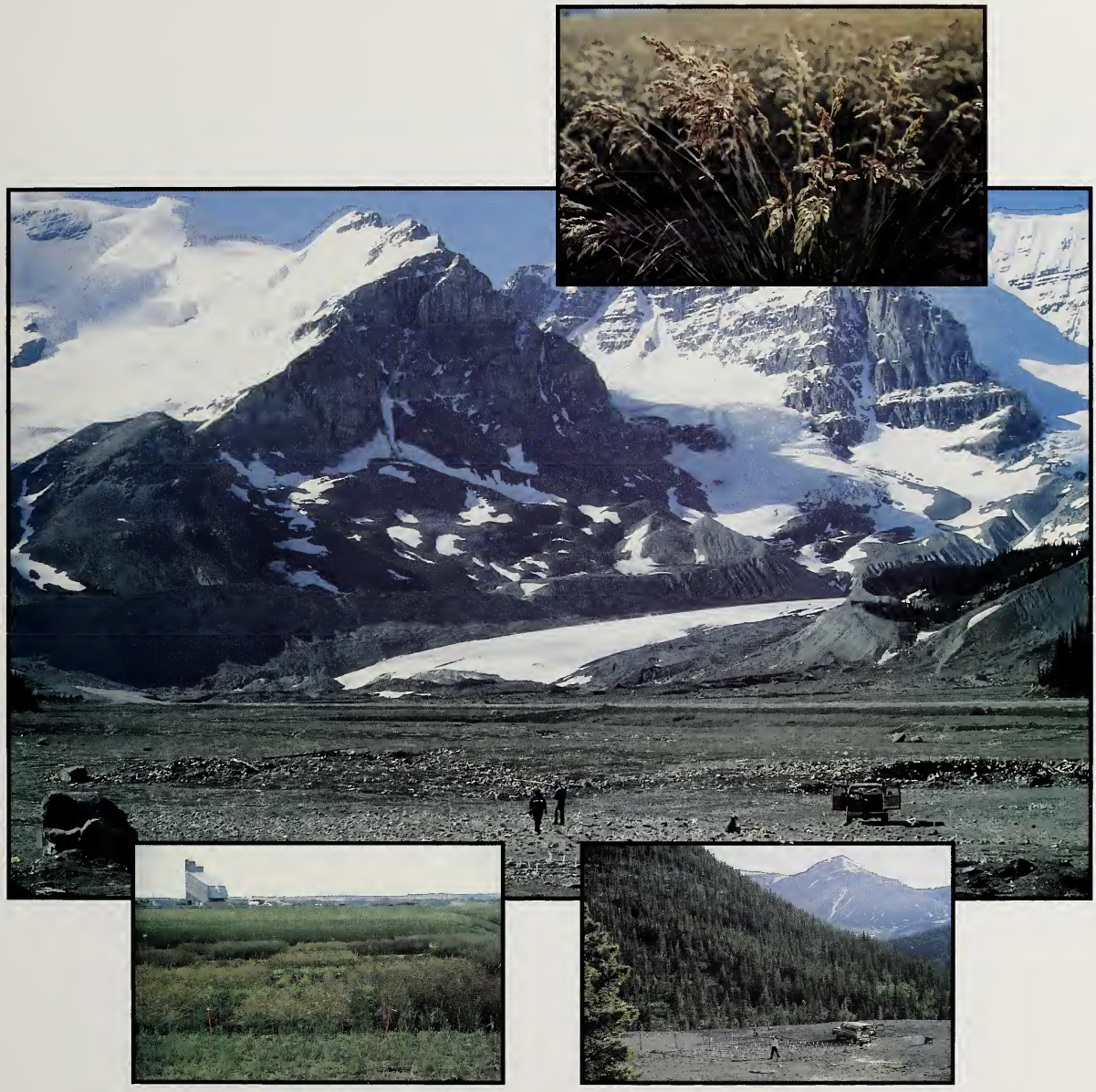
Development of Two Alpine Bluegrass Reclamation Varieties



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DEVELOPMENT OF TWO ALPINE BLUEGRASS RECLAMATION VARIETIES

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TABLE OF CONTENTS

PAGE

LIST OF TABLES

PAGE

LIST OF FIGURES

PAGE

LIST OF APPENDICES

PAGE

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ABSTRACT

To address the need for seed of native grasses adapted for reclaiming disturbed sites in the mountains and foothills, the Alberta Environmental Centre initiated a research project aimed at developing and releasing varieties of native grasses. Four native grass species were included in this project: alpine bluegrass (*Poa alpina*), slender wheatgrass (*Elymus trachycaulus*, including awnless slender wheatgrass [ssp. *trachycaulus*], awned slender wheatgrass [ssp. *subsecundus*], and broadglumed wheatgrass [ssp. *violaceus*]), Rocky Mountain fescue (*Festuca saximontana*), and spike trisetum (*Trisetum spicatum*). Plants of these species were collected from the eastern slopes of the Rocky Mountains in 1984 and 1985. Alpine bluegrass was one of the most promising species of these four. It establishes and grows well on a wide range of soils and is an active colonizer on most disturbances in subalpine and alpine environments. Alpine bluegrass is non-competitive and allows other native plant species to invade a reclaimed site. This helps to create a more natural plant community on reclaimed land.

Fifteen lines of alpine bluegrass were selected for evaluation in provenance trials at Vegreville, Columbia Icefields, Sunshine Village, and Mountain Park. Data from these trials were used to select eight alpine bluegrass lines for final evaluation in multilocation trials at Vegreville, Beaverlodge, Plamondon, Columbia Icefields, and Mountain Park. Based on the information collected in these trials, two reclamation varieties of alpine bluegrass were released by the Alberta Environmental Centre. AEC Blueridge alpine bluegrass was released in 1994. It is a high-elevation variety adapted to elevations as high as 2500 m. AEC Glacier alpine bluegrass, which was released in 1994, is adapted to elevations as high as 2400 m and is better adapted to drier conditions than AEC Blueridge. Although these varieties were released as pure lines, we recommend that they be incorporated into seed mixtures containing other native plant species and varieties to maximize genetic and species diversity and improve the likelihood of obtaining a good plant cover in any one location. In addition to developing and releasing these reclamation varieties, research has also been conducted to develop recommendations for growing these varieties for seed production and for use in reclamation and revegetation.

1 INTRODUCTION

Increasing public awareness about the importance of biodiversity and ecosystem integrity has led to increased interest in the use of native plants in reclamation, revegetation, and restoration. Sites in the mountains and foothills may be disturbed by such activities as resource extraction, pipeline and road construction, recreation and recreational development, and forestry operations. At high elevations, reclamation and revegetation of disturbed sites is especially difficult due to harsh environmental conditions. Commercially available varieties of introduced plant species often cannot survive at high elevations so they cannot provide long-term cover. At lower elevations, introduced species may be highly competitive and persistent (Hardy BBT Ltd. 1990) and will not allow native plants to invade a reclaimed site. Thus, sites revegetated with introduced species may always maintain their distinct vegetative cover, disrupting the natural ecosystems surrounding them.

The major advantage of using native plants in reclamation is that they are adapted to the area in which they are found. Native species are generally better adapted to low soil fertility and the short growing seasons characteristic of high elevations (Hardy BBT Ltd. 1990). Brown et al. (1976) reported that introduced grasses, while initially successful on high elevation sites, declined in vigour and productivity by the third growing season. Native grasses, on the other hand, were more vigourous and had greater productivity. Since they are adapted to lower nutrient conditions (Hardy BBT Ltd. 1990), native plants require fewer inputs to maintain a good stand over the long term (Thornburg 1982). Native plants fit well into the surrounding ecosystem and help to maintain ecosystem integrity when used in reclamation plantings. Native species are generally not highly competitive and will allow other native plants to invade naturally from surrounding, undisturbed areas.

The agrology of native plants is poorly understood so establishment and maintenance of plant stands may be difficult (Joyce 1993; Bradley 1994). Stand establishment is often slow, weed control is difficult due to the non-competitive nature of native species, and seed yield may be low and unpredictable (Joyce 1993). Introduced species have been widely used in reclamation partly because of the availability of inexpensive seed. The high cost of native grass seed reflects its low availability and high cost of production (Joyce 1993). Use of locally-collected seed in reclamation may be desirable in some situations (Hardy BBT Ltd. 1990; Mahler 1990), but seed

collection is very expensive and seed production in the wild is unpredictable. For large-scale reclamation projects, the cost of collected seed is often prohibitive. In addition, seeds produced in alpine environments germinate more slowly and exhibit more dormancy than those produced in prairie nurseries (Hermesh and Acharya 1992). Therefore, the best alternative is to use commercial sources of native plant seed but such sources are not readily available.

To address the problem of seed availability, the Alberta Environmental Centre (AEC) initiated research in 1984 with the objective of selecting, testing, developing, and releasing varieties of native grasses suitable for use in reclamation of disturbed lands in the mountains and foothills of Alberta. Four native species with potential for use in reclamation were chosen for development: alpine bluegrass (*Poa alpina* L.), slender wheatgrass (*Elymus trachycaulus* (Link) Gould in Shinners, including awnless slender wheatgrass [ssp. *trachycaulus*], awned slender wheatgrass [ssp. *subsecundus* (Link) Gould], and broadglumed wheatgrass [ssp. *violaceus* (Horneman) A.& D. Love]), Rocky Mountain fescue (*Festuca saximontana* Rydb.), and spike trisetum (*Trisetum spicatum* (L.) Richt.). These species were chosen because they occur in a wide range of habitats and colonize disturbed sites.

This report documents the development and release of two varieties of alpine bluegrass. Alpine bluegrass is a cool-season, perennial bunch-grass (Hardy BBT Ltd. 1989). It is found in subalpine to alpine meadows and rocky slopes and has a circumpolar distribution (Moss 1983). Apomixis is common in alpine bluegrass biotypes of northern countries (Müntzing 1954; Müntzing and Müntzing 1971) and plants collected in Alberta also appear to reproduce apomictically. Alpine bluegrass will grow on bare soils, acidic mine spoils, and talus slopes and has been described as an active colonizer on most disturbances in alpine environments (Hardy BBT Ltd. 1989). It is ideally suited to reclamation of disturbed sites at high elevations.

