccc. When the individual tables were examined more closely, however, the nature of the relationship was found to vary from trial to trial. That is, although there is sometimes a weak relationship between these 2 variables, the nature of the relationship does not show a consistent pattern from trial to trial. Consequently, we are unable to draw meaningful silvicultural conclusions from these data.

Table 16 also shows that Tot.ns made a statistically significant contribution as a covariate in 4 of the 8 trials in the Spot Scarifier Group. As might be expected, Tot.ns was more important as a covariate in those trials that had the greatest average levels of Tot.ns. The 4 trials for which Tot.ns was not useful as a covariate averaged 4 to 5.5 deciduous stems per 10 m^2 competition plot. The 4 trials for which Tot.ns was useful as a covariate, however, averaged 15 to 25 deciduous stems per 10 m^2 plot.

In every case where Tot.ns made a significant contribution as a covariate, its effect on crop tree growth was negative. This is clear from the fact that the regression coefficients are all negative (Table 16). Example 1 in the box below shows how to gauge the impact of Tot.ns on a particular growth response in a particular trial.

<u>Example 1</u>. Calculation of the effect of Tot.ns on Ci92 in Trial 4 - 4.

The regression coefficient is – 0.36 $cm \cdot tree^{-1}$ (Table 16). The average level of Tot.ns in Trial 4 - 4 is 15.2 stems per $10m^2$ competition plot. Consequently,

$$\text{Effect of Tot.ns on Ci92} = -0.36\ (\text{Tot.ns} - 15.2)$$

Thus, if Tot.ns were as high as, say, 30 trees per plot, the predicted effect on Ci92 would be $-0.36\ (30 - 15.2) = -5.3$ cm; a decrease in height increment.

2.5.3 Effects of Scp on crop tree responses

A summary of the effects of the level of shrub competition (Scp) on crop tree growth responses is presented in Table 17. The Ccc column of Table 17 shows that on all but 2 of the Spot Scarifier trials, Scp had no apparent effect on Crop tree Condition Code (Ccc). In the 2 cases where the contingency table showed some degree of relationship, the effect was too slight to be of practical interest.

The rightmost 4 columns in Table 17 present the coefficients associated with Scp when Scp is included as a covariate in the ANOVA linear model. The ANCOVA model has the following general structure:

$$Y_{ijk..} = \mu + \beta_2\ \text{Scp.2} + \beta_3\ \text{Scp.3} + \text{[terms associated with blocks, treatments, and error]}$$

where μ = overall constant
Scp.2 = 1 whenever Scp = 2, else 0
Scp.3 = 1 whenever Scp = 3, else 0

β_2 and β_3 are regression coefficients associated with Scp.2 and Scp.3 respectively

Example 2 in the box below is based on response Ci92 in Trial 4 - 23. The example illustrates how the coefficients in Table 17 measure the effect of Scp on crop tree response.

<u>Example 2</u>. Calculation of the effect of Scp on Ci92 in Trial 4 - 23.

The coefficients associated with Scp and Ci92 in Trial 4 - 23 are

$$\mu = 35.4 \text{ cm}$$
$$\beta_2 = -3.2 \text{ cm}$$
$$\beta_3 = -9.5 \text{ cm}$$

- The linear model predicts that crop trees on shrub-free plots (Scp =1) will suffer no reduction in Ci92 due to Scp since Scp.2 = 0 and Scp.3 = 0.
- The model predicts that crop trees on plots with moderate shrub competition (Scp = 2) will suffer a reduction of 3.2 cm in Ci92 since Scp.2 = 1 and Scp.3 = 0.
- And, the model predicts that crop trees on plots with heavy shrub competition (Scp = 3) will suffer a reduction of 9.5 cm in Ci92 since Scp.2 = 0 and Scp.3 = 1.

Although Table 17 represents an enormous amount of data reduction, the information contained in its covariate coefficients is sufficiently complex to obscure any patterns that may exist across the entire Spot Scarifier Group. Regularities do exist, however, and they may be stated as follows for those trials in which dummy variables Scp.2 and/or Scp.3 are statistically significant covariates.

1. The constant, μ, in the linear model represents the overall, expected, crop tree response for a tree grown under the following conditions: Tot.ns is at the trial-wide average value, there are no shrubs, and there are no forbs or grass. For example, in the case of Trial 4 – 4, the value of μ associated with Ci92 is 29.7. This means that under the competition conditions just described, the expected average height increment of crop trees in 1992 is 29.7 cm. (The units of μ are always the same as those of the response variable in question.)

2. There is a fairly regular relationship between the coefficients β_2 and β_3 and the coefficient μ. Fig 2 illustrates this for β_2. The equation of the regression line in Fig 2 is of the general form

$$\beta_2 = \text{intercept} + \text{slope}(\mu) \qquad \text{Eq 2}$$

where

β_2 = amount of growth depression

μ = growth potential under conditions that are free of shrubs, forbs and grass with a trial-wide average density of deciduous trees (Tot.ns)

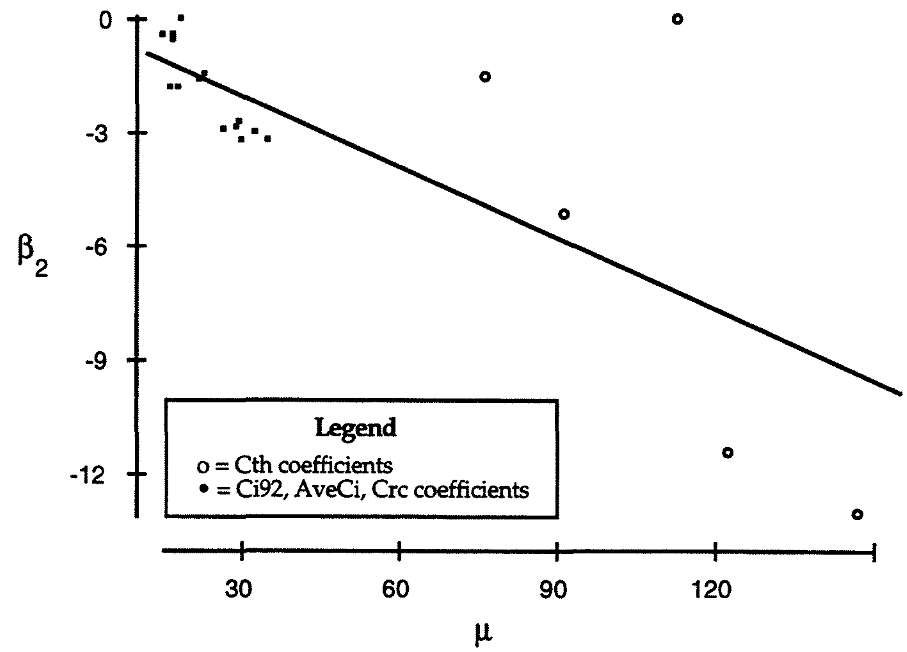


Fig 2. The regression coefficient, β_2, associated with the moderate level of shrub competition, dummy variable Scp.2, from the Spot Scarifier Group ANOVA's plotted against the constant, μ, from the same ANOVA's.

Given the data of Table 17 (and plotted in Fig 2), the least squares regression line is

$$\beta_2 = -0.14 - 0.06\,\mu \qquad \text{Eq 3}$$
$$R^2 = 55 \text{ percent}$$

The intercept in Eq 3 is not significantly different from zero and so Eq 3 can be rewritten

amount of growth depression = slope x (growth potential ... etc. ...)

which can be rearranged to read

$$\text{slope} = \frac{\text{amount of growth depression}}{\text{growth potential ... etc. ...}}$$

It follows that the slope in the regression of β_2 on μ can be interpreted as the *relative reduction in growth due to moderate shrub competition* (assuming, of course, that the intercept is zero).

Applying this result to Table 17 leads to the following conclusion:

Across all trials in the Spot Scarifier Group, moderate levels of shrub competition resulted, on average, in a 6 percent reduction in crop tree growth. This result *seems* to hold for all 4 crop tree growth responses.

3. Following an analogous procedure using β_3 and μ results in Fig 3.

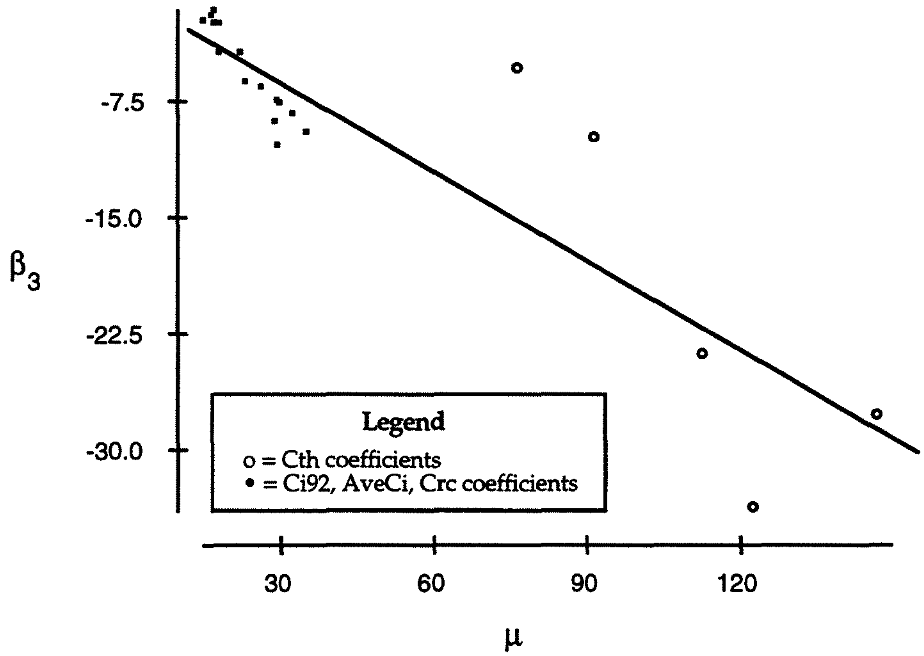


Fig 3. The regression coefficient, β_3, associated with the heavy level of shrub competition, dummy variable Scp.3, from the Spot Scarifier Group ANOVA's plotted against the constant, μ, from the same ANOVA's.

In this case the least squares regression is

$$\beta_3 = -0.47 - 0.19\,\mu \qquad \text{Eq 4}$$
$$R^2 = 79 \text{ percent}$$

Once again, the intercept is not significantly different than zero and so the general conclusion is:

Across all trials in the Spot Scarifier Group, heavy shrub competition resulted, on average, in a 19 percent reduction in crop tree growth. This result seems to hold *for all 4 crop tree growth responses.*

Note: Close inspection of Figs 1 and 2 suggests that it might be best to summarize the group of 5 points associated with the Cth response (represented by the open circles on the right side of the scatter plots) separately from the group of points on the left, which are due to Ci92, AveCi and Crc. We investigated the possibility and found the results to be inconclusive.

The evidence in favour of separate regressions is:

a) the visual appearance of the Figs 1 and 2 and

b) the fact that when the separate regressions are computed, the 2 regression lines have effectively the same slope (but different intercepts).

The argument in support of a single regression line is:

a) the regressions on the Cth subset of data are not significant due to the small size of the data set

b) the pattern that *appears* to be present in Figs 1 and 2 does not show up in the analysis of the Fcp data presented in the next section (although there may be biological mechanisms, as yet unknown, that cause Scp and Fcp to operate differently)

We conclude that while a separate mechanism for Cth is possible, the evidence for separate models is not compelling. Consequently, we favour the, possibly oversimplified, single-regression summary reported above.

2.5.4 Effects of Fcp on crop tree responses

A summary of the effects of the level of forb and grass competition (Fcp) on crop tree growth responses is presented in Table 18. The Ccc column of Table 18 shows that Fcp and Crop tree Condition Code (Ccc) do not operate independently of one another. Table 19 summarizes the nature of the relationship. The table shows that crop trees on forb and grass free plots were more likely than expected to be "single-stemmed and healthy" and less likely than expected to be dead. Conversely, crop trees on plots with heavy forb and grass competition were less likely than expected to be "single-stemmed and healthy" and more likely than expected to be dead.

Table 19. Median (M) and lower and upper hinge (H) summaries of the standardized residuals found in Fcp-by-Ccc contingency tables from 7 Spot Scarifier Trials: by Fcp and Ccc.

Crop tree condition code	**Level of forb and grass competition**		
	forb and grass–free Fcp = 1	moderate forb/grass Fcp = 2	heavy forb/grass Fcp = 3
Ccc = 0	**M = 3.1** Q's = 2.7, 4.1	M = –0.2 Q's = –3.3, 0.2	**M = –3.6** Q = –5.0, –3.4
Ccc = 1	M = –0.9 Q's = –1.0, 0.0	M = 1.6 Q's = 0.2, 2.4	M = –0.5 Q's = –1.6, 0.2
dead or missing	**M = –5.7** Q's = –7.2, –3.6	M = 0.7 Q's = –2.0, 4.6	**M = 7.3** Q's = 5.3, 9.5

The rightmost 4 columns in Table 18 contain the coefficients associated with Fcp when it is used (by means of dummy variables Fcp.2 and Fcp.3) as a covariate in the ANOVA linear model. The coefficients may be interpreted following the same line of reasoning developed in the previous section. The following conclusions seem to hold across the entire Spot Scarifier Group of trials:

1. Forbs and grasses always had an important negative effect on crop tree growth.

2. A moderate level of forb and grass competition resulted, on average, in a 29 percent reduction in crop tree growth. This result seems to hold *for all 4 crop tree growth responses* (Fig 4).

3. A heavy level of forb and grass competition resulted, on average, in a 44 percent reduction in crop tree growth. This result seems to hold *for all 4 crop tree growth responses* (Fig 5).

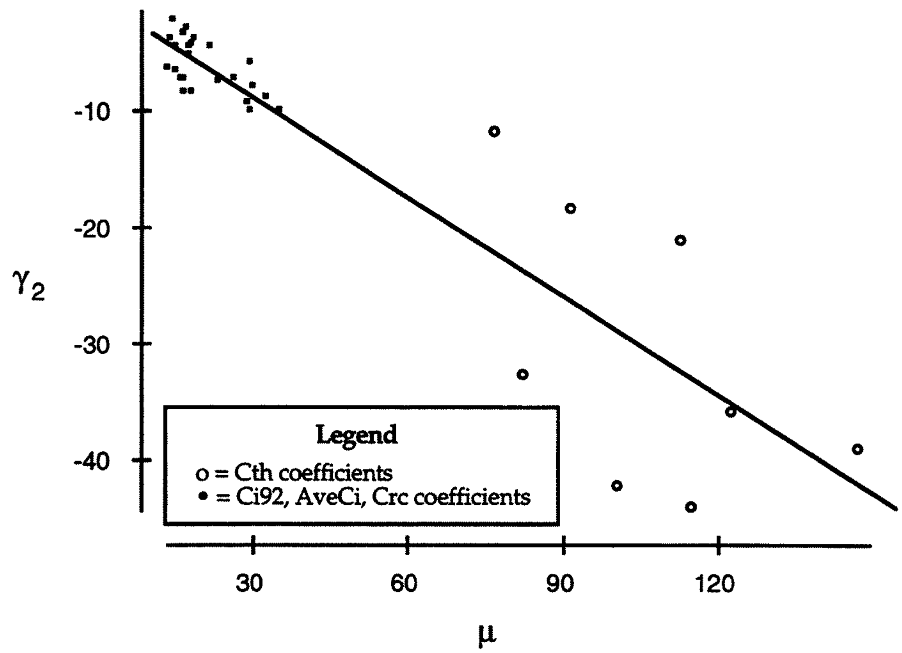


Fig 4. The regression coefficient, γ_2, associated with the moderate level of forb and grass competition, dummy variable Fcp.2, from the Spot Scarifier Group ANOVA's plotted against the constant, μ, from the same ANOVA's.

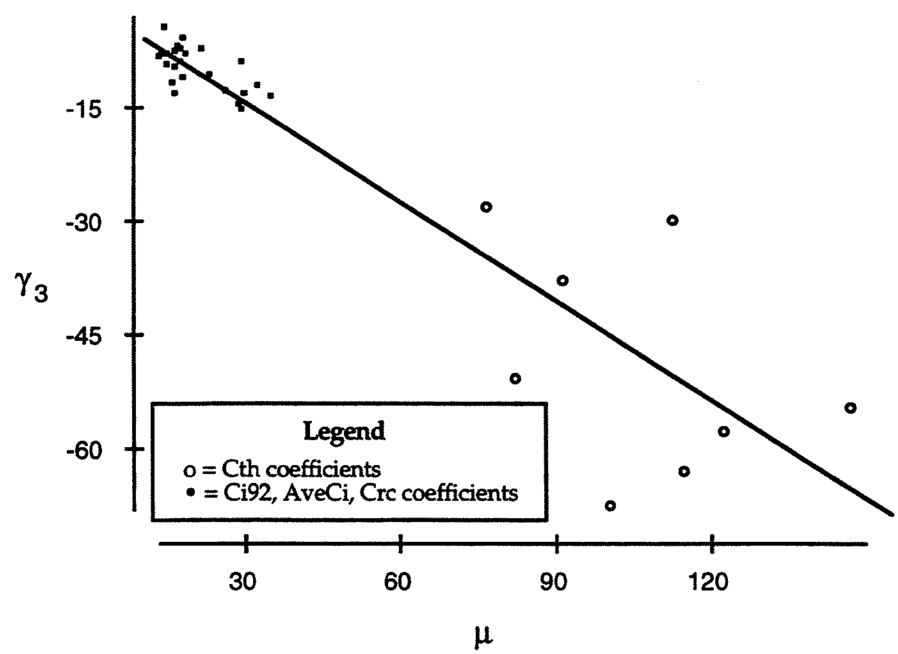


Fig 5. The regression coefficient, γ_3, associated with the heavy level of forb and grass competition, dummy variable Fcp.3, from the Spot Scarifier Group ANOVA's plotted against the constant, μ, from the same ANOVA's.

2.6 Interactions among competing vegetation

Spearman rank correlation analysis was used to measure the degree of independence between Tot.ns (total number of stems on the 10 m^2 competition plot) and Dth (total height of the tallest deciduous stem on the 10 m^2 competition plot). Otherwise contingency tables were used to investigate the degree of independence between various pairs of vegetative competition variables. Here, Tot.ns and Dth were replaced with Tot.ns class and Dth class, respectively. The other 2 variables in this analysis were Scp (level of shrub competition) and Fcp (level of forb and grass competition).

Table 20 presents the results, which may be summarized as follows:

1. There is a weak correlation between Tot.ns and Dth 5 of the 8 trials (correlation coefficients of $\rho = 0.4$ to 0.6). But even on Trial 4 – 30, were the highest correlation was found, about 60 percent of the variation in the Dth data seems unrelated to Tot.ns.

2. In the case of the contingency table analyses, a lack of independence was observed in up to half of the trials depending on the pair of variables in question. And, even when the relationships are statistically significant, they are, on average, too weak to be of much practical interest.

Table 20. Degree of co-relation between pairs of measures of vegetative competition: by trial. Values under "Tot.ns (or Tot.ns Class)" with subhead "Dth" are Spearman rank correlation coefficients. Values in all other columns are Chi-squared statistics associated with the contingency table indicated by the column heading. Empty cells indicate that the variables in question operate independently.[a]

Bräcke Spot / Sinkilla Patch Group of trials

Trial	Tot.ns (or Tot.ns Class)			Dth Class		Scp
	Dth	Scp	Fcp	Scp	Fcp	Fcp
4 – 0	$\rho = 0.268$	$\chi^2 = 83.5$ *				$\chi^2 = 21.3$ *
4 – 1	$\rho = 0.401$	$\chi^2 = 43.7$ *				$\chi^2 = 28.3$ *
4 – 4	$\rho = 0.519$		$\chi^2 = 65.9$ *		$\chi^2 = 142.6$ *	$\chi^2 = 75.9$ *
4 – 7	$\rho = 0.447$	$\chi^2 = 24.4$ *	$\chi^2 = 28.3$ *	$\chi^2 = 34.4$ *	$\chi^2 = 27.6$ *	
4 – 20 Sw	$\rho = 0.541$					
4 – 20 Pl	$\rho = 0.293$	$\chi^2 = 31.8$ *	$\chi^2 = 59.3$ *	$\chi^2 = 57.2$ *	$\chi^2 = 96.8$ *	
4 – 23	$\rho = 0.215$		$\chi^2 = 55.7$ *	$\chi^2 = 48.9$ *		
4 – 30	$\rho = 0.620$					

[a] n.s. = $Pr(\chi^2) > 0.05$ (accept that the classification variables operate independently)
* = $0.01 \le Pr(\chi^2) \le 0.05$
** = $0.001 \le Pr(\chi^2) \le 0.01$
*** = $0.0001 \le Pr(\chi^2) \le 0.001$

3.0 MOUNDERS

3.1 Overview of the group

The 8 Bräcke Mounder Group includes 7 trials that were planted to white spruce and 1 trial that was planted to lodgepole pine. One of the trials, 4 - 17 at Wandering River, was dropped due to the extremely high level of mortality. At the time of measurement, the remaining 7 trials were between 7 and 10 years of age. Microsite positions planted include: top of overturn, hinge of overturn, bottom of the Bräcke scalp, hand scalped and unscarified control. The microsite positions included in individual trials varies, however, across the Group. Consult Table 21 for details.

3.2 Effects of microsite position on seedling condition

This section follows the methods of section 2.2. The crop tree condition codes are defined in Table 3.

Table 22 shows that there was considerable variation across trials in the proportion of Ccc = 0 trees. Specifically, Trial 4 - 10 had a relatively low proportion of Ccc = 0 trees while Trials 4 - 13, 4 - 11, 4 - 14 and 4 - 19 all had relatively high proportions of Ccc = 0 trees.

Table 22 also suggests that microsite position had a slight effect on the proportion of Ccc = 0 trees. The top and hinge positions seem to be slightly better than the bottom of scalp position. Only one trial, 4 - 8, clearly deviates from this pattern.

3.3 Effects of microsite positions on seedling growth

The methods of this section are identical to those used in section 2.3.

The expected means by microsite position and trial are presented in the tables below for response variables Ci92 (Table 23), AveCi (Table 24), Crc (Table 25) and Cth (Table 26). Within the same trial, the top of overturn position consistently produced larger trees than did the bottom of scalp position. Trees on the hinge position tended to be of intermediate size.

Table 21. Overview of the Bräcke Mounder trials.[a]

Trial Nº. / Location	Species[a] / Date planted	Date measured / Age	No. trees planted	Nº. trees surviving	Nº. trees in Ccc=0[b]	Microsites planted[c]	Other treatments
4 – 10 Red Earth	S_w 9 Aug 83	1992 9 years	800	684	240	Bräcke T, H, S, C	none
4 – 11 Fox Creek	S_w 21,22 Jn 84	1992 8 years	800	609	504	Bräcke T, H, S, hs	none
4 – 12 Fox Creek	P_l 21,22 Jn 84	1992 8 years	800	475	289	Bräcke T, H, S, C	none
4 – 13 Prairie Ck.	S_w 17 Sept 83	1993 10 years	640	481	457	Bräcke T, H	none
4 – 14 Kakwa	S_w 9 Sept 85	1993 8 years	960	683	587	Bräcke T, H, S	none
4 – 17 Wandering River	S_w 12 June 85	1992 7 years	1800	105	72	Bräcke T, H, S	none
4 – 17 Wandering River	S_w 22 Aug 85	1992 7 years	1200	32	22	Bräcke T, H, S	none
4 – 18 Fort Vermilion	S_w 20 June 85	1992 7 years	800	402	321	Bräcke T, H, S, C	none
4 – 18 Fort Vermilion	S_w 29 Aug 85	1992 7 years	600	447	304	Bräcke T, H, S	none
4 – 19 Prairie Ck.	S_w 17 Sept 85	1993 8 years	960	701	5639	Bräcke T, H, S	none

[a] S_w = white spruce; P_l = lodgepole pine.

