AN EVALUATION OF THE INFLUENCE OF GRASS/LEGUME MIXTURES ON TREE SPECIES AT THE JUDY CREEK TEST MINE.

ALAN J. KENNEDY

Environmental Coordinator, Esso Resources Canada Ltd., Oil Sands and Coal Department, 237 - 4 Avenue S.W. Calgary, Alberta T2P 0H6.

ABSTRACT

The influence of competition of agronomic mixtures on out planted lodgepole pine and white spruce was investigated on study plots at the Judy Creek test Mine from 1979 to 1983. Two agronomic seed mixtures considered competitive and two seed mixtures considered less competitive were evaluated in terms of effects on survival and growth performance of the two tree species.

Data were collected on soil quality, seed mixture application rate, vegetation cover and biomass, and tree survival and growth. Results from five years of study indicate the following conclusions.

1. Chemical and physical properties of soil materials were similar among treatments with the exception of moisture content, which was much lower on two treatments.

2. Applying seed mixtures at 15 kg/ha or 30 kg/ha did not affect total living cover during the study period.

3. Total living cover and biomass data did not indicate increased cover corresponding to predetermined high cover seed mixes. Low soil moisture likely limited seed mix cover and biomass.

4. Tree mortality of both species was not consistently related to competitive seed mixtures.

5. Lodgepole pine growth was independent of seed mixture and moisture regime. White spruce growth was related to moisture regime.

INTRODUCTION

On severely disturbed sites in Alberta seeding with appropriate agronomic grass-legume mixtures is required to obtain control of soil erosion (Alberta Environment 1977). However, resulting herbaceous vegetative cover can affect performance of commercial soft wood tree species (Sims and Mueller-Dombois 1968) and may be detrimental to attaining a post mining comercial forestry land use.

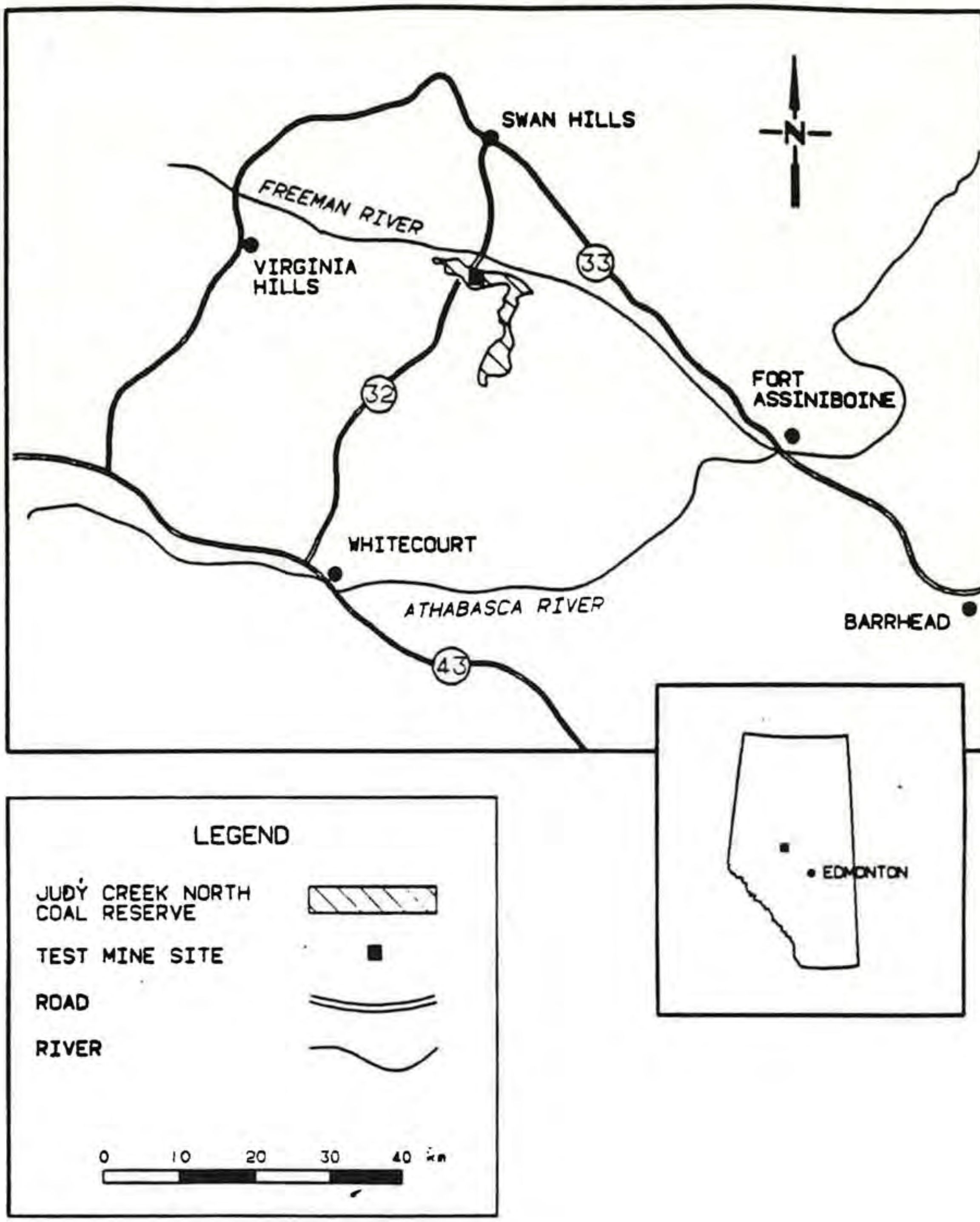
The influence of competition for water and nutrients, space, and light exerted by erosion controlling herbaceous material with interplanted trees may be a significant factor in the ultimate performance of the outplanted trees. The ability to reduce intra specific competition between agronomic material and trees while adequately controlling erosion is a key challenge in meeting both short and long term land reclamation objectives in the Eastern Slopes of Alberta.

During the winter of 1978 Esso Resources constructed a coal test mine on the Judy Creek North Coal Reserve. The test mine was designed to obtain a 10,000 tonne bulk sample of coal to determine burning characteristics (Esso Minerals Canada 1979). Reclamation procedures subsequent to the test mine construction provided a site suitable for study of the effects of agronomic herbaceous cover on the survival and growth of lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*). This paper describes the methodology for the competition experiment and discusses the results of five years of study.

STUDY AREA

The Judy Creek Test Mine is located within the Judy Creek North Coal Reserve approximately 56 kilometers (km) south of Swan Hills, Alberta and 2 km east of Highway 32. The test mine is located in the NW 1/4, Section 14, Township 64, Range 10, west of the 5th meridian (Figure 1).

FIGURE 1. LOCATION MAP FOR JUDY CREEK TEST MINE



F120,067,01,860517,852,01

An area of 17.3 hectares (ha) was cleared for test mine operations in December, 1978; of which the test pit itself comprised 1.5 ha. An additional 2 ha area (2 km in length) was cleared as an access road to highway 32.

The test mine area is regionally characterized by warm summers and cold winters. Mean daily temperatures vary from a low of -17 degrees C (in January) to a high of 20 degrees C (in July). Average annual total precipitation is about 53 centimeters of which approximately 33% is received as snowfall. The prevailing wind directions are west and northwest.

The test mine lies at the western edge of the western plains physiogeographic region, in what is termed the Rocky Mountain Foothills area of Alberta. Elevations in the area range from 600 m on the Freeman River to over 1400 m in the Swan Hills. The hydrography of the area is dominated by the Freeman River, the Judy Creek, and the Christmas Creek; all tributaries of the Athabasca River.

Forest cover in the test mine area is dominated by stands of white spruce and lodgepole pine. Pine and spruce occur as a mosaic of even-aged pure stands, depending on slope, or as stands of various mixtures of pine and spruce mixed-wood forests of either pine or spruce and aspen (*Populus tremuloides*) or balsam poplar (*Populus balsamifera*). Shrublands occur as clumps of mainly willow (*Salix sp.*) along the riparian sites or, to a minor extent on roadways and access clearings.

METHODS AND MATERIALS

Study Design

Competition from herbaceous cover was evaluated on twenty-four 12.5 m x 30 m plots (Figure 2). The plots were situated on the backfilled test pit portion of the test mine and were comprised of 70 cm of mixed A, B horizon Gray Luvisol soil over a till subsoil (Figure 3). Treatments of herbaceous cover were applied in a random block design.