In 1984, plants of alpine bluegrass were collected in the eastern slopes of the Rocky Mountains. Following initial selections, all selected lines were extensively tested in the mountains and foothills and at plains sites from 1987 to 1994. Potential varieties should be compared to standard varieties over a period of years at several locations (Allard 1960). This ensures that all released varieties will perform well, both in their areas of adaptation and for seed production at lower elevations. In addition to developing varieties, research was conducted to determine the most appropriate techniques for growing alpine bluegrass for seed production and reclamation.

2 VARIETY DESCRIPTIONS

2.1 AEC Blueridge Alpine Bluegrass

AEC Blueridge alpine bluegrass, *Poa alpina* L., was released by the Alberta Environmental Centre in 1994 for use in reclaiming disturbed sites in the mountains and foothills of Alberta. AEC Blueridge is the first variety of alpine bluegrass released in Canada. It is adapted to the short growing seasons of high elevations and can grow rapidly and produce mature seed at elevations as high as 2500 m.

2.1.1 Origin and Breeding

AEC Blueridge (designated as line 1760) was derived from a single plant collected in 1985 from a site (elevation 2150 m) near the Alberta-British Columbia border. It was part of a collection of alpine bluegrass plants from 235 sites in the eastern slopes of the Rocky Mountains. The seed from this plant has been multiplied and tested through successive generations. AEC Blueridge has been primarily evaluated for seed production, growth, and vigour. Breeder seed was first bulked in 1989 (in the third generation from collected plants).

2.1.2 Varietal Characteristics

AEC Blueridge alpine bluegrass is a perennial bunch-grass which reproduces apomictically, a characteristic common in alpine bluegrass (Müntzing 1954; Müntzing and Müntzing 1971). Plants are generally 15 to 35 cm tall and leaves are mostly basal. Leaf blades are 8 to 12 cm long and 2 to 5 mm wide, ending in a boat-shaped tip. The head is an open panicle, pyramidal in shape. There are five to six florets per spikelet and spikelets have a purplish colour. Glumes are unequal and have short tip awns less than 1 mm long. Lemmas are hairy, especially on the keel and marginal nerves. Lemmas have no awn tips.

2.1.3 Performance

AEC Blueridge alpine bluegrass was compared to Nugget Kentucky bluegrass (*Poa pratensis*) and Reubens Canada bluegrass (*Poa compressa*) in evaluation trials because there are no other varieties of alpine bluegrass. This complicated the evaluation because alpine bluegrass is a bunch-grass whereas Kentucky bluegrass and Canada bluegrass have rhizomatous growth

habits (Hodgson et al. 1971; Jacklin 1976). In trials at mountain sites, AEC Blueridge clearly outperformed both check varieties, producing greater cover and higher seed yields (Table 1). In some cases, AEC Blueridge produced seed when the check varieties produced none. This was due in part to the early maturity of AEC Blueridge. At the mountain sites, it is ripe by late July to early August while seed of Nugget or Reubens may not ripen until late September or early October. At elevations as high as 2400 m AEC Blueridge produced seed heads, although these heads did not always ripen by the beginning of September. AEC Blueridge had seed yields similar to those of both Nugget and Reubens in the first year of seed production at plains locations (Table 2). It produced fewer heads than either check variety and seed size was intermediate between Nugget and Reubens (Tables 2, 3, 4). AEC Blueridge matured approximately 2 wk earlier than Nugget and 3 to 4 wk earlier than Reubens. It also tended to be shorter than the check varieties. In the second year of seed production, AEC Blueridge had seed yields similar to those of Nugget but less than those of Reubens (Table 3). In the third year of seed production (one site only), seed yields were again similar to those of Nugget but much less than those of Reubens (Table 3).

2.1.4 Utilization

AEC Blueridge alpine bluegrass is primarily for use in reclaiming and revegetating disturbed sites in the mountains and foothills of Alberta up to an elevation of approximately 2500 m. Its primary advantage over other varieties of bluegrass is its early maturity. It is capable of growing rapidly and producing mature seed in the short growing seasons found at high elevations. It may also be useful at more northerly locations where the growing season can be very short. When grown at low elevations, AEC Blueridge alpine bluegrass is short-lived (4 to 5 yr).

2.1.5 Seed Distribution

Breeder seed of AEC Blueridge alpine bluegrass will be maintained by the Alberta Environmental Centre, Vegreville, Alberta. Foundation and Certified seed will be multiplied and distributed by Prairie Seeds Ltd., RR # 1, South Edmonton, Alberta, T6H 4N6.

Table 1. Performance of AEC Blueridge alpine bluegrass, Nugget Kentucky bluegrass, and Reubens Canada bluegrass in small plot trials seeded in 1990 at Columbia Icefields (elevation 1860 m, Jasper National Park, Alberta) and Mountain Park (elevation 1800 m, south of Hinton, Alberta) in 1992 to 1994.

Location	Year Harvested	Variety	Percent Cover (%)	Seed Yield (mg m^{-1})	Number of Heads (no. m^{-1})	Plant Height (cm)
Columbia Icefields	1992	AEC Blueridge	81.7	4.6	0.6	21.0
		Nugget	14.2	0.0	0.0	-
		Reubens	60.8	1.2	0.7	21.0
		SE[†]	7.8	3.8	0.3	1.0
Columbia Icefields	1993	AEC Blueridge	17.5	-[‡]	-	-
		Nugget	2.8	-	-	-
		Reubens	14.2	-	-	-
		SE	3.9	-	-	-
Columbia Icefields	1994	AEC Blueridge	45.0	4.3	0.2	20.0
		Nugget	4.2	0.0	0.0	-
		Reubens	20.8	0.5	0.1	17.0
		SE	10.0	5.0	0.2	1.3
Mountain Park	1992	AEC Blueridge	20.0	34.3	2.4	20.8
		Nugget	6.7	5.6	0.2	-
		Reubens	18.3	12.2	5.6	23.8
		SE	2.1	8.5	0.9	1.4
Mountain Park	1993	AEC Blueridge	32.5	33.8	4.1	19.3
		Nugget	12.0	0.0	0.5	14.5
		Reubens	27.5	0.0	3.2	19.6
		SE	2.7	7.7	0.8	1.2
Mountain Park	1994	AEC Blueridge	56.7	174.2	7.6	18.7
		Nugget	10.8	5.8	1.2	13.0
		Reubens	40.8	23.2	3.7	28.0
		SE	9.4	25.3	1.3	1.7
Mean		AEC Blueridge	42.2	50.2	3.0	20.0
		Nugget	8.4	2.3	0.4	13.8
		Reubens	30.4	7.4	2.7	21.9

[†]Standard error based on 45 degrees of freedom.
[‡]No or few seed heads produced in trial.

Table 2. Performance of AEC Blueridge alpine bluegrass, Nugget Kentucky bluegrass, and Reubens Canada bluegrass in the first year of seed production in small plot trials at Vegreville (elevation 640 m), Beaverlodge (elevation 730 m), and Plamondon (elevation 560 m), Alberta.

Location	Year		Variety	Seed Yield (kg ha^{-1})	Number of Heads (no. m^{-1})	Time to Maturity (days[†])	Plant Height (cm)	1000 Seed Weight (mg)
	Seeded	Harvested						
Vegreville	1990	1991	AEC Blueridge	155	231	79	30.5	516
			Nugget	282	431	87	36.0	537
			Reubens	234	560	99	52.5	374
			SE[‡]	29	49	0.4	1.0	13
Vegreville	1991	1992	AEC Blueridge	124	254	85	30.2	561
			Nugget	75	482	96	36.8	696
			Reubens	207	892	103	39.5	498
			SE	28	41	1.0	1.1	32
Vegreville	1992	1993	AEC Blueridge	613	301	82	36.8	465
			Nugget	538	601	98	39.4	578
			Reubens	351	660	115	61.7	226
			SE	54	41	1.6	1.4	11
Beaverlodge	1991	1992	AEC Blueridge	56	196	82	29.3	556
			Nugget	45	101	97	23.8	658
			Reubens	238	420	97	42.2	429
			SE	29	39	1.5	1.1	31
Plamondon	1992	1993	AEC Blueridge	108	125	83	32.9	252
			Nugget	25	68	92	30.2	261
			Reubens	107	361	92	48.3	126
			SE	17	19	0.0	1.5	13
Mean			AEC Blueridge	211	221	82	31.9	470
			Nugget	193	337	94	33.2	546
			Reubens	227	579	101	48.8	331

[†] Days from April 15 to maturity.

[‡] Standard error based on 45 degrees of freedom.

Table 3. Performance of AEC Blueridge alpine bluegrass, Nugget Kentucky bluegrass, and Reubens Canada bluegrass in the second year of seed production in small plot trials at Vegreville (elevation 640 m), Beaverlodge (elevation 730 m), and Plamondon (elevation 560 m), Alberta.

Location	Year		Variety	Seed Yield (kg ha^{-1})	Number of Heads (no. m^{-1})	Time to Maturity (days[†])	Plant Height (cm)	1000 Seed Weight (mg)
	Seeded	Harvested						
Vegreville	1990	1992	AEC Blueridge	17	127	82	34.2	510
			Nugget	18	255	95	35.0	554
			Reubens	228	1820	103	46.2	449
			SE[‡]	19	70	1.3	1.5	33
Vegreville	1991	1993	AEC Blueridge	118	179	75	35.6	580
			Nugget	325	405	96	42.7	584
			Reubens	288	1502	116	69.0	231
			SE	41	42	0.3	1.0	14
Vegreville	1992	1994	AEC Blueridge	60	144	87	37.9	456
			Nugget	69	383	95	47.5	514
			Reubens	55	1060	104	62.0	311
			SE	13	143	2.2	1.7	35
Beaverlodge	1991	1993	AEC Blueridge	242	182	68	32.5	488
			Nugget	152	292	104	36.3	583
			Reubens	166	1146	117	39.6	243
			SE	39	28	0.0	1.3	22
Plamondon	1992	1994	AEC Blueridge	202	484	83	43.0	527
			Nugget	53	530	109	43.9	529
			Reubens	101	785	109	70.6	224
			SE	37	67	0.0	1.9	22
Mean			AEC Blueridge	128	223	79	36.6	512
			Nugget	123	373	100	41.1	553
			Reubens	168	1263	110	57.5	292

[†] Days from April 15 to maturity.
[‡] Standard error based on 45 degrees of freedom.