[b] Crop tree condition code (Ccc) is zero when the reference tree is single-stemmed and healthy.

[c] T = top of overturn; H = hinge; S = bottom of scalp; C = unscarified control; hs = hand scalped

Table 22: Percentage of crop trees assessed as "single-stemmed and healthy" (Ccc = 0): by species, trial, and microsite position.

Bräcke Mounder Group of trials

Microsite position	White spruce Trials: 4-10 40 cc Aug 83	4-11 40 cc June 84	4-13 40/65 cc Sept 83	4-14 40/65 Sept 85	4-18 40 cc June 85	4-18 40 cc Aug 85	4-19 40/65 cc Sept 85	*Sw Pos means*	Lodgepole Pine Trial: 4-12 40 cc June 84
top of overturn	43	69.5	72.8	64.7	4.5	37.5	69.4	*53.1*	39
hinge of overturn	33	64	70	64	50.5	61.5	72.1	*63.7*	40.5
bottom of scalp	(16)	(59.5)	•	(54.7)	(59.5)	(53)	(58.1)	•	32
control	(28)	(59)	•	•	(46)	•	•	•	33
Trial means [a]	*38.0*	*66.8*	*71.4*	*64.4*	*27.5*	*49.5*	*70.8*	*55.5*	*36.1*

[a] Top and hinge positions only.

Table 23: Expected Ci92 means from the MANOVA: by species, trial, and microsite position.

Bräcke Mounder Group of trials

Microsite position	White spruce Trials: 4-10 40 cc Aug 83	4-11 40 cc June 84	4-13 40/65 cc Sept 83	4-14 40/65 Sept 85	4-18 40 cc June 85	4-18 40 cc Aug 85	4-19 40/65 cc Sept 85	*Sw Pos means*	Lodgepole Pine Trial: 4-12 40 cc June 84
top of overturn	22.5 ab	15.9 a	12.9 a	6.6 a	12.5 a	12.2 a	10.4 a	*13.3*	40.1 a
hinge of overturn	21.2 bc	14.6 a	11.7 b	5.2 b	12.0 a	7.3 b	9.5 b	*11.6*	37.3 ab
bottom of scalp	(18.8 c)	(12.4 b)	•	(4.7 b)	(11.3 a)	(7.4 b)	(8.9 b)	•	43.2 b
control	(24.9 a)	(14.51 a	•	•	(11.3 a)	•	•	•	39.7 a
Trial means [a]	*21.8*	*15.3*	*12.3*	*5.9*	*12.2*	*9.8*	*10.0*	*12.5*	*40.1*

[a] Top and hinge positions only.

Table 24: Expected AveCi means from the MANOVA: by species, trial, and microsite position.

Bräcke Mounder Group of trials

Microsite position	White spruce Trials: 4-10 40 cc Aug 83	4-11 40 cc June 84	4-13 40/65 cc Sept 83	4-14 40/65 Sept 85	4-18 40 cc June 85	4-18 40 cc Aug 85	4-19 40/65 cc Sept 85	*Sw Pos means*	Lodgepole Pine Trial: 4-12 40 cc June 84
top of overturn	16.0 b	14.1 a	14.3 a	8.6 a	10.4 a	10.6 a	12.7 a	*12.4*	39.9 a
hinge of overturn	16.0 b	13.2 ab	12.6 b	6.8 b	10.5 a	7.2 a	11.3 b	*11.1*	35.2 bc
bottom of scalp	(15.0 b)	(12.0 b)	•	(5.8 c)	(10.3 a)	(7.4 b)	(10.0 c)	•	32.2 c
control	(17.9 a)	(13.2 ab)	•	•	(9.8 a)	•	•	•	37.5 ab
Trial means [a]	*16.0*	*13.7*	*13.4*	*7.7*	*10.4*	*8.9*	*12.0*	*11.8*	*36.2*

[a] Top and hinge positions only.

Table 25: Expected Crc means from the MANOVA: by species, trial, and microsite position.

Bräcke Mounder Group of trials

Microsite position	4-10 40 cc Aug 83	4-11 40 cc June 84	4-13 40/65 cc Sept 83	4-14 40/65 Sept 85	4-18 40 cc June 85	4-18 40 cc Aug 85	4-19 40/65 cc Sept 85	Sw Pos means	Lodgepole Pine Trial 4-12 40 cc June 84
	White spruce Trials								
top of overturn	13.7 a	13.1 a	14.8 a	8.7 a	9.7 ab	8.9 a	13.1 a	11.7	33.7 a
hinge of overturn	12.8 b	11.6 b	12.7 b	7.4 b	9.5 a	6.5 b	12.0 b	10.4	27.2 b
bottom of scalp	(13.0 ab)	(11.0 b)	•	(6.3 c)	(9.1 ab)	(5.7 b)	(10.9 c)	•	26.2 b
control	(13.6 ab)	(11.4 b)	•	•	(8.5 b)	•	•	•	32.3 a
Trial means [a]	13.2	12.3	13.8	8.0	9.6	7.7	12.5	11.0	29.4

[a] Top and hinge positions only.

Table 26: Expected Cth means from the MANOVA: by species, trial, and microsite position.

Bräcke Mounder Group of trials

Microsite position	4-10 40 cc Aug 83	4-11 40 cc June 84	4-13 40/65 cc Sept 83	4-14 40/65 Sept 85	4-18 40 cc June 85	4-18 40 cc Aug 85	4-19 40/65 cc Sept 85	Sw Pos means	Lodgepole Pine Trial 4-12 40 cc June 84
	White spruce Trials								
top of overturn	84.3 b	95.8 a	78.4 a	45.9 a	68.5 ab	65.2 a	69.2 a	72.5	230.1 a
hinge of overturn	87.6 ab	86.9 b	70.5 b	40.5 b	72.0 a	48.1 b	66.4 a	67.4	194.0 b
bottom of scalp	(87.4 ab)	(80.1 b)	•	(35.1 c)	(70.8 ab)	(48.0 b)	(59.0 b)	•	185.5 b
control	(93.8 a)	(83.2 b)	•	•	(65.0 b)	•	•	•	223.9 a
Trial means [a]	85.9	91.4	74.4	43.2	70.3	56.6	67.8	70.0	208.4

[a] Top and hinge positions only.

Unscarified controls, where they were planted, compare favourably with the best (top of overturn) mechanically prepared microsite position.

Trees on the lodgepole pine trial 4 - 12 at age 8 were considerably larger than any of the white spruce trials in the Group.

3.4 Effects of microsite positions on competing vegetation

The methods of analysis used in this section are identical to those of section 2.4.

Table 27 shows that Tot.ns class, Dth class, and Scp all operate independently of microsite position. A relationship does exist, however, between microsite position and the degree of forb and grass competition (Fcp). Table 28 reveals the general pattern of the relationship. The table shows that the top of overturn position was more likely to be forb and grass-free and less likely to have heavy forb and grass competition than expected. Conversely, the bottom of scalp position was less likely to be forb and grass free and more likely to have heavy forb and grass competition than expected.

Table 27. Effect of microsite position on measures of competing vegetation.[1]

Bräcke Mounder Group of trials

Crop species / Trial number	Vegetative competition variable			
	Tot.ns	Dth	Scp	Fcp
White spruce 4-10	$\chi^2 = 15.39$ p=0.081	$\chi^2 = 4.55$ n.s.	$\chi^2 = 10.96$ p=0.089	$\chi^2 = 12.78$ p=0.04
4-11	$\chi^2 = 4.21$ n.s.	$\chi^2 = 11.75$ n.s.	$\chi^2 = 11.24$ p=0.08	$\chi^2 = 40.39$ ***
4-13	$\chi^2 = 1.75$ n.s.	$\chi^2 = 0.51$ n.s.	$\chi^2 = 0.45$ n.s,	$\chi^2 = 10.37$ **
4-14	$\chi^2 = 2.02$ n.s.	$\chi^2 = 1.29$ n.s.	$\chi^2 = 3.80$ n.s.	$\chi^2 = 60.82$ ***
4-18	$\chi^2 = 9.67$ n.s.	$\chi^2 = 6.86$ n.s.	$\chi^2 = 5.62$ n.s.	$\chi^2 = 17.34$ **
4-19	$\chi^2 = 4.55$ n.s.	$\chi^2 = 0.79$ n.s.	$\chi^2 = 2.36$ n.s.	$\chi^2 = 56.50$ ***
Lodgepole pine 4-12	$\chi^2 = 6.63$ n.s.	$\chi^2 = 3.68$ n.s.	$\chi^2 = 4.41$ n.s.	$\chi^2 = 12.48$ p=0.052

1 n.s. = $Pr(\chi^2) > 0.05$ (accept that the classification variables operate independently)
* = $0.01 \le Pr(\chi^2) \le 0.05$
** = $0.001 \le Pr(\chi^2) \le 0.01$
*** = $0.0001 \le Pr(\chi^2) \le 0.001$

Table 28. Median (M) and quartile (Q) summary of the standardized residuals from 6 microsite by Fcp contingency tables.

Bräcke Mounder Group of trials

Degree of forb and grass comp.	Microsite position		
	Top	Hinge	Scalp
Fcp = 1 (forb & grass–free)	M = +3.03 Q's = +1.80, +3.73	M = –0.48 Q's = –0.92, –0.17	M = –2.1 Q's = –3.23, –1.58
Fcp = 2 (moderate f & g)	M = –0.43 Q's = –1.28, +0.94	M = +0.72 Q's = +0.40, +0.84	M = –0.53 Q's = –1.55, 1.13
Fcp = 3 (heavy f & g)	M = –1.60 Q's = –2.62, –0.78	M = –0.02 Q's = –0.22, +0.10	M = +1.84 Q's = +0.67, +2.67

3.5 Effects of competing vegetation on seedling growth

3.5.1 Effects of Tot.ns (and Tot.ns class) on crop tree responses

The indicators of the effects of the total number of competing deciduous stems (Tot.ns and Tot.ns class) are presented in Table 29. On 5 of the 8 trials, Tot.ns Class showed a statistically significant co–relationship with Ccc Class. The most noteworthy feature of the individual contingency tables summarized under Ccc in Table 29 is that mortality was significantly *higher than expected* on plots with a *low density* of deciduous stems. On these 5 trials, mortality in the lowest Tot.ns Class ran between 19 and 76 percent higher than expected as follows: 86 dead when 72 were expected, 89 dead vs. 71 expected, 62 dead vs. 41 expected, 97 dead vs. 56 expected, and 45 dead vs. 25 expected. On these same 5 trials, the mortality on plots with high levels of deciduous stems was correspondingly lower than expected. Otherwise, deciduous competition seems to have had little effect on crop tree condition.

In order to gauge the effect of Tot.ns on crop tree response variables Ci92, AveCi, Crc and Cth, it is necessary to interpret the regression coefficients from the ANOVA linear model (Table 29). The predicted effect of Tot.ns on a crop tree response variable, Y, is

$$\text{predicted effect of Tot.ns on } Y = \beta\,(\text{Tot.ns} - \overline{\text{Tot.ns}}) \qquad \text{Eq 4}$$

where Y = a crop tree response such as Ci92, AveCi, Crc, or Cth

β = the regression coefficient in Table 29

$\overline{\text{Tot.ns}}$ = the trial–wide average level of Tot.ns

The example in the box below illustrates the arithmetic. The effect of Tot.ns on AveCi, Crc, and Cth can be understood in a similar manner.

<u>Example 3</u>. Calculation of the effect of Ton.ns on Ci92 in Trial 4 – 13.

a. regression coefficient, β, from Table 29 = – 0.13

b. trial–wide average level of Tot.ns, $\overline{\text{Tot.ns}}$, = 7.9 trees per 10 m^2 plot

c. predicted effect of Tot.ns on Ci92 = – 0.13 (Tot.ns – 7.9) cm

Relation c above predicts that a crop tree on a plot with 8 deciduous trees per 10 m^2 plot, approximately the trial-wide average, would require no adjustment due to Tot.ns as the following calculation shows:

predicted effect of Tot.ns on Ci92 = – 0.13 (**8** – 7.9) = – 0.013 cm

It may well be that 8 deciduous stems had a negative effect on crop tree height increment, but this effect has already been accommodated by the constant, μ, in the overall linear model.

A crop tree on a plot with no deciduous trees would be expected to have produced slightly more Ci92 than a crop tree on a plot at the trial wide average of 7.9 trees by the following amount:

predicted effect of Tot.ns on Ci92 = – 0.13 (**0** – 7.9) = + 1.03 cm

A crop tree on a plot with 25 deciduous trees would be expected to have produced less Ci92 than a crop tree on a plot at the trial wide average of 7.9 trees by the following amount:

predicted effect of Tot.ns on Ci92 = – 0.13 (**25** – 7.9) = – 2.22 cm

Table 29. Effect of total number of deciduous stems (Tot.ns) on crop tree response variables. [a]

Bräcke Mounder Group of trials

Crop spp.	Crop tree response variables				
Trial	**Ccc**	**Ci92**	**AveCi**	**Crc**	**Cth**
white spruce 4–10	$\chi^2 = 23.5$ p = 0.0007	n.s.	n.s.	n.s.	n.s.
4–11	$\chi^2 = 68.1$ $p \leq 0.0001$	–0.19	–0.20	–0.12	(–0.52) p=0.10
4–13	$\chi^2 = (7.3)$ p = 0.29	–0.13	–0.10	–0.09	(–0.27) p=0.06
4–14	$\chi^2 = 40.3$ $p \leq 0.0001$	–0.05	(0.03)	–0.05	(0.08)
4–18 (June 20)	$\chi^2 = 4.6$ n.s.	–0.13	–0.13	–0.09	–0.65
4–18 (Aug 29)	$\chi^2 = 29.4$ ***	–0.22	–0.17	–0.07	–0.64
4–19	$\chi^2 = (2.7)$ p = 0.84	(+0.04)	(+0.02)	(–0.03)	(+0.08)
Lodgepole pine 4–12	$\chi^2 = 36.8$ $p \leq 0.0001$	–0.86	–0.57	–0.71	n.s.

[a] Values in parentheses are not significantly different from zero.

Except for the case of Trial 4 - 18, Tot.ns was not related to total height (Cth) in the white spruce trials in the Bräcke Mounder Group.

Since there is only one lodgepole pine trial (4 - 12) in the Bräcke Mounder Group, it is easy to put the effect of Tot.ns in perspective. The average value of Tot.ns on Trial 4 - 12 was 5.2 deciduous stems per 10 m^2 plot (5 200 stems per ha). Table 30 summarizes the predicted effects of increasing Tot.ns by 10 deciduous stems per 10 m^2 plot above $\overline{\text{Tot.ns}}$ on lodgepole pine response variables.

Table 30. An illustration of the predicted effect of Tot.ns on 4 lodgepole pine response variables (Trial 4 - 12).

Response variable	Typical value of response variable	Predicted effect of adding 10 deciduous stems per 10 m^2 plot
Ci92	37 cm per year	decrease Ci92 8.6 cm per year
AveCi	36 cm per year	decrease AveCi 5.7 cm per year
Crc	30 mm	decrease Crc 7.1 mm
Cth	200 cm	no significant effect on Cth

3.5.2 Effects of Scp on crop tree responses

In the case of the white spruce trials, the level of shrub competition (Scp) seems to have had no effect on either crop tree condition (Ccc) or any of the growth and final size response variable across the Bräcke Mounder Group (Table 31). The occasional exceptions to this statement seem to indicate such weak effects as to be of little practical importance.

In the case of the single lodgepole pine trial (4 - 12), the effect of Scp on Ccc is seen in the contingency table (Table 32). The table may be summarized as follows: Under shrub-free condition, "single-stemmed, healthy" trees occur about 9 percent more than expected and mortality runs about 7 percent less than expected (based on the corresponding row totals). Under heavy shrub competition, "single-stemmed, healthy" trees occur about 28 percent less frequently than expected and mortality runs about 25 percent higher than expected. It appears, therefore, that increasing shrub competition was associated with, if not the cause of, a decrease in the proportion of "single-stemmed, healthy" trees and an increase in the proportion of dead trees.

Table 31. Effect of abundance of shrubs (Scp) on crop tree response variables.[a]

Bräcke Mounder Group of trials

Crop spp. Trial	Crop tree response variables				
	Ccc	Ci92	AveCi	Crc	Cth
white spruce 4-10	$\chi^2 = (5.8)$ p = 0.21	n.s.	n.s.	n.s.	n.s.
4-11	$\chi^2 = 15.7$ p = 0.0035	$\mu = 22.9$ $\beta_2 = (+0.4)$ $\beta_3 = -3.0$	$\mu = 21.7$ $\beta_2 = (+0.4)$ $\beta_3 = -2.9$	$\mu = 17.5$ $\beta_2 = (-0.1)$ $\beta_3 = -2.0$	$\mu = 124.6$ $\beta_2 = +8.9$ $\beta_3 = -10.5$
4-13	$\chi^2 = (0.92)$ p = 0.92	n.s.	n.s.	n.s.	n.s.
4-14	$\chi^2 = (1.8)$ p = 0.78	$\mu = 10.5$ $\beta_2 = (-0.2)$ $\beta_3 = -1.7$	$\mu = 11.7$ $\beta_2 = (0.0)$ $\beta_3 = -1.7$	$\mu = 13.1$ $\beta_2 = (+0.1)$ $\beta_3 = -1.3$	$\mu = 62.1$ $\beta_2 = (+0.3)$ $\beta_3 = (-5.9)$
4-18 (June 20)	$\chi^2 = (8.1)$ p = 0.09	$\mu = 24.9$ $\beta_2 = (-0.9)$ $\beta_3 = -3.9$	$\mu = 21.2$ $\beta_2 = (-0.6)$ $\beta_3 = -2.7$	$\mu = 15.0$ $\beta_2 = (-0.4)$ $\beta_3 = -1.5$	$\mu = 125.3$ $\beta_2 = (-4.3)$ $\beta_3 = -12.5$
4-18 (Aug 29)	$\chi^2 = 21.6$ p = 0.0002	$\mu = 22.9$ $\beta_2 = (-0.4)$ $\beta_3 = -1.5$	$\mu = 20.5$ $\beta_2 = (-0.1)$ $\beta_3 = -1.3$	$\mu = 12.7$ $\beta_2 = (0.0)$ $\beta_3 = -0.6$	$\mu = 106.8$ $\beta_2 = (-0.9)$ $\beta_3 = -5.8$
4-19	$\chi^2 = (6.6)$ p = 0.16	$\mu = 15.2$ $\beta_2 = (-0.6)$ $\beta_3 = +0.4$	$\mu = 16.6$ $\beta_2 = (-0.6)$ $\beta_3 = (-1.2)$	$\mu = 16.8$ $\beta_2 = -1.1$ $\beta_3 = (-1.7)$	$\mu = 87.6$ $\beta_2 = (-1.8)$ $\beta_3 = (-8.1)$
Lodgepole pine 4-12	$\chi^2 = 62.3$ $p \leq 0.0001$	$\mu = 45.9$ $\beta_2 = -8.7$ $\beta_3 = -10.9$	$\mu = 42.2$ $\beta_2 = -6.6$ $\beta_3 = -8.5$	$\mu = 36.5$ $\beta_2 = -6.6$ $\beta_3 = -9.6$	$\mu = 229.0$ $\beta_2 = -34.9$ $\beta_3 = -39.8$

[a] Values in parentheses are not significantly different from zero.

The predicted effect shrub competition (Scp) on 4 lodgepole crop tree responses Ci92, AveCi, Crc, and Cth in Trial 4 - 12 are illustrated in Table 33. The results presented are based on covariate coefficients given in Table 31 and the arithmetic methods described in Section 2.5.2. In every case, the predicted effects of moderate shrub competition were only slightly less than the effects of heavy shrub competition.

Table 32. Number of lodgepole pine crop trees: by level of shrub competition (Scp) and crop tree condition (Ccc).

Trial 4 – 12

Crop condition code (Ccc)	Level of shrub competition (Scp)			Row totals
	shrub-free	moderate	heavy	
<u>0 = single-stem and healthy</u> • N<u>o</u>. observed • obs as % col .total • difference in %'s	228 *52.9%* **+ 9.1%** [a]	39 *42.9%* –0.9%	21 *15.7%* **–28.1 %**	288 *43.8%*
<u>1 = multi-topped</u> • N<u>o</u>. observed • obs as % col .total • difference in %'s	45 *10.4%* –2.5%	18 *19.4%* +6.5%	22 *16.4%* +3.5%	85 *12.9%*
<u>dead</u> • N<u>o</u>. observed • obs as % col .total • difference in %'s	158 *36.7%* **–6.6 %**	36 *38.7%* –4.6%	91 *67.9%* **+24.6 %**	285 *43.3%*
Column totals	431	93	134	658

[a] The value +9.1 % is computed as follows: The cell count 228 represents 52.9 % of the "shrub-free" column total of 431. In contrast, the total of the first row 288 represents 43.8 % of the "Row totals" column total 658. So, the cell count 288 is 52.9 – 43.8 = 9.1 % greater than the count expected if shrub competition had no effect on crop tree condition.

Table 33. An illustration of the predicted effect of Scp on 4 lodgepole pine response variables.

Trial 4 – 12

Response variable	Typical value of response variable	Predicted effect of moderate shrubs	Predicted effect of heavy shrubs
Ci92	37 cm per year	decrease Ci92 9 cm per year	decrease Ci92 11 cm per year
AveCi	36 cm per year	decrease AveCi 7 cm per year	decrease AveCi 8 cm per year
Crc	30 mm	decrease Crc 7 mm	decrease Crc 10 mm
Cth	200 cm	decrease Cth 35 cm	decrease Cth 40 cm

3.5.3 Effects of Fcp on crop tree responses

A summary of the effects of the level of forb and grass competition (Fcp) on crop tree growth responses is presented in Table 34. The Ccc column of Table 25 shows that Fcp and

Crop tree Condition Code (Ccc) do not operate independently of one another. Table 35 summarizes the nature of the relationship. The table shows that crop trees on forb and grass-free plots were more likely than expected to be "single-stemmed and healthy" and less likely than expected to be dead. Conversely, crop trees on plots with heavy forb and grass competition were less likely than expected to be "single-stemmed and healthy" and more likely than expected to be dead. The rightmost 4 columns in Table 34 contain the coefficients associated with Fcp when it is used as a covariate in the ANOVA linear model. The coefficients may be interpreted following the same line of reasoning

The following conclusions seem to hold across the entire Bräcke Mounder Group of trials:

1. Forbs and grasses always had an important negative effect on crop tree growth.

2. A moderate level of forb and grass competition resulted, on average, in a 37 percent reduction in crop tree growth. This result seems to hold *for all 4 crop tree growth responses* (Fig 6).

3. A heavy level of forb and grass competition resulted, on average, in a 39 percent reduction in crop tree growth. This result too seems to hold *for all 4 crop tree growth responses* (Fig 7).