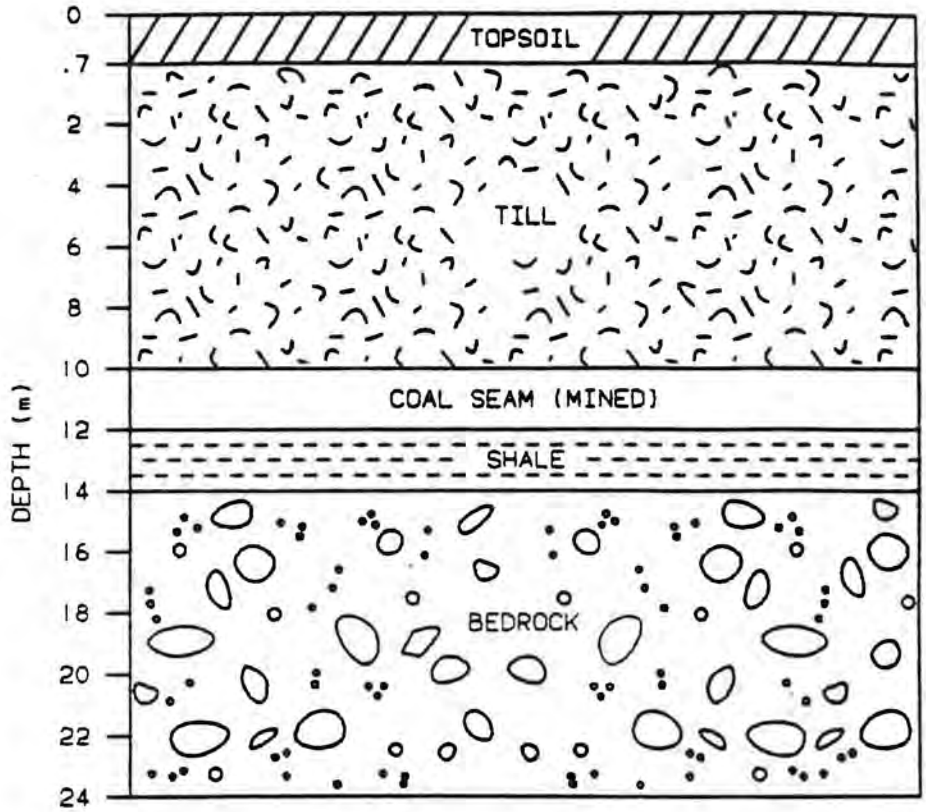
FIGURE 2. PLOT SCHEME FOR COMPETITION EXPERIMENT

GRASS SEEDING REGIME		
PLOT	SEED MIX NO.	BROADCAST SEEDING RATE (KG/HA)
1,6,12	2	30
3,7,9	2	15
4,5,11	4	30
2,8,10	4	15
13,20,23	1	30
16,18,24	1	15
14,17,22	3	30
15,19,21	3	15

DOWNSLOPE END			
1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	20
21	22	23	24
UPSLOPE END			

F120,339.01,851211 MLM

FIGURE 3. CROSS SECTION OF COMPETITION EXPERIMENTAL PLOTS



F120.340.01.851211.892 MLM

Seeding Regime

Within the study area four different grass/legume seed mixtures were applied at either 15 kg/ha or 30 kg/ha (Figure 2). Tables 1 to 4 give the composition of each seed mixture applied to the competition plots. Mixtures 1 and 2 contained sod- and bunch-forming grass species recommended for erosion control (Alberta Energy and Natural Resources 1979). However, the grasses used in seed mixtures 3 and 4 were only bunch-forming and are less likely to provide a dense competitive cover (Watson et al. 1980). All plots were broadcast seeded with a hand-operated cyclone seeder. The plots were fertilized once only by hand broadcaster with N(23) - P (23) - K(0) at a rate of 160 kg/ha.

Tree Outplanting

Nine lodgepole pine and white spruce seedlings were planted in alternating, equally-spaced rows in each study plot (n = 216 trees per species). The trees were planted June 2, 1979 using both V-bar (2/3 of trees) and shovel mattock (1/3 of trees) techniques. Each tree was marked for study with a 1 m wooden stake and metal identification tag. Lodgepole pine seedlings were one year old and white spruce seedlings were two years old at time of planting. All seedlings had been container grown from similar genetic stock at the Blue Ridge Lumber (Ltd.) nurseries near Whitecourt, Alberta.

TABLE 1. COMPETITION SEED MIX ONE, A GENERAL GRASS (SOD/BUNCHGRASS) AND LEGUME SEED MIXTURE SUITABLE FOR MESIC AREAS

Species	Variety	Percent of Mix (by wt.)	Features
Grasses			
Canada bluegrass	Common	20	Low maintenance, tolerance to grazing, aggressive, drought tolerant
Creeping red fescue	Boreal	15	Tolerant to grazing, good seedling vigor, sod forming
Slender wheatgrass	Revenue	10	Strong root system for erosion control
Crested wheatgrass	Fairway	15	Good seedling vigor, can withstand traffic
Timothy	Climax	10	Rapid establishment, fibrous roots
Smooth brome	Carlton	10	Long-lived, sod forming
Legumes			
Alfalfa	Drylander	10	Superior winter hardiness, drought resistant
Red clover	Altaswede	10	Short-lived, winter hardy, acid tolerant
		100	

TABLE 2. COMPETITION SEED MIX TWO, A GENERAL GRASS (SOD/BUNCHGRASS) AND LEGUME SEED MIXTURE SUITABLE FOR MOIST AREAS

Species	Variety	Percent of Mix (by wt.)	Features
Grasses			
Creeping bentgrass	Emerald	10	Stoloniferous, prefers moist areas
Creeping red fescue	Boreal	25	Deep rooted, strong rhizomes
Reed canarygrass	Frontier	25	Flood tolerant, rapid establishment
Tall wheatgrass	Orbit	20	Rhizomatous, adapted to moist areas
Timothy	Climax	5	Rapid establishment, fibrous roots, moisture tolerant
Legumes			
Alisike clover	Aurora	10	Flood tolerant, superior winter hardiness, acid tolerant
Red clover	Altaswede	5	Winter hardy, short-lived acid tolerant
		100	

TABLE 3. COMPETITION SEED MIX THREE, A GRASS (BUNCHGRASS) AND LEGUME SEED MIXTURE SUITABLE FOR MESIC AREAS

Species	Variety	Percent of Mix (by wt.)	Features
Grasses			
Slender wheatgrass	Revenue	30	Strong root system for erosion control
Crested wheatgrass	Fairway	35	Good seedling vigor, can withstand traffic, not too tall
Timothy	Climax	15	Rapid establishment, fibrous roots
Legumes			
Alfalfa	Drylander	10	Superior winter hardiness, drought resistant
Red clover	Altaswede	10	Short-lived, winter hardy, acid tolerant
		100	

TABLE 4. COMPETITION SEED MIX FOUR, A GRASS (BUNCHGRASS) AND LEGUME SEED MIXTURE SUITABLE FOR MOIST AREAS

Species	Variety	Percent of Mix (by wt.)	Features
Grasses			
Reed canarygrass	Frontier	25	Flood tolerant
Tall wheatgrass	Orbit	45	Rhizomatous, adapted to moist areas
Timothy	Climax	15	Rapid establishment, fibrous roots, moisture tolerant
Legumes			
Alsike clover	Aurora	10	Flood tolerant, superior winter hardiness, acid tolerant
Red clover	Altaswede	5	Winter hardy, short-lived, acid tolerant
		100	

Data Collection and Analysis

Soil samples were taken from each plot from 1979 to 1981 and in 1983. Four subsamples from the 0 to 15 cm soil layer were taken at randomly spaced locations within each plot. Analysis of soil samples followed procedures reported in McKeague (1978). From 1979 to 1981, the following chemical parameters were determined: levels of available macronutrients including nitrogen (as NO_3 - N), phosphorous (as P), potassium (as K), and sulfur (as SO_4-S); ph; electrical conductivity; and organic matter content. During 1983 the same parameters were measured, and also the following; calcium carbonate equivalence; cation exchange capacity; and sodium absorption ratio. Measurement of physical soil properties included moisture content, texture, consistence, structure, and bulk density. To calibrate soil moisture content, results were plotted on available soil moisture curves (ie. Foth 1978), and field capacity and wilting point were determined for the appropriate soil texture. For the Judy Creek replaced soil material, field capacity was determined to be about 40% soil moisture and wilting point was approximately 20% soil moisture.

Measurements of vegetation cover were made on each plot during August 1979, and June and August of 1980, 1981 and 1983. Vegetation cover on each plot was determined through the observation of the portion of ground covered by revegetation species within forty 2 dm x 5 dm quadrats. Plant cover within each quadrat was estimated using a modified form of the Braun-Blauquet method (Kershaw 1973).

As a method of further investigating vegetation competition, standing and below ground biomass were also determined on the plots in 1981 and 1983. Three plots representing each seed mixture treatment were sampled at three random locations. Above ground biomass samples were obtained by clipping all standing plant material to ground level within a 0.25 m^2 square quadrat. Samples were placed in appropriately-sized paper bags and returned to the laboratory where they were oven-dried at 80°C for 24 hours and weighed. Below ground biomass samples were taken at each of the above ground sample locations. Three 7 cm diameter tubes were used to remove 20 cm long cores. Each core was bagged individually in plastic and returned to the laboratory. Each core was then soaked in detergent solution for 24 hours to disperse soil particles. Roots then were extracted by washing each core through two sieves (4.75 mm and 2.00 mm mesh). Roots retained by sieves were combined, oven-dried at 80°C for 24 hours and weighed.

Estimations of tree mortality and growth were conducted on each marked seedling during August 1979 and June and August of 1980 to 1984 (with the exception of 1982, when only tree mortality was evaluated).

Tree mortality was recorded by determining the status of each tree (i.e., living or dead). An assessment of the causes of mortality was also made when possible. Mortality causes were recorded as follows: 1) planting dead 2) competition dead, 3) small mammal dead, 4) large mammal dead, 5) flooded dead. Tree growth was recorded by measuring the height of each marked tree with a graduated meter rod. Height was considered a true indicator of growth and therefore basal diameter was not measured. Incremental growth was determined by measuring the new vertical leader growth each year.