Table 4. Performance of AEC Blueridge alpine bluegrass, Nugget Kentucky bluegrass, and Reubens Canada bluegrass in the third year of seed production in small plot trials at Vegreville (elevation 640 m), Alberta. Plots were seeded in 1991 and harvested in 1994.

Variety	Seed Yield ($kg\ ha^{-1}$)	Number of Heads ($no.\ m^{-1}$)	Time to Maturity (days[†])	Plant Height (cm)	1000 Seed Weight (mg)
AEC Blueridge	33	181	79	42.3	472
Nugget	7	231	102	44.1	535
Reubens	21	970	104	76.0	276
SE[‡]	14	78	1.4	2.7	16

[†] Days from April 15 to maturity.
[‡] Standard error based on 45 degrees of freedom.

2.2 AEC Glacier Alpine Bluegrass

The Alberta Environmental Centre released AEC Glacier alpine bluegrass, *Poa alpina* L., in 1995 for use in reclamation and revegetation of disturbed sites at high elevations. As the second alpine bluegrass variety released by the Centre, AEC Glacier was released to complement AEC Blueridge alpine bluegrass. AEC Glacier is adapted to high elevations and is capable of rapid growth and seed production in short growing seasons. It also appears to be more drought tolerant than AEC Blueridge.

2.2.1 Origin and Breeding

AEC Glacier was derived from a single plant collected in 1985 from a site (elevation 1880 m) in Phillip's Pass near the Crowsnest Pass in southwestern Alberta. It was part of a collection of alpine bluegrass plants from 235 sites in the eastern slopes of the Rocky Mountains. The seed from this plant was designated as line 1003 and has been multiplied and tested through successive generations. AEC Glacier has been primarily evaluated for seed production at plains sites, and for growth and vigour at mountain locations. Breeder seed was first bulked in 1989 (in the third generation from collected plants).

2.2.2 Varietal Characteristics

AEC Glacier alpine bluegrass is a perennial bunch-grass which reproduces apomictically, a characteristic common in northern biotypes of alpine bluegrass (Müntzing 1954; Müntzing and Müntzing 1971). Plants are generally 15 to 40 cm tall and leaves are mostly basal. Leaf blades are 8 to 12 cm long and 3 to 7 mm wide, ending in a boat-shaped tip. The head is an open panicle, pyramidal in shape. There are five to six florets per spikelet and spikelets have a bronze colour although the glumes may be somewhat purplish. Glumes are unequal and have short tip awns less than 1 mm long. Lemmas have pronounced hyaline margins and are hairy, especially on the keel and marginal nerves. Lemma tips have no awns.

2.2.3 Performance

Nugget Kentucky bluegrass (*Poa pratensis*) and Reubens Canada bluegrass (*Poa compressa*) were used as checks in alpine bluegrass evaluation trials because there were no varieties of alpine bluegrass available for comparison. This complicated the evaluation because

alpine bluegrass is a bunch-grass whereas Kentucky bluegrass and Canada bluegrass have rhizomatous growth habits (Hodgson et al. 1971; Jacklin 1976). In trials at mountain sites, AEC Glacier outperformed the check varieties, producing greater cover and higher seed yields (Table 5). Percent cover values for AEC Glacier were similar to those for AEC Blueridge although AEC Blueridge produced more seed. Like AEC Blueridge, AEC Glacier ripened by late July to early August while seed of Nugget or Reubens did not ripen until late September or early October, when heavy frosts have probably reduced seed viability. At elevations as high as 2400 m AEC Glacier produced seed heads, but these heads ripened by the beginning of September only when the growing seasons were favourable (longer). AEC Glacier had higher seed yields than Nugget, Reubens, or AEC Blueridge in the first year of seed production at plains locations (Table 6). It produced fewer heads than the other varieties but it seemed to be more capable of filling seed heads during the dry conditions encountered in most years at these sites. This is reflected by its high seed weights, second only to the large-seeded Nugget. In the second and third years of seed production, AEC Glacier maintained its seed yield advantage over the other varieties (Tables 7, 8). AEC Glacier matured approximately 1 wk earlier than AEC Blueridge, 3 to 4 wk earlier than Nugget, and 4 to 5 wk earlier than Reubens. It tended to be shorter than Nugget and Reubens but was similar to AEC Blueridge in height.

2.2.4 Utilization

AEC Glacier alpine bluegrass is primarily for use in reclaiming and revegetating disturbed sites in the mountains and foothills of Alberta up to an elevation of approximately 2400 m. Its primary advantage over other bluegrass species is its early maturity. It is capable of growing rapidly and producing mature seed in the short growing seasons found at high elevations. AEC Glacier appeared to have more drought tolerance than AEC Blueridge, producing greater seed yields under dry conditions. When grown at low elevations, AEC Glacier alpine bluegrass is short-lived (4 to 5 yr).

2.2.5 Seed Distribution

Breeder seed of AEC Glacier will be maintained by the Alberta Environmental Centre, Vegreville, Alberta. The multiplication and distribution of Foundation and Certified seed will be handled by Prairie Seeds Ltd., RR # 1, South Edmonton, Alberta, T6H 4N6.

Table 5. Performance of AEC Glacier alpine bluegrass, AEC Blueridge alpine bluegrass, Nugget Kentucky bluegrass, and Reubens Canada bluegrass in small plot trials seeded in 1990 at Columbia Icefields (elevation 1860 m, Jasper National Park, Alberta) and Mountain Park (elevation 1800 m, south of Hinton, Alberta).

Location	Year Harvested	Variety	Percent Cover (%)	Seed Yield (mg m^{-1})	Number of Heads (no. m^{-1})	Plant Height (cm)
Columbia Icefields	1992	AEC Glacier	84.2	5.9	0.6	20.0
		AEC Blueridge	81.7	4.6	0.6	21.0
		Nugget	14.2	0.0	0.0	-
		Reubens	60.8	1.2	0.7	21.0
		SE[†]	7.8	3.8	0.3	1.0
Columbia Icefields	1993	AEC Glacier	17.5	-[‡]	-	-
		AEC Blueridge	17.5	-	-	-
		Nugget	2.8	-	-	-
		Reubens	14.2	-	-	-
		SE	3.9	-	-	-
Columbia Icefields	1994	AEC Glacier	53.3	0.0	0.0	-
		AEC Blueridge	45.0	4.3	0.2	20.0
		Nugget	4.2	0.0	0.0	-
		Reubens	20.8	0.5	0.1	17.0
		SE	10.0	5.0	0.2	1.3
Mountain Park	1992	AEC Glacier	18.3	10.8	0.6	19.3
		AEC Blueridge	20.0	34.3	2.4	20.8
		Nugget	6.7	5.6	0.2	-
		Reubens	18.3	12.2	5.6	23.8
		SE	2.1	8.5	0.9	1.4
Mountain Park	1993	AEC Glacier	24.2	3.7	0.4	15.3
		AEC Blueridge	32.5	33.8	4.1	19.3
		Nugget	12.0	0.0	0.5	14.5
		Reubens	27.5	0.0	3.2	19.6
		SE	2.7	7.7	0.8	1.2
Mountain Park	1994	AEC Glacier	50.8	74.0	4.5	18.2
		AEC Blueridge	56.7	174.2	7.6	18.7
		Nugget	10.8	5.8	1.2	13.0
		Reubens	40.8	23.2	3.7	28.0
		SE	9.4	25.3	1.3	1.7
Mean		AEC Glacier	41.4	18.9	1.2	18.2
		AEC Blueridge	42.2	50.2	3.0	20.0
		Nugget	8.4	2.3	0.4	13.8
		Reubens	30.4	7.4	2.7	21.9

[†]Standard error based on 45 degrees of freedom.
[‡]No or few seed heads produced in trial.

Table 6. Performance of AEC Glacier alpine bluegrass, AEC Blueridge alpine bluegrass, Nugget Kentucky bluegrass, and Reubens Canada bluegrass in the first year of seed production in small plot trials at Vegreville (elevation 640 m), Beaverlodge (elevation 730 m), and Plamondon (elevation 560 m), Alberta.

Location	Year		Variety	Seed Yield (kg ha^{-1})	Number of Heads (no. m^{-1})	Time to Maturity (days[†])	Plant Height (cm)	1000 Seed Weight (mg)
	Seeded	Harvested						
Vegreville	1990	1991	AEC Glacier	108	84	78	30.2	536
			AEC Blueridge	155	231	79	30.5	516
			Nugget	282	431	87	36.0	537
			Reubens	234	560	99	52.5	374
			SE[‡]	29	49	0.4	1.0	13
Vegreville	1991	1992	AEC Glacier	393	179	74	34.6	548
			AEC Blueridge	124	254	85	30.2	561
			Nugget	75	482	96	36.8	696
			Reubens	207	892	103	39.5	498
			SE	28	41	1.0	1.1	32
Vegreville	1992	1993	AEC Glacier	1072	346	71	37.7	531
			AEC Blueridge	613	301	82	36.8	465
			Nugget	538	601	98	39.4	578
			Reubens	351	660	115	61.7	226
			SE	54	41	1.6	1.4	11
Beaverlodge	1991	1992	AEC Glacier	87	154	75	27.6	578
			AEC Blueridge	56	196	82	29.3	556
			Nugget	45	101	97	23.8	658
			Reubens	238	420	97	42.2	429
			SE	29	39	1.5	1.1	31
Plamondon	1992	1993	AEC Glacier	142	72	76	33.8	263
			AEC Blueridge	108	125	83	32.9	252
			Nugget	25	68	92	30.2	261
			Reubens	107	361	92	48.3	126
			SE	17	19	0.0	1.5	13
Mean			AEC Glacier	360	167	75	32.8	491
			AEC Blueridge	211	221	82	31.9	470
			Nugget	193	337	94	33.2	546
			Reubens	227	579	101	48.8	331

[†] Days from April 15 to maturity.

[‡] Standard error based on 45 degrees of freedom.

Table 7. Performance of AEC Glacier alpine bluegrass, AEC Blueridge alpine bluegrass, Nugget Kentucky bluegrass, and Reubens Canada bluegrass in the second year of seed production in small plot trials at Vegreville (elevation 640 m), Beaverlodge (elevation 730 m), and Plamondon (elevation 560 m).