Table 34. Effect of abundance of forbs and grasses (Fcp) on crop tree response variables.[a]

Bräcke Mounder Group of trials

Crop spp. Trial	Crop tree response variables				
	Ccc	Ci92	AveCi	Crc	Cth
white spruce 4-10	$\chi^2 = 132.0$ $p \le 0.0001$	$\mu = 24.0$ $\gamma_2 = -6.2$ $\gamma_3 = -7.6$	$\mu = 17.2$ $\gamma_2 = -4.3$ $\gamma_3 = -6.1$	$\mu = 14.4$ $\gamma_2 = -2.4$ $\gamma_3 = -3.6$	$\mu = 87.8$ $\gamma_2 = -18.0$ $\gamma_3 = -25.7$
4-11	$\chi^2 = 79.0$ $p \le 0.0001$	$\mu = 22.9$ $\gamma_2 = -5.1$ $\gamma_3 = -9.5$	$\mu = 21.7$ $\gamma_2 = -5.6$ $\gamma_3 = -9.5$	$\mu = 17.5$ $\gamma_2 = -3.4$ $\gamma_3 = -6.4$	$\mu = 124.6$ $\gamma_2 = -30.8$ $\gamma_3 = -49.8$
4-13	$\chi^2 = 94.6$ $p \le 0.0001$	$\mu = 17.6$ $\gamma_2 = -5.8$ $\gamma_3 = -8.8$	$\mu = 17.8$ $\gamma_2 = -4.5$ $\gamma_3 = -7.9$	$\mu = 18.0$ $\gamma_2 = -4.6$ $\gamma_3 = -7.5$	$\mu = 92.3$ $\gamma_2 = -19.7$ $\gamma_3 = -35.6$
4-14	$\chi^2 = 36.5$ $p \le 0.0001$	$\mu = 10.5$ $\gamma_2 = -2.5$ $\gamma_3 = -5.6$	$\mu = 11.7$ $\gamma_2 = -2.5$ $\gamma_3 = -5.4$	$\mu = 13.1$ $\gamma_2 = -3.3$ $\gamma_3 = -6.3$	$\mu = 62.1$ $\gamma_2 = -12.4$ $\gamma_3 = -26.6$
4-18 (June 20)	$\chi^2 = 88.2$ $p \le 0.0001$	$\mu = 24.9$ $\gamma_2 = -6.9$ $\gamma_3 = -12.2$	$\mu = 21.2$ $\gamma_2 = -5.9$ $\gamma_3 = -10.0$	$\mu = 15.0$ $\gamma_2 = -2.3$ $\gamma_3 = -4.9$	$\mu = 125.3$ $\gamma_2 = -28.2$ $\gamma_3 = -51.9$
4-18 (Aug 29)	$\chi^2 = 16.8$ $p \le 0.0021$	$\mu = 22.9$ $\gamma_2 = -3.9$ $\gamma_3 = -10.4$	$\mu = 20.5$ $\gamma_2 = -5.7$ $\gamma_3 = -9.3$	$\mu = 12.7$ $\gamma_2 = -2.1$ $\gamma_3 = -4.1$	$\mu = 106.8$ $\gamma_2 = -21.2$ $\gamma_3 = -43.2$
4-19	$\chi^2 = 185.4$ $p \le 0.0001$	$\mu = 15.2$ $\gamma_2 = -6.0$ $\gamma_3 = -10.0$	$\mu = 16.6$ $\gamma_2 = -5.3$ $\gamma_3 = -9.4$	$\mu = 16.8$ $\gamma_2 = -4.6$ $\gamma_3 = -7.7$	$\mu = 87.6$ $\gamma_2 = -23.0$ $\gamma_3 = -41.2$
Lodgepole pine 4-12	$\chi^2 = 379.7$ $p \le 0.0001$	$\mu = 45.9$ $\gamma_2 = -21.2$ $\gamma_3 = -15.4$	$\mu = 42.2$ $\gamma_2 = -19.2$ $\gamma_3 = -15.1$	$\mu = 36.5$ $\gamma_2 = -17.2$ $\gamma_3 = -11.7$	$\mu = 229.0$ $\gamma_2 = -108.2$ $\gamma_3 = -91.0$

[a] Values in parentheses are not significantly different from zero.

Table 35. Median (M) and quartile (Q) summary of the standardized residuals from 8 Fcp by Ccc class contingency tables.

Bräcke Mounder Group of trials

Crop tree condition code	Degree of forb and grass competition		
	Fcp = 1 (forb & grass-free)	Fcp = 2 (moderate f & g)	Fcp = 3 (heavy f & g)
Ccc = 0 (single-stem & healthy)	M = +2.66 Q's = +1.21, +4.60	M = +1.02 Q's = –0.24, +2.21	M = –3.10 Q's = –4.65, –1.21
Ccc = 1 (multi-topped)	M = +0.08 Q's = –1.12, +1.92	M = +1.84 Q's = +0.58, +2.81	M = –0.35 Q's = –1.99, +0.12
dead	M = –3.35 Q's = –5.54, –1.52	M = –3.34 Q's = –4.57, –2.08	M = +5.07 Q's = +2.44, +7.59

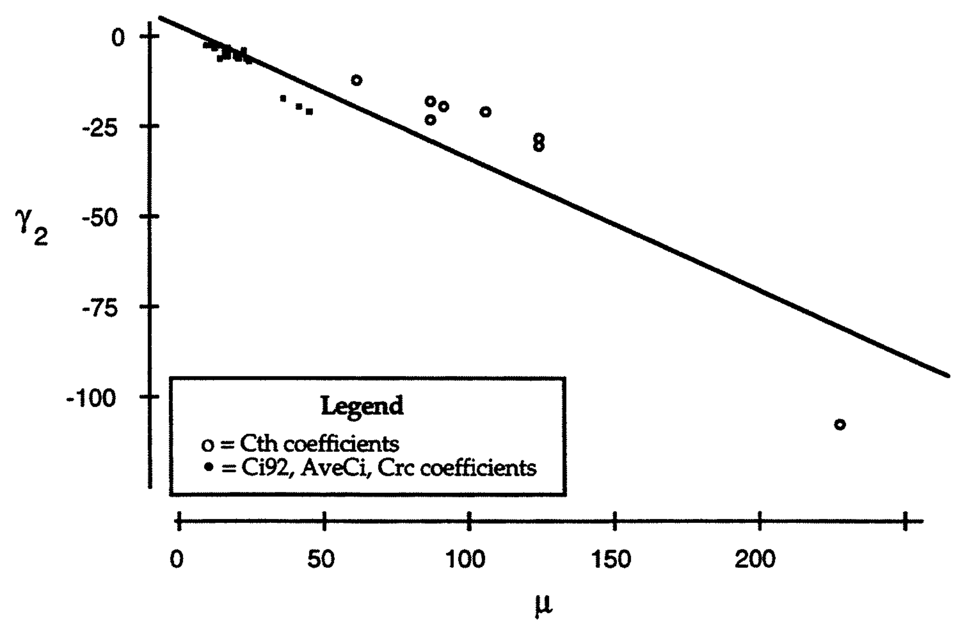


Fig 6. The regression coefficient, γ_2, associated with the moderate level of forb and grass competition, dummy variable Fcp.2, from the Bräcke Mounder Group of ANOVA's plotted against the constant, μ, from the same ANOVA's.

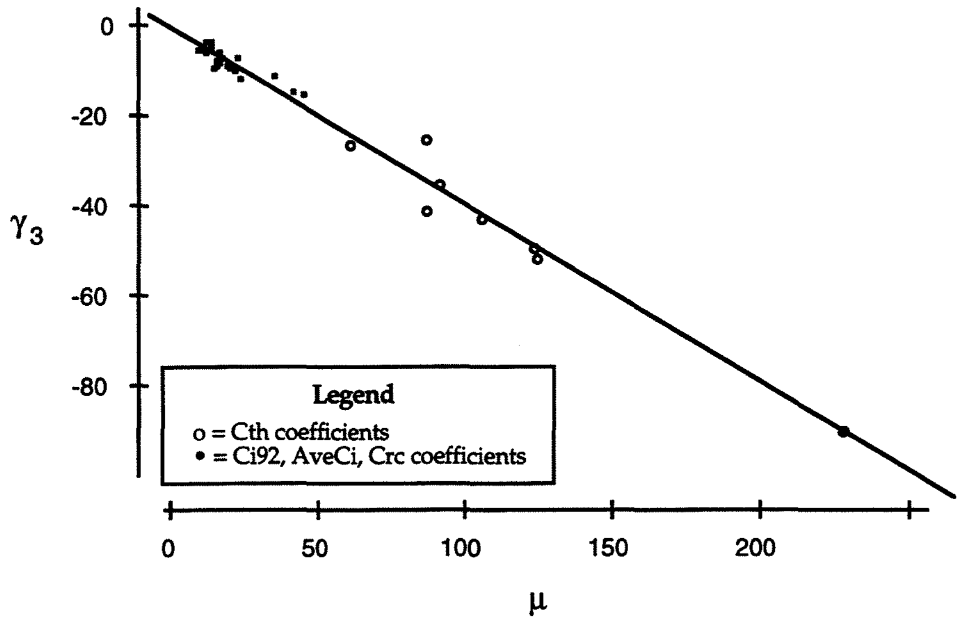


Fig 7. The regression coefficient, γ_3, associated with the moderate level of forb and grass competition, dummy variable Fcp.3, from the Bräcke Mounder Group of ANOVA's plotted against the constant, μ, from the same ANOVA's.

3.6 Interactions among competing vegetation

Table 36 gives little evidence of silviculturally important interactions among the various measures of competing vegetation. Using the methods of section 2.6 we conclude:

1. Tot.ns and Dth are only weakly correlated in 3 of the 7 trials (correlation coefficients of ρ = 0.4 to nearly 0.6). The highest correlation was found on Trial 4 - 14 and even there approximately 60 percent of the variation in the Dth data seems to be unrelated to Tot.ns.

2. In the case of the contingency table analyses summarized in the right-most 5 columns of Table 36, the relationships are generally weak and consequently of little practical interest.

Table 36. Interactions among competing vegetation. [1]

Bräcke Mounder Group of trials

Trial	Tot.ns			Dth		Scp
	Dth	Scp	Fcp	Scp	Fcp	Fcp
4-10	$\rho = -0.012$	$\chi^2 = 38.10$ ***	$\chi^2 = 9.68$ n.s.			
4-11	$\rho = 0.240$	$\chi^2 = 70.96$ ***	$\chi^2 = 13.08$ p=0.04	$\chi^2 = 32.63$ ***		$\chi^2 = 24.29$ ***
4-12	$\rho = 0.140$		$\chi^2 = 42.81$ ***	$\chi^2 = 50.49$ ***		$\chi^2 = 46.72$ ***
4-13	$\rho = 0.514$	$\chi^2 = 14.87$ *		$\chi^2 = 36.38$ ***		
4-14	$\rho = 0.573$		$\chi^2 = 51.77$ ***		$\chi^2 = 19.16$ **	
4-18	$\rho = -0.240$		$\chi^2 = 19.47$ **			
4-19	$\rho = 0.418$		$\chi^2 = 18.25$ **			$\chi^2 = 12.48$ *

[1] n.s. = $Pr(\chi^2) > 0.05$ (accept that the classification variables operate independently)
* = $0.01 \leq Pr(\chi^2) \leq 0.05$
** = $0.001 \leq Pr(\chi^2) \leq 0.01$
*** = $0.0001 \leq Pr(\chi^2) \leq 0.001$

4.0 MARTTIINI

4.1 Overview of the group

All 10 trials in the Marttiini Plow Group were planted to white spruce. At the time of measurement, the trials were between 6 and 9 years of age. Microsite positions planted include: top of berm, hinge of berm, and slope of trench. Consult Table 37 for details.

4.2 Effects of microsite position on seedling condition

In this section, we look at the effect of microsite position on crop tree condition (see Table 3 for the condition codes). Table 38 reports the survival percentage by trial and microsite position. Table 39 reports the percentage of trees planted in the "single-stemmed and healthy" category, also by trial and microsite position.

The overall survival rate for the Marttiini Plow Group of trials was 80 percent (Table 38). Looking across trials, the average percent survival varied from a low of 51 percent (in both the June and August plantings of Trial 4 - 16) to a high of 94 percent (in the August, 1986 planting of Trial 4 - 15).

Looking across microsite positions, the slope of trench position and the hinge of berm position showed the highest survival rates (84 percent overall). The top of berm position showed the lowest survival rate (73 percent overall).

When we focus our attention on "single-stemmed and healthy" trees (Table 39) we see the following trends. Overall 40 percent of the trees planted in the Marttiini Plow Group were rated "single-stemmed and healthy" upon final measurement. With 2 exceptions, when we look across trials we see little variation in this overall average value. The exceptions are Trial 4 - 3, which at 26 percent Ccc = 0 trees was well below the overall average, and Trial 4 - 9, which at 58 percent Ccc = 0 trees was well above average.

Looking across microsite positions, the general pattern is as follows: The highest proportion of Ccc = 0 trees was produced on the slope of trench position. Forty-five (45) percent of the trees planted on the slope of trench finished in the Ccc = 0 condition class. The hinge of berm position ran only slightly behind the slope of trench with 42 percent of the trees planted there finishing in Ccc = 0. The top of berm position ran a distant third with 32 percent of the trees planted finishing in the Ccc = 0 category.

When we look within individual trials, we see a few striking exceptions to the general pattern across microsites. The most notable exception is the August 1986 planting on Trial 4 - 15. Here, the microsite position effects are opposite the Group-wide trend with the top of berm position showing the best results (55 percent Ccc=0 trees) and the slope of trench position worst (34 percent Ccc=0 trees). In other cases, the trend is in the same direction seen in the Group-wide average but steeper. Trials 4 - 5, the June 1985 planting of 4 - 15, 4 - 27, and 4 - 28 are examples of this "steeper than average" pattern.

When the trials are arranged by planting date and then age, a possible seasonal/age trend is suggested. Within the May/June plantings, the top of berm is even worse than the Group-wide average and the slope of trench is even better; within the August plantings the pattern is reversed with the top of berm becoming the best position and the slope of trench the worst. In every case, the evaluation of "better" and "worse" is with respect to the production of crop trees that are rated "single-stemmed, healthy."

Table 37. Overview of the Marttiini Plow trials.

Trial Nº. / Location	Species[a] / Date planted	Date measured / Age	Nº. trees planted	Nº. trees surviving	Nº. trees in Ccc=0[b]	Microsites planted[c]	Other treatments
4 – 3 Calling Lk.	S_w 13 July '83	1992 9 years	720	507	185	Marttiini T, H, S	none
4 – 5 Calling Lk.	S_w 12 July '83	1992 9 years	720	595	307	Marttiini T, H, S	none
4 – 9 Red Earth	S_w 10 Aug '83	1992 9 years	600	521	347	Marttiini T, H, S	none
4 – 15 Red Earth	S_w 6 June '85	1992 7 years	1200	964	435	Marttiini T, H, S	3+0 bareroot cold stored, 40 cc
4 – 15 Red Earth	S_w 28 Aug '85	1992 7 years	1800	1434	654	Marttiini T, H, S	3+0 bareroot hot planted, 40 cc, 65 cc
4 – 15 Red Earth	S_w 7 Aug '86	1992 6 years	1800	1696	844	Marttiini T, H, S	40 cc, 65 cc 90 cc
4 – 16 Wandering River	S_w 12 June '85	1992 7 years	1800	1101	707	Marttiini T, H, S	3+0 bareroot cold stored, 40 cc 1st crop 40 cc 2nd crop
4 – 16 Wandering River	S_w 20 Aug '85	1992 7 years	600	304	239	Marttiini T, H, S	none
4 – 27 Calling Lk.	S_w May '87	1993 6 years	2400	2077	976	Marttiini T, H, S	none
4 – 28 Calling Lk.	S_w 15 May '87	1993 6 years	1800	1689	662	Marttiini T, H, S	3 fertilizer treatments

[a] S_w = white spruce; P_l = lodgepole pine.

[b] Crop tree condition code (Ccc) is zero when the reference tree is single-stemmed and healthy.

[c] T = top of berm; H = hinge of berm; S = slope of trench.

Table 38. Percent survival: by Trial and microsite position.

Marttiini Plow Group of trials

Microsite position	Trial N°. / Stock Type / Planting Date										Posit'n means
	4-3 40cc July 83	4-5 40cc July 83	4-9 40cc Aug 83	4-15 3+0/40 June 85	4-15 3+0/40/65 Aug 85	4-15 40/65/90 Aug 86	4-16 3+0/40 June 85	4-16 40 cc Aug 85	4-27 40/65/90 May 87	4-28 65 cc May 87	
	... %...	... %...	... %...	... %...	... %...	... %...	... %...	... %...	... %...	... %...	... %...
top of berm	88	92	86	52	59	91	46	48	78	88	72.8
hinge of berm	96	88	81	94	90	94	50	54	91	95	83.5
slope of trench	86	82	93	95	90	97	56	50	92	98	84.0
Trial means	*90.2*	*87.6*	*86.8*	*80.3*	*79.7*	*94.2*	*50.9*	*50.7*	*86.6*	*93.9*	*80.1*

Table 39. Percent of trees planted that were coded "single-stemmed and healthy": by Trial and microsite position.

Marttiini Plow Group of trials

Microsite position	Trial N°. / Stock Type / Planting Date										Posit'n means
	4-3 40cc July 83	4-5 40cc July 83	4-9 40cc Aug 83	4-15 3+0/40 June 85	4-15 3+0/40/65 Aug 85	4-15 40/65/90 Aug 86	4-16 3+0/40 June 85	4-16 40 cc Aug 85	4-27 40/65/90 May 87	4-28 65 cc May 87	
	... %...	... %...	... %...	... %...	... %...	... %...	... %...	... %...	... %...	... %...	... %...
top of berm	21	21	58	19	26	55	35	37	24	21	31.7
hinge of berm	21	45	51	42	48	51	39	44	44	38	42.3
slope of trench	35	51	64	48	35	34	44	39	53	51	45.4
Trial means	*25.7*	*39.0*	*57.7*	*36.3*	*36.3*	*46.7*	*39.3*	*40.0*	*40.3*	*36.7*	*39.8*

4.3 Effects of microsite positions on seedling growth

The expected means of crop tree size and growth rate variables by microsite position and trial are presented in the tables below: Ci92 (Table 40), AveCi (Table 41), Crc (Table 42) and Cth (Table 43). Within the same trial, the top of berm position consistently produced larger, faster growing trees than did the slope of trench position. Trees on the hinge of berm position tended to be intermediate in size and rate of growth.

Looking across trials, we see a wide range of size and growth rate responses. Differences in response due to difference in plantation age at measurement are clearly apparent. Other possible explanations for trial-to-trial differences in response include differences in planting site quality, planting date, and stock type.

Tables 40. Expected Ci92 means from the MANOVA: by trial and microsite position.

Marttiini Plow Group of trials

Microsite position	4-3 July 83	4-5 July 83	4-9 Aug 83	4-15 June 85		4-15 August 85		
	40cc	40cc	40cc	3+0 bare (cold)	40 cc	3+0 bare (hot)	40cc	65cc
top of berm	23.1 a	24.6 ab	20.2 a	27.3 a	21.8 a	24.1 a	21.4 a	20.4 a
hinge of berm	29.1 ab	23.6 b	19.2 a	23.8 b	19.9 ab	20.7 ab	14.7 b	14.8 b
slope of trench	19.4 b	27.0 a	20.1 a	18.9 c	17.9 b	16.4 b	7.8 c	9.1 c
Trial means	*23.9*	*25.1*	*19.8*	*23.3*	*19.9*	*20.4*	*14.6*	*14.8*

...more

Microsite position	4-15 Aug 86			4-16 June 85			4-16 Aug 85	4-27 May 87	4-28 May 87	*Posit'n means*
	40cc	65cc	90cc	3+0 bare (cold)	40cc (1st)	40cc (2nd)	40cc (1st)			
top of berm	14.1 a	15.1 a	16.6 a	16.7 a	19.1 a	18.0 a	14.2 a	17.7 a	16.2 a	*19.4*
hinge of berm	10.8 b	11.1 b	13.1 b	18.0 a	18.5 ab	15.4 b	11.4 b	15.9 a	14.4 b	*17.4*
slope of trench	5.8 c	4.6 c	10.1 c	17.3 a	16.4 b	15.4 b	8.2 c	15.6 a	15.2 a	*14.4*
Trial means	*10.2*	*10.2*	*13.3*	*17.4*	*18.0*	*16.28*	*11.27*	*16.4*	*15.3*	*17.1*

Tables 41. Expected AveCi means from the MANOVA: by trial and microsite position.

Marttiini Plow Group of trials

Microsite position	4-3 July 83	4-5 July 83	4-9 Aug 83	4-15 June 85		4-15 August 85		
	40cc	40cc	40cc	3+0 bare (cold)	40 cc	3+0 bare (hot)	40cc	65cc
top of berm	18.7 a	22.4 a	15.8 a	20.6 a	17.9 a	19.5 a	16.0 a	15.5 a
hinge of berm	14.2 b	21.4 a	15.6 a	18.7 b	18.1 a	17.0 b	12.1 b	12.4 b
slope of trench	12.3 c	22.5 a	15.5 a	15.1 c	16.0 b	14.0 c	7.6 c	8.6 c
Trial means	*15.0*	*22.1*	*15.6*	*18.1*	*17.4*	*16.8*	*11.9*	*12.2*

...more

Microsite position	4-15 Aug 86			4-16 June 85			4-16 Aug 85	4-27 May 87	4-28 May 87	*Posit'n means*
	40cc	65cc	90cc	3+0 bare (cold)	40cc (1st)	40cc (2nd)	40cc (1st)			
top of berm	11.8 a	12.4 a	13.6 a	18.7 a	17.8 a	17.1 a	13.7 a	16.3 ab	17.0 a	*16.8*
hinge of berm	9.5 b	10.1 b	11.7 b	17.9 a	17.9 a	15.1 a	12.0 b	16.8 a	15.9 b	*15.1*
slope of trench	6.5 c	5.9 c	9.7 c	16.0 a	15.6 a	14.8 a	8.0 c	15.8 b	16.5 ab	*13.0*
Trial means	*9.3*	*9.4*	*11.7*	*17.5*	*17.1*	*15.7*	*11.2*	*16.3*	*16.5*	*14.9*

Tables 42. Expected Crc means from the MANOVA: by trial and microsite position.
Marttiini Plow Group of trials

Microsite position	4-3 July 83	4-5 July 83	4-9 Aug 83	4-15 June 85		4-15 August 85		
	40cc	40cc	40cc	3+0 bare (cold)	40 cc	3+0 bare (hot)	40cc	65cc
top of berm	20.7 a	23.4 a	15.9 a	15.4 a	15.6 a	15.3 a	11.9 a	11.3 a
hinge of berm	15.3 b	20.8 b	15.5 a	14.3 b	15.4 a	14.6 a	10.0 b	9.4 b
slope of trench	14.5 b	20.4 b	15.1 a	13.1 c	14.3 b	13.3 b	8.1 c	7.8 c
Trial means	*16.8*	*21.5*	*15.5*	*14.3*	*15.1*	*14.4*	*10.0*	*9.5*

...more

Microsite position	4-15 Aug 86			4-16 June 85			4-16 Aug 85	4-27 May 87	4-28 May 87	*Posit'n means*
	40cc	65cc	90cc	3+0 bare (cold)	40cc (1st)	40cc (2nd)	40cc (1st)			
top of berm	8.4 a	8.8 a	9.4 a	23.3 a	20.5 a	21.8 a	16.8 a	15.5 a	16.2 a	*15.9*
hinge of berm	7.3 b	7.7 b	8.4 b	19.8 b	19.3 a	17.2 b	13.7 b	14.7 a	15.6 a	*14.0*
slope of trench	6.8 b	6.6 c	7.9 b	17.6 b	15.8 b	16.4 b	10.8 c	15.0 a	16. a	*13.0*
Trial means	*7.5*	*7.7*	*8.6*	*20.2*	*18.5*	*18.5*	*13.7*	*15.1*	*16.2*	*14.3*

Tables 43. Expected Cth means from the MANOVA: by trial and microsite position.
Marttiini Plow Group of trials

Microsite position	4-3 July 83	4-5 July 83	4-9 Aug 83	4-15 June 85		4-15 August 85		
	40cc	40cc	40cc	3+0 bare (cold)	40 cc	3+0 bare (hot)	40cc	65cc
top of berm	119.1 a	151.3 a	106.9 a	107.6 a	105.9 ab	111.8 a	81.1 a	78.6 a
hinge of berm	85.4 b	148.2 a	109.5 a	105.1 a	111.5 a	105.3 a	67.1 b	67.3 b
slope of trench	73.6 c	126.2 b	92.7 b	87.8 b	98.5 b	88.4 b	45.5 c	48.8 c
Trial means	*92.7*	*141.9*	*103.0*	*100.2*	*105.3*	*101.8*	*64.6*	*64.9*

...more

Microsite position	4-15 Aug 86			4-16 June 85			4-16 Aug 85	4-27 May 87	4-28 May 87	*Posit'n means*
	40cc	65cc	90cc	3+0 bare (cold)	40cc (1st)	40cc (2nd)	40cc (1st)			
top of berm	60.0 a	63.2 a	66.9 a	126.6 a	116.9 a	114.0 a	85.0 a	86.3 ab	94.6 b	*98.6*
hinge of berm	53.6 b	56.9 b	62.9 b	118.3 a	119.9 a	102.3 ab	72.2 b	95.6 a	102.9 a	*93.2*
slope of trench	40.6 c	37.9 c	54.0 c	100.4 a	91.9 b	93.2 b	50.1 c	88.5 b	104.9 a	*77.8*
Trial means	*51.4*	*52.7*	*61.3*	*115.1*	*109.6*	*103.2*	*69.1*	*90.1*	*100.8*	*89.9*

4.4 Effects of microsite positions on competing vegetation

The cross-trial summary of chi-square statistics associated contingency tables of microsite position by various measures of vegetative competition is given in Table 44. The rational behind this summary is explained in Section 2.4.