Soil samples were combined by treatment and a mean and standard error determined for each treatment for the entire study period. Vegetation cover was determined for each plot and year by calculating the mean percentage cover of each plant species recorded on the 20 quadrats. Standard errors were calculated to determine variability from the means. A one-way analysis of variance and Dunçan's multiple range test, (Sokal and Rholf 1969) were used to determine the statistical relationship between soil depth treatments and vegetation cover of plant species group. Data on tree mortality, growth and condition were combined by treatment and differences tested using an analysis of variance and Duncan's multiple range tests. All data base management and statistical analyses were conducted using the Statistical Analysis System (SAS 1982).

RESULTS

Soil Quality

The physical properties of the soil material replaced on each treatment of the experiment are given in Table 5. The particle size distribution data indicate that the soil material from all treatments is similar and can be classified as a clay loam. Structure and consistence were identical between treatments throughout the study period. Mean bulk density data were also similar between treatments, and no one treatment showed values that indicated potential tree root penetration difficulties. The similarity in these physical properties of the soil materials is expected, as identical replacement techniques were used for each treatment. Percentage moisture content was observed to be lower on treatments 1 and 3 than on treatments 2 and 4. The differences ranged from 5.8% to 10% between treatments. The consistently low moisture content on treatments 1 and 3 has implications to vegetation growth. These treatments afforded moisture levels only 5% - 7% above the estimated wilting point of the soil, which may have affected nonwoody plant growth as well as mortality and growth of outplanted trees.

The chemical parameters of soil materials replaced on each treatment are given in Table 6. Values for all chemical parameters were very similar and within the ranges suitable for growth of lodgepole pine and white spruce. Similar values for chemical parameters were expected, due to the identical materials handling and cultivation techniques exercised on each treatment.

TABLE 5. PHYSICAL PROPERTIES OF SOIL MATERIAL ON COMPETITION EXPERIMENTAL PLOTS

TREATMENT	SOIL PROPERTY TEXTURE % PARTICLE SIZE Sand	 Silt	 Clay	 STRUCTURE (0-15 cm)	 CONSISTENCE (Moist)	 BULK DENSITY (g/cm^3)	 MOISTURE CONTENT (%)
Seed mix 1	39.86	30.45	27.93	granular	friable	1.22±.05	27.2±.05
Seed mix 2	33.51	36.75	29.74	granular	friable	1.26±.01	33.0±1.1
Seed mix 3	38.55	32.24	29.20	granular	friable	1.14±.05	25.9±1.5
Seed mix 4	37.09	32.26	30.15	granular	friable	1.24±.14	35.5±6.2

TABLE 6. CHEMISTRY OF SOIL MATERIALS FROM COMPETITION EXPERIMENTAL PLOTS

TREATMENT	YEAR	pH	CONDUCTIVITY (mmhos/cm)	AVAILABLE MACRONUTRIENTS (ppm) NO_3-N	P	K	So_4-S	CEC (meq/100 g)	$CaCO_3$ Equivalence (%)	SAR	ORGANIC MATTER (%)
Seed Mixture 1	1979	6.1	0.10	1.3	7.0	88.3	1.7				1.7
	1980	6.0	0.20	1.0	9.0	160.0	3.0				2.8
	1981	5.8	0.10	2.0	8.0	136.0	4.0				2.3
	1983	6.0	0.25	0.2	6.0	117.5	12.0	25.8	0.16	.5	
$\bar{X}\pm$SE		5.9±0.02	0.16±.004	1.12±.05	7.5±.17	125.5±1.2	5.1±.27				2.2±0.02
Seed Mixture 2	1979	5.9	0.1	1.0	8.0	93.3	2.6				1.8
	1980	5.8	0.2	1.0	10.0	145.0	3.0				2.4
	1981	5.6	0.1	2.0	10.0	140.0	2.0				2.1
	1983	5.6	0.25	0.1	8.0	127.5	7.0	22.9	0.10	.9	
$\bar{X}\pm$SE		5.7±0.02	0.16±.004	1.02±.04	9.0±.17	126.5±1.2	3.6±.27				2.1±0.02
Seed Mixture 3	1979	6.1	0.1	1.3	7.0	88.3	1.7				1.7
	1980	6.0	0.2	1.0	9.0	160.0	3.0				2.8
	1981	5.8	0.1	2.0	8.0	136.0	4.0				2.3
	1983	6.1	0.2	0.4	6.0	105.0	5.0	22.6	0.12	.5	
$\bar{X}\pm$SE		6.0±0.02	0.15±.009	1.18±.05	7.5±.17	122.3±1.9	3.4±.26				2.2±0.02
Seed Mixture 4	1979	5.9	0.10	1.0	8.0	93.0	2.6				1.8
	1980	5.8	0.20	1.0	10.0	145.0	3.0				2.4
	1981	5.6	0.10	2.0	10.0	140.0	2.0				2.1
	1983	5.8	0.25	0.5	6.5	112.5	7.5	24.3	0.14	.5	
$\bar{X}\pm$SE		5.8±0.04	0.16±.009	1.13±.05	8.6±.17	122.7±1.2	3.7±.26				[illegible]

Vegetation Cover

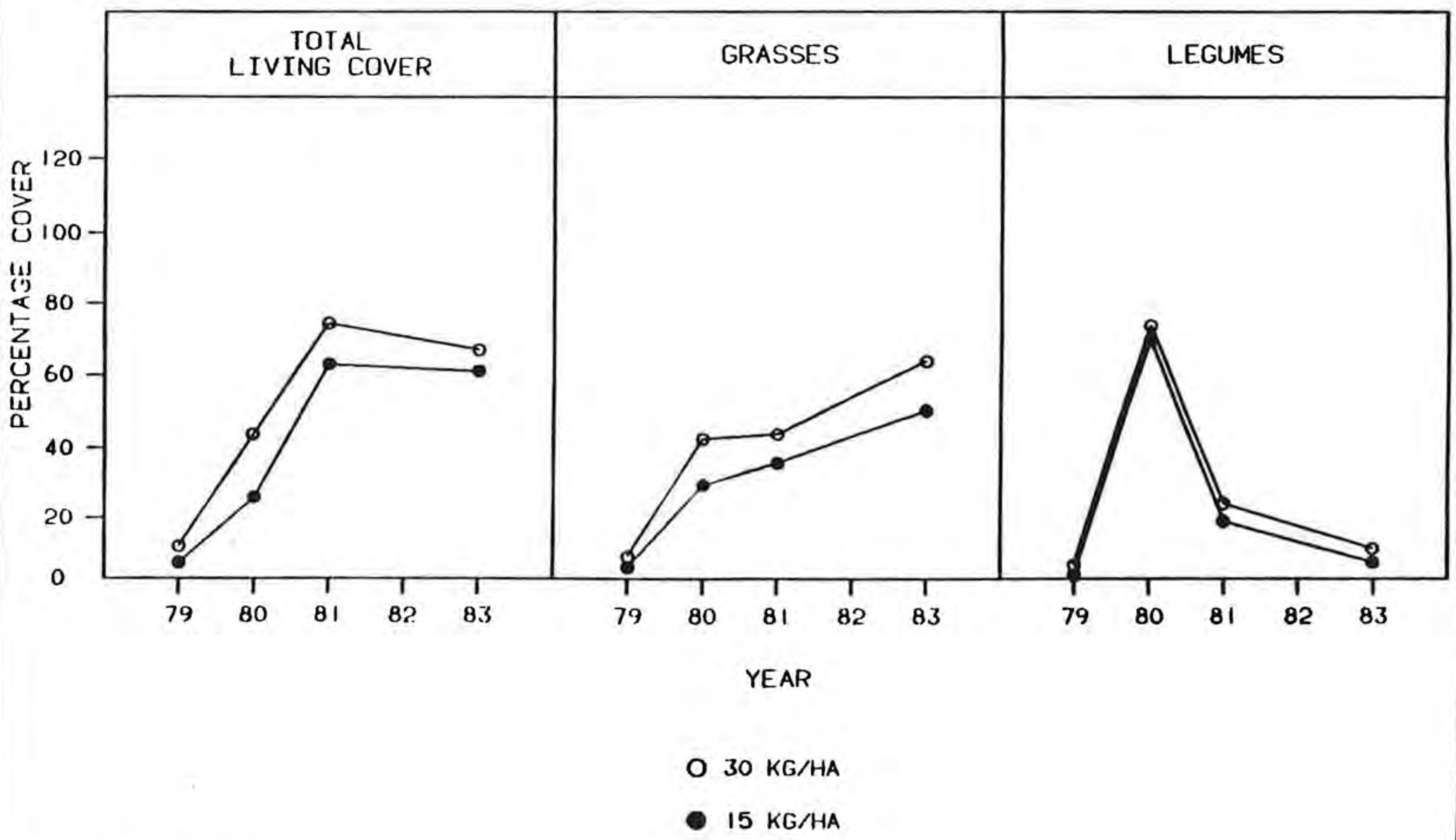
The effects of the two different seed application rates on vegetation cover during each year of study are shown in Figure 4. Application rate had little discernible effect on vegetation cover, although the 30 kg/ha rate showed slightly higher cover values than the 15 kg/ha rate. These differences were not significant for grasses ($F = 1.01$, $P = 0.0701$), legumes ($F = 0.92$, $P = 0.2860$) or total living cover ($F = 0.83$, $P = 0.2497$).