Location	Year		Variety	Seed Yield (kg ha^{-1})	Number of Heads (no. m^{-1})	Time to Maturity (days†)	Plant Height (cm)	1000 Seed Weight (mg)
	Seeded	Harvested						
Vegreville	1990	1992	AEC Glacier	75	171	73	37.5	553
			AEC Blueridge	17	127	82	34.2	510
			Nugget	18	255	95	35.0	554
			Reubens	228	1820	103	46.2	449
			SE‡	19	70	1.3	1.5	33
Vegreville	1991	1993	AEC Glacier	298	157	72	40.1	615
			AEC Blueridge	118	179	75	35.6	580
			Nugget	325	405	96	42.7	584
			Reubens	288	1502	116	69.0	231
			SE	41	42	0.3	1.0	14
Vegreville	1992	1994	AEC Glacier	102	152	73	36.5	533
			AEC Blueridge	60	144	87	37.9	456
			Nugget	69	383	95	47.5	514
			Reubens	55	1060	104	62.0	311
			SE	13	143	2.2	1.7	35
Beaverlodge	1991	1993	AEC Glacier	338	132	68	31.6	499
			AEC Blueridge	242	182	68	32.5	488
			Nugget	152	292	104	36.3	583
			Reubens	166	1146	117	39.6	243
			SE	39	28	0.0	1.3	22
Plamondon	1992	1994	AEC Glacier	396	340	76	43.3	584
			AEC Blueridge	202	484	83	43.0	527
			Nugget	53	530	109	43.9	529
			Reubens	101	785	109	70.6	224
			SE	37	67	0.0	1.9	22
Mean			AEC Glacier	242	190	72	37.8	557
			AEC Blueridge	128	223	79	36.6	512
			Nugget	123	373	100	41.1	553
			Reubens	168	1263	110	57.5	292

† Days from April 15 to maturity.

‡ Standard error based on 45 degrees of freedom.

Table 8. Performance of AEC Glacier alpine bluegrass, AEC Blueridge alpine bluegrass, Nugget Kentucky bluegrass, and Reubens Canada bluegrass in the third year of seed production in small plot trials at Vegreville (elevation 640 m), Alberta. Plots were seeded in 1991 and harvested in 1994.

Variety	Seed Yield ($kg\ ha^{-1}$)	Number of Heads ($no.\ m^{-1}$)	Time to Maturity (days[†])	Plant Height (cm)	1000 Seed Weight (mg)
AEC Glacier	147	215	70	42.4	502
AEC Blueridge	33	181	79	42.3	472
Nugget	7	231	102	44.1	535
Reubens	21	970	104	76.0	276
SE[‡]	14	78	1.4	2.7	16

[†] Days from April 15 to maturity.
[‡] Standard error based on 45 degrees of freedom.

3 DEVELOPMENT OF VARIETIES

3.1 Collection of Plant Material and Initial Selection

Systematic collections of plants of alpine bluegrass were made in 1984 and 1985. These collections were part of a germplasm collection of four species; plants of slender wheatgrass, spike trisetum, and Rocky Mountain fescue were also collected at the same time. A total of 317 collection sites were used and alpine bluegrass plants were found at 235 of these sites. Collection sites were located in the eastern slopes of the Rocky Mountains from the United States border in the south to Jasper townsite, Jasper National Park, in the north (Fig. 1). Alpine bluegrass collection sites varied in elevation from 900 m to 2770 m. These elevational and latitudinal gradients were used to maximize genetic diversity within the germplasm collection. Most plants were collected from disturbed or poorly vegetated sites. At each site, approximately 10 plants of each species were collected. Plants were dug up with roots and attached soil, bagged, and stored on ice during transportation to Vegreville. Plants were kept in transit for a maximum of three days.

Collected plants were transplanted into pots and nurtured for two weeks in growth chambers with day/night temperatures of 22/15°C. Plants were then hardened in sheltered outdoor conditions before being transplanted into a field nursery. A total of 2551 plants of alpine bluegrass were transferred to a field nursery with over 98% transplantation success. Initially, 446 plants of alpine bluegrass were selected from the field nursery. Of these, approximately 133 plants produced sufficient seed when grown in growth chambers for evaluation in progeny tests established in 1985 and 1986. Observations including general vigour, disease resistance, winter survival, height, tiller number, seed yield, and time to maturity were taken on all progeny rows. Based on the results of these trials, 15 lines of alpine bluegrass were selected for further evaluation in provenance trials. Because alpine bluegrass reproduces by apomixis (Müntzing 1954; Müntzing and Müntzing 1971), a pedigree selection method was used in the development of plant varieties of this species. Therefore, each line was derived from the seed of a single collected plant and maintained separately through successive generations.

3.2 Provenance Trials

3.2.1 Materials and Methods

Provenance trials were established to evaluate 15 selected alpine bluegrass lines at three mountain locations and at Vegreville. Two agronomic varieties, Reubens Canada bluegrass (*Poa compressa* L.), and Nugget Kentucky bluegrass (*P. pratensis* L.), were included for comparison.

Trials were established at Vegreville (elevation 640 m), Columbia Icefields (Jasper National Park, elevation 1860 m), Lookout Mountain (Sunshine Village in Banff National Park, elevation 2400 m), and Mountain Park (south of Hinton, elevation 1800 m) (Fig. 1). The site at Columbia Icefields was located on an abandoned gravel pit area, approximately 2 km north of the Athabasca Glacier. At Lookout Mountain, the trials were situated on a ski slope, and the site at Mountain Park was located on an abandoned coal tailings pile. At all three mountain sites, there was little or no topsoil present.

Both direct seeding and transplanting were used to establish these trials. At Vegreville, seeded provenance trials were established in 1987 (S1) and 1989 (S2) and the transplanted trial was established in 1987. At Columbia Icefields, one seeded trial was established in 1987 and two transplanted trials were established in 1988 (T1) and 1989 (T2). A second trial seeded in 1988 did not emerge or survive well and was later discarded. At Lookout Mountain, trials were seeded in 1987 (S1) and 1988 (S2) and the transplanted trial was established in 1987. The site at Mountain Park included only one transplanted provenance trial, established in 1989.

All seeded plots consisted of single 2 m rows, seeded by hand at the mountain sites in late June or July and with a small plot seeder at Vegreville in late May or June. Seeded provenance trials were replicated four times except for the trial at Columbia Icefields which had only three replicates. For transplanted trials, plants were seeded into root-trainers in the greenhouse in February or March, and hardened in sheltered outdoor conditions prior to transplanting into field trials in late June or early July. At Vegreville and Lookout Mountain, 20 plants per plot were used for each trial. At Columbia Icefields (T1) and Mountain Park, four plants per plot were used and in trial T2 at Columbia Icefields, each plot consisted of only three plants due to limited availability of plants. Five replicates were used in each transplanted provenance trial, except for T2 at Columbia Icefields which had only four replicates. All provenance trials were arranged in randomized complete block designs.

Data collected from these trials included: winter survival, plant height, plant width, flag leaf length, flowering date, number of heads produced, maturity date, seed yield, and above-ground biomass. However, not all of these data were collected in every year at every site due to time limitations and limitations imposed by the climate at the mountain sites. For example, biomass was not taken in every year to avoid killing the plants by depleting root reserves. Analyses of variance of all data were conducted for each site in each year and for combined analyses over years using the general linear models (GLM) procedure of the SAS statistical package (SAS Institute, Inc. 1990). Mean separation was accomplished using Duncan's new multiple range test.

3.2.2 Results and Discussion

At mountain sites, plant establishment was generally better in transplanted trials than in seeded trials due to poor soil conditions. Soil analyses showed that there was no available nitrogen in the soil at Columbia Icefields and little nitrogen in soil at Mountain Park. There was no available phosphorous at either site. Soil analyses also showed that there was 56 to 98 kg available potassium ha^{-1} at Mountain Park, and 14 to 24 kg ha^{-1} at Columbia Icefields. In spite of these low nutrient levels, the native grasses thrived in most trials at the mountain sites.

In transplanted provenance trial 1 at Columbia Icefields, plants survived well and in 1994, most plots still consisted of four plants. The largest mean number of heads was produced in 1989 but the highest mean seed yield was produced in 1994 (Table 9). Lines 752, 1760 (AEC Blueridge), and 1588 produced the most seed per plant. Line 1760 also produced the most above-ground biomass. Plant height and width were similar for all alpine bluegrass lines. Nugget Kentucky bluegrass was the shortest and both Nugget and Reubens Canada bluegrass produced the widest plants, due to their rhizomatous growth habit. In the second transplanted provenance trial at Columbia Icefields, the most heads and highest seed yields were observed in 1990 (Table 10). The top three lines for seed yield were 745, 752 and 1588. Line 1760 was not planted in this trial due to a shortage of plants when the trial was established. Lines 745 and 752 also produced the most heads per plant. Once again, Nugget produced very short plants and Reubens had the widest plants. There was little variation in flag leaf length in either transplanted trial at Columbia Icefields (Tables 9, 10).

The transplanted provenance trial at Mountain Park appeared to be more variable from year to year than the trials at Columbia Icefields. Very little seed was produced in 1991 and 1993 although seed yields in 1990, 1992, and 1994 (Table 11) were comparable to those of the first transplanted provenance trial at Columbia Icefields (Table 9). Reubens Canada bluegrass and lines 745 and 1214 produced the most heads but heads produced on plants of Reubens were very small so it had only the fourth highest seed yield (Table 11). The highest mean seed yields per plant were produced by lines 1245, 1214, and 1003 (AEC Glacier). Reubens had the most above-ground biomass, partially due to the advantage gained by its rhizomatous growth habit. Lines 1214, 1229, and 1003 also had high biomass values. Nugget had the shortest plants and Reubens had the widest plants.

At Lookout Mountain, alpine bluegrass flowered but seed was still green when we visited the site to collect data in early September each year. Therefore, no seed yield data were obtained for this site. The most heads were produced in 1990 with lines 752, 745, and 864 producing the most heads per plant (Table 12). Above-ground biomass was highest in 1989 and lowest in 1993. It is uncertain whether this reflects a trend in declining plant productivity or was due to changing weather conditions. There was little variation among lines for plant height, width, or flag leaf length.