Table 44 suggests a possible relationship between microsite position and the degree of shrub competition (Scp) on all but one of the trials (4 - 9) in the Marttiini Plow Group. Table 45 summarizes the pattern over 10 trials. The summary statistics (median and quartiles of the standardized residuals from each cell) show that the relationship is in fact irregular and therefore of little silvicultural interest.

Table 44 also suggests a possible relationship between microsite position and the degree of forb and grass competition (Fcp). Table 46 summarizes the pattern of the relationship. The table shows that the top and hinge of berm positions are less likely than expected to be forb/grass free and more likely than expected to support heavy forb/grass competition. Conversely, the slope of trench position is more likely than expected to be forb/grass free and less likely than expected to support heavy forb/grass competition.

4.5 Effects of competing vegetation on seedling growth

Table 47 shows that the total number of deciduous stems per 10 m^2 competition plot (Tot.ns) had little effect on crop tree response variables. The Tot.ns class by Ccc contingency tables were statistically significant in 6 of 10 trials. The magnitude of the effect was too small and the pattern of the relationship too irregular to be of silvicultural interest.

Likewise, Tot.ns seldom made a statistically significant contribution to the ANOVA's of Ci92, AveCi, Crc, and Cth. And when Tot.ns was an effective covariate, its effect was sometimes positive and sometimes negative. As a result, Tot.ns is of little interest to the silviculturist.

Table 48 shows that the degree of shrub competition (Scp) had little or nothing to do with crop tree condition (Ccc), size (Crc and Cth), and growth rate (Ci92 and AveCi) response variables.

Table 44. Effect of microsite position on measures of competing vegetation.[1]

Marttiini Plow Group of trials

Crop species Trial	Vegetative competition variable			
	Tot.ns	Dth	Scp	Fcp
White spruce				
4 – 3	$\chi^2 = 56.79$ ***	$\chi^2 = 6.46$ n.s.	$\chi^2 = 21.85$ ***	$\chi^2 = 35.37$ ***
4 – 5	$\chi^2 = 9.76$ n.s.	$\chi^2 = 22.30$ **	$\chi^2 = 24.80$ ***	$\chi^2 = 6.20$ n.s.
4 – 9	$\chi^2 = 11.75$ p=0.067	$\chi^2 = 3.56$ n.s.	$\chi^2 = 8.99$ p=0.06	$\chi^2 = 28.35$ ***
4 – 15 June 85	$\chi^2 = 2.79$ n.s.	$\chi^2 = 5.37$ n.s.	$\chi^2 = 32.89$ ***	$\chi^2 = 133.5$ ***
4 – 15 Aug 85	$\chi^2 = 10.58$ n.s.	$\chi^2 = 19.12$ *	$\chi^2 = 85.62$ ***	$\chi^2 = 179.9$ ***
4 – 15 Aug 86	$\chi^2 = 11.07$ n.s.	$\chi^2 = 6.74$ n.s.	$\chi^2 = 141.1$ ***	$\chi^2 = 163.4$ ***
4 – 16 June 85	$\chi^2 = 2.06$ n.s.	$\chi^2 = 3.75$ n.s.	$\chi^2 = 38.90$ ***	$\chi^2 = 140.3$ ***
4 – 16 Aug 85	$\chi^2 = 2.17$ n.s.	$\chi^2 = 8.60$ n.s.	$\chi^2 = 26.87$ ***	$\chi^2 = 94.77$ ***
4 – 27	$\chi^2 = 67.5$ ***	$\chi^2 = 33.35$ ***	$\chi^2 = 121.6$ ***	$\chi^2 = 319.9$ ***
4 – 28	$\chi^2 = 20.11$ **	$\chi^2 = 15.62$ *	$\chi^2 = 29.06$ ***	$\chi^2 = 270.3$ ***

1 n.s. = $Pr(\chi^2) > 0.05$ (accept that the classification variables operate independently)
* = $0.01 \le Pr(\chi^2) \le 0.05$
** = $0.001 \le Pr(\chi^2) \le 0.01$
*** = $0.0001 \le Pr(\chi^2) \le 0.001$

Table 45. Median and quartile summaries of standardized residuals from 10 microsite by Scp contingency tables.

Marttiini Plow Group of trials

Degree of shrub comp.	**Microsite position**		
	Top	Hinge	Slope
Scp = 1 (shrub-free)	M = +0.96 Q's = –1.83, +1.95	M = –0.08 Q's = –0.57, +0.21	M = –0.61 Q's = –1.45, +2.65
Scp = 2 (moderate shrubs)	M = –1.64 Q's = –3.15, +0.92	M = +0.29 Q's = –0.07, +1.84	M = +0.27 Q's = –0.85, +2.65
Scp = 3 (heavy shrubs)	M = +0.13 Q's = –2.54, +1.94	M = –0.34 Q's = –1.58, +0.51	M = +1.17 Q's = –3.32, +2.64

Table 46. Median and quartile summaries of standardized residuals from 10 microsite by Fcp contingency tables.

Marttiini Plow Group of trials

Degree of forb and grass comp.	**Microsite position**		
	Top	Hinge	Slope
Fcp = 1 (forb & grass–free)	M = –1.74 Q's = –4.65, –0.31	M = –2.17 Q's = –3.44, –0.02	M = **+3.44** Q's = +0.86, +7.30
Fcp = 2 (moderate f & g)	M = –2.30 Q's = –3.75, +0.74	M = +0.50 Q's = –1.19, +0.81	M = +0.40 Q's = –0.90, +5.62
Fcp = 3 (heavy f & g)	M = +2.32 Q's = +1.46, +4.06	M = +1.06 Q's = –0.17, +2.58	M = **–4.28** Q's = –7.26, –1.18

Table 47. Effect of total number of deciduous stems (Tot.ns) on crop tree response variable.[a]

Marttiini Plow Group of trials

White Spruce Trial	Crop tree response variables				
	Ccc	Ci92	AveCi	Crc	Cth
4 – 3	$\chi^2 = (6.6)$ $p = 0.36$	(0.05)	(–0.08)	–0.14	–0.80
4 – 5	$\chi^2 = 23.1$ $p = 0.0008$	n.s.	n.s.	n.s.	n.s.
4 – 9	$\chi^2 = 34.9$ $p \leq 0.0001$	(0.09)	(0.07)	(–0.03)	(0.40)
4 – 15 June 85	$\chi^2 = 10.4$ $p = 0.11$	(–0.08)	(–0.04)	–0.16	(–0.17)
4 – 15 Aug 85	$\chi^2 = 12.7$ $p = 0.05$	–0.12	(–0.06)	–0.15	–0.39
4 – 15 Aug 86	$\chi^2 = 10.4$ $p = 0.11$	–0.24	–0.18	–0.12	–0.62
4 – 16 June 85	$\chi^2 = 47.4$ $p \leq 0.0001$	0.39	0.16	(0.04)	(0.67)
4 – 16 Aug 85	$\chi^2 = 22.4$ $p = 0.001$	(0.08)	(–0.04)	–0.25	(–0.30)
4 – 27	$\chi^2 = 71.9$ $p \leq 0.0001$	(0.10)	(0.03)	(0.01)	(0.10)
4 – 28	$\chi^2 = (4.8)$ $p = 0.56$	(0.10)	(0.03)	(0.01)	(0.10)

[a] Values in parentheses are not significantly different from zero.

Table 48. Effect of abundance of shrubs (Scp) on crop tree response variables.[a]

Marttiini Plow Group of trials

Trial	Crop tree response variables				
	Ccc	Ci92	AveCi	Crc	Cth
4 – 3	$\chi^2 = (4.9)$ p = 0.29	$\mu = 20.5$ β_2 = n.s. β_3 = n.s.	$\mu = 16.5$ $\beta_2 = (0.9)$ $\beta_3 = (-2.9)$	$\mu = 19.4$ $\beta_2 = (0.3)$ $\beta_3 = -3.4$	$\mu = 106.7$ $\beta_2 = (2.1)$ $\beta_3 = -20.5$
4 – 5	$\chi^2 = (6.3)$ p = 0.17	$\mu = 30.1$ $\beta_2 = (-0.6)$ $\beta_3 = -8.1$	$\mu = 25.9$ $\beta_2 = (-0.3)$ $\beta_3 = -6.2$	$\mu = 25.2$ $\beta_2 = (0.5)$ $\beta_3 = -5.0$	$\mu = 163.8$ $\beta_2 = (-1.1)$ $\beta_3 = -30.6$
4 – 9	$\chi^2 = (5.4)$ p = 0.96	$\mu = 20.6$ $\beta_2 = (-0.8)$ $\beta_3 = (-0.7)$	$\mu = 16.4$ $\beta_2 = (-0.2)$ $\beta_3 = (-0.2)$	$\mu = 17.2$ $\beta_2 = -1.7$ $\beta_3 = -1.8$	$\mu = 104.7$ $\beta_2 = (-1.9)$ $\beta_3 = (-5.2)$
4 – 15 June 85	$\chi^2 = 24.1$ $p < 0.0001$	$\mu = 25.3$ $\beta_2 = (-0.1)$ $\beta_3 = (-0.7)$	$\mu = 20.3$ $\beta_2 = (0.3)$ $\beta_3 = (0.1)$	$\mu = 17.0$ $\beta_2 = 1.0$ $\beta_3 = (-0.6)$	$\mu = 117.4$ $\beta_2 = (-1.2)$ $\beta_3 = (-0.8)$
4 – 15 Aug 85	$\chi^2 = 12.4$ p = 0.01	$\mu = 20.9$ $\beta_2 = 1.7$ $\beta_3 = (-0.8)$	$\mu = 17.0$ $\beta_2 = (1.0)$ $\beta_3 = (-1.2)$	$\mu = 14.4$ $\beta_2 = 1.3$ $\beta_3 = (-1.0)$	$\mu = 93.1$ $\beta_2 = 5.9$ $\beta_3 = (-2.9)$
4 – 15 Aug 86	$\chi^2 = 17.3$ p= 0.002	$\mu = 17.1$ $\beta_2 = (1.1)$ $\beta_3 = (-1.4)$	$\mu = 14.7$ $\beta_2 = (0.6)$ $\beta_3 = -1.2$	$\mu = 10.3$ $\beta_2 = 0.8$ $\beta_3 = -1.1$	$\mu = 72.6$ $\beta_2 = (2.6)$ $\beta_3 = -5.1$
4 – 16 June 85	$\chi^2 = 13.8$ p= 0.008	$\mu = 17.2$ $\beta_2 = 1.9$ $\beta_3 = (0.0)$	$\mu = 17.9$ $\beta_2 = (0.9)$ $\beta_3 = (-0.9)$	$\mu = 20.6$ $\beta_2 = (-0.6)$ $\beta_3 = -1.6$	$\mu = 117.4$ $\beta_2 = (1.2)$ $\beta_3 = (-2.8)$
4 – 16 Aug 85	$\chi^2 = (5.5)$ p = 0.23	$\mu = 13.8$ $\beta_2 = 2.9$ $\beta_3 = (0.3)$	$\mu = 14.8$ $\beta_2 = (1.8)$ $\beta_3 = (0.4)$	$\mu = 18.2$ $\beta_2 = (-0.9)$ $\beta_3 = -2.6$	$\mu = 90.0$ $\beta_2 = (5.8)$ $\beta_3 = (-3.8)$
4 – 27	$\chi^2 = 38.3$ $p \leq 0.0001$	$\mu = 19.2$ $\beta_2 = (0.1)$ $\beta_3 = (-0.9)$	$\mu = 19.6$ $\beta_2 = (-0.7)$ $\beta_3 = -1.3$	$\mu = 18.0$ $\beta_2 = -1.1$ $\beta_3 = -1.3$	$\mu = 107.4$ $\beta_2 = -5.6$ $\beta_3 = -11.5$
4 – 28	$\chi^2 = 9.9$ p = 0.04	$\mu = 17.9$ $\beta_2 = (-0.9)$ $\beta_3 = (-0.2)$	$\mu = 19.5$ $\beta_2 = (-0.7)$ $\beta_3 = (-0.1)$	$\mu = 19.3$ $\beta_2 = (-1.0)$ $\beta_3 = (-1.3)$	$\mu = 119.1$ $\beta_2 = (-3.2)$ $\beta_3 = (-7.3)$

[a] Values in parentheses are not significantly different from zero.

Table 49 shows that the degree of forb and grass competition (Fcp) was often strongly related with crop tree condition (Ccc). The general pattern of the relationship (summarized in Table 50) is as follows: Forb– and grass–free plots produced more than the expected number of Ccc = 0 trees and suffered less than the expected level of mortality. Conversely, plots with heavy forb and grass competition produced fewer than expected Ccc = 0 trees and suffered more than the expected level of mortality.

The right-most 4 columns in Table 49 report the coefficients associate with dummy variables Fcp.2 and Fcp.3, which code for Fcp = 2 and Fcp = 3 when Fcp is used as a covariate in the crop tree response variable ANOVA's. The practical interpretation of these coefficients is explained in Section 2.5.3.

Fig 8 shows covariate coefficient γ_2 plotted against the ANOVA constant, μ. The regression of γ_2 on μ is

$$\gamma_2 = -0.8 - 0.18\,\mu \qquad \text{Eq 5}$$
$$R^2 = 52.4\ \%$$

The intercept is not significantly different from zero.

Following the reasoning developed in Section 2.5.3, we conclude that across all trials in the Marttiini Plow Group, moderate levels of forb and grass competition resulted, on average, in an 18 percent reduction in crop tree growth. This conclusion seems to hold for *all 4* crop tree growth responses.

We note that Eq 5 clearly violates the regression assumption of homogeneous variance about the regression line. An alternative analysis that yields well–behaved residuals is based on the log–log transformation. The fitted model is

$$\log(0.65 - \gamma_2) = -0.47 + 0.84 \log \mu \qquad \text{Eq 6}$$
$$R^2 = 54.3\ \%$$

where the constant 0.65 was determined by trial and error to produce homogeneous variance. The trouble with Eq 6 is that its coefficients are not so easily interpreted as are those of Eq 5. Consequently, we prefer Eq 5, in spite of its technical deficiencies, to Eq 6.

Table 49. Effect of abundance of forbs and grasses (Fcp) on crop tree response variables.[a]
Marttiini Plow Group of trials

Trial	Crop tree response variables				
	Ccc	Ci92	AveCi	Crc	Cth
4 – 3	$\chi^2 = (2.4)$ p =0.64	$\mu = 20.5$ $\gamma_2 = (0.2)$ $\gamma_3 = (-2.2)$	$\mu = 16.5$ $\gamma_2 = (-1.2)$ $\gamma_3 = -3.6$	$\mu = 19.4$ $\gamma_2 = -1.8$ $\gamma_3 = -5.8$	$\mu = 106.7$ $\gamma_2 = -7.6$ $\gamma_3 = -33.3$
4 – 5	$\chi^2 = 15.2$ p = 0.004	$\mu = 30.1$ $\gamma_2 = (-3.4)$ $\gamma_3 = -8.3$	$\mu = 25.9$ $\gamma_2 = -1.5$ $\gamma_3 = -6.9$	$\mu = 25.2$ $\gamma_2 = -3.0$ $\gamma_3 = -7.0$	$\mu = 163.8$ $\gamma_2 = (-11.2)$ $\gamma_3 = -43.8$
4 – 9	$\chi^2 = 254.1$ $p \leq 0.0001$	$\mu = 20.6$ $\gamma_2 = -5.1$ $\gamma_3 = -10.9$	$\mu = 16.4$ $\gamma_2 = -4.7$ $\gamma_3 = -9.3$	$\mu = 17.2$ $\gamma_2 = -3.2$ $\gamma_3 = -7.7$	$\mu = 107.4$ $\gamma_2 = -26.5$ $\gamma_3 = -52.5$
4 – 15 June 85	$\chi^2 = 360.2$ $p \leq 0.0001$	$\mu = 25.3$ $\gamma_2 = -4.7$ $\gamma_3 = -8.8$	$\mu = 20.3$ $\gamma_2 = -4.4$ $\gamma_3 = -7.4$	$\mu = 17.0$ $\gamma_2 = -3.1$ $\gamma_3 = -4.7$	$\mu = 117.4$ $\gamma_2 = -23.1$ $\gamma_3 = -36.2$
4 – 15 Aug 85	$\chi^2 = 222.8$ $p \leq 0.0001$	$\mu = 20.9$ $\gamma_2 = -3.5$ $\gamma_3 = -7.8$	$\mu = 17.0$ $\gamma_2 = -2.8$ $\gamma_3 = -6.6$	$\mu = 14.4$ $\gamma_2 = -2.0$ $\gamma_3 = -4.9$	$\mu = 93.1$ $\gamma_2 = -12.3$ $\gamma_3 = -32.3$
4 – 15 Aug 86	$\chi^2 = 19.1$ p = 0.0007	$\mu = 17.1$ $\gamma_2 = -2.2$ $\gamma_3 = -5.5$	$\mu = 14.7$ $\gamma_2 = -1.5$ $\gamma_3 = -4.4$	$\mu = 10.3$ $\gamma_2 = -0.8$ $\gamma_3 = -2.4$	$\mu = 72.6$ $\gamma_2 = -6.1$ $\gamma_3 = -17.4$
4 – 16 June 85	$\chi^2 = 190.0$ $p \leq 0.0001$	$\mu = 17.2$ $\gamma_2 = -8.8$ $\gamma_3 = -13.4$	$\mu = 17.9$ $\gamma_2 = -8.4$ $\gamma_3 = -13.1$	$\mu = 20.6$ $\gamma_2 = -6.7$ $\gamma_3 = -10.1$	$\mu = 117.4$ $\gamma_2 = -48.4$ $\gamma_3 = -77.8$
4 – 16 Aug 85	$\chi^2 = 47.5$ $p \leq 0.0001$	$\mu = 13.8$ $\gamma_2 = -6.5$ $\gamma_3 = -9.3$	$\mu = 14.8$ $\gamma_2 = -6.9$ $\gamma_3 = -9.9$	$\mu = 18.2$ $\gamma_2 = -5.1$ $\gamma_3 = -7.8$	$\mu = 90.0$ $\gamma_2 = -35.6$ $\gamma_3 = -53.4$
4 – 27	$\chi^2 = 275.1$ $p \leq 0.0001$	$\mu = 19.2$ $\gamma_2 = -5.0$ $\gamma_3 = -9.1$	$\mu = 19.6$ $\gamma_2 = -4.8$ $\gamma_3 = -9.2$	$\mu = 18.0$ $\gamma_2 = -4.0$ $\gamma_3 = -7.6$	$\mu = 107.4$ $\gamma_2 = -23.7$ $\gamma_3 = -46.0$
4 – 28	$\chi^2 = 182.0$ $p \leq 0.0001$	$\mu = 17.9$ $\gamma_2 = -3.3$ $\gamma_3 = -7.7$	$\mu = 19.5$ $\gamma_2 = -3.2$ $\gamma_3 = -8.5$	$\mu = 19.3$ $\gamma_2 = -3.2$ $\gamma_3 = -8.1$	$\mu = 119.1$ $\gamma_2 = -16.7$ $\gamma_3 = -46.3$

[a] Values in parentheses are not significantly different from zero.

Table 50. Median and quartile summaries of standardized residuals from 10 Fcp x Ccc Class contingency tables.

Marttiini Plow Group of trials

Crop tree condition code	Degree of forb and grass competition		
	Fcp = 1 (forb & grass-free)	Fcp = 2 (moderate f & g)	Fcp = 3 (heavy f & g)
Ccc = 0 (single stemmed, healthy)	M = +3.54 Q's = +1.30, +5.28	M = –0.40 Q's = –0.99, +1.02	M = –4.06 Q's = –5.23, –0.84
Ccc = 1 (multi-stemmed, healthy)	M = –0.75 Q's = –4.41, +0.71	M = +1.62 Q's = +0.17, +2.90	M = –0.68 Q's = –1.65, –0.39
dead	M = –5.06 Q's = –5.55, –1.62	M = –2.36 Q's = –5.15, –0.81	M = +8.34 Q's = +2.55, +12.52

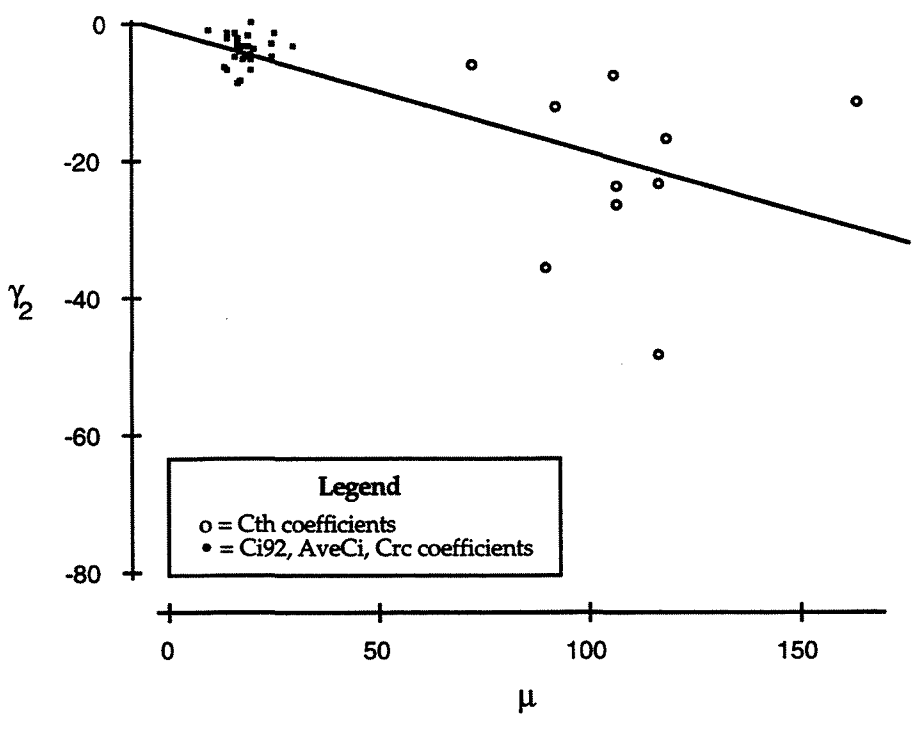


Fig 8. The regression coefficient, γ_2, associated with the moderate level of shrub competition, dummy variable Scp.2, from the Marttiini Plow Group of ANOVA's plotted against the constant, μ, from the same ANOVA's.