The percentage covers of each planted species for the entire study period are given in Table 7. Reed canary grass and creeping red fescue were consistently the most abundant species on all of the competition study plots. Creeping red fescue and reed canary grass were the most abundant species in the sod/bunch grass seed mixtures, and reed canary grass and timothy were the most abundant species in the bunch grass seed mixtures. Other species were recorded at low or marginal abundances. In the legume species group, red clover had higher cover estimates than the other planted legumes. Mean percentage cover values for total living cover are shown in Figure 5. In terms of total living cover, significant differences were found between treatments 2 and 4 relative to 1 and 3 over the entire study period ($F = 4.10$, $P = 0.0559$).

Vegetation Biomass

Above ground biomass of seeded agronomic species is given in Table 8. Seed mixtures 2 and 4 were recorded at significantly higher total biomass than seed mixtures 1 and 3 ($F = 11.01$, $P = 0.0001$). Above ground biomass data shows a similar trend as the percentage total living cover data. Below ground biomass values recorded on the competition plots are given in Table 9. Seed mixtures 2 and 4 consistently showed greater below ground biomass than seed mixtures 1 and 3 ($F = 12.05$, $P = 0.0001$).

FIGURE 4. APPLICATION RATES AND PERCENTAGE VEGETAL COVER ON COMPETITION EXPERIMENT

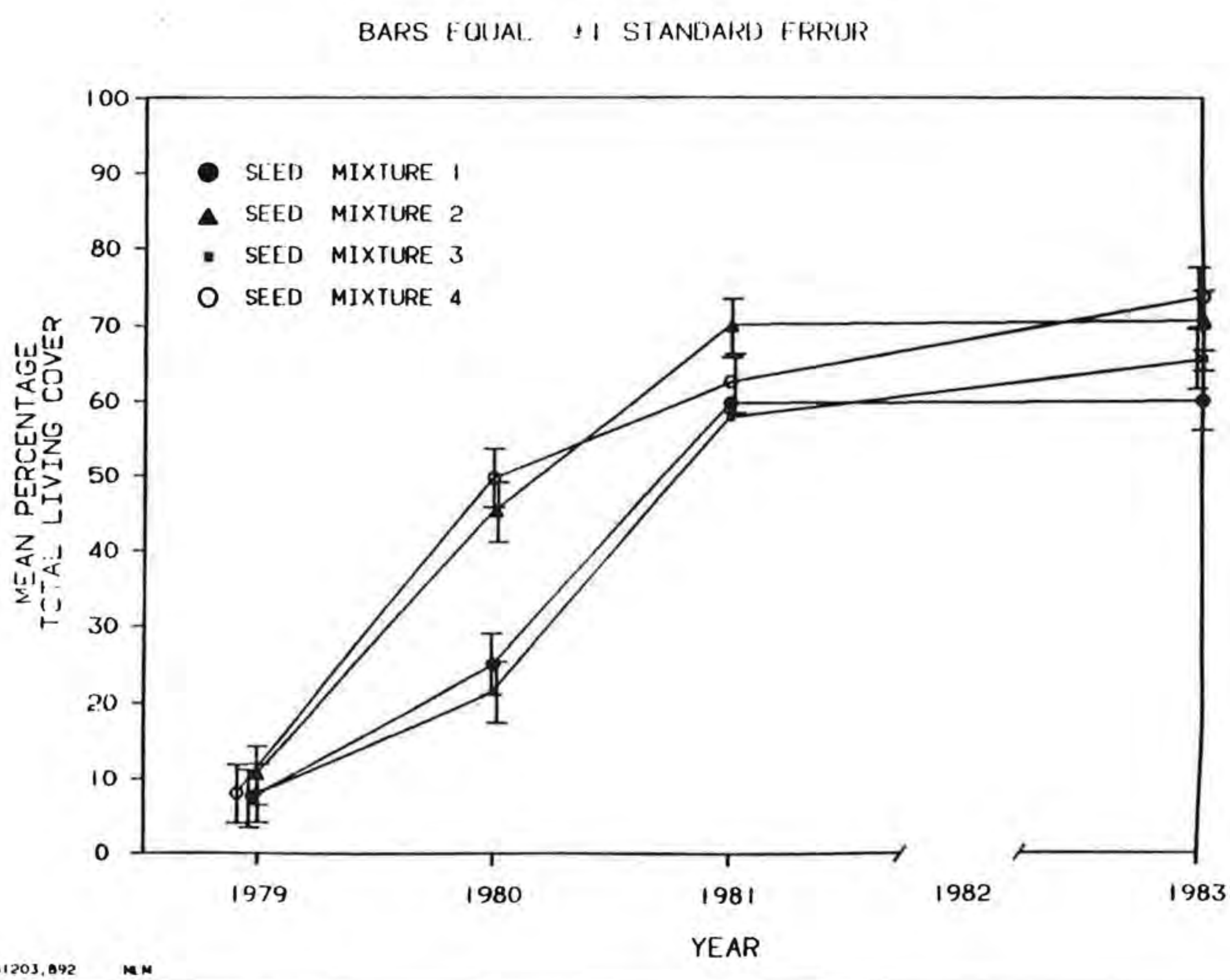


F120,347,01,851211,01 MLM

TABLE 7. SPECIES ABUNDANCE AS INDICATED BY COVER ESTIMATES FOR COMPETITION EXPERIMENT

TREATMENT	MEAN PERCENTAGE COVER
Seed Mixture 1	
Canada Bluegrass	3.10±1.58
Crested Wheatgrass	---
Slender Wheatgrass	3.17±0.88
Smooth Brome	6.30±4.53
Timothy	3.25±2.53
Creeping Red Fescue	28.92±12.08
Red Clover	5.45±4.53
Alfalfa	1.74±2.20
Seed Mixture 2	
Creeping Bentgrass	---
Tall Wheatgrass	---
Creeping Red Fescue	23.82±4.41
Reed Canary Grass	27.92±7.67
Timothy	1.20±0.90
Alsike Clover	2.57±2.22
Red Clover	4.12±3.10
Seed Mixture 3	
Crested Wheatgrass	---
Slender Wheatgrass	10.80±5.48
Timothy	18.17±8.38
Red Clover	1.05±0.43
Alfalfa	---
Seed Mixture 4	
Tall Wheatgrass	---
Reed Canary Grass	45.59±23.16
Timothy	6.50±3.82
Red Clover	17.53±29.20
Alsike Clover	1.63±2.21

FIGURE 5. TOTAL LIVING COVER BY TREATMENT FOR COMPETITION EXPERIMENT



212

TABLE 8: ABOVE GROUND BIOMASS OF HERBACEOUS SPECIES ON COMPETITION EXPERIMENT

TREATMENT	MEAN ABOVE GROUND BIOMASS (g/m2)*			Significance**
	Standing	Litter	Total	
Seed Mixture 1	111±14.5	189±26.2	300±18.4	A
Seed Mixture 2	384±19.4	259±31.4	643.26.2	B
Seed Mixture 3	174±25.3	197±27.9	371±22.9	A
Seed Mixture 4	349±27.4	254±35.4	603±29.7	B

TABLE 9: BELOW GROUND BIOMASS OF HERBACEOUS SPECIES ON COMPETITION EXPERIMENT

TREATMENT	MEAN BELOW GROUND BIOMASS (g/m2)*				Significance**
	0 - 10 cm	10 - 20 cm	20 - 30 cm	TOTAL	
Seed Mixture 1	75±25.4	38±4.3	18±6.4	131±8.4	A
Seed Mixture 2	162.5±19.4	81.5±11.2	32±7.9	276.13.4	B
Seed Mixture 3	103±12.9	13±3.3	10±2.1	126±11.1	A
Seed Mixture 4	149±5.6	40±4.9	33±6.2	222±9.4	B