In the seeded provenance trial at Columbia Icefields, the most seed and heads were produced in 1990 (Table 13). Lines 745 and 752 had the highest number of heads. However, there were no significant differences in seed yield even though line 1267 had almost twice as much seed as the second best line (line 752). This was due to high variability from year to year. Percent cover remained fairly consistent over time with Reubens and Nugget giving the best cover values although there were no significant differences. Reubens and Nugget also produced the widest plants. Flag leaf length was similar for all lines and the check varieties. At Lookout Mountain, lines in the seeded provenance trials were evaluated for percent cover, number of heads, and plant height (Table 14). Due to high variability at this site, there were no significant differences among lines for any of the observed data. The best plant cover was observed in 1991 and line 1001 had the highest mean cover in both trials. The most heads were produced in 1993.

At Vegreville, Reubens and lines 1003 (AEC Glacier) and 1760 (AEC Blueridge) produced the most seed in the transplanted provenance trial (Table 15). Seed yield was similar in both years of this trial. Reubens also produced the most seed heads, followed by lines 752

and 745. Above-ground plant biomass was greatest for lines 1448, 1760, and 1588. Plant height and width were similar for all lines although Reubens had the tallest and widest plants. Alpine bluegrass lines ranged in maturity from 67 days after April 15 for lines 864 and 907 to 85 days for line 752. Reubens and Nugget matured last (87 days). Line 1267 had the heaviest seeds and line 1245 had the lightest seeds.

In the first seeded provenance trial at Vegreville, number of heads and seed yield decreased from the first to the second year of seed production (Table 16). However, these data remained fairly constant in the second trial. Mean number of heads and seed yield were highest for Reubens, followed by line 745 and Nugget. However, differences in seed yield among lines were not significant. The most above-ground biomass was produced by Reubens and lines 1588 and 1760. Time to maturity was similar to that observed in the transplanted provenance trial, with line 864 maturing first (67 days) and Nugget and Reubens maturing last (87 and 92 days, respectively). Nugget produced the heaviest seeds while Reubens had the lightest seeds.

Overall, it was difficult to pick out lines that clearly outperformed all others at all sites. Line 1760, later released as AEC Blueridge, did well at Columbia Icefields, but because of a shortage of plants, it was not evaluated at Mountain Park. Lines 1760 and 1003 (released as AEC Glacier) also performed well in provenance trials at Vegreville. Based on performance in these trials, five single lines, lines 907, 1003, 1448, 1588, and 1760, were chosen for further evaluation in multilocation trials. Other lines were also included as part of three line mixes.

Fig. 1. Collection area and locations used to test selected lines of alpine bluegrass.

Table 9. Performance of selected alpine bluegrass lines in Transplanted Provenance Trial 1 (established in 1988) at Columbia Icefields in 1989 to 1994.

	Number of Heads		Seed Yield		Above-ground Biomass		Plant Height		Plant Width		Flag Leaf Length	
	No. plant^{-1}	rank	mg plant^{-1}	rank	mg plant^{-1}	rank	cm	rank	cm	rank	cm	rank
YEAR (n=85):												
1989	8.4A[†]	1	-	-	-	-	9.5D	6	6.4D	5	1.6A	2
1990	2.8B	2	24B	3	714A	1	22.7A	1	8.1B	2	1.6A	1
1991	1.7D	6	7C	5	435B	2	21.7AB	3	5.0E	6	0.9B	3
1992	2.5BC	4	40A	2	-	-	20.7B	4	7.2C	3	-	-
1993	1.9CD	5	17B	4	-	-	22.1A	2	6.4D	4	-	-
1994	2.7B	3	42A	1	-	-	17.9C	5	10.2A	1	-	-
LINE:												
745	6.1b	4	40bc	4	464def	9	14.3f	15	5.8ef	14	1.3bcdef	8
752	10.2a	1	68ab	1	899abc	3	16.4def	13	8.0bc	4	1.6bc	3
864	1.3de	13	8de	14	260f	15	18.9bcd	8	6.0def	10	1.4bcde	5
907	1.8cde	8	17cde	9	322f	13	19.0bcd	7	6.1def	9	0.8ef	14
1001	0.7e	15	14de	12	382ef	10	20.8abc	6	6.0def	13	0.8f	15
1003	0.5e	16	5de	16	322f	13	15.1ef	14	5.3f	16	0.9def	13
1079	1.5de	12	16cde	10	615bcdef	7	18.2cde	10	7.4bcde	6	1.2bcdef	9
1207	1.2de	14	6de	15	292f	14	16.5ef	12	5.7f	15	1.0def	11
1214	1.7cde	9	13de	13	344f	12	18.0cde	11	6.0def	11	1.1cdef	10
1229	2.5cde	7	29cd	5	568cdef	8	22.3a	3	6.7cdef	7	1.5bcd	4
1245	1.6de	10	15de	11	380ef	11	21.6ab	4	6.0def	12	1.4bcde	6
1267	1.6de	11	22cde	7	662bcdef	6	18.9bcd	9	7.6bcd	5	0.9def	12
1588	3.1cd	6	60ab	3	777abcde	5	21.1abc	5	6.7cdef	8	1.6bc	3
1760	3.8c	6	61ab	2	1102a	1	22.6a	2	8.5b	3	1.7b	2
Reubens	6.5b	3	28cde	6	974ab	2	23.8a	1	11.9a	2	2.5a	1
Nugget	7.7b	2	18cde	8	832abcd	4	11.1g	16	11.9a	1	1.3bcdef	4
n	30		25		10		30		30		15	

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 10. Performance of selected alpine bluegrass lines in Transplanted Provenance Trial 2 (established in 1989) at Columbia Icefields in 1990 to 1994.

	Number of Heads		Seed Yield		Plant Height		Plant Width		Flag Leaf Length	
	No. plant^{-1}	rank	mg plant^{-1}	rank	cm	rank	cm	rank	cm	rank
YEAR (n=64):										
1990	1.5A[†]	1	10.2A	1	19.3A	1	3.9B	2	1.0A	1
1991	0.7B	2	2.9B	2	16.0B	3	2.8C	5	1.1A	2
1992	0.6B	3	2.4B	3	13.1C	4	3.6B	4	-	-
1993	0.3C	5	1.5B	5	18.6A	2	3.6B	3	-	-
1994	0.3C	4	2.1B	4	10.1D	5	5.2A	1	-	-
LINE:										
745	2.0a	1	8.6a	1	12.4e	13	3.3c	12	0.8bc	7
752	1.4ab	2	7.9ab	2	11.3e	14	3.3c	11	0.8bc	6
864	0.9bc	4	1.8c	12	13.3de	12	3.2c	13	0.5c	8
907	0.5bc	8	4.1abc	8	14.8cde	11	3.2c	13	1.4b	2
1001	0.2c	14	1.6c	13	19.1abcd	6	3.6c	5	0.8bc	7
1003	0.6bc	7	4.1abc	7	19.5abc	5	3.5c	7	1.1bc	3
1079	0.2c	12	2.7bc	9	19.8abc	4	3.2c	13	1.0bc	4
1207	0.5bc	9	2.1c	11	16.4bcde	10	3.3c	9	0.8bc	7
1214	0.7bc	6	4.5abc	6	16.8bcde	9	3.6c	5	0.8bc	7
1229	0.0c	15	0.0c	16	-	-	3.4c	8	-	-
1245	0.2c	13	1.4c	14	18.6abcd	7	3.3c	10	0.9bc	5
1267	0.2c	11	4.5abc	5	23.2a	1	3.5c	6	1.0bc	4
1448	0.5bc	10	2.5bc	10	20.0abc	3	4.0bc	4	1.0bc	4
1588	0.8bc	5	5.5abc	3	18.4abcd	8	4.1bc	3	0.8bc	7
Reubens	1.4ab	3	5.0abc	4	21.8ab	2	8.5a	1	2.6a	1
Nugget	0.2c	11	0.3c	15	6.0f	15	4.6b	2	1.0bc	4
n	20		20		20		20		8	

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 11. Performance of selected alpine bluegrass lines in transplanted provenance trial (established in 1989) at Mountain Park in 1990 to 1994.

	Number of Heads		Seed Yield		Above-ground Biomass		Plant Height		Plant Width		Flag Leaf Length	
	No. plant^{-1}	rank	mg plant^{-1}	rank	mg plant^{-1}	rank	cm	rank	cm	rank	cm	rank
YEAR (n=80):												
1990	2.4A[†]	1	21A	2	438A	1	19.9A	1	5.7B	3	1.4A	1
1991	1.2C	3	4B	5	252B	2	15.4C	4	3.3C	5	1.1B	2
1992	2.0B	2	21A	3	-	-	18.1B	2	5.2B	4	-	-
1993	0.7D	4	7B	4	-	-	16.1C	3	6.9A	1	-	-
1994	0.7D	5	22A	1	-	-	16.1C	3	6.8A	2	-	-
LINE (n=30):												
745	2.7b	2	20a	5	320bc	9	13.7gh	14	3.4c	15	1.2bc	5
752	2.4bc	4	14a	7	248c	13	13.0hi	15	3.2c	16	1.0bc	8
864	0.6ef	11	3a	16	285c	10	16.1efg	12	3.5c	14	1.0bc	8
907	0.5ef	13	8a	11	263c	12	15.0fgh	13	3.7c	13	1.0bc	8
1001	0.5ef	14	3a	15	322bc	8	17.3def	10	3.9c	12	0.9c	10
1003	0.9def	9	29a	3	441b	4	20.4abc	3	4.8c	4	1.2bc	5
1079	0.4ef	15	8a	10	351bc	6	17.3def	11	4.5c	7	1.1bc	7
1207	1.9bcd	5	16a	6	360bc	5	17.9cdef	8	4.0c	11	1.1bc	6
1214	2.6b	3	33a	2	456b	2	18.1cde	7	4.5c	6	1.1bc	6
1229	0.5ef	12	7a	12	447b	3	19.7abcd	4	4.0c	10	0.9bc	9
1245	1.6bcdef	7	38a	1	240c	14	19.2bcd	5	4.8c	3	1.3bc	3
1267	0.3f	16	5a	13	281c	11	17.7cdef	9	4.6c	5	1.0bc	8
1448	0.6ef	10	4a	14	222c	16	19.1bcd	6	4.4c	9	1.5b	2
1588	1.2cdef	8	14a	8	338bc	7	21.6ab	2	4.5c	8	1.3bc	3
Reubens	4.0a	1	22a	4	699a	1	22.5a	1	17.3a	1	2.6a	1
Nugget	1.7bcde	6	13a	9	239c	15	10.5i	16	13.7b	2	1.2bc	4
n	25		25		10		25		25		10	

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 12. Performance of selected alpine bluegrass lines in transplanted provenance trial (established in 1987) at Sunshine Village in 1989 to 1993.