Fig 9 shows covariate coefficient γ_3 plotted against the ANOVA constant, μ. The regression of γ_3 on μ is

$$\gamma_2 = -0.67 - 0.39\,\mu \qquad \text{Eq 7}$$
$$R^2 = 80.6\ \%$$

The intercept is not significantly different from zero.

Following the reasoning developed above, we conclude that across all trials in the Marttiini Plow Group, heavy levels of forb and grass competition resulted, on average, in a 39 percent reduction in crop tree growth. This conclusion seems to hold for *all 4* crop tree growth responses.

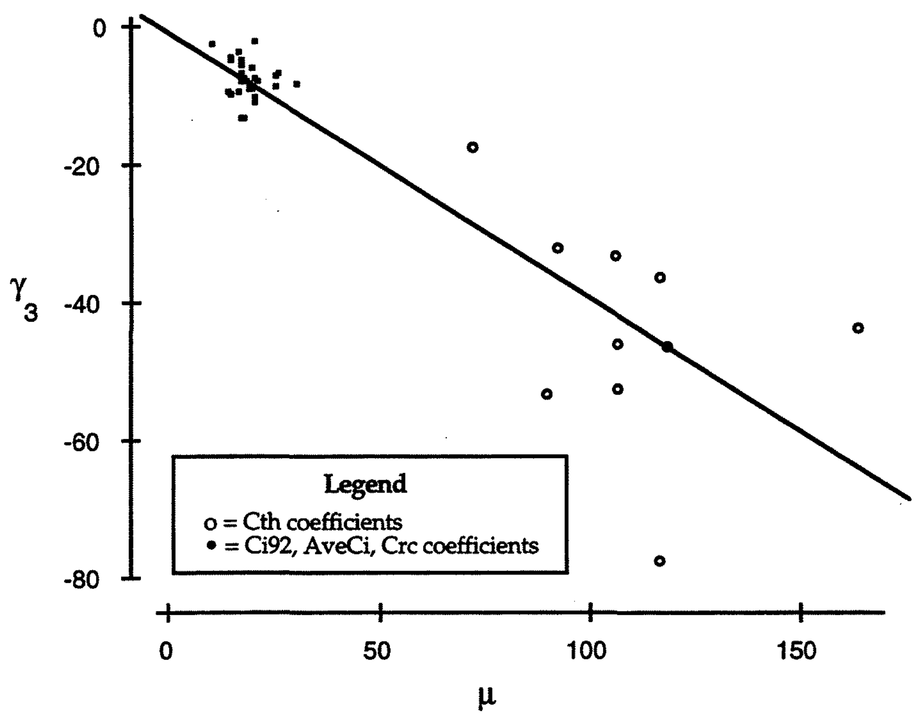


Fig 9. The regression coefficient, γ_3, associated with the heavy level of shrub competition, dummy variable Scp.3, from the Marttiini Plow Group of ANOVA's plotted against the constant, μ, from the same ANOVA's.

Once again, a log-log transformed version of the regression overcomes the problem of heterogeneous variance seen in Fig 9 but results in a fitted model that is difficult interpret silviculturally.

4.6 Interactions among competing vegetation

Table 51 suggests the existence of possibly important relationships between Tot.ns and Fcp (summarized in Table 52) and between Scp and Fcp (summarized in Table 53).

Table 51. Interactions among competing vegetation.[1]

Marttiini Plow Group of trials

Trial	Tot.ns			Dth		Scp
	Dth	Scp	Fcp	Scp	Fcp	Fcp
4-3	$\rho = 0.124$	$\chi^2 = 7.04$ n.s.	$\chi^2 = 14.91$ *		$\chi^2 = 24.78$ **	
4-5	$\rho = 0.534$	$\chi^2 = 6.88$ n.s.	$\chi^2 = 12.88$ *	$\chi^2 = 15.20$ p=0.055	$\chi^2 = 20.48$ **	$\chi^2 = 34.07$ ***
4-9	$\rho = 0.439$	$\chi^2 = 9.85$ n.s.	$\chi^2 = 10.32$ n.s.			$\chi^2 = 9.82$ *
4-15 June 85	$\rho = 0.274$	$\chi^2 = 40.32$ ***	$\chi^2 = 2.59$ n.s.			$\chi^2 = 33.56$ ***
4-15 Aug 85	$\rho = 0.333$	$\chi^2 = 85.81$ ***	$\chi^2 = 8.90$ n.s.			$\chi^2 = 54.38$ ***
4-15 Aug 86	$\rho = 0.329$	$\chi^2 = 20.30$ **	$\chi^2 = 16.04$ *			$\chi^2 = 14.07$ **
4-16 June 85	$\rho = 0.163$	$\chi^2 = 18.36$ **	$\chi^2 = 42.23$ ***		$\chi^2 =$ ***	$\chi^2 = 47.57$ ***
4-16 Aug 85	$\rho = 0.628$	$\chi^2 = 6.34$ n.s.	$\chi^2 = 55.58$ ***		$\chi^2 =$ ***	$\chi^2 = 33.58$ ***
4-27	$\rho = 0.366$	$\chi^2 = 32.26$ ***	$\chi^2 = 100.2$ ***			$\chi^2 = 38.57$ ***
4-28	$\rho = 0.504$	$\chi^2 = 12.18$ n.s.	$\chi^2 = 25.36$ ***			

1 n.s. = $Pr(\chi^2) > 0.05$ (accept that the classification variables operate independently)
* = $0.01 \le Pr(\chi^2) \le 0.05$
** = $0.001 \le Pr(\chi^2) \le 0.01$
*** = $0.0001 \le Pr(\chi^2) \le 0.001$

Table 52 shows that in fact the relationship between Tot.ns and Fcp is too weak and irregular to be of silvicultural interest.

Table 53 shows that there is a weak positive correlation between the level of shrub competition and the level of forb and grass competition. That is, shrub–free plots tend to be forb and grass–free as well; plots with heavy shrub competition tend to have heavy forb and grass competition as well.

Table 52. Median and quartile summaries of standardized residuals from 10 Tot.ns Class by Fcp contingency tables.

Marttiini Plow Group of trials

Degree of forb and grass comp.	**Tot.ns Class (Nº. stems per 10 m^2 plot)**			
	0 – 6	**7 – 9**	**10 – 13**	**14+**
Fcp = 1 (forb & grass–free)	M = –0.90 lo Q = –2.70 hi Q = –0.10	M = –0.01 lo Q = –0.63 hi Q = +0.66	M = +0.29 lo Q = –0.27 hi Q = +0.97	M = +1.33 lo Q = –0.47 hi Q = +2.41
Fcp = 2 (moderate f & g)	M = –0.28 lo Q = –0.85 hi Q = +1.26	M = –0.50 lo Q = –0.97 hi Q = +0.26	M = +0.23 lo Q = –0.58 hi Q = +0.59	M = –0.28 lo Q = –0.56 hi Q = +1.24
Fcp = 3 (heavy f & g)	M = +1.38 lo Q = +0.39 hi Q = +2.41	M = +0.28 lo Q = –0.37 hi Q = +1.11	M = –0.68 lo Q = –1.55 hi Q = –0.46	M = –1.18 lo Q = –2.09 hi Q = +0.46

Table 53. Median and quartile summaries of standardized residuals from 8 Scp by Fcp contingency tables.

Marttiini Plow Group of trials

Degree of forb and grass comp.	**Degree of shrub competition**		
	Scp = 1 (shrub-free)	**Scp = 2** (moderate shrubs)	**Scp = 3** (heavy shrubs)
Fcp = 1 (forb & grass-free)	M = +1.47 Q's = +0.53, +1.89	M = -1.22 Q's = -1.60, +0.05	M = +2.72 Q's = -3.50, -0.67
Fcp = 2 (moderate f & g)	M = -0.56 Q's = -1.32, +0.73	M = +0.81 Q's = -0.22, +2.40	M = -0.70 Q's = -1.93, +1.47
Fcp = 3 (heavy f & g)	M = -1.26 Q's = -1.78, -0.70	M = +0.37 Q's = -0.02, +1.06	M = +3.10 Q's =+ 1.46, +3.88

5.0 COMPARISON OF CROP TREE RESPONSE AS AFFECTED BY PLANTING DATE, STOCK TYPE AND MICROSITE POSITION

Thus far, we have been summarizing results across trials within 3 major Groups of trials that are based on 3 different methods of mechanical site preparation. In Chapter 2.0 we looked at the Bräcke Spot/Sinkilla Patch Group, in Chapter 3.0 the Bräcke Mounder Group, and in Chapter 4.0 the Marttiini Plow Group. In this and the following chapter, we take an even wider perspective and look across the whole project for patterns in crop tree response of possible silvicultural interest. In this chapter, we begin this inquiry by looking at patterns in crop tree responses that seem to be associated with planting date, stock type and "generic" microsite position.

By generic microsite position, we mean microsite position interpreted broadly as follows:

generic top = top of overturn (Spots and Mounders) or top of berm (Marttiini Plow)

generic hinge = hinge of overturn (Spots and Mounders) or hinge of berm (Marttiini Plow)

generic scalp = bottom of scalp (Spots and Mounders) or slope of trench (Marttiini Plow)

The crop response variables analyzed in this and the following chapter are: 2 measures of crop tree survival and condition (% Survival and % in Ccc = 0); 1 measure of crop tree growth rate (AveCi); and 1 measure of crop tree size (Cth). In the case of both AveCi and Cth, our measures of response are the *expected* means from the within-trial MANOVA's. Expected means have been adjusted to the trial-wide average values of all variables used as covariates in the MANOVA linear model. As in the chapters above, whenever we analyze measures of crop tree growth rate and size we restrict our attention to the "single-stemmed and healthy" component of the crop. That is, we select for trees classified as Ccc = 0 before performing any analyses.

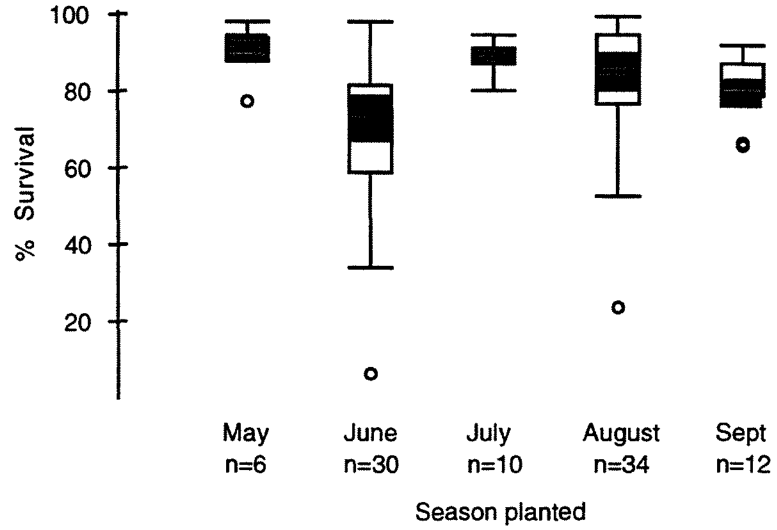
5.1 White spruce

5.1.1 Percent survival

Overall survival rates for white spruce seem to depend little on the month of planting with the possible exception of June (Fig 10). June planted trials suffered a somewhat higher rate of mortality than did trials planted in May, July, August, or September.

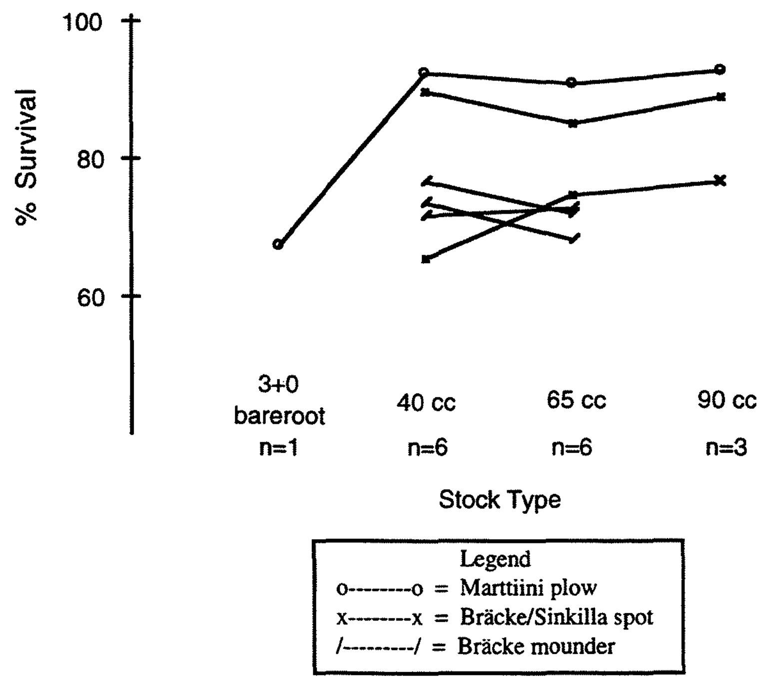
Fig 11 shows percent survival by stock type. Only projects with more than one stock type are included in this figure. The results indicate that container volume (40, 65, 90 cc) had little effect on percent survival – the most evident differences are due to trial, not stock type within trial. The single observation of 3+0 bareroot stock is insufficient to allow a general conclusion to be drawn.

Microsite position seems to have had little, if any, influence on survival (Fig 12).



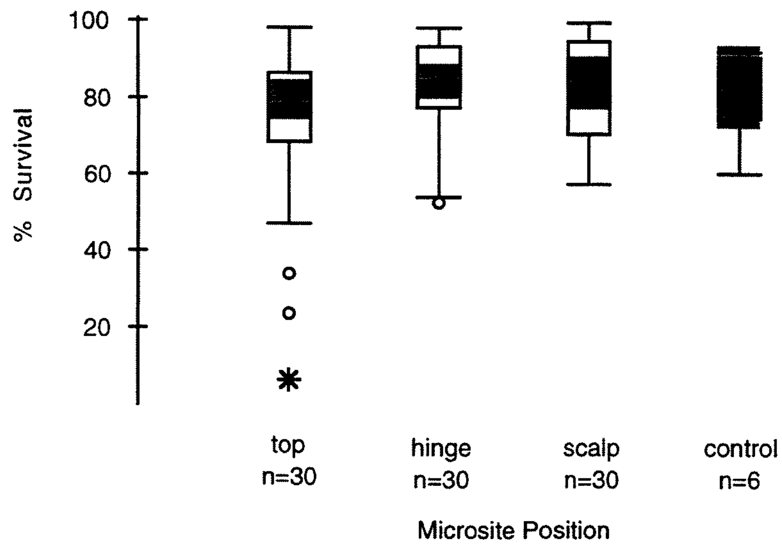
Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types and microsite positions.

Fig 10. Percentage of planted white spruce crop trees that survived to the assessment date: by month of planting.



Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all planting dates and microsite positions but limited to trials that include more than one stock type.

Fig 11. Percentage of planted white spruce crop trees that survived to the assessment date: by nursery stock type. Results on the same line are from the same project.



Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types and planting dates.

Fig 12. Percentage of planted white spruce crop trees that survived to the assessment date: by microsite position.

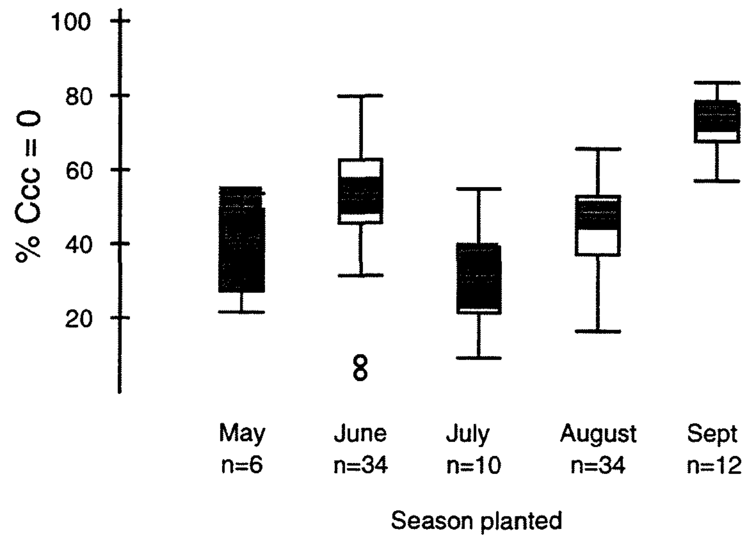
5.1.2 Percent "Single-stemmed and healthy"

When we summarize the percentage of white spruce crop trees rated Ccc = 0 by month of planting, we see some evidence of meaningful variation. If we take the May results for reference, the June median was better than May; July was worse than May and worst overall; August returned to approximately the June level; and September was best of all (Fig 13).

In saying this, however, we note a problem that runs throughout the interpretations presented in these last 2 chapters. The problem is that the whole project was not designed to test hypotheses that span more than one trial. As a result, many factors are confounded at the Site Preparation Group level and the whole project level. For example, in Fig 13 only 2 white spruce trials were planted in May. Both of these were at Calling Lake and both were site prepared with the Marttiini Plow. We have no way of knowing, therefore, whether the observed results are due to the month of planting (May), the type of site preparation (Marttiini), the planted location (Calling Lake) or some combination of these and other hidden variables.

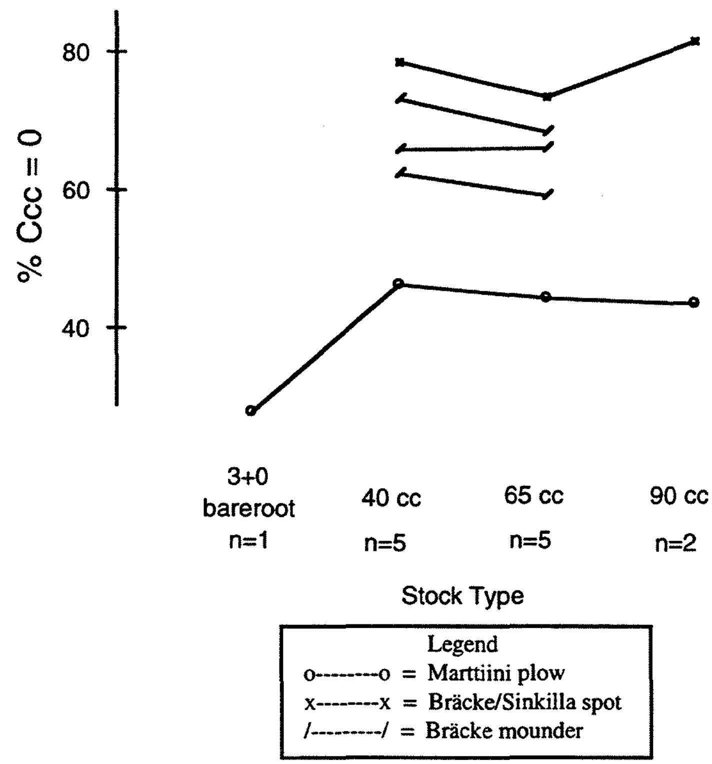
Fig 14 illustrates the apparent effect of nursery stock type on the proportion of trees assessed as "single-stemmed and healthy." Again, the most reliable information comes from the 40 cc and 65 cc containers as these were widely planted throughout the project. Although survival was generally higher in the 65 cc containers (Fig 10), the proportion of trees rated Ccc = 0 trees was higher in the 40 cc containers. It seems unwise to comment on the bareroot and 90 cc results given the meager representation of these stock types in the database.

The apparent effect of generic microsite position on the proportion of "single-stemmed and healthy" trees is illustrated in Figs 15. The proportion of trees rated Ccc = 0 tended to increase slightly from the generic "top" position (where we see the smallest proportion of Ccc = 0 trees) to the generic "scalp" position (where we see the highests proportion of Ccc = 0 trees). The generic "hinge" and unscarified control positions were intermediate.



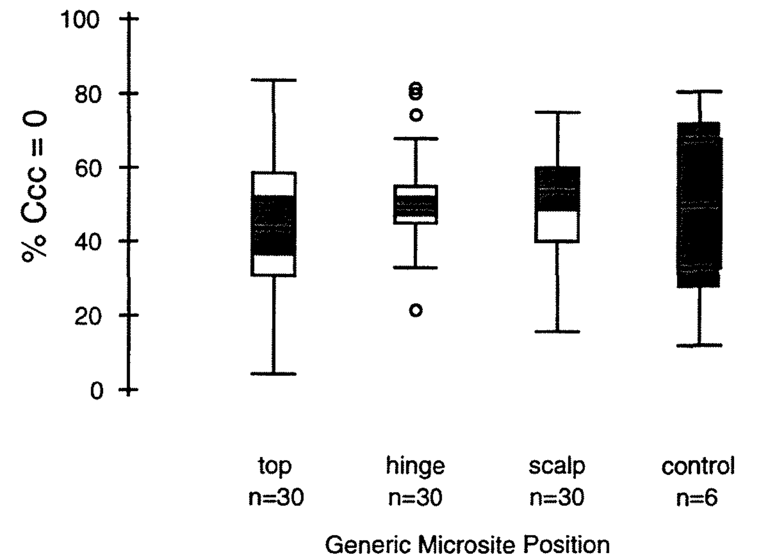
Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types and microsite positions.

Fig 13. Percentage of planted white spruce crop trees that were assessed "single-stemmed and healthy" (Ccc = 0): by month of planting.



Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all planting dates and microsite positions but limited to projects with multiple stock types.

Fig 14. Percentage of planted white spruce crop trees that were assessed "single-stemmed and healthy" (Ccc = 0): by nursery stock type.



Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types and planting dates.

Fig 15. Percentage of planted white spruce crop trees that were assessed "single-stemmed and healthy" (Ccc = 0): by generic microsite position.