* Values are mean (and S.E.) for nine samples/year/treatment

** Means with the same letter are not significantly different

Tree Mortality

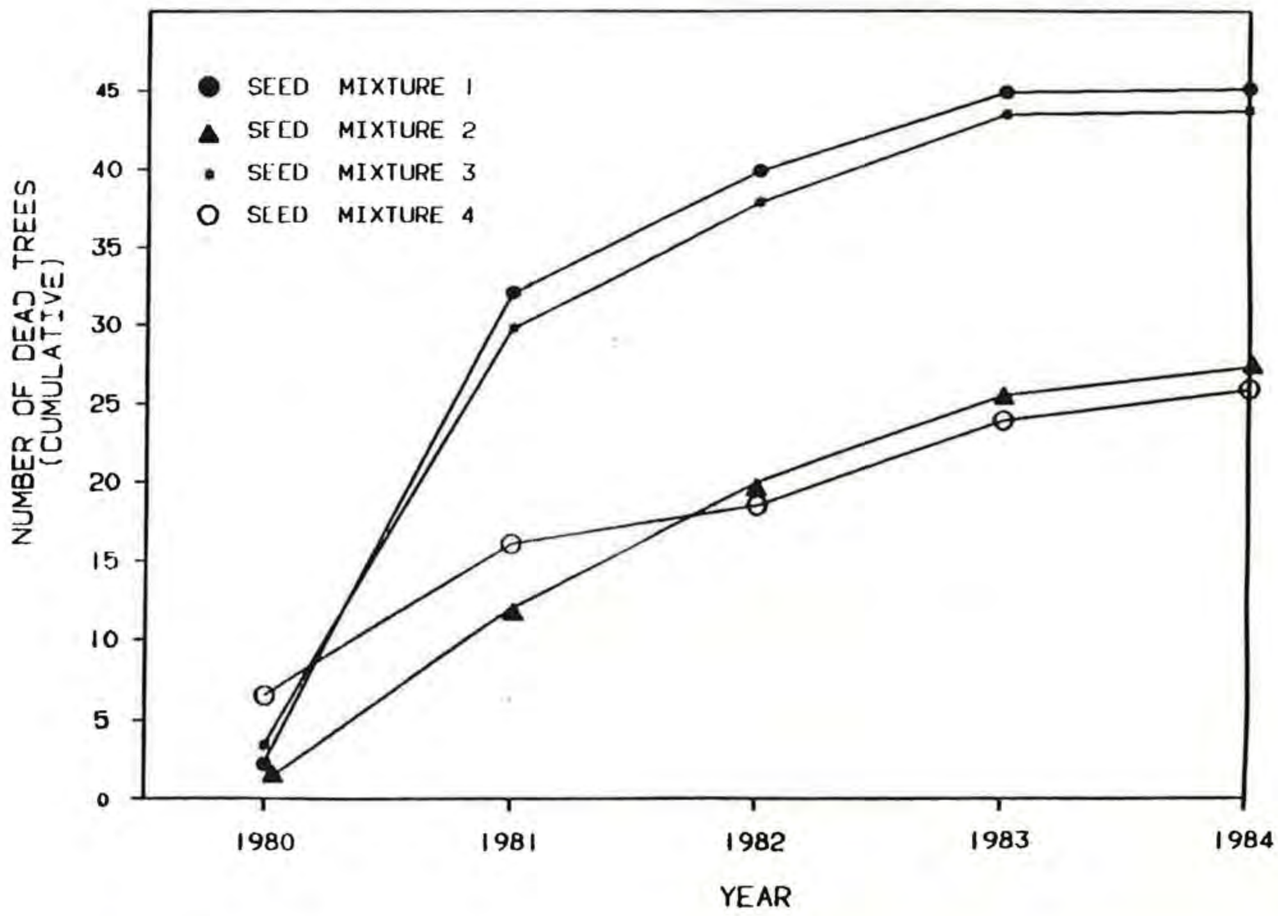
Data on the mortality of lodgepole pine outplanted on the competition plots are shown in Figure 6. Seed mixtures 1 and 3 had consistently higher mortality than seed mixtures 2 and 4 throughout the study period ($F = 18.25$, $P = 0.0001$). White spruce showed a similar trend in mortality as lodgepole pine (Figure 7) with treatments 1 and 3 being recorded at significantly higher mortality than treatments 2 and 4 ($F = 21.01$, $P = 0.0001$).

Tree Growth

Total growth and total yearly incremental growth for lodgepole pine, as indicated by height measurements, are shown in Figure 8 and 9 respectively. Total height of lodgepole pine was similar on each treatment under investigation ($F = 3.03$, $P = 0.0614$). Incremental yearly growth was also similar for each treatment for each year of study ($F = 4.17$, $P = 0.0718$).

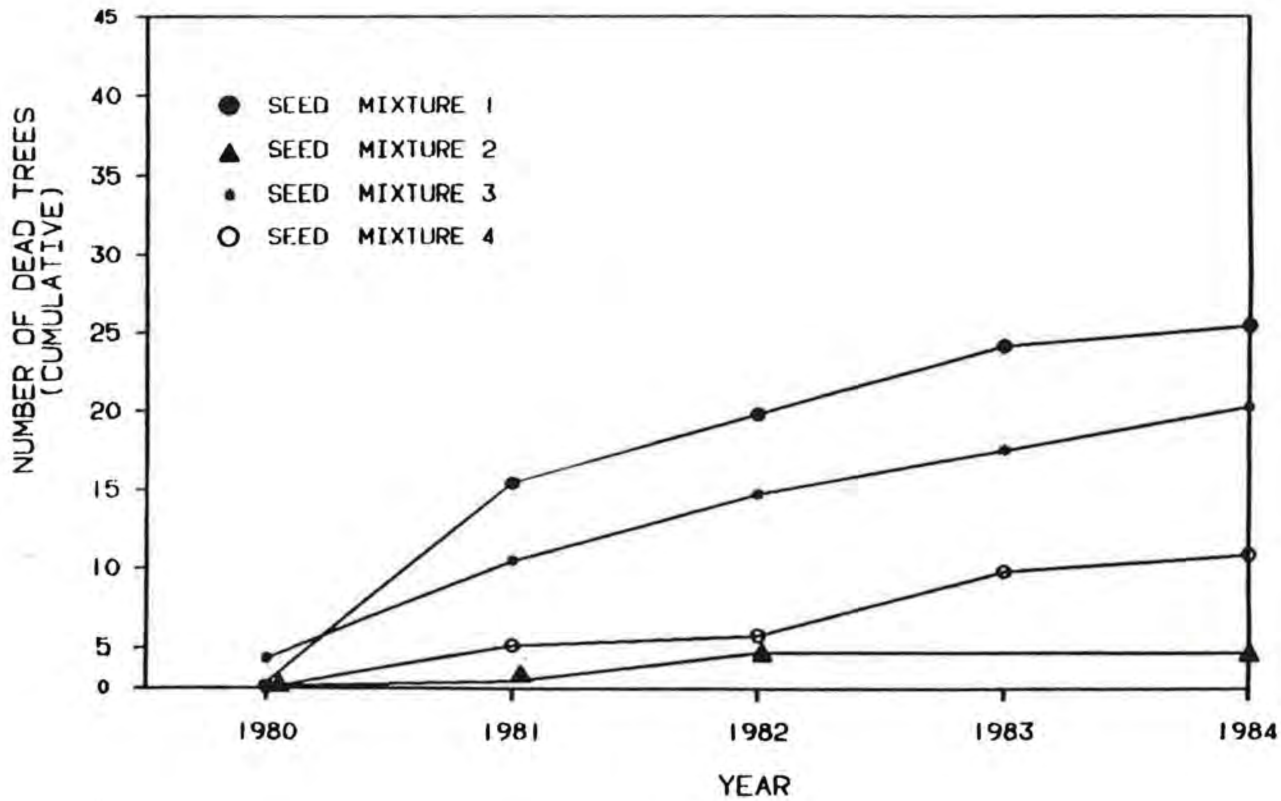
White spruce total growth and yearly growth are shown in Figure 10 and 11 respectively. Total height of white spruce was significantly different between seed mixtures 1 and 3 and seed mixtures 2 and 4 ($F = 23.65$, $P = 0.0001$). Incremental yearly growth showed a similar but much reduced trend ($F = 2.89$, $P = 0.0507$).