	Number of Heads		Above-ground Biomass		Plant Height		Plant Width		Flag Leaf Length	
	No. plant^{-1}	rank	mg plant^{-1}	rank	cm	rank	cm	rank	cm	rank
YEAR (n=85):										
1989	1.7B[†]	2	374A	1	12.2A	1	-	-	1.9A	1
1990	2.2A	1	221B	2	8.8BC	3	5.3A	1	1.3B	2
1991	0.8C	4	-	-	8.5C	4	-	-	-	-
1993	0.9C	3	108C	3	9.6B	2	4.6B	2	-	-
LINE:										
745	2.9a	2	223a	9	6.4e	16	5.0a	7	1.6cdefg	8
752	3.3a	1	232a	8	6.7de	15	4.4a	13	2.1bc	3
864	1.8b	3	265a	3	11.8ab	3	4.7a	10	1.1efg	14
907	0.6bc	16	161a	16	9.6bc	9	4.2a	16	0.9fg	16
1001	1.0bc	12	297a	2	10.2abc	7	4.8a	9	1.6cdefg	9
1003	0.8bc	15	238a	7	7.9cde	13	4.5a	13	1.2defg	13
1079	1.0bc	13	252a	5	9.6bc	10	6.0a	1	1.1efg	15
1207	1.1bc	11	188a	14	8.0cde	12	5.0a	8	1.8cdef	6
1214	1.2bc	7	223a	10	7.8cde	14	5.6a	3	1.3cdefg	10
1229	1.1bc	10	210a	12	12.2ab	2	4.2a	15	1.2cdefg	12
1245	1.2bc	9	220a	11	10.1abc	8	4.4a	14	1.3cdefg	11
1267	0.6c	17	204a	13	9.4bcd	11	4.6a	11	0.8g	17
1448	1.6bc	4	308a	1	12.9a	1	5.6a	4	2.9a	1
1588	1.4bc	6	244a	6	11.3ab	5	5.2a	6	1.8cde	5
1760	1.6bc	5	257a	4	11.7ab	4	5.5a	5	2.8ab	2
Reubens	1.2bc	8	165a	15	10.2abc	7	4.5a	12	1.7cdefg	7
Nugget	1.0bc	14	157a	17	10.3abc	6	5.9a	2	2.0bcd	4
n	20		15		20		10		10	

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 13. Performance of selected alpine bluegrass lines in seeded provenance trial (established in 1987) at Columbia Icefields in 1989 to 1994.

	Number of Heads		Seed Yield		Cover		Plant Height		Plant Width		Flag Leaf Length	
	No. m^{-1}	rank	mg m^{-1}	rank	%	rank	cm	rank	cm	rank	cm	rank
YEAR (n=51):												
1989	5.0BC[†]	4	-	-	19C	6	4.8C	6	-	-	-	-
1990	16.0A	1	131A	1	24BC	4	19.9A	1	4.7AB	2	1.4A	1
1991	6.0B	3	14B	4	25B	2	18.2A	3	3.0D	5	1.2A	2
1992	6.5B	2	19B	3	22BC	5	14.4B	4	4.0BC	3	-	-
1993	1.1C	6	6B	5	32A	1	18.2A	2	3.5CD	4	-	-
1994	1.3C	5	20B	2	24B	3	14.4B	5	5.2A	1	-	-
LINE:												
745	12.5a	1	39a	5	20a	11	9.9ef	16	4.0bcd	8	1.2a	6
752	11.5ab	2	70a	2	16a	13	10.4ef	14	3.8bcd	9	1.0a	8
864	3.3cde	13	24a	14	14a	14	13.2de	13	3.2bcd	12	1.6a	3
907	6.1abcde	7	36a	6	19a	12	14.2cd	12	3.0bcd	13	1.4a	4
1001	6.7abcde	5	23a	15	35a	5	15.3bcd	11	4.1bcd	6	1.6a	2
1003	1.9de	15	33a	9	22a	9	16.6abcd	8	3.3bcd	11	1.1a	7
1079	1.6de	16	24a	13	6a	16	16.1abcd	10	2.0d	17	1.0a	8
1207	3.6cde	12	31a	10	11a	15	18.8ab	5	2.7cd	15	1.0a	8
1214	5.5abcde	9	28a	11	22a	10	17.4abc	6	4.0bcd	7	1.0a	8
1229	5.4abcde	10	7a	16	27a	7	18.9ab	4	2.1d	16	1.0a	8
1245	0.8e	17	6a	17	5a	17	9.0f	17	2.9cd	14	1.4a	4
1267	6.4abcde	6	135a	1	36a	4	16.2abcd	9	4.6bcd	4	1.3a	5
1448	5.8abcde	8	56a	4	25a	8	19.7a	1	4.4bcd	5	0.9a	9
1588	9.2abc	3	62a	3	40a	3	17.2abc	7	5.1abc	3	1.1a	7
1760	4.7bcde	11	35a	7	27a	6	19.1ab	3	3.8bcd	10	1.2a	6
Reubens	8.8abcd	4	34a	8	41a	2	19.4a	2	5.7ab	2	2.7a	1
Nugget	2.7cde	14	27a	12	46a	1	10.0ef	15	7.4a	1	1.2a	6
n	18		15		18		18		15		6	

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 14. Performance of selected alpine bluegrass lines in seeded provenance trials (established in 1987 and 1988) at Sunshine Village in 1989 to 1993.

	Trial 1						Trial 2					
	Cover		Number of Heads		Plant Height		Cover		Number of Heads		Plant Height	
	%	rank	no. m^{-1}	rank	cm	rank	%	rank	no. m^{-1}	rank	cm	rank
YEAR (n=68):												
1989	21B[†]	3	-	-	-	-	10D	4	-	-	-	-
1990	12C	4	-	-	-	-	17C	3	-	-	-	-
1991	64A	1	0.2B	2	-	-	39A	1	0.1B	2	-	-
1993[‡]	24B	2	3.0A	1	10.2	-	21B	2	1.3A	1	9.2	-
LINE:												
745	29a	11	2.1a	5	12.7a	2	20a	11	1.4a	3	7.0a	12
752	29a	11	0.5a	14	7.5a	14	26a	4	0.4a	10	14.5a	1
864	26a	13	3.0a	2	8.5a	10	16a	17	0.2a	11	9.0a	8
907	35a	4	1.8a	8	8.0a	12	17a	14	0.9a	6	6.0a	14
1001	40a	1	2.2a	3	9.5a	7	36a	1	1.0a	5	9.5a	6
1003	35a	3	0.8a	13	10.0a	6	24a	5	1.6a	1	8.2a	9
1079	33a	7	1.8a	7	12.4a	3	16a	16	0.2a	12	7.5a	11
1207	33a	6	1.9a	6	11.8a	5	21a	9	0.2a	12	10.8a	4
1214	19a	15	0.9a	12	11.8a	5	17a	15	0.8a	7	11.2a	3
1229	29a	10	1.7a	9	11.9a	4	23a	7	0.6a	8	9.3a	7
1245	27a	12	1.0a	11	13.0a	1	26a	3	1.0a	5	10.0a	5
1267	38a	2	0.4a	15	13.0a	1	18a	12	1.4a	2	7.8a	10
1448	30a	9	0.1a	16	9.0a	9	27a	2	0.6a	9	13.5a	2
1588	32a	8	2.2a	4	8.2a	11	24a	6	0.0a	13	-	-
1760	33a	5	2.2a	3	9.2a	8	17a	13	1.1a	4	6.2a	13
Reubens	20a	14	1.5a	10	9.5a	7	22a	8	0.0a	13	-	-
Nugget	26a	13	3.2a	1	7.8a	13	21a	10	0.0a	13	-	-
n	16		8		4		16		8		4	

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).
[‡]No data were collected in 1992 due to an early snowfall at the site.

Table 15. Performance of selected alpine bluegrass lines in the transplanted provenance trial (established in 1987) at Vegreville in 1988 and 1989.

	Number of Heads		Seed Yield		Above-ground Biomass		Plant Height		Plant Width		Time to Maturity		1000 Seed Weight	
	no. plant^{-1}	rank	g plant^{-1}	rank	g plant^{-1}	rank	cm	rank	cm	rank	days[†]	rank	mg	rank
YEAR (n=85):														
1988	52A[‡]	2	2.9A	1	39.7	-	-	-	-	-	73B	1	426B	2
1989	53A	1	2.4A	2	-	-	28.5	-	19.3	-	81A	2	473A	1
LINE:														
745	101bc	3	2.5a	10	24.2ef	16	19.7c	17	19.5abcde	7	84ab	14	418cde	11
752	121b	2	2.0a	12	22.1f	17	26.8bc	10	16.2cde	13	85a	15	426cde	9
864	38de	11	2.0a	13	43.4bcd	5	26.2bc	12	20.3abcd	6	67g	2	415de	13
907	35de	12	2.5a	11	27.6def	15	29.4ab	6	15.5de	14	67g	1	411de	15
1001	26e	15	3.5a	4	35.7cdef	12	28.4ab	9	17.6bcde	9	75de	8	483abc	5
1003	40de	8	3.9a	2	36.7bcdef	11	30.2ab	5	17.2cde	11	73def	7	510ab	4
1079	29de	14	3.2a	7	39.4bcde	7	31.8ab	2	18.4bcde	8	71efg	5	517a	3
1207	39de	9	1.7a	15	33.1cdef	14	26.8bc	10	20.4abcd	5	76cd	10	440cde	7
1214	38de	10	1.9a	14	34.6cdef	13	28.4ab	9	21.8abc	3	75de	9	415de	12
1229	18e	17	1.3a	16	41.4bcd	6	23.8bc	14	17.3cde	10	70fg	3	408de	16
1245	18e	16	0.3a	17	38.0bcdef	9	26.7bc	11	16.3cde	12	72def	6	380e	17
1267	32de	13	3.3a	6	37.6bcdef	10	29.0ab	7	14.0e	15	71efg	4	537a	1
1448	44de	7	3.1a	8	68.7a	1	31.6ab	3	21.8abc	3	81b	12	420cde	10
1588	62cde	5	3.4a	5	49.7bc	3	28.8ab	8	21.0abcd	4	81b	13	413de	14
1760	56cde	6	3.9a	3	52.7b	2	31.0ab	4	23.2ab	2	80bc	11	453bcd	6
Reubens	206a	1	4.8a	1	46.0bc	4	36.2a	1	24.8a	1	87a	17	426cde	8
Nugget	77cd	4	2.8a	5	38.5bcdef	8	25.5bc	13	19.5abcde	7	87a	16	531a	2
n	10		10		5		5		5		10		10	

[†]Days from April 15 to maturity.