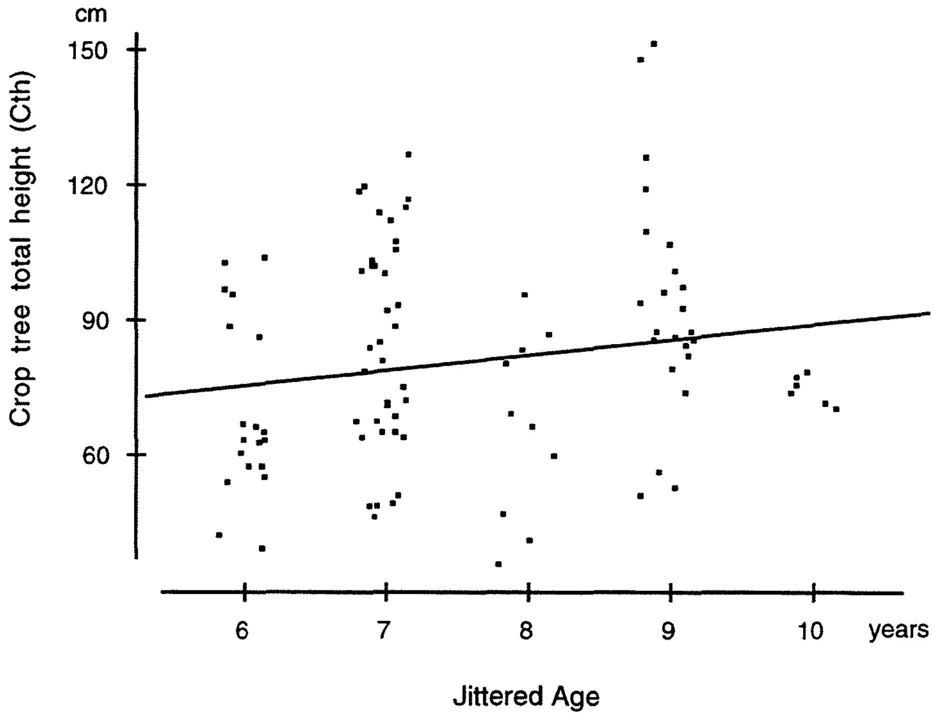
5.1.3 Total height (Cth)

Since the trials in this analysis were planted over several years, we removed the effect of tree "age" (actually, years since planting) from total height (Cth) before analyzing the Cth response to site preparation method, stock type, and generic microsite. The Cth vs. age scatter plot is shown in Fig 16. The regression of Cth on age is weak (R^2 = 3.4 %, s.e. = 23.8 cm) and not quite statistically significantly at the $\alpha = 0.05$ level. Nonetheless, since trees are known to get taller as they get older, we subtracted the regression line shown in Fig 15 from the Cth data and analyzed the Cth vs. age residuals with respect to site preparation method, stock type, and generic microsite.

Fig 17 shows the apparent effect of month of planting on white spruce total height (adjusted for age). May-planted trees tended to be taller and August- / September-planted trees shorter than the Cth / age regression model predicts. June- / July-planted trees were intermediate. Certainly at least part of this effect is due to the fact that May-planted trees produce height growth during their first season in the field whereas September-planted trees do not.

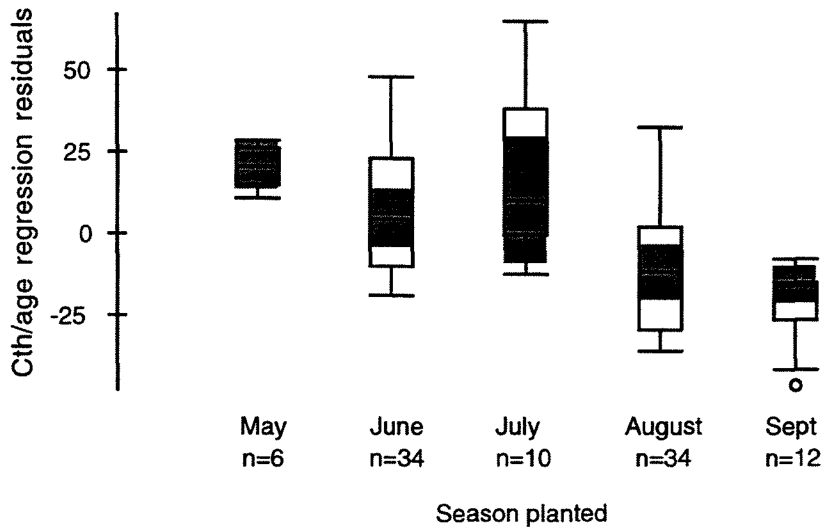
The apparent effect of site preparation method on the Cth vs. age residuals is shown in Fig 18. The Marttiini trials performed best on average. Spots and Mounders show more or less the same performance.

Fig 19 shows the apparent effect of nursery stock type on Cth vs. age residuals. The superficial impression is potentially misleading, however. For example, Fig 19 shows that the 3+0 bareroot stock performed better than the 90 cc container stock. This is true but does not tell the whole story. The 90 cc container stock data all come from one trial which was planted in August. The bareroot data on the other hand come from 4 trials, 3 of which were planted in June and 1 in August.



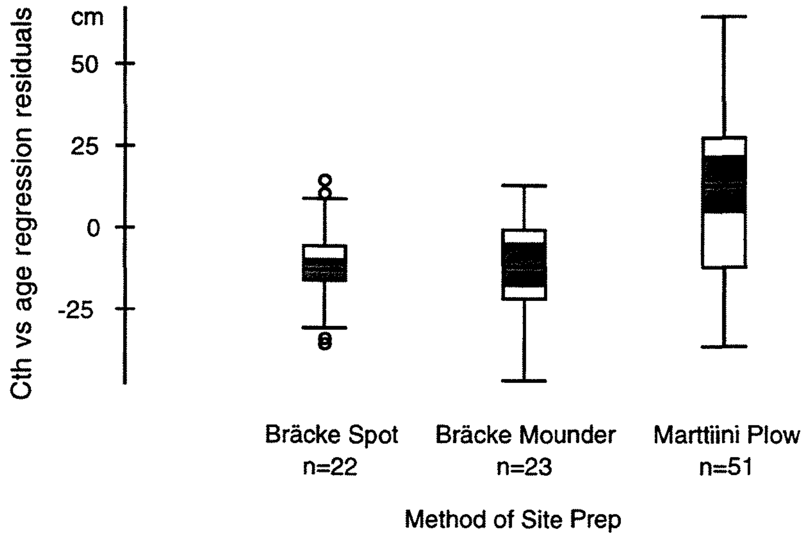
Source: *Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types, microsite positions and planting dates.*

Fig 16. Total height of white spruce crop trees (Cth): by years since planting ("age"). Measured age has been jittered ± 0.2 years to make it easier to see into the individual groups.



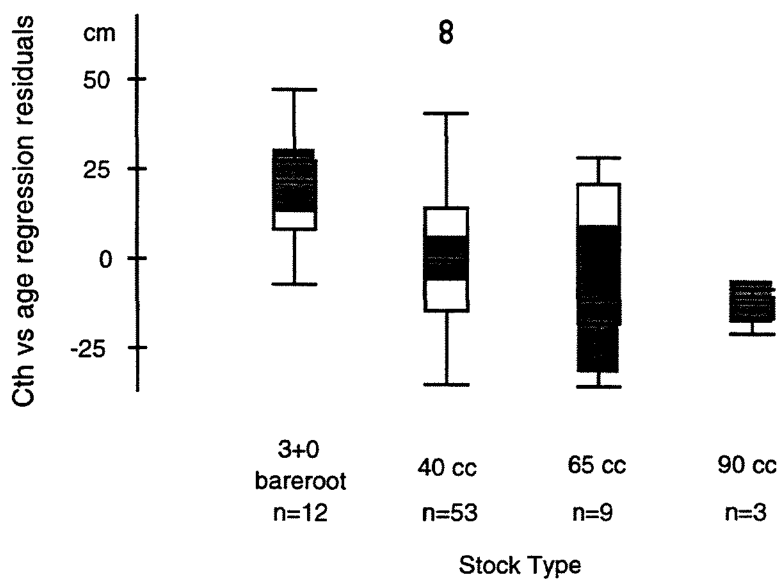
Source: *Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types, microsite positions and planting dates.*

Fig 17. Residuals from the white spruce total height vs. age regression: by month of planting. The residuals are measured in centimetres.



Source: All stock types, microsite positions and planting dates.

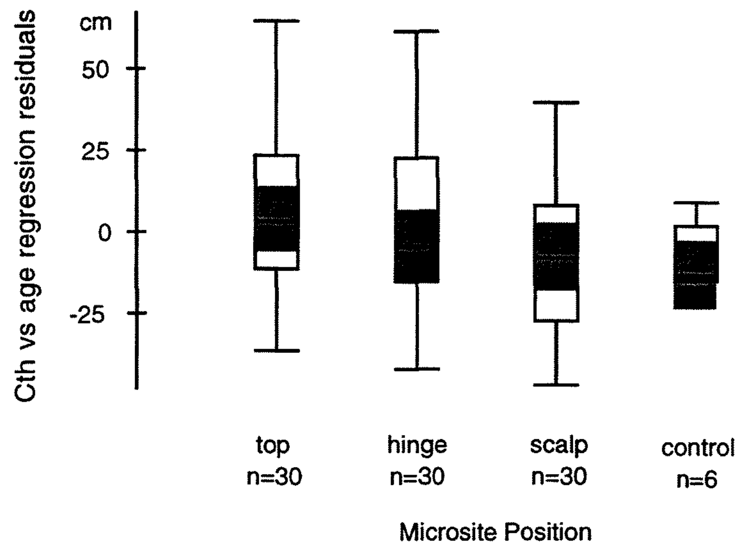
Fig 18. Residuals from the white spruce total height vs. age regression: by site preparation treatment group.



Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all planting dates and microsite positions but limited to projects with multiple stock types.

Fig 19. Residuals from the white spruce total height vs. age regression: by nursery stock type.

The apparent effect of generic microsite position on total height (adjusted for age) is shown in Fig 20. The tallest trees were consistently found on the "top" position followed by the "hinge." The "scalp" and unscarified control positions produced the shortest trees after adjusting for age.

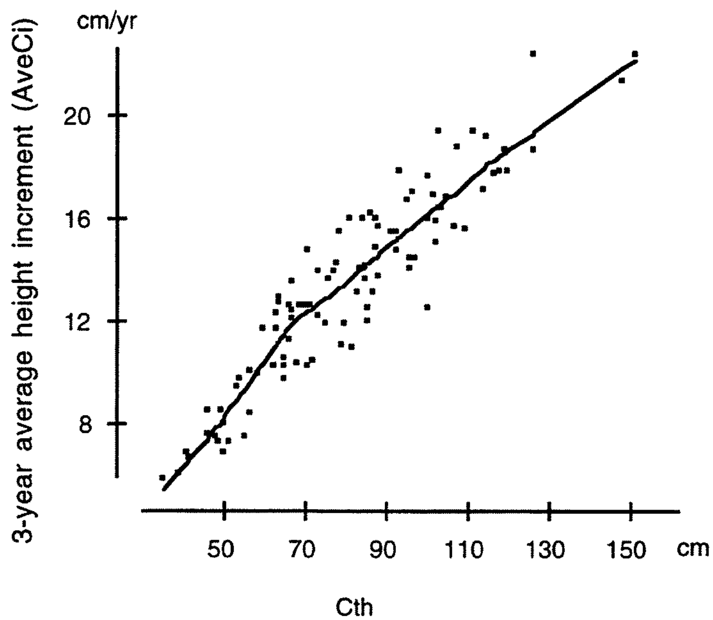


Source: *Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types and planting dates.*

Fig 20. Residuals from the white spruce total height vs. age regression: by generic microsite position.

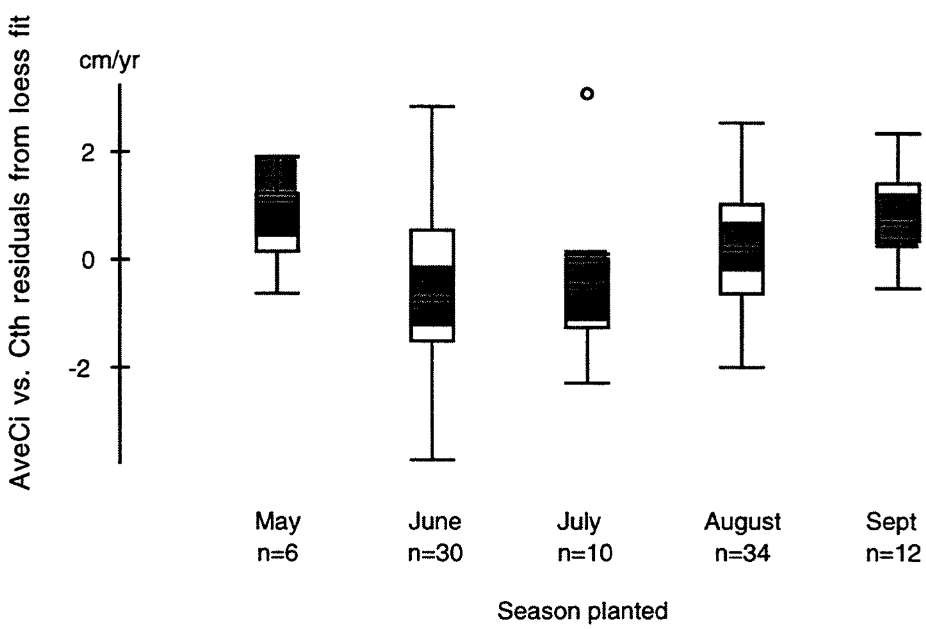
5.1.4 Average height increment (AveCi)

Within broad limits, AveCi tends to increase with Cth. Big trees generally speaking produce big increments (Fig 21). Since we have already analyzed Cth, we removed the apparent Cth component of AveCi before proceeding with the AveCi analysis. The scatter plot of AveCi vs. Cth is slightly nonlinear and so we used a smoothing, or nonparametric regression, technique called loess (Cleveland 1993) rather than simple linear regression to represent the trend. The plots that follow show the residuals about the loess fit against month of planting (Fig 22), site preparation method (Fig 23), nursery stock type (Fig 24), and generic microsite position (Fig 25). The trends in all of these plots account for at most 1 to 2 cm per year and are, consequently, of little silvicultural interest.



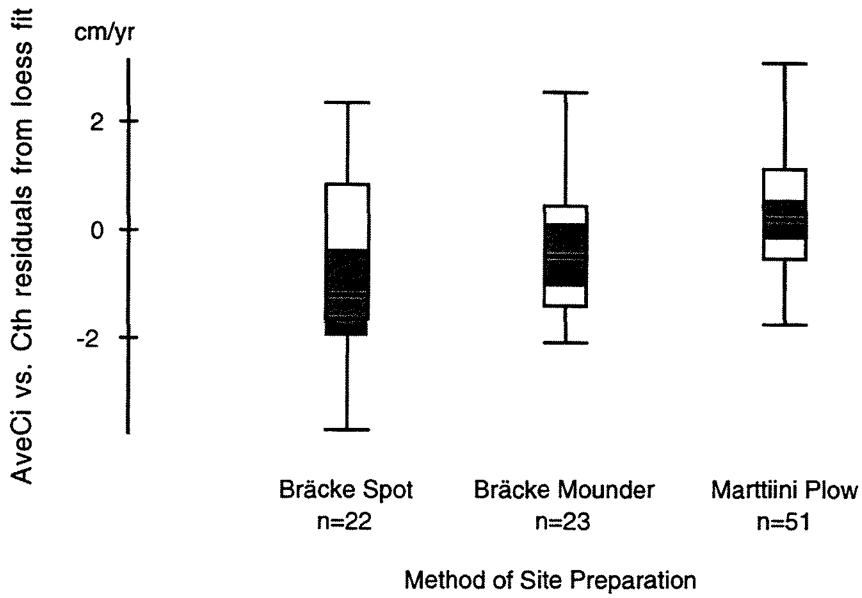
Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types, planting dates and microsite positions.

Fig 21. Scatter plot of AveCi vs. Cth. The curve superimposed on the scatter plot traces the loess fit.



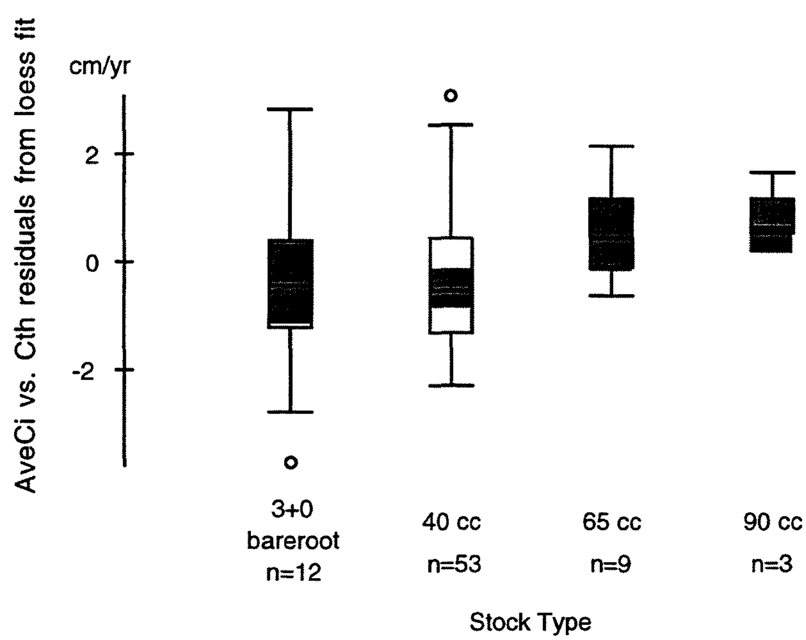
Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types and microsite positions.

Fig 22. Residuals about the white spruce AveCi vs. Cth loess fit: by month of planting.



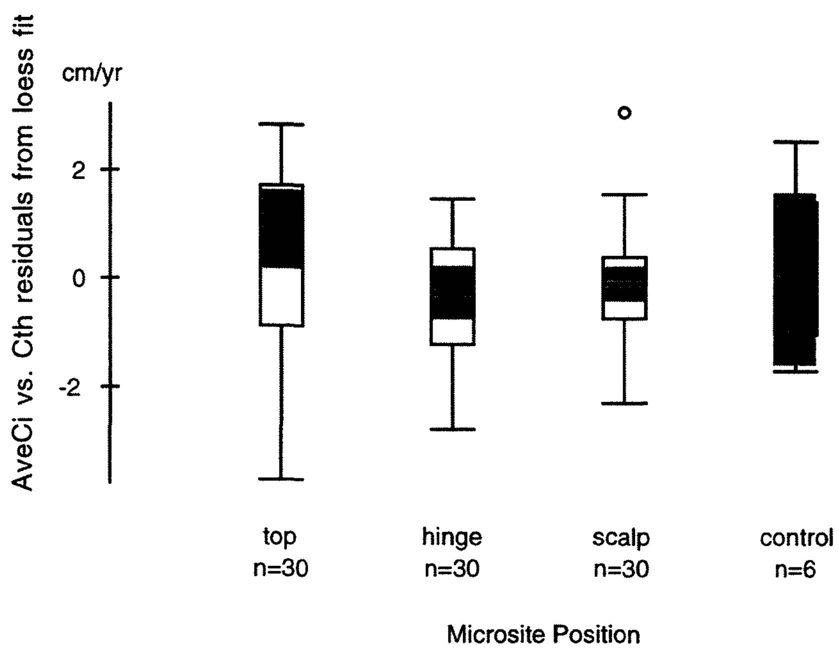
Source: All planting dates, stock types and microsite positions.

Fig 23. Residuals about the white spruce AveCi / Cth loess fit: by site preparation method.



Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all planting dates and microsite positions.

Fig 24. Residuals about the white spruce AveCi / Cth loess fit: by nursery stock type.



Source: Bräcke/Sinkilla spot, Bräcke mounder, and Marttiini plow treatment groups; all stock types and planting dates.

Fig 25. Residuals about the white spruce AveCi / Cth Loess Smooth: by generic microsite position.

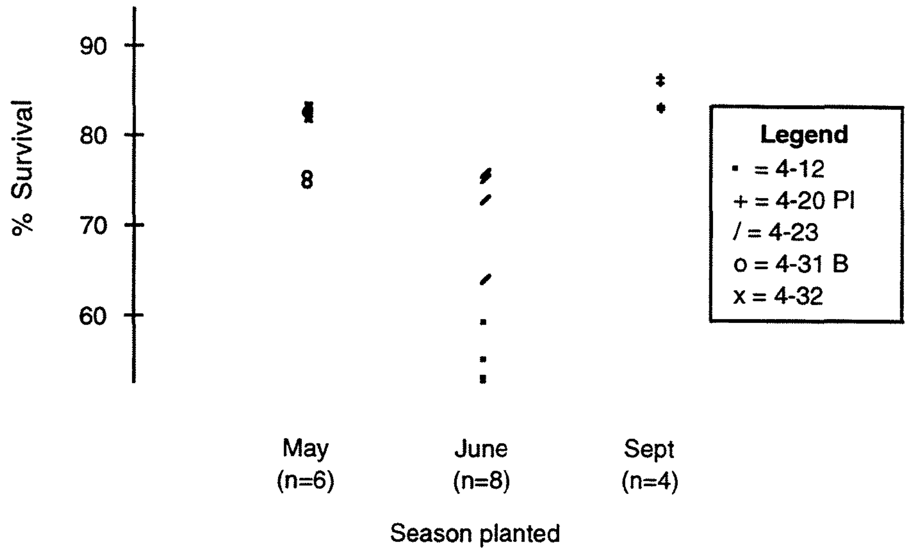
5.2 Lodgepole pine

There are only a few lodgepole pine trials. Major differences are between locations rather than between cultural factors such as microsite position. The cautionary note about hidden variables (see the second paragraph of section 5.1.2) is even more relevant here than it was for white spruce. For example, planting date and type of site preparation treatment are confounded making it impossible to isolate the effects of these 2 factors on lodgepole pine response variables. In addition, the vast majority of lodgepole trials used 40 cc containers and so we have not used nursery stock type as an independent variable in these analyses. Finally, we have included data from 2 Double Offset Disk Harrow trials (Trials 4-31 B and 4-32) in the lodgepole pine data base.

5.2.1 Percent survival

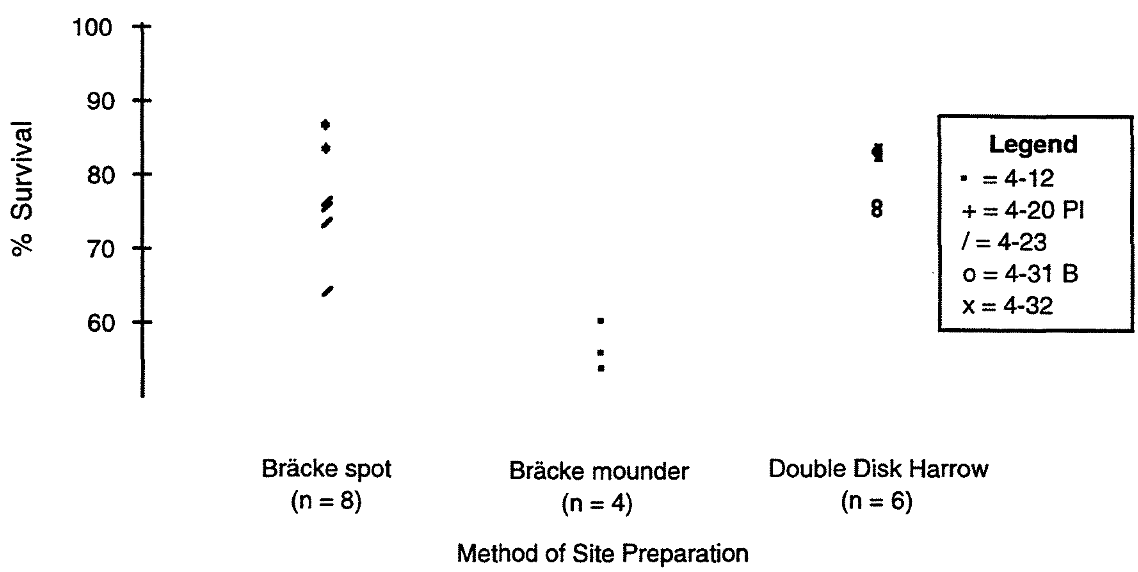
Fig 26 illustrates the relationship between percent survival and month of planting. The 2 Double Offset Disk Harrow trials were planted in May. The single Bräcke Mounder trial was planted in June. The Bräcke Spot trials were planted in June and September. We leave the risky job of interpretation to the reader.