FIGURE 6. MORTALITY OF LODGEPOLE PINE ON COMPETITION EXPERIMENT PLOTS



F120,351,01,851203,892,01 MLM

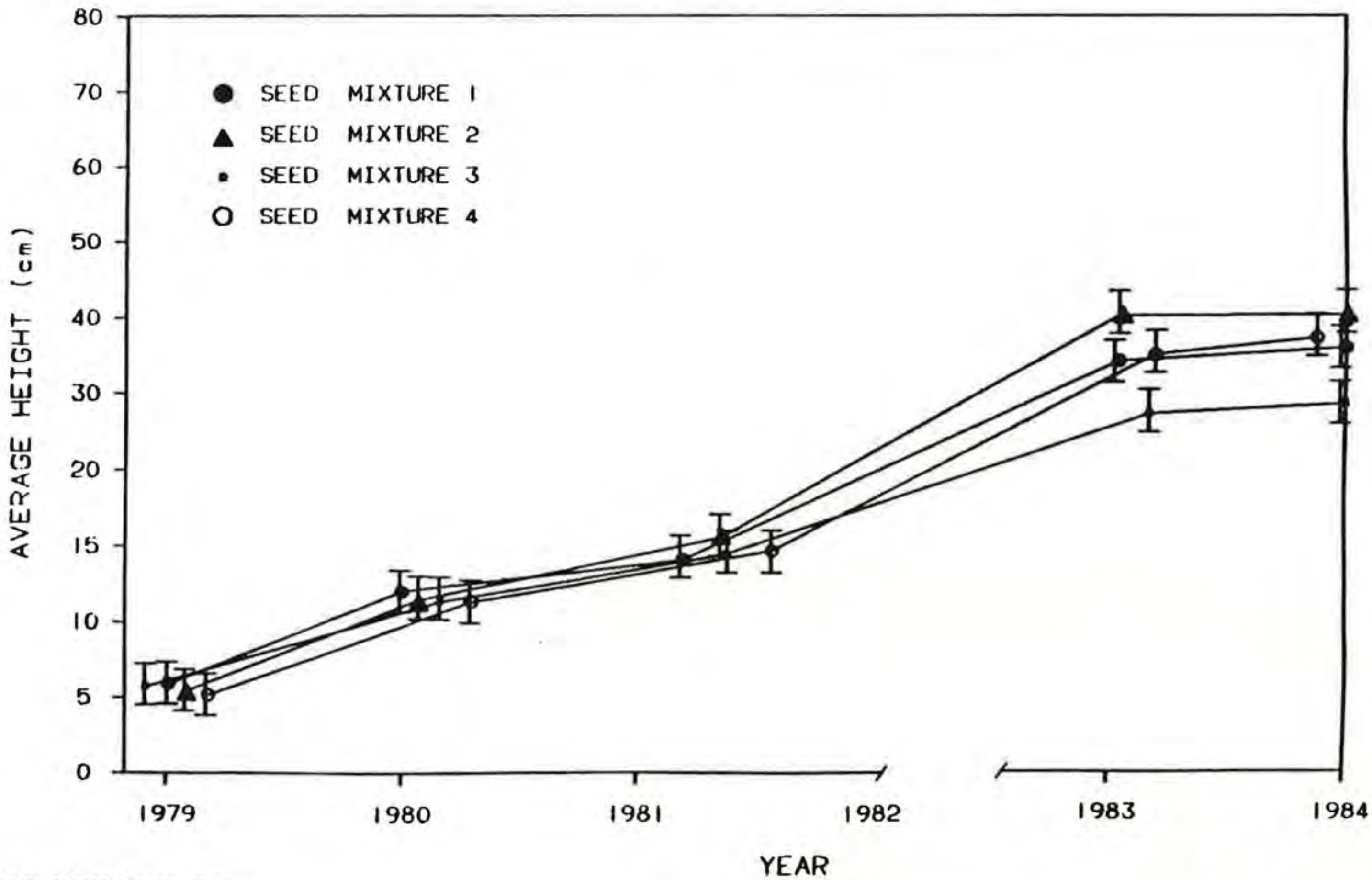
FIGURE 7. MORTALITY OF WHITE SPRUCE ON COMPETITION EXPERIMENT PLOTS



F120,352,01,851203,892.01 MLM

FIGURE 8. GROWTH OF LODGEPOLE PINE AS INDICATED BY TOTAL HEIGHT MEASUREMENTS FOR COMPETITION EXPERIMENT

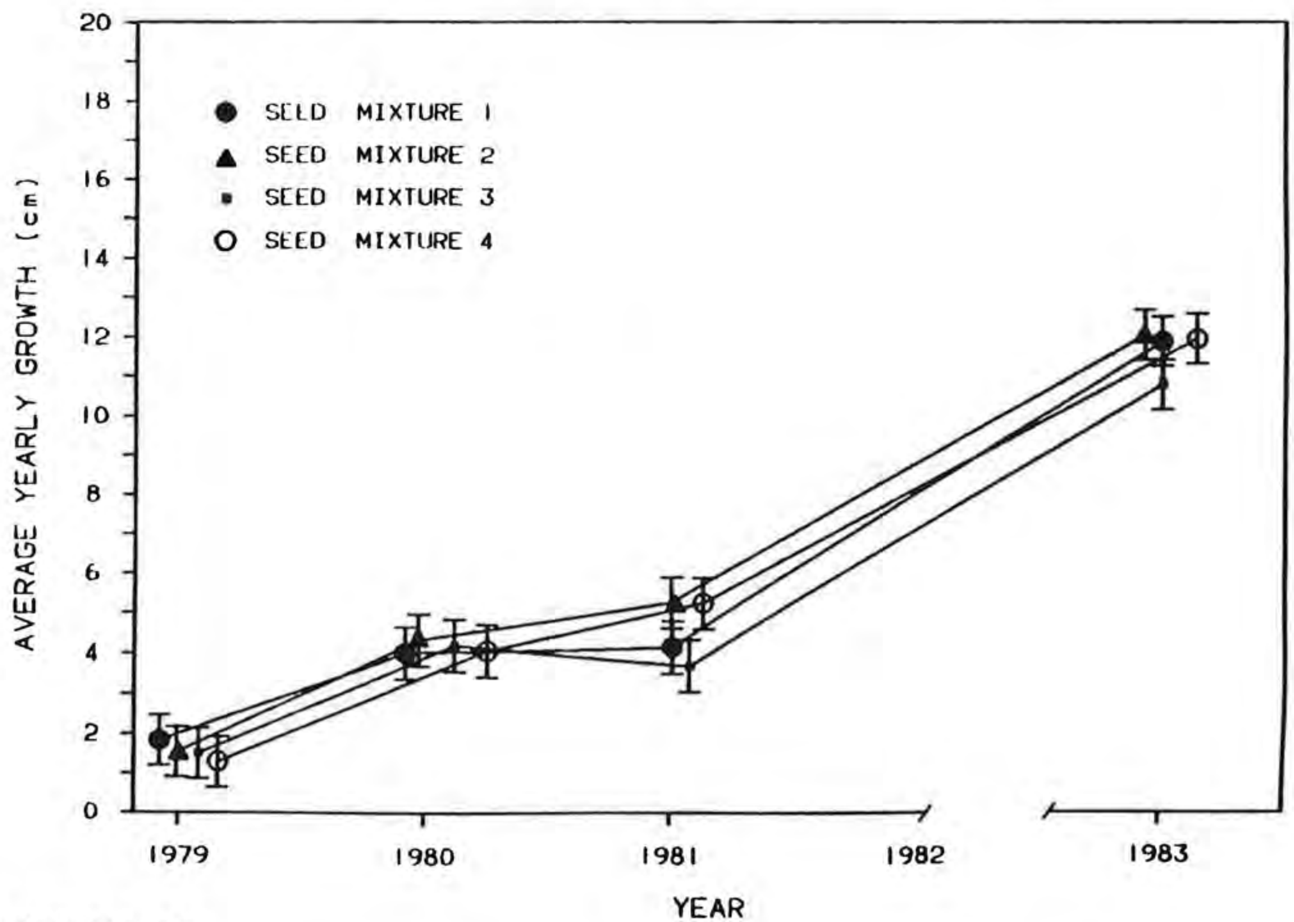
BARS EQUAL ±1 STANDARD ERROR



F120,353,01,851203,892,01 MLM

FIGURE 9. GROWTH OF LODGEPOLE PINE AS INDICATED BY INCREMENTAL HEIGHT MEASUREMENTS FOR COMPETITION EXPERIMENT

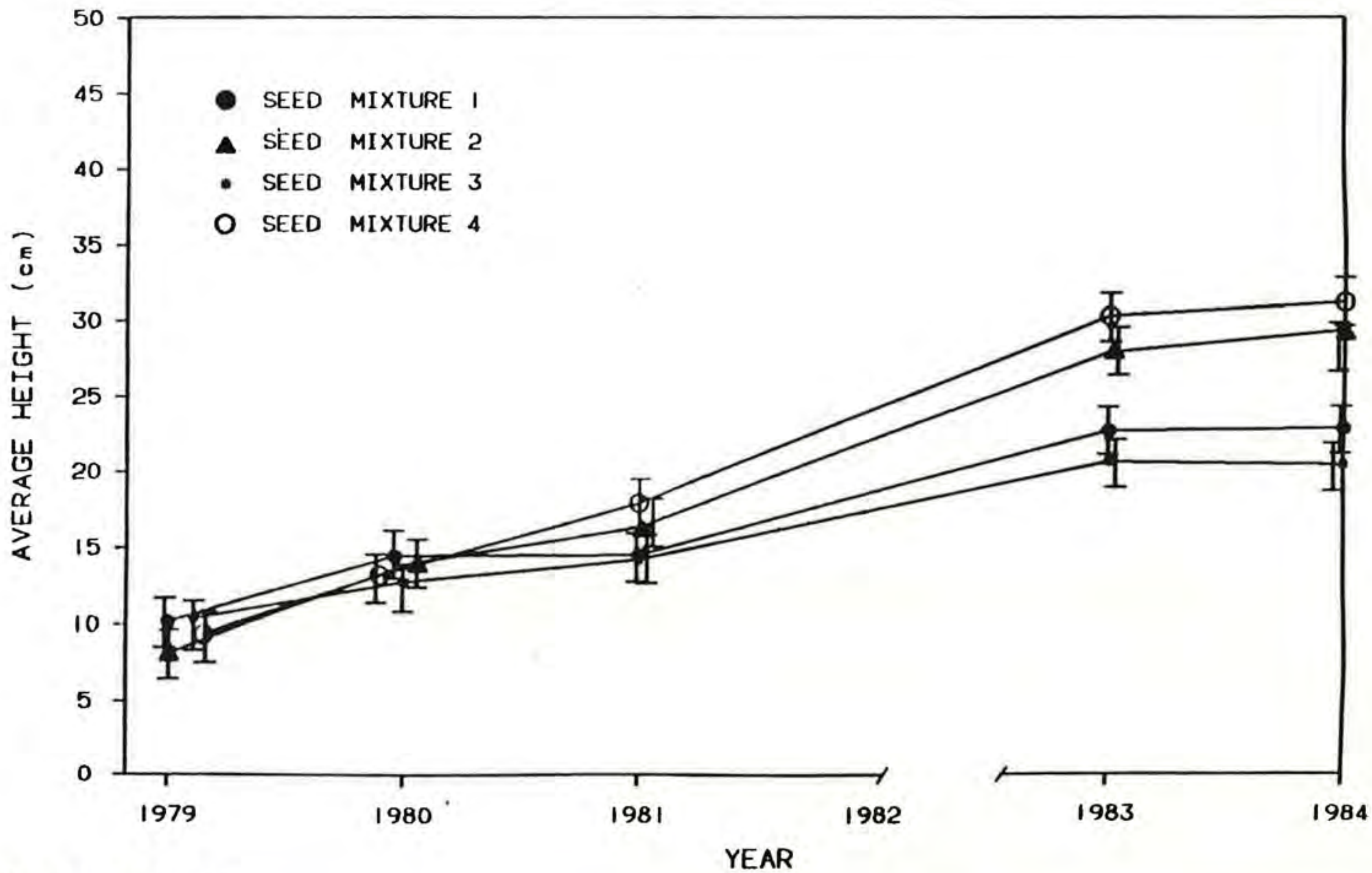
BARS EQUAL ±1 STANDARD ERROR



F120.354.01.851203.892.01 MLM

FIGURE 10. GROWTH OF WHITE SPRUCE AS INDICATED BY TOTAL HEIGHT MEASUREMENTS FOR COMPETITION EXPERIMENT

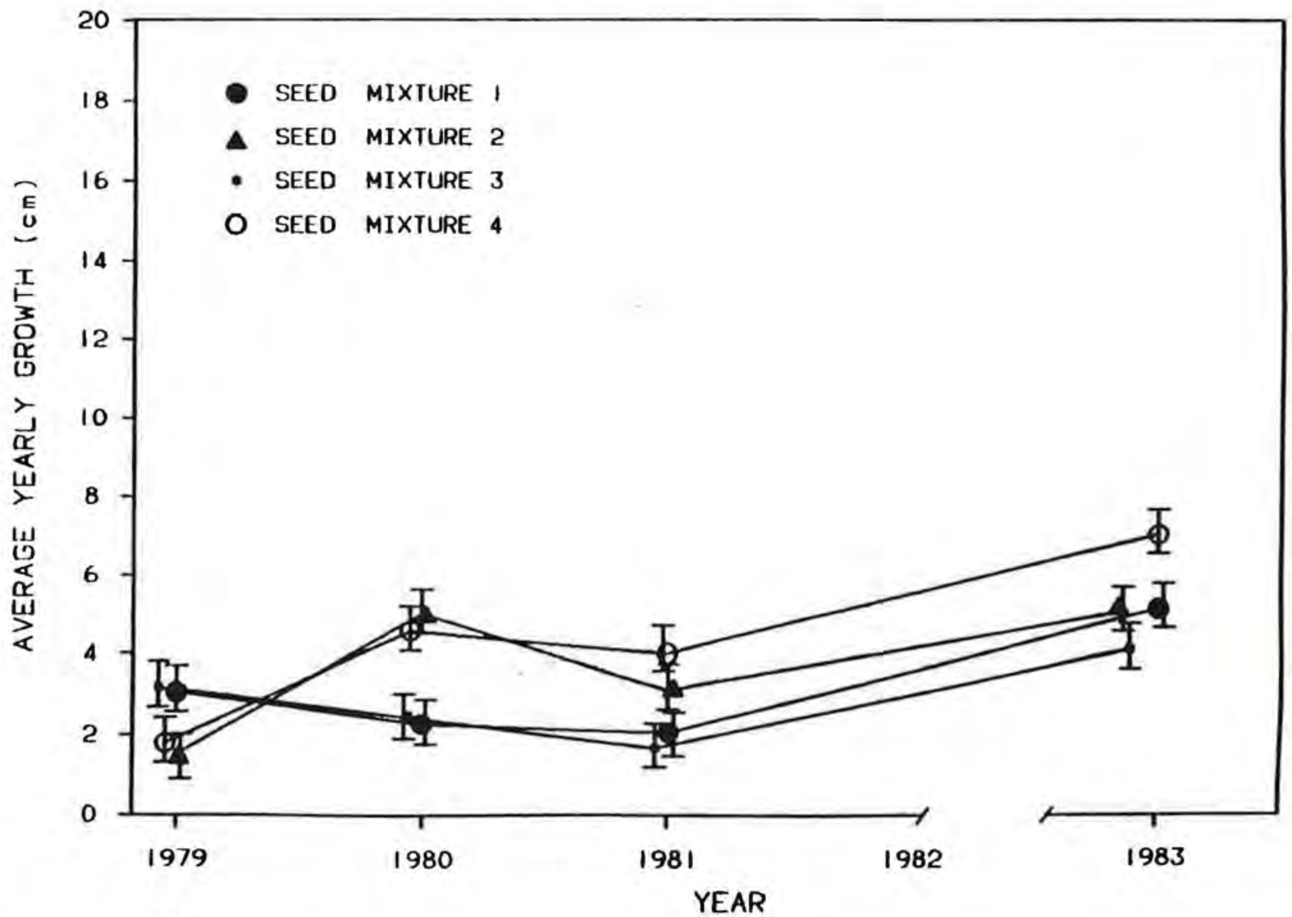
BARS EQUAL ±1 STANDARD ERROR



F120,358,01,851203,892,01 MLN

FIGURE 11. GROWTH OF WHITE SPRUCE AS INDICATED BY INCREMENTAL HEIGHT MEASUREMENTS FOR COMPETITION EXPERIMENT

BARS EQUAL ±1 STANDARD ERROR



F120,356,01,851203,892,01 MLM

DISCUSSION

Results from the competition experiment are best discussed in two sections; those results related to herbaceous vegetation cover, and those related to tree survival and growth. Results on herbaceous vegetation cover include discussion of application rates, species abundance, cover estimates, and biomass. Results of tree survival and growth include discussion of tree growth and mortality.

Herbaceous Vegetation

The seeding rate of any particular seed mix is determined by the efficiency of seed distribution and the expected rate of survival of the seeds. Application rates for individual species and mixes are well-known for most agronomic species (e.g., U.S.D.A. 1948; Saskatchewan Agriculture 1975; Alberta Agriculture 1976). Using the previously-mentioned studies and site specific environmental data; it is possible to estimate appropriate application rates for mined-area reclamation purposes (U.S.D.A. 1979). For the Judy Creek Test Mine site, as application rate of between 15 kg/ha and 30 kg/ha was estimated (Esso Minerals Canada 1979).

During the period of study, vegetation cover was observed to be very similar with both 15 kg/ha or 30 kg/ha seeding rates. These results agree with other studies in the mountain/foothills biomes of Alberta. King, (1984) found that an increase in seeding rate from 16.8 to 28.0 kg/ha provided only 2% - 5% more cover after 3 years of growth. Macyk, (1984) has shown that cover is not increased substantially through increasing seeding rate to over 20 kg/ha on reclamation sites near Grande Cache, Alberta.

Interspecific competition within a developing reclaimed plant community is well known and has been documented under a variety of different circumstances. Smoliak and Johnston (1975) and Schuman et al. (1982) found that fast-growing, tall species such as crested wheatgrass are far more competitive than other range grasses at the seedling stage. Slender wheatgrass was recommended by Schuman et al. (1982) as an alternative to the highly-competitive species. Johnston , (1961) and Johnston and Smoliak, (1971) examined the early establishment and competition in plant communities with mixed native and agronomic species within the foothills of southern Alberta. Seedlings of timothy and crested wheatgrass were found to be most agressive, and the authors concluded these species were more competitive than naturalized