[‡]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$)

Table 16. Performance of selected alpine bluegrass lines in seeded provenance trials at Vegreville in 1988 to 1991.

	Number of Heads		Seed Yield		Above-ground Biomass		Plant Height		Time to Maturity		1000 Seed Weight		Flag Leaf Length	
	no. m^{-1}	rank	g m^{-1}	rank	g m^{-1}	rank	cm	rank	days[†]	rank	mg	rank	cm	rank
TRIAL AND YEAR (n=68):														
S1 1988[‡]	256A[§]	1	14.0A	1	144	-	-	-	69C	1	451B	2	-	-
S1 1989	183B	2	8.3B	2	-	-	34.5A	1	76B	2	489A	1	-	-
S2 1990	151B	4	4.0C	4	-	-	23.8B	3	81A	4	-	-	4.7A	1
S2 1991	152B	3	4.7C	3	-	-	32.4A	2	80A	3	372C	3	4.5A	2
LINE:														
745	407b	2	11.4a	2	70f	17	26.6a	16	84b	14	398bc	14	6.1ab	2
752	220bcd	4	2.7a	17	90ef	16	21.9a	17	85b	15	381c	16	3.6cde	15
864	106d	11	5.3a	15	98ef	14	29.7a	7	67e	1	385c	15	3.8cde	13
907	108d	10	5.6a	14	108ef	12	28.0a	13	70de	3	446b	6	4.1bcde	11
1001	84d	14	8.3a	6	120ef	10	27.6a	15	75cd	10	526a	2	4.1cde	12
1003	78d	15	8.2a	7	148bcde	6	29.4a	8	73cd	8	506a	5	4.8abcde	8
1079	74d	16	7.9a	9	138cdef	7	27.7a	14	70de	2	509a	3	4.6abcde	10
1207	153cd	8	6.6a	11	93ef	15	28.9a	11	72cde	7	401bc	13	3.3e	17
1214	136d	9	6.5a	12	100ef	13	29.0a	10	71cde	4	411bc	12	3.7cde	14
1229	86d	12	6.0a	13	110ef	11	31.7a	4	72cde	6	442b	7	4.8abcde	9
1245	84d	13	4.0a	16	134def	8	29.4a	9	74cd	9	421bc	10	3.5de	16
1267	59d	17	6.9a	10	128ef	9	30.0a	6	71cde	5	507a	4	6.3a	1
1448	169bcd	6	8.9a	5	197bcd	5	32.2a	2	76cd	12	424bc	9	5.5abcd	4
1588	168bcd	7	8.0a	8	209b	2	31.0a	5	77c	13	420bc	11	5.2abcde	6
1760	191bcd	5	10.5a	4	205bc	3	31.8a	3	76cd	11	429bc	8	5.0abcde	7
Reubens	796a	1	17.8a	1	282a	1	39.3a	1	92a	17	320d	17	5.4abcde	5
Nugget	393bc	3	11.1a	3	204bc	4	28.7a	10	87ab	16	556a	1	5.6abc	3
n	16		16				12		16		12		8	

[†]Days from April 15 to maturity.

[‡]Trial S1 was seeded in 1987 and S2 was seeded in 1989.

[§]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

3.3 Multilocation Trials

3.3.1 Materials and Methods

Eight lines of alpine bluegrass, including three mixtures of lines, were selected for final testing in multilocation trials. These selections were based on previous performance in provenance trials. Line mixtures were included for evaluation because it was thought that mixtures would have better general adaptations than single lines. However, because of difficulty in producing breeder seed of line mixtures, it was later decided that only single lines would be released as varieties. The selections included lines 907, 1003, 1448, 1588, 1760, and three line mixtures, M1 (lines 1448, 1588 and 1760), M2 (lines 907, 1003, 1214), and M3 (lines 864, 907, 1079, and 1229). Reubens Canada bluegrass and Nugget Kentucky bluegrass were used as check varieties in all trials.

Multilocation trials were seeded in 1990 and 1991 at Vegreville, Beaverlodge (elevation 730 m), Columbia Icefields, and Mountain Park (Fig. 1). A third trial was established at Vegreville and Plamondon (elevation 560 m) in 1992 to replace the first trial which did not emerge well at Beaverlodge. Mid- to late May seeding dates were used for the plains sites and late June seeding dates were used at the mountain sites. At plains sites, each plot consisted of five 6 m rows, with a 40 cm row spacing. At Columbia Icefields and Mountain Park, each plot consisted of a single 2 m row with a 1 m spacing between plots. Plots were seeded with a small plot seeder at the plains sites but were seeded by hand in the mountains. Approximately 500 g (equivalent to 2500 kg ha^{-1}) of peat moss was incorporated into the soil to a depth of about 30 cm prior to seeding at the mountain locations. This was done to compensate for the very poor, coarse soils found at these sites. A randomized complete block design with six blocks was used for all trials.

Seed yield was the primary characteristic studied, especially at the plains sites. Plants were harvested by hand and the seed was later threshed and cleaned to determine seed yield. Winter survival, percent cover, plant height, flowering date, number of heads produced, maturity date, and 1000 seed weight were also evaluated where possible. Winter survival and percent cover were estimated visually. Plant height was estimated by measuring three random plants per plot. At plains sites, seed yield was determined by harvesting seed from the three centre rows of each plot. At mountain sites, seed was harvested from the entire plot. Flowering date could

only be recorded at the Vegreville site because other sites were too far away to keep an accurate record of plant development. Although we originally planned to evaluate the ability of each line to produce viable seed under high elevation conditions, this could not be accomplished due to the small amounts of seed produced at the mountain sites.

Analyses of variance of all data were conducted for each year and for combined analyses over years and locations using the general linear models (GLM) procedure of the SAS statistical package (SAS Institute, Inc. 1990). Mean separation was conducted using Duncan's new multiple range test.

3.3.2 Results and Discussion

In multilocation trials at mountain sites, it took at least two years of establishment before alpine bluegrass flowered. At Columbia Icefields, plants in Trial 1 flowered and set seed in 1992 but in 1993, the growing season was cool, wet, and short (see Appendix C) so very few heads were produced (Table 17). In Trial 2, most plants had died by 1994 so no more data were collected. This trial was located in a different part of the site and may have been affected by different soil conditions or different weather conditions (drier) when the plants were seedlings. Mean percent cover in this trial was only 1% in 1993. In Trial 1, percent cover ranged from only 14% in 1993 to 68% in 1992. Because cover estimates are subjective, some of the variation among years may be due to different people estimating cover values. Lines 1003 (AEC Glacier) and 1760 (AEC Blueridge) had the highest mean cover values. Nugget had the lowest cover with a mean value of only 7%. Lines M3, 1588, and 907 produced the most heads and the most seed. There were no significant differences among lines for seed yield, plant height, or plant width.

At Mountain Park, both trials survived well and seed was harvested from Trial 1 in 1992 to 1994 and from Trial 2 in 1994. Percent cover values ranged from 9.9% for Trial 2 in 1992 to 37.5% for Trial 1 in 1994 (Table 18) and were higher than those observed at Columbia Icefields (Table 17). Although Reubens produced more heads than any selected line, it had the second lowest seed yield; only Nugget produced less seed (Table 18). Line 1760 was second in number of heads and first in seed yield. Nugget had the shortest plants and there were no significant differences for plant width.

In the first year of seed production (second year of growth) at plains sites, some winterkill was observed in Trial 1 at Vegreville but all other trials had mean winter survival

values of 93% or greater (Table 19). The 1990/91 winter seemed to be more severe than the 1991/92 winter at Vegreville, possibly due to the early arrival of snow in October. First year seed yields ranged from 79 kg ha^{-1} in Trial 2 at Beaverlodge, to 688 kg ha^{-1} in Trial 3 at Vegreville. The low yields in Trial 2 at Beaverlodge were due to poor emergence. The number of heads produced was lowest at Plamondon and highest in Trial 3 at Vegreville. Line 1003 had the best seed yields (with a mean of 376 kg ha^{-1}), even though it produced the fewest heads. It appears to be more drought tolerant than the other lines and was able to fill more seeds than the other lines under the dry conditions found at most sites in the first year of seed production. Plant height was similar for the selected lines and Nugget, but Reubens was significantly taller. There was a range in time to maturity among alpine bluegrass lines with line 907 maturing first (at 71 days after April 15) and line 1760 maturing last (82 days). On average, Nugget matured 12 days after line 1760 and Reubens matured 8 days after Nugget. Nugget produced the heaviest seeds while Reubens produced the smallest seeds.

Winter survival was reduced in Trial 1 at Vegreville and at Beaverlodge in the second year of seed production (Table 20). At Vegreville, seed yields were generally lower in the second year of seed production than in the first year (Table 19). However, at Beaverlodge and Plamondon, improved moisture conditions led to increased seed yields in the second year (Table 20). Number of heads produced was lowest at Beaverlodge but it still produced the highest mean seed yield. Line 1003 once again had the highest seed yields although it only ranked eighth in number of heads. Of the single lines of alpine bluegrass, line 1760 ranked second in seed yield with a higher yield than Nugget but lower yield than Reubens. Reubens had the tallest plants and line 907 had the shortest. Reubens and Nugget had the widest plants, due to their rhizomatous growth habit. Line 907 matured first and Reubens matured last, as in the first year of seed production. Seed weights were similar for all lines and Nugget, but Reubens had significantly smaller seeds.

Only one trial was maintained to the third year of seed production, Trial 2 at Vegreville. All lines had good winter survival except line 907 which had a mean survival of only 72% (Table 21). Reubens with its rhizomatous nature, produced far more heads than any line but it ranked only eighth in seed yield. As in other years, line 1003 had the highest seed yield. Overall, mean seed yields were lower than those observed in previous years. Plants of Reubens

were much taller than plants of all other lines. Line 907 matured first and Reubens and Nugget matured last. As before, Nugget had the largest seeds and Reubens had the smallest.

Of the single lines, line 1003 clearly outperformed all lines and the check varieties at the plains sites. This line was released as AEC Glacier alpine bluegrass. At mountain sites, there was no clear indication of the best line but line 1760 did perform well in the multilocation trials and in the provenance trials. It also did well at the plains sites. Line 1760 was released as AEC Blueridge alpine bluegrass.

In our breeder seed plots, which were harvested with a combine as opposed to hand harvesting in small plot trials, average seed yield for AEC Blueridge alpine bluegrass was 66 kg ha^{-1}. For AEC Glacier, only one seed harvest has been made so far and it yielded only 5 kg ha^{-1}. This was due to some winterkill on that plot. Seed yields for AEC Glacier are expected to be much higher in 1995 as that plot has recovered and has produced many more seed heads. Lower seed yields on breeder seed plots, as compared to small plots, are expected due to some shattering losses during combining. Yields observed on breeder seed plots will more closely approximate those to be expected on larger seed fields of these varieties.

Table 17. Mean performance of selected alpine bluegrass lines in multilocation trials at Columbia Icefields in 1991 to 1994.

	Cover		Number of Heads		Seed Yield		Plant Height		Plant Width	
	%	rank	no. m^{-1}	rank	mg m^{-1}	rank	cm	rank	cm	rank
LOCATION (n = 60):										
Trial 1 - 1991[†]	35.2B[‡]	4	0.1B	4	-	-	-	-	-	-
Trial 1 - 1992	67.5A	1	0.8A	1	6.8A	1	20.0A	1	3.3B	2
Trial 1 - 1993	13.6C	5	0.1B	3	-	-	-	-	-	-
Trial 1 - 1994	40.8B	2	0.3B	2	5.7A	2	19.7A	2	4.8A	1
Trial 2 - 1992	35.2B	3	-	-	-	-	-	-	-	-
Trial 2 - 1993	1.1D	6	-	-	-	-	-	-	-	-
LINE:										
M1 (1448+1588+1760)	36.4ab	3	0.2ab	6	1.4a	8	21.5a	3	4.7a	3
M2 (907+1003+1214)	36.1ab	5	0.4ab	4	8.0a	5	17.7a	8	3.7a	6
M3 (864+907+1079+1229)	33.6ab	7	0.5a	1	13.5a	1	18.3a	7	3.5a	7
907	33.1ab	8	0.5a	2	11.9a	2	16.2a	9	2.9a	9
1003	40.7a	1	0.1ab	7	3.0a	7	20.0a	5	3.3a	8
1448	36.0ab	6	0.4a	3	9.6a	4	23.2a	1	4.5a	5
1588	36.1ab	4	0.5a	1	9.7a	3	21.7a	2	5.1a	1
1760	39.9a	2	0.2ab	6	4.5a	6	20.8a	4	4.8a	2
Reubens	23.1b	9	0.2ab	5	0.8a	9	19.7a	6	4.5a	4
Nugget	7.3c	10	0.0b	8	0.0a	10	-	-	2.9a	10
n	36		24		12		12		12	

[†]Trial 1 was seeded in 1990 and Trial 2 was seeded in 1991.
[‡]Means within a column followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 18. Mean performance of selected alpine bluegrass lines in multilocation trials at Mountain Park in 1991 to 1994.

	Cover		Number of Heads		Seed Yield		Plant Height		Plant Width	
	%	rank	no. m^{-1}	rank	mg m^{-1}	rank	cm	rank	cm	rank
LOCATION (n = 60):										
Trial 1 - 1991[†]	24.2BC[‡]	4	0.4C	5	-	-	-	-	-	-
Trial 1 - 1992	35.1A	2	1.8B	3	15.9B	4	19.8A	1	3.2B	4
Trial 1 - 1993	22.4BC	5	2.2B	2	16.8B	3	18.4AB	3	3.8B	3
Trial 1 - 1994	37.5A	1	4.5A	1	70.0A	1	18.7AB	2	5.5A	1
Trial 2 - 1992	9.9D	7	-	-	-	-	-	-	-	-
Trial 2 - 1993	15.4CD	6	0.2C	6	-	-	-	-	-	-
Trial 2 - 1994	29.2AB	3	1.6B	4	22.3B	2	17.6B	4	3.9B	2
LINE:										
M1 (1448+1588+1760)	27.2abc	4	1.3cd	7	27.5bc	5	20.9ab	2	3.9a	6
M2 (907+1003+1214)	26.6bc	6	2.2abc	3	41.2b	3	19.0bc	5	3.5a	10
M3 (864+907+1079+1229)	13.0e	10	1.2cd	8	20.4bc	8	15.7de	8	3.5a	9
907	18.2de	8	1.6bcd	6	27.5bc	6	15.3ef	9	3.6a	8
1003	33.5ab	2	1.1cd	9	26.3bc	7	17.2cde	7	4.0a	5
1448	27.0abc	5	1.8bcd	4	41.7b	2	20.6ab	3	4.8a	2
1588	29.4abc	3	1.7bcd	5	32.9bc	4	18.3bcd	6	4.5a	4
1760	34.9a	1	2.9ab	2	78.2a	1	19.8abc	4	4.7a	3
Reubens	25.1cd	7	3.5a	1	13.7bc	9	21.9a	1	5.0a	1
Nugget	13.3e	9	0.4d	10	3.4c	10	12.9f	10	3.8a	7
n	42		36		24		24		24	

[†]Trial 1 was seeded in 1990 and Trial 2 was seeded in 1991.
[‡]Means within a column followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 19. Mean performance of selected alpine bluegrass lines in the first year of seed production in multilocation trials at Vegreville, Beaverlodge, and Plamondon.

	Survival		Number of Heads		Seed Yield		Plant Height		Time to Maturity		1000 Seed Weight	
	%	rank	no. m^{-1}	rank	kg ha^{-1}	rank	cm	rank	days[†]	rank	mg	rank
LOCATION (n = 60):												
Vegreville Trial 1 - 1991[‡]	70C[§]	4	235C	3	149B	3	32.5B	4	80B	2	497B	3
Vegreville Trial 2 - 1992	93B	3	326B	2	176B	2	32.6B	3	82A	4	537A	1
Vegreville Trial 3 - 1993	100A	1	391A	1	688A	1	39.6A	1	83A	5	468C	4
Beaverlodge Trial 2 - 1992	99A	2	183CD	4	79C	5	28.7C	5	80B	1	534A	2
Plamondon Trial 3 - 1993	100A	1	135D	5	91C	4	34.9B	2	82A	3	242D	5
LINE (n = 28):												
M1 (1448+1588+1760)	94a	5	222c	5	196a	9	32.4bc	5	80cde	5	487bc	3
M2 (907+1003+1214)	91a	7	201c	8	314a	2	31.3bc	8	75def	4	479bc	5
M3 (864+907+1079+1229)	87a	9	188c	9	259a	4	32.3bc	6	73f	2	474bc	7
907	87a	9	206c	7	282a	3	29.4c	10	71f	1	440c	9
1003	93a	6	174c	10	376a	1	32.7bc	4	75ef	3	507b	2
1448	96a	1	221c	6	185a	10	33.8b	2	81cd	6	475bc	6
1588	94a	4	236c	3	200a	8	31.0bc	9	81cd	7	449c	8
1760	95a	2	228c	4	219a	6	31.9bc	7	82c	8	485bc	4
Reubens	94a	3	594a	1	236a	5	48.6a	1	102a	10	345d	10
Nugget	90a	8	356b	2	211a	7	33.5bc	3	94b	9	563a	1

[†]Days from April 15 to maturity.
[‡]Trial 1 was seeded in 1990, Trial 2 was seeded in 1991, and Trial 3 was seeded in 1992.
[§]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 20. Mean performance of selected alpine bluegrass lines in the second year (1992) of seed production in multilocation trials at Vegreville, Beaverlodge, and Plamondon.

	Survival		Number of Heads		Seed Yield		Plant Height		Time to Maturity		1000 Seed Weight	
	%	rank	no. m^{-1}	rank	kg ha^{-1}	rank	cm	rank	days[†]	rank	mg	rank
LOCATION (n=60):												
Vegreville Trial 1 - 1992[‡]	60B[§]	5	361AB	2	56B	4	36.3C	4	82B	3	484B	3
Vegreville Trial 2 - 1993	95A	3	323BC	3	186A	2	41.6B	2	80C	2	537A	1
Vegreville Trial 3 - 1994	96A	2	282BC	4	51B	5	39.2BC	3	84A	4	473B	4
Beaverlodge Trial 2 - 1993	76B	4	266C	5	205A	1	32.4D	5	76D	1	473B	5
Plamondon Trial 3 - 1994	100A	1	445A	1	177A	3	46.8A	1	85A	5	526A	2
LINE (n = 28):												
M1 (1448+1588+1760)	82bc	5	169b	9	102bc	8	37.2bc	5	78cd	6	520a	4
M2 (907+1003+1214)	90abc	3	206b	5	199ab	2	36.3bc	8	74cd	4	507a	8
M3 (864+907+1079+1229)	75c	9	167b	10	122bc	6	36.4bc	7	72cd	2	511a	7
907	77bc	8	192b	6	115bc	7	34.3c	9	71d	1	481a	9
1003	90abc	4	180b	8	233a	1	37.4bc	3	72cd	3	557a	1
1448	80bc	7	234b	3	69c	9	37.3bc	4	79c	8	534a	3
1588	80bc	7	185b	7	64c	10	34.1c	10	79cd	7	516a	5
1760	80bc	6	214b	4	135bc	4	36.4bc	6	78cd	5	511a	6
Reubens	100a	1	1297a	1	173ab	3