Fig 27 illustrates the % Survival response by method of site preparation. The same difficulty with interpretation noted above also applies here. For example, is the poor performance of the Bräcke Mounder group due to the Mounder itself or to the season of planting or to the particular location?



Source: *Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow site preparation treatment groups; all stock types and microsite positions.*

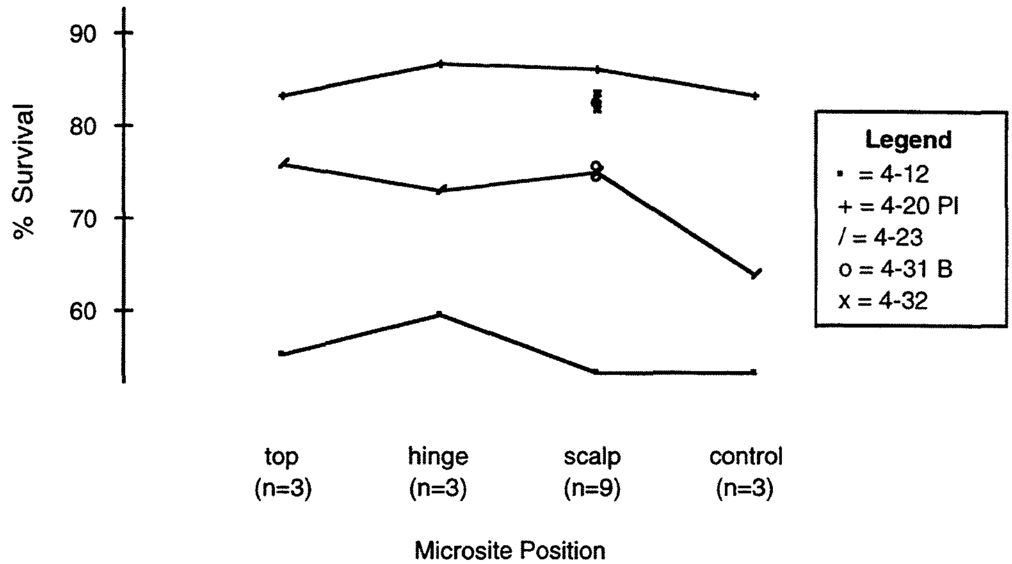
Fig 26. Percent lodgepole pine survival: by month of planting.



Source: *All stock types, planting dates and microsite positions.*

Fig 27. Percent lodgepole pine survival: by site preparation treatment group.

The % Survival response to microsite position is shown in Fig 28. Results from the same trial are connected with a solid line. The relatively large number of scalp means is due to the fact that the Double Offset Disk Harrow trials have no other microsite position. Differences in response seem to have more to do with location (or something confounded with location like planting date) than they do with microsite position.

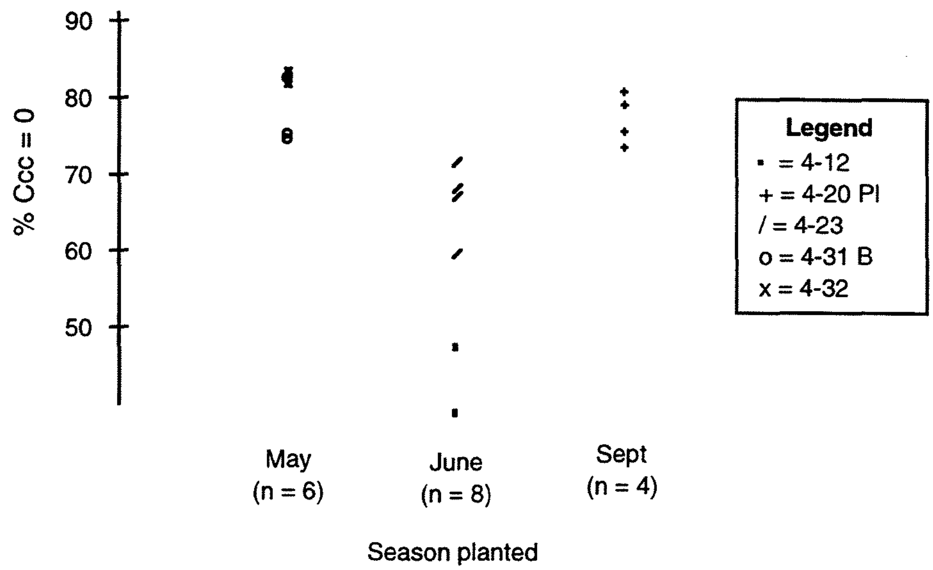


Source: Bräcke / Sinkilla spot, Bräcke mounder, and Double Offset Disk Harrow site preparation treatment groups; all stock types and planting dates.

Fig 28. Percent lodgepole pine survival: by generic microsite position.

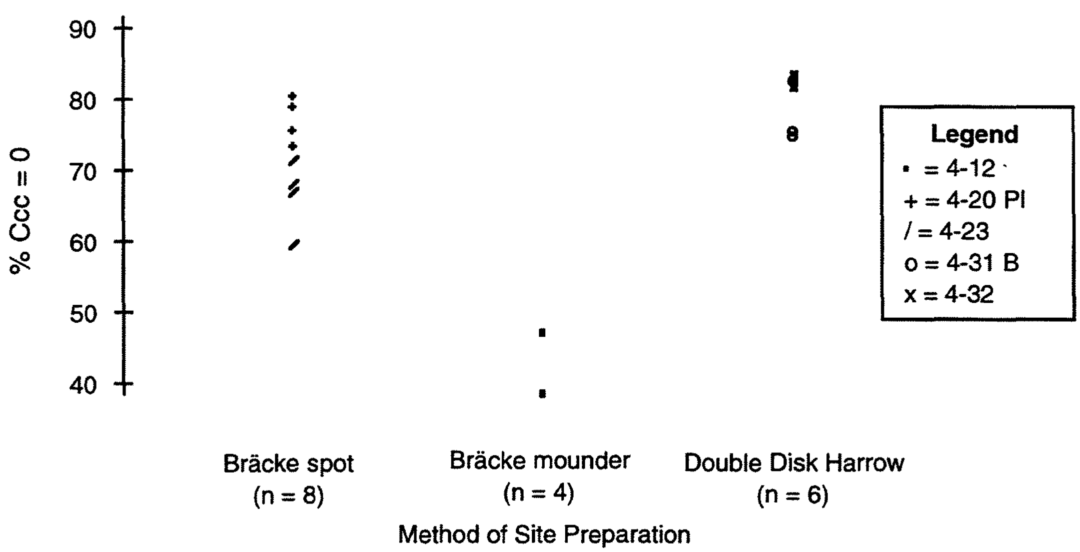
5.2.2 Percent Classified "Single-stemmed and healthy" (Ccc = 0)

The % Ccc = 0 results are presented in the following order: %Ccc=0 by month of planting (Fig 29), by site preparation method (Fig 30), and by generic microsite position (Fig 31). Now that we have noted how difficult it is to interpret these plots we simply present the displays and leave it to the reader to speculate about possible interpretations.



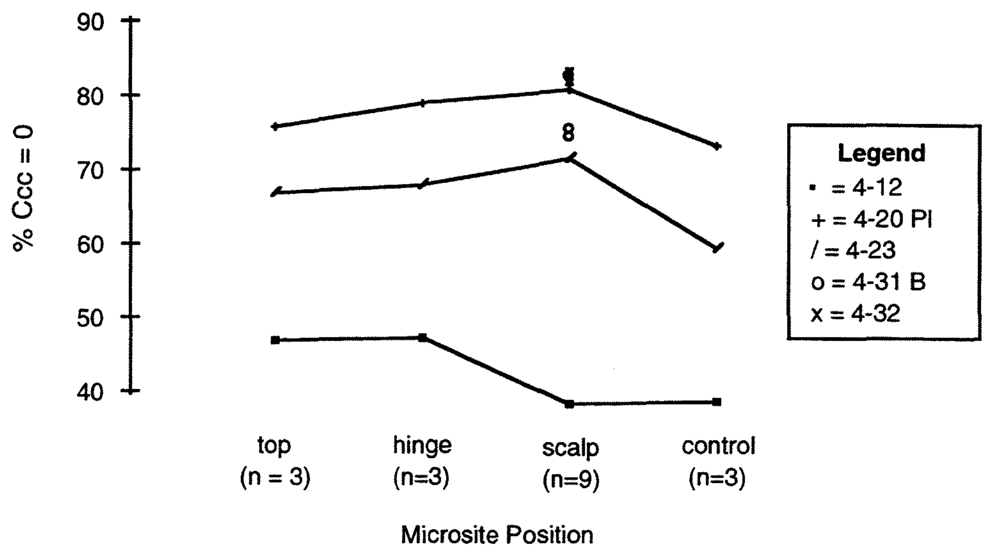
Source: *Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow site preparation treatment groups; all stock types and microsite positions.*

Fig 29. Percent "single-stemmed and healthy (Ccc = 0): by month of planting.



Source: All site stock types, planting dates and microsite positions.

Fig 30. Percent lodgepole pine crop trees rated "single-stemmed and healthy" (Ccc = 0): by site preparation method.



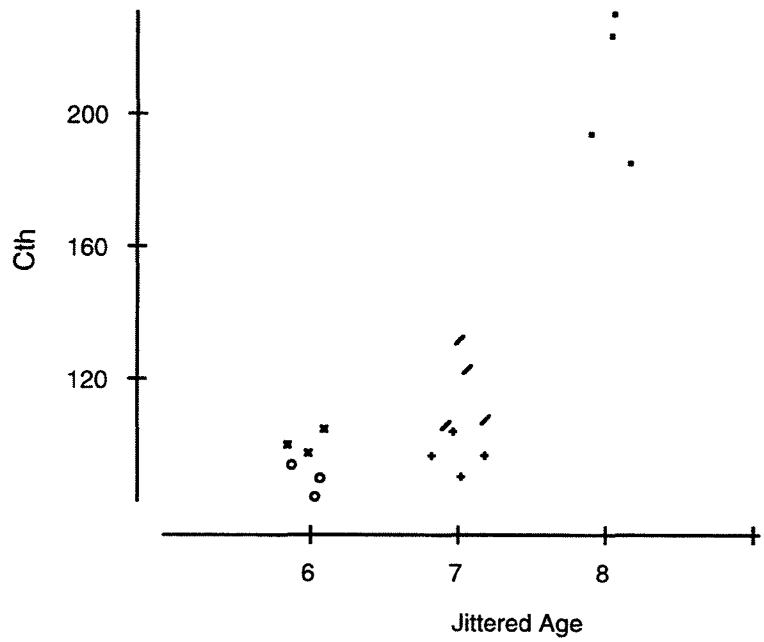
Source: *Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow site preparation treatment groups; all stock types and planting dates.*

Fig 31. Percent lodgepole pine crop trees rated "single-stemmed and healthy" (Ccc = 0): by generic microsite position.

5.2.3 Cth: adjusted for age

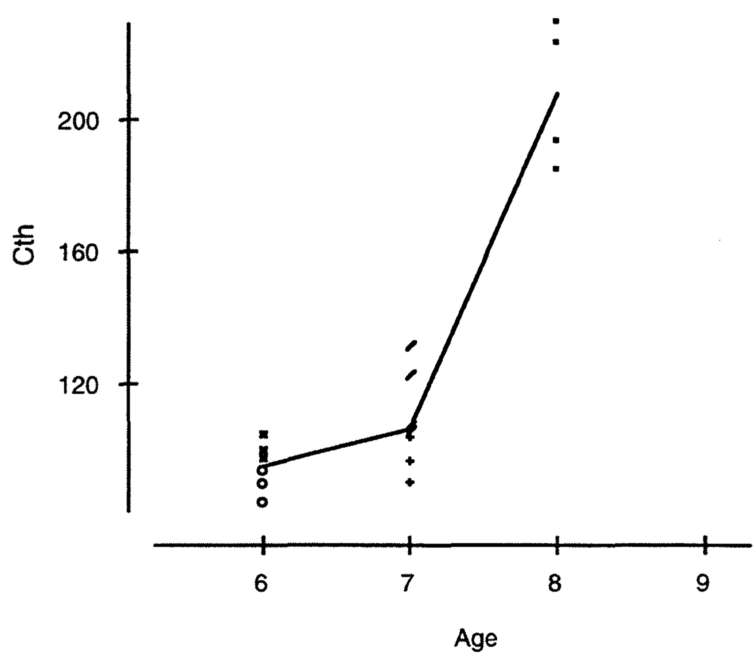
We proceed here as in Section 5.1.3. Briefly, we model the effect of age on Cth by computing the loess fit from the Cth vs. age scatter plot (Fig's 30 and 31). Then we subtract the loess fit to extract the as yet unexplained noise in the Cth means. Finally, we examine the noise (residuals from the Cth vs. age loess fit) according to the following groupings: by month of planting (Fig 34), by site preparation method (Fig 35), and by generic microsite position (Fig 36).

No doubt some of the "age effect" is due to other factors. For example, the 8-year-old Cth means all come from the same trial (4 - 12). Trial 4 - 12 is on a productive site and it was planted with 40 cc containers in June following Bräcke Mounder site preparation. Have any of these factors contributed to the apparent "age effect"? Almost certainly. Our point, once again, is that inferences drawn under these circumstances must be held tentatively.



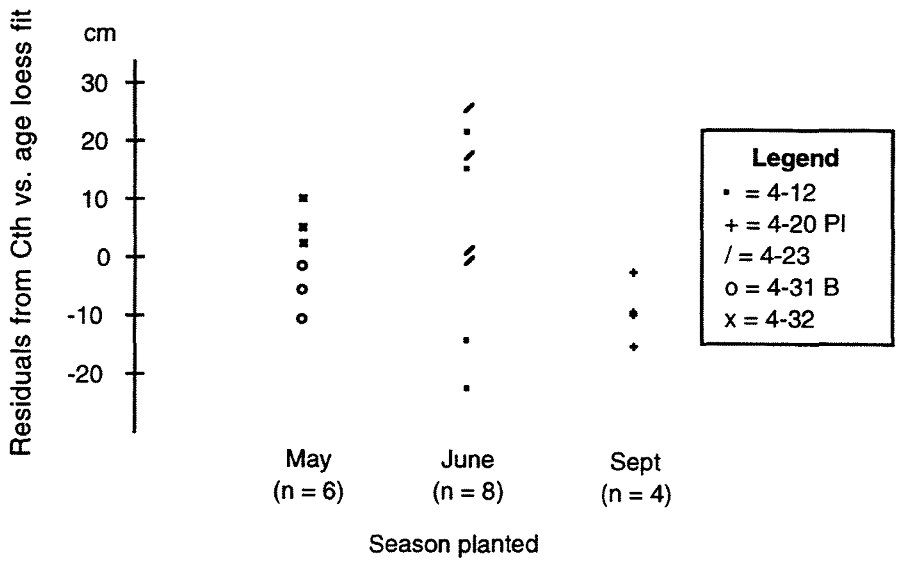
Source: *Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow treatment groups; all stock types, planting dates and microsite positions.*

Fig 32. Jittered scatter plot of lodgepole pine Cth vs. years since planting ("age").



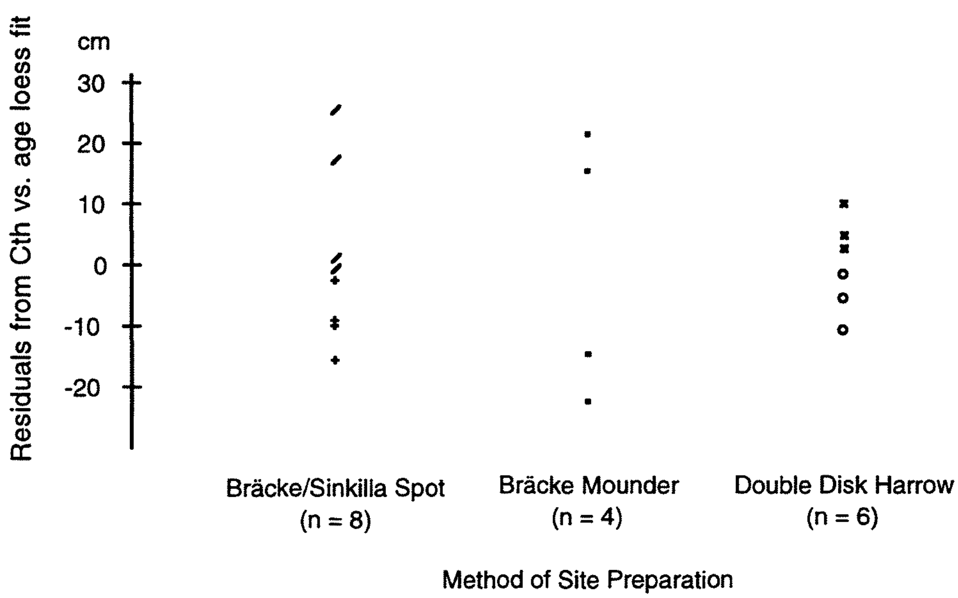
Source: *Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow treatment groups; all stock types, planting dates and microsite positions.*

Fig 33. Scatter plot of Cth vs. years since planting ("age") with loess fit superimposed.



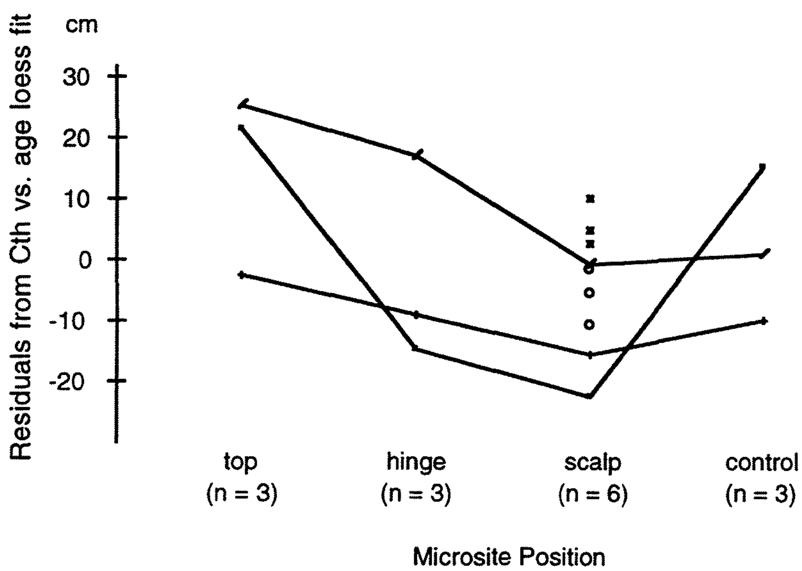
Source: *Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow site preparation treatment groups; all stock types and microsite positions.*

Fig 34. Residuals about the lodgepole pine Cth vs. "age" loess fit: by month of planting.



Source: All planting dates, stock types and microsite positions.

Fig 35. Residuals about the lodgepole pine Cth vs. "age" loess fit: by site preparation method.



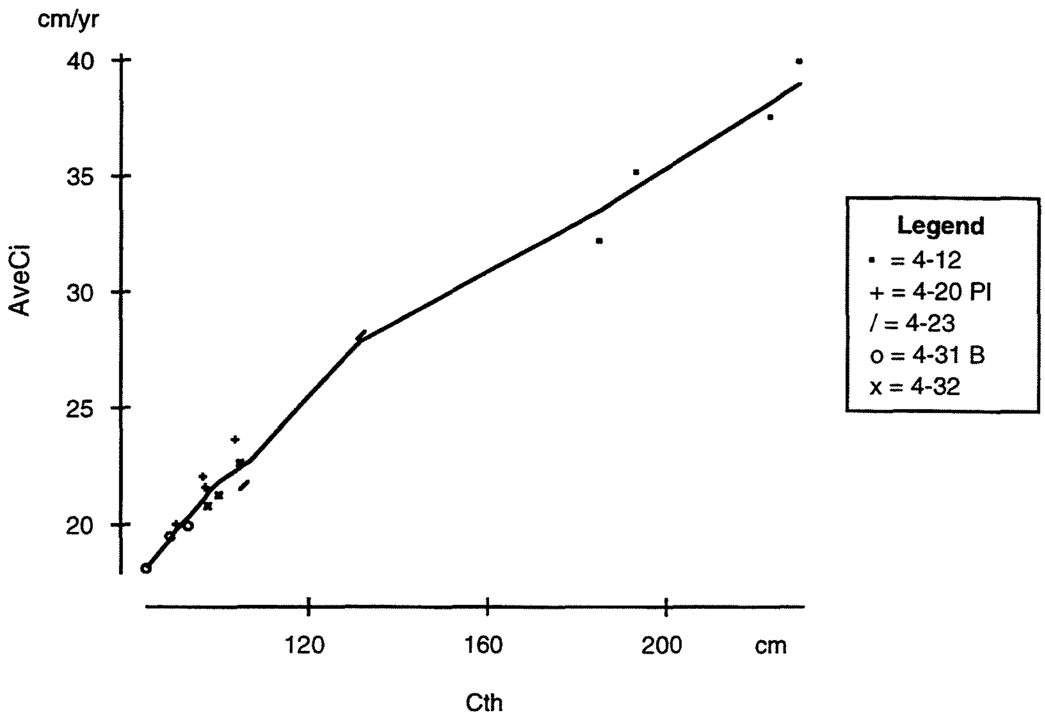
Source: *Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow site preparation treatment groups; all planting dates and stock types.*

Fig 36. Residuals about the lodgepole pine Cth vs. "age" loess fit: by generic microsite position.

5.2.4 AveCi: adjusted for Cth

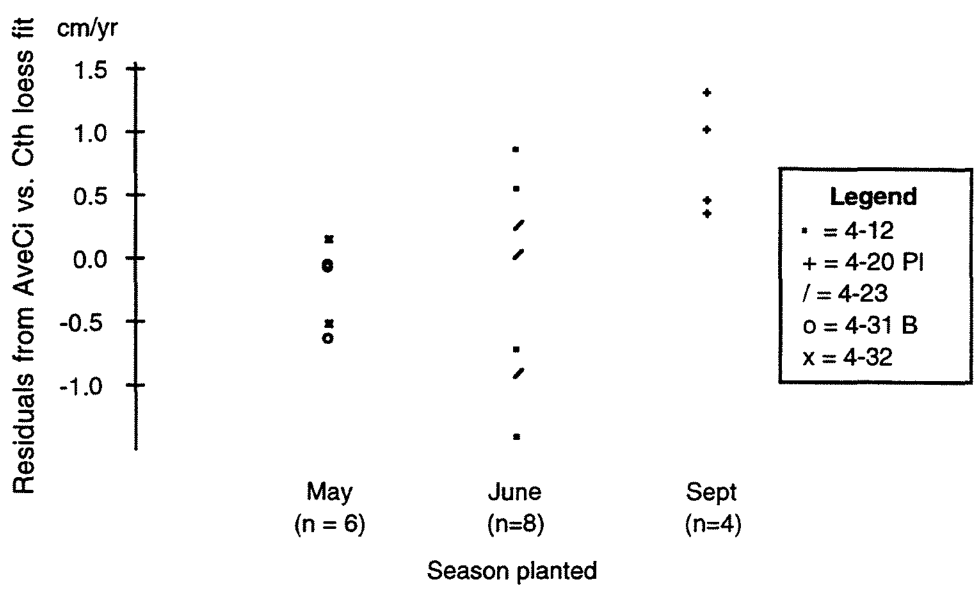
We proceed as in Section 5.1.4. Briefly, we model the effect of Cth on AveCi by computing the loess fit from the AveCi vs. Cth scatter plot (Fig 37). Then we subtract the loess fit to extract the as yet unexplained "noise" in the AveCi means. Finally, we examine this noise under the following groupings: by month of planting (Fig 38), by site preparation method (Fig 39), and by generic microsite position (Fig 40).