species such as brome grass. Walker, (1983) evaluated early successional changes in seed mixtures in north-central Saskatchewan and concluded that timothy and reed canary grass completely dominated the poorly-drained sites, while creeping red fescue dominated well-drained sites. Dryness, (1974) showed that grasses in a grass/legume-seed mix applied to forest access roads in the mountain/foothills of Oregon provided too much competition for legumes. Smoliak and Hanna, (1977) found that early growth rates of three species of legumes were significantly different.

Results from the present experiment are in agreement with those studies previously mentioned in that a few species of grasses appeared to dominate in terms of abundance. Reed canary grass and creeping red fescue were consistently most abundant within the seed mixtures with which they were planted. In the absence of these species, timothy was most abundant. Grasses, in general, were observed to be more long-lived than the legumes seeded.

Tree Survival and Growth

Previous studies on the problem of competition between grass/legume seed mixtures and outplanted trees have provided results that are not consistent between studies. Several authors (i.e., Fedkenheuer 1979; Vogel and Berg 1973) have found that grasses seeded for erosion control, particularly sod grasses, provide too much competition for space and moisture to allow shrubs and trees to establish. Studies specifically on pine have shown that on some sites survival and growth of this genus is restricted by a rapidly-developing grass cover (Baron 1962; Duffy 1974).

Sims and Mueller-Dombois (1968) have shown that, on soils where white spruce roots were competing with faster growing herbaceous vegetation, tree growth was severely reduced or the spruce was eliminated altogether. However, results not consistent to those above have also been reported in the literature. For example, Clark and Mclean (1975) stated that the survival of lodgepole pine was not affected by density of grass or the species of grass sown. As well, Eis (1981) found that, even though the presence of herbaceous vegetation slowed white spruce growth rates, it was rarely found to cause significant mortality and failure of regeneration. Fedkenheur et al., (1980) found a relationship between biomass and woody plant survival, but not for cover and survival. King (1983), in a study conducted within 50 km of the Judy Creek Test Mine, found that survival and growth of pine and spruce seedlings were independent of seed mix and seeding rate treatments.

The data obtained from the present study indicate that, at the Judy Creek Test Mine, pine and spruce survival and growth are independent of cover treatment. Treatments with significantly lower covers and biomass showed higher mortalities and reduced growth rates for both tree species examined. Previous works by Day (1963), Day (1964), Wilde et al. (1968), Fedkenheur (1968), and Eis (1965) have demonstrated the importance of soil moisture availability to pine and spruce seedling survival and growth. A relationship between reduced moisture availability and lower survival and growth of both tree species was apparent.

Therefore, because of the inconsistent affect of cover treatment to tree survival and growth but a consistent moisture deficiency affect, moisture regime may have been more important to reforestation than competition from herbaceous plants.

ACKNOWLEDGMENTS

I wish to acknowledge Messrs. G. Mann, N. Krpan, and Dr. G. Capobianco, Esso Resources Canada Limited, for their continued support throughout the research program. I also thank the drafting, reprographics, and business documentation units of Esso Resources for logistical support. The following individuals and agencies extended considerable effort and provided valuable input to the present study:

Mr. H. Martens and Mr. C. Warner, Hardy and Associates (1978) Ltd.
Mr. D. F. Penner, McCourt Management Ltd.
Mr. L. B. Noble, Esso Resources Canada Limited
Mr. J. Flood, Esso Resources Canada Limited
Mr. F. Williamson, TransAlta Utilities Corporation

Literature Cited

Alberta Environment. 1977. Guidelines for the reclamation of land affected by a surface disturbance. Edmonton, Alta 10 pp.

Alberta Agriculture. 1976. Alberta farm guide. Queen's Printer, Edmonton, Alta. 336 pp.

Alberta Energy and Natural Resources. 1979. Alberta forest regeneration survey manual. Alberta Forest Service. Edmonton, Alta. 110 pp.

Baron, F.J. 1962. Effects of different grasses on ponderosa pine seedling establishment. USDA Forest Service, Pacific Southwest Forest and Range Exp. Station. Research Note No. 199. 8 pp.

Clark, M.B. and A. Mclean. 1975. Growth of lodgepole pine seedlings in competition with different densities of grass. B.C. Forest Serv. Research Note No. 70. 10 pp.

Day, R. 1963. Spruce seedling mortality caused by adverse summer microclimate in the Rocky Mountains. Can. Dept. of forests. Forest Research Branch. Publ. No. 1003. 36 pp.

Day R. 1964. The microenvironments occupied by spruce and fir regeneration in the Rocky Mountains. Can. Dept. of Forests. Forests Research Branch. Publ. No. 1037. 21 pp.

Dyrness, C.T. 1975. Grass-legume mixtures for erosion control along forest roads in western Oregon. J. Soil and Water Conserv. 30:169-173.

Duffy, D. 1974. Planting grass and pine for erosion control. Tree Planter's Notes. 25:10-13.

Eis, S. 1965. Development of white spruce and alpine fir seedlings on cut over areas in the central interior of British Columbia. For Chron. 41:419-431.

Elis, S. 1981. Effect of vegetative competition on regeneration of white spruce. Can J. Forest Sci. 11:1-8.

Esso Minerals Canada. 1979. Reclamation plan for Judy Creek test pit. Unpubl. Rep. to Energy Resources Conservation Board. 78 pp.

Foth, H.D. 1978. Fundamentals of soil science. John Wiley and Sons. N.Y. 436 pp.

Fedkenheuer, A.W. 1968. Soil conditions influencing the growth of forest plantations established on furrowed and ridged clay soils. M.Sc. Thesis. University of Wisconsin. Maddison, Wn 53 pp.

Fedkenheuer, A.W. 1979. Native Shrub research for oil sands reclamation. Prof. Paper 1979-4, Syncrude Canada. 14 pp.

Fedkenheur, A.W., H.M. Heacock, and D.L. Lewis. 1980. Early performance of native shrubs and trees planted on amended Athabasca oil sand tailings. Reclamation Review. 3:47-55.

Johnston, A. 1960. Some factors affecting germination, emergence, and early growth of three range grasses. Can. J. Plant Sci. 41:59-70.

Johnston, A., and S. Smoliak, 1971. Evaluating competition among timothly seedlings. Can J. Plant Sci. 51:425-427.

Kershaw, K.A. 1973. Quantitative and dynamic plant ecology. Edward Arnold Publishers. London, England. 306 pp.

King, P. 1984. Woody plant demonstrations and trials on disturbances in the eastern slopes. Pages 318-353 IN: P.F. Ziemkiewicz (Ed.) Revegetation methods for Alberta's mountains and foothills. RRTAC Report #85-1.

King, P.J. 1983. Influence of agronomic grass-legume mixtures on the performance of commercial softwood tree species used in reclamation. IN: Proceedings of 8th annual meeting of C.L.R.A. Waterloo, Ontario. pp 277-296.

Macyk, T.M. 1984. Development of a reclamation technology for the foothills-mountains region of Alberta. IN: Proceedings 9th annual meeting of Can. Land Recl. Assoc. Calgary, Alberta. Aug 20-24, 1984. 15 pp.

McKeaque, J.A. 1978. Manual of soil sampling and methods of analysis. Canadian Soil Survey Committee Report. Canadian Society of Soil Science. Ottawa, Ont. 212 pp.

SAS. 1982. SAS users guide: Statistics. Statistical Analysis System. Cary, North Carolina. 494 pp.

Saskatchewan Agriculture. 1975. Guide to farm practice in Saskatchewan 1975. Univ. of Saskatchewan Saskatoon. 94 pp.

Schuman, G.E., F. Raugi, and D.T. Both. 1982. Production and competition of crested wheat grass-native grass mixtures. Agronomy Journal. 74:23-26.

Sims, H.P., and D. Mueller-Dumbois. 1968. Effects of grass competition and depth to water table on height of coniferous tree seedlings. Ecology 49"597-603.

Smoliak, S., and A. Johnston. 1975. Seedling competition of some grasses in mono and mixed cultures under greenhouse conditions. Can J. Plant Sci. 55:935-940.

Smoliak, S., and M.R. Hanna. 1977. Seedling competition of some forage legumes in mono and mixed cultures under greenhouse conditions. Can J. Plant Sci. 57:897-903.

Sokal, R.R., and F.J. Rohlf. 1969. Biometry. W.H. Freeman and Co. San Francisco. 776 pp.

U.S.D.A. 1948. Year book of agriculture: Grass-seed and culture. U.S. Government Printing Office, Washington D.C. 892 pp.

U.S.D.A. 1979. User guide to vegetation. USDA Forest Service General technical report INT-64. 85 pp.

Vogel, W.G., and W.A. Berg. 1973. Fertilizer and herbaceous cover influence establishment of direct seeded black spruce on coal mine spoils. Pages 189-198 IN: R.J. Hutnik and G. Davis (Eds.). Ecology and Reclamation. Gordon and Breach Scientific Publ. New York.

Walker, D.G. 1983. Effect of revegetation treatments on soil erosion, plant establishment and species composition in the Great Sand Hills of Saskatchewan. IN: Proceedings of 8th Annual meeting of the C.L.R.A. Waterloo, Ontario Aug. 21-24, 1983. pp 213-227.

Watson, L., R. Parker, and D. Polster. 1980. Manual of plant species suitability for reclamation in Alberta. RRTAC Report No. 80-5. (2 vols.) 805 pp.

Wilde, S.A., B.H. Shaw, and A.W. Fedkenheur. 1968. Weeds as a factor depressing forest growth. Weed Res. 8:916-204.

PROCEEDINGS

ALBERTA RECLAMATION CONFERENCES

1985
Planning and Certification of Land Reclamation
April 16-17, 1985
Edmonton Inn, Edmonton

1986
Reclamation in the Eastern Slopes of Alberta
September 25-26, 1986
Overlander Lodge, Hinton

C.B. Powter
R.J. Fessenden
D.G. Walker
Compilers

CLRA ALBERTA CHAPTER AC

CANADIAN LAND RECLAMATION ASSOCIATION

P R O C E E D I N G S

1985 AND 1986
ALBERTA RECLAMATION CONFERENCES
ALBERTA CHAPTER, CANADIAN LAND RECLAMATION ASSOCIATION

1985: Planning and Certification of Land Reclamation, April 16-17, 1985, Edmonton Inn, Edmonton

1986: Reclamation in the Eastern Slopes of Alberta, September 25-26, 1986, Overlander Lodge, Hinton, Alberta

Powter, C.B., R.J. Fessenden and D.G. Walker, compilers.

ACKNOWLEDGEMENTS

The Chapter gratefully acknowledges the time and effort put into organizing the 1985 conference by Paul King, Dave Walker, Bob Fessenden, and Chris Powter and the 1986 conference by Chris Powter, Dave Walker, and Bob Fessenden. The Chapter also thanks Debra Scott, Glen Singleton, and Doug Mead for assistance during the conferences.

Much appreciation is also due to the Research Management Division, Alberta Environment, the Reclamation and Reforestation Branch, Alberta Forest Service, and the Terrain Sciences Department, Alberta Research Council for providing manpower, supplies and mailing facilities for the conference pamphlets. Special thanks to Meliza Canafranca and Susan Panker, Research Management Division for typing (patiently) the programs and other material and to Dave Walker and his Mac for the cover art.

Most of the work, however, was done by the speakers who prepared the papers and delivered the talks to us and we offer them a strong vote of thanks.

Last, but not least, thanks to the two hotels for excellent accomodations and facilities.

For more information on the Alberta Chapter of the Canadian Land Reclamation Association please write to CLRA, Box 682, Guelph, Ontario, Canada N1H 6L3.

The papers contained in this proceedings are the original, unedited manuscripts provided by the authors.

This report may be cited as:

Powter, C.B., R.J. Fessenden and D.G. Walker. 1987. Proceedings of the 1985 and 1986 Alberta Reclamation Conferences. Alberta Chapter, Canadian Land Reclamation Association. AC/CLRA Report #87-1. 272 pp.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONCLUDED)

NOTE: N/A means the paper was not submitted. We suggest you contact the speakers directly for more information.