All of our previous words of caution regarding conclusions drawn from small sets of data that contain many hidden variables apply here as well.



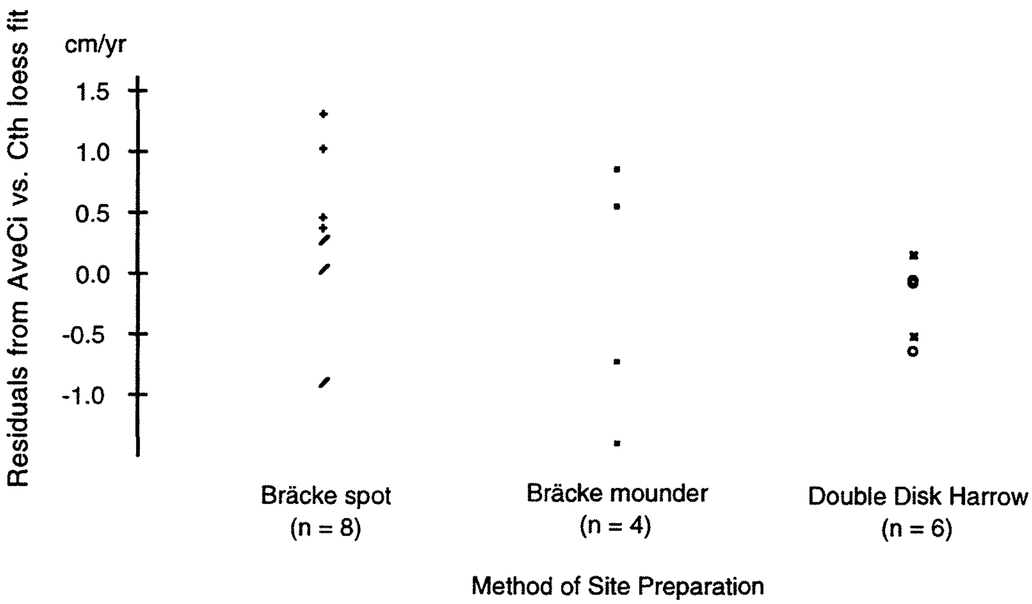
Source: Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow treatment groups; all stock types, planting dates and microsite positions.

Fig 37. Scatter plot of AveCi vs. Cth with loess fit superimposed.



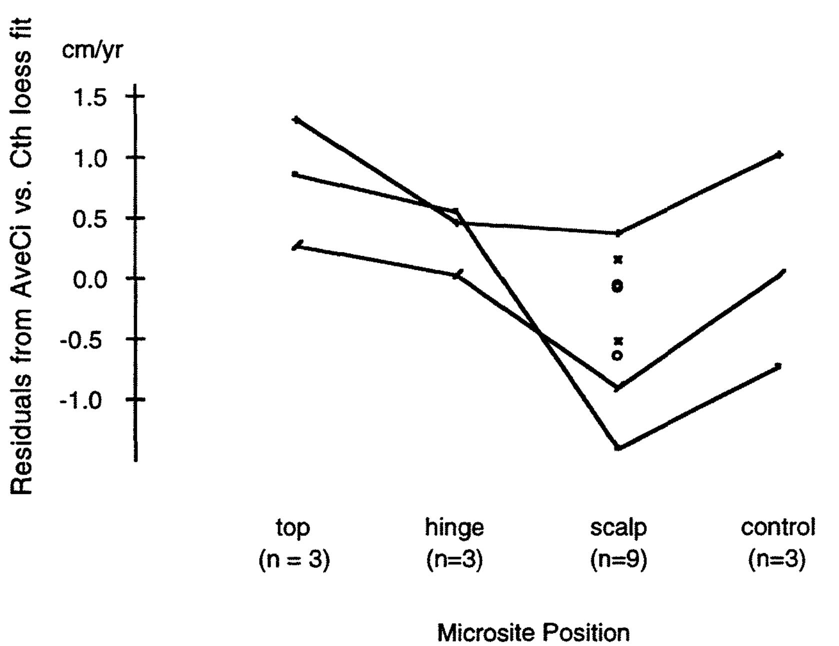
Source: Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow treatment groups; all stock types and microsite positions.

Fig 38. Residuals about lodgepole pine AveCi vs. Cth loess fit: by month of planting.



Source: All planting dates, stock types and microsite positions.

Fig 39. Residuals from the lodgepole pine AveCi vs. Cth loess fit: by site preparation method.



Source: Bräcke spot, Bräcke mounder, and Double Offset Disk Harrow treatment groups; all planting dates and stock types.

Fig 40. Residuals about the lodgepole pine AveCi vs. Cth loess fit: by generic microsite position.

6.0 FURTHER PROJECT-WIDE ANALYSES

6.1 The project-wide database

Selected items of information from each trial were collected into a single project-wide database. Table 54 summarizes the various categories of information included in this database.

Table 54. Categories of information included in the project-wide database.

Information category	Representative variables included in the category
basic identification	trial number, location name
ecological variable	ecological subregion, elevation, moisture regime and drainage class
competing vegetation	summary information about Tot.ns, Dth, Fcp, and Scp
cultural treatments	microsite positions, stock type and fertilizer treatment codes
crop tree responses	expected means from within trial MANOVA's for: Ci92, AveCi, Crc and Cth

6.2 Total height over age trends: by species, cultural treatments, and ecological variables

6.2.1 Cth vs. age trends: by species (Spots, Mounders, and Marttiinis only)

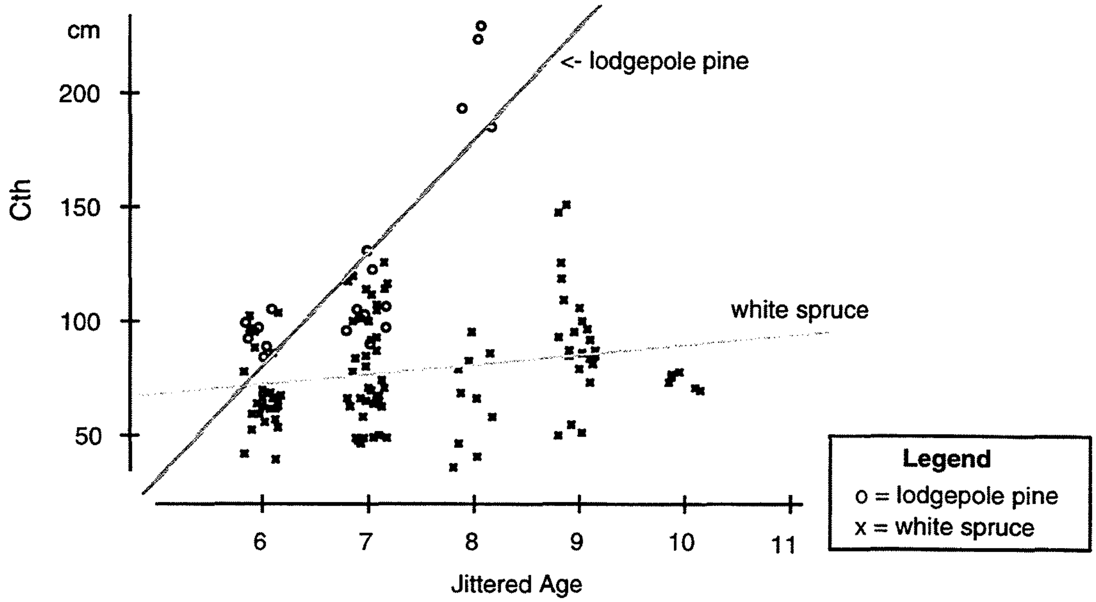
Fig 41 illustrates clearly the faster height growth of lodgepole pine over white spruce. The data have been selected to include only the Bräcke spot, Bräcke mounder and Marttiini plow trials. The linear regressions superimposed on the figure give a further, although crude, indication of the clear height growth advantage of pine over spruce in these trials. The slope of the spruce regression is not significantly different from zero.

6.2.2 Total height over age trends: by site preparation method (white spruce Spots, Mounders, and Marttiinis only)

In Fig 42, we focus on the white spruce trials and look for patterns in the Cth vs. age scatter plot that are associated with method of site preparation. This is another approach to the analysis performed in Section 5.1.3 (for example, see Fig 18). Fig 42 suggests that the Marttiini Plow trials performed better than either the Bräcke/Sinkilla Spot trials or the Bräcke Mounder trials – the same conclusion indicated by Fig 18.

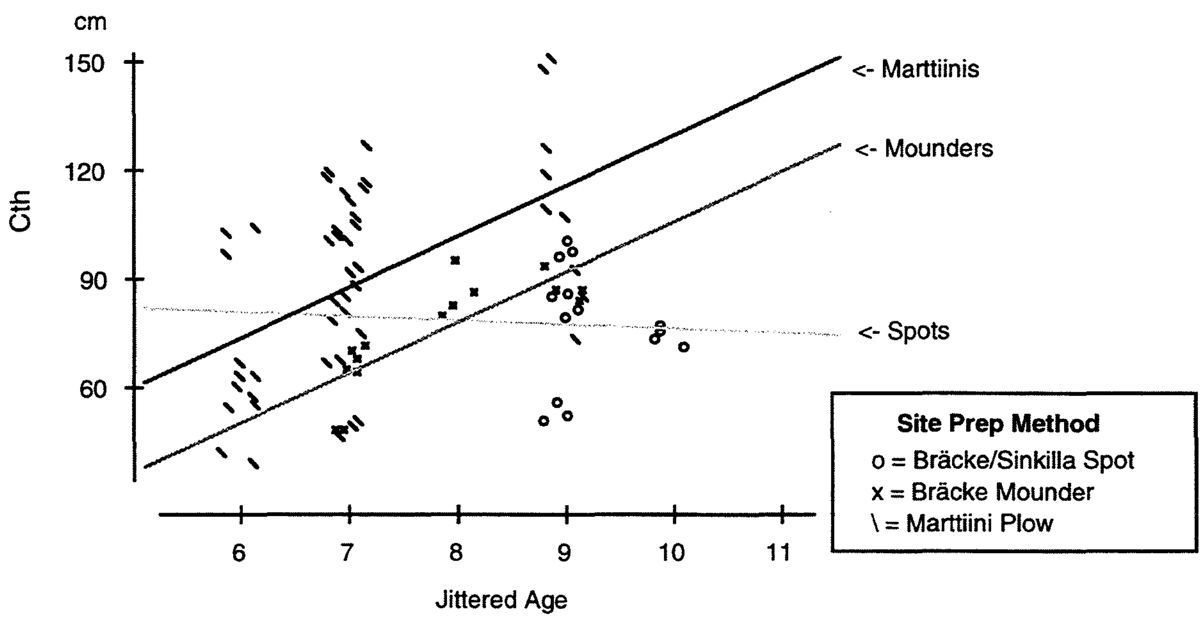
6.2.3 Total height over trends: by drainage class (white spruce spots, Mounders, and Marttiinis only)

Fig 43 emphasizes the apparent effect (or lack thereof) of soil Drainage Class on the Cth vs. age regression for white spruce. It is difficult to know what to make of these results. On the surface, it appears that well drained soils promote white spruce height growth while moderately well drained soils inhibit height growth. By this interpretation, imperfectly and poorly drained soils have a neutral effect on white spruce height growth. We suspect, however, that hidden variables are lurking in the background of this apparent relationship.



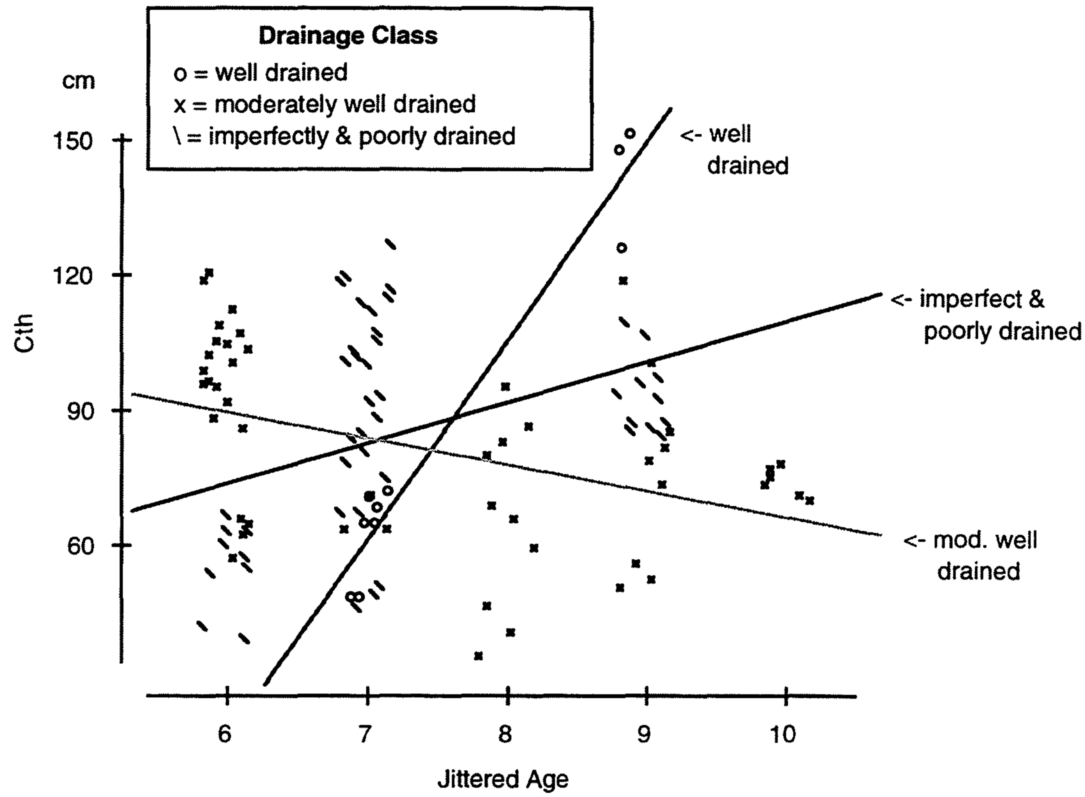
Source: All site preparation treatment groups

Fig 41. Scatter plot of Cth vs. jittered age. The lodgepole pine and white spruce subpopulations are indicated. Linear regressions of Cth vs. age are superimposed for each species.



Source: All site preparation treatment groups (white spruce trials)

Fig 42. Scatter plot of Cth vs. jittered age for white spruce trials. Subpopulations indicate the 3 major site preparation groups (Spots, Mounders, Marttiinis). Linear regressions of Cth vs. age are superimposed for each Site Prep Group.



Source: All site preparation treatment groups (white spruce trials)

Fig 43. Scatter plot of Cth vs. jittered age for white spruce trials. Subpopulations indicate soil Drainage Classes. Linear regressions of Cth vs. age are superimposed for each Drainage Class.

6.2.4 Cth vs. age trends: simultaneous effects of multiple independent variables (white spruce spots, mounders, and Marttiini plow only)

Thus far we have been looking for possible effects of various categorical variable on the Cth vs. age scatter plot. We have examined the apparent simple effects of species, site preparation method, and drainage class. In this section, we broaden our focus to include the simultaneous effects of multiple independent variables, both categorical and continuous, on Cth. Our approach is based on the multiple linear regression model. One of many possible models is presented in Table 55. The fitted multiple linear regression model indicated by Table 55 is given in Eq 8.

Table 55. Linear regression of white spruce Cth on multiple independent variables. All trials are in one of the following 3 major site preparation groups: Bräcke/Sinkilla Spot, Bräcke Mounder, Marttiini Plow.

Regression ANOVA Table

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	48008.1	12	4000.68	26.5
Residual	14215.1	94	151.225	

$R^2 = 77.2$ %
s.e. = 12.30 cm with 94 df

Regression Coefficients and Associated Statistics

Variable[a]	Coefficient	s.e. of Coeff	t-ratio	Prob
Constant	32.7	14.68	2.23	0.0284
Age	5.6	1.721	3.24	0.0017
• May planting	36.8	5.989	6.14	≤ 0.0001
• June planting	18.6	3.158	5.88	≤ 0.0001
• July planting	16.9	5.288	3.20	0.0019
• Marttiini site prep	15.8	3.986	3.96	0.0001
• 40 cc stock type	– 9.4	3.322	-2.82	0.0059
• top microsite	13.9	2.942	4.71	≤ 0.0001
• hinge microsite	9.5	2.929	3.26	0.0016
• well drained	10.4	5.397	1.93	0.0562
• mod-well drained	–12.9	4.231	-3.06	0.0029
% Scp = 3	0.59	0.1544	3.80	0.0003
% Fcp = 3	– 0.39	0.0675	-5.83	≤ 0.0001

[a] Categorical variables are preceded with the "•" symbol. Each of these variables is represented in the regression model by means of a (0, 1) dummy variable.

$$\hat{Cth}_{ijk\,(etc)} = 32.7 + 5.6\,(Age) + 36.8\,(May) + 18.6\,(June) + 16.9\,(July) + 18.6\,(Marttiini) - 9.4\,(40\,cc) + 13.9\,(Top) + 9.5\,(Hinge) + 10.4\,(WD) - 12.9\,(MWD) + 0.59\,(\%Scp{=}3) - 0.39\,(\%Fcp{=}3) \qquad \text{Eq 8}$$

where

$\hat{Cth}_{ijk\,(etc)}$ = the predicted average height of trees in the "ijk ... etc" treatment group

Age = the "age" (years since planting) of trees in the group

May = 1 if the treatment group was planted in May
= 0 otherwise

June = 1 if the treatment group was planted in June
= 0 otherwise

July = 1 if the treatment group was planted in July
= 0 otherwise

Marttiini = 1 if the treatment group was site prepared with a Marttiini Plow
= 0 otherwise

40 cc = 1 if the treatment group was planted with 40 cc containers
= 0 otherwise

Top = 1 if the treatment group planted on the "generic" top microsite position
= 0 otherwise

Hinge = 1 if the treatment group planted on the "generic" hinge microsite position
= 0 otherwise

WD = 1 if the treatment group was on a well drained soil
= 0 otherwise

MWD = 1 if the treatment group was on a moderately well drained soil
= 0 otherwise

%Scp=3 = the percentage of plots in the treatment group that were assessed to have "heavy" shrub competition

%Fcp=3 = the percentage of plots in the treatment group that were assessed to have "heavy" forb and grass competition

The regression coefficients in Eq 8 each have a straightforward interpretation with respect to white spruce total height. In the case of the continuous variables (Age, %Scp=3 and %Fcp=3) the partial contribution of each variable to predicted total height is simply the product of each variable's coefficient **times** the value of the variable itself. To illustrate this for Age, suppose that a particular trial is 8 years old. Then the predicted height at age 8 includes the additive component 5.6 x 8 as follows:

$$\hat{Cth}_{ijk\,(etc)} = 32.7 + [\ 5.6 \cdot Age\ ] + \cdots \text{ other components } \cdots$$
$$= 32.7\ (cm) + [\ 5.6 \left(\frac{cm}{year}\right) \cdot 8\ (years)\ ] + \cdots \text{ other components } \cdots$$
$$= 32.7\ (cm) + [\ 44.8\ (cm)\ ] + \cdots \text{ other components } \cdots$$

In the case of the categorical variables (e.g., Marttiini, WD, Top, and 40 cc) the partial contribution of each variable to predicted total height is

= the value of the coefficient whenever the value of the dummy variable is 1

= 0 otherwise.

To illustrate this for the dummy variable representing well-drained soil, WD, suppose that the 8-year-old trial from the example above is planted on a well drained soil. Then the predicted height at age 8 includes not only the additive component for age (5.79 x 8) but also an additional component for the well drained soil, as follows:

$$\hat{Cth}_{ijk\,(etc)} = 32.7 + [\ 5.6 \cdot Age\ ] + \cdots + [\ 10.86 \cdot WD] + \cdots \text{ other components } \cdots$$
$$= 32.7\ (cm) + [\ 44.8\ (cm)\ ] + \cdots + [\ 10.86\ (cm) \cdot 1] + \cdots \text{ other components } \cdots$$

If on the other hand, the trial in question was on a soil drainage class other than well drained, then the contribution of WD to the predicted height would be zero.

Given these facts about the regression coefficients, the predicted effects of the variables included in the regression model are those given in Table 56.

6.3 Comparison of top and hinge microsite positions by moisture regime

We suspected that the relative effectiveness of the top vs. hinge microsite positions might depend upon the moisture regime in question. We investigated this question on the 2 most abundant moisture regimes in the database, Moisture Regimes 5 and 6.

The results, summarized in Table 57, seem to indicate that the top position was possibly more productive than the hinge position on Moisture Regime 5. The MANOVA Wilks Lamda statistic was barely significant at the $\alpha = 0.05$ level, but the univariate t-tests were not significant. The 2 microsite positions are effectively the same on Moisture Regime 6. In both cases the differences may be too slight, even if they are real, to be of practical interest.

Table 56. Magnitude of the predicted effects of predictor variables in Eq 8.

Variable	Predicted effect	Comments
Age	5.6 cm• yr^{-1}	Continuous
Planting Dates		Categorical; variables in this set are mutually exclusive.
May planting	36.8 cm	
June planting	18.6 cm	
July planting	16.9 cm	
(Aug, Sept planting)	(0 cm)	
Site Prep Methods		Categorical; variables in this set are mutually exclusive.
Marttiini	15.8 cm	
(Spots & Mounders)	(0 cm)	
Stock Types		Categorical; variables in this set are mutually exclusive.
40 cc stock type	– 9.4 cm	
(bareroot, 65 cc, 90 cc)	(0 cm)	
Microsite Positions		Categorical; variables in this set are mutually exclusive.
top	13.9 cm	
hinge	9.5 cm	
(scalp, control)	(0 cm)	
Soil Drainage Class		Categorical; variables in this set are mutually exclusive.
well drained	10.4 cm	
mod-well drained	– 12.9 cm	
(imperfectly, poorly drained)	(0 cm)	
Vegetative Competition		
% Scp = 3	0.59 cm• $\%^{-1}$	Continuous.
% Fcp = 3	– 0.39 cm• $\%^{-1}$	Continuous.

Table 57. Average response for 4 crop tree variables: by Moisture Regime and Microsite Position.

Crop response	Moisture regime 5 [a]			Moisture regime 6 [b]		
	top	hinge	LSD prob[c]	top	hinge	LSD prob[c]
Ci92 (cm)	17.4	14.6	0.21	16.1	15.0	0.53
AveCi (cm)	15.3	13.4	0.20	15.0	14.0	0.38
Crc (mm)	13.0	11.6	0.36	17.5	15.1	0.12
Cth (cm)	84.4	78.9	0.61	93.1	88.5	0.56

[a] The probability of the Wilks Lamda statistic for M.R. 5 under the MANOVA null hypothesis of no difference between the multivariate centroids is 0.05.

[b] The probability of the Wilks Lamda statistic for M.R. 6 under the MANOVA null hypothesis of no difference between the multivariate centroids is 0.56.

[c] This column reports the probability of the LSD test statistic under the null hypothesis of no difference between the univariate treatment means.

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APPENDIX

LEGEND FOR BOXPLOTS

Boxplot displays contain much information in a highly encoded form. The legend presented below indicates how the boxplots presented throughout this report may be deciphered.

The following definitions apply: The **median** is the middle value in the summarized batch of numbers. Upper and lower **quartiles** span the middle 50 percent of the batch. **Fences** for identifying **outliers** are set at the high quartile plus 1.5 quartile spreads and low quartile minus 1.5 quartile spreads. **Adjacent** values are the outermost observations that still lie inside these fences. The **shaded box** identifies the 95 percent confidence interval for comparing the medians of two or more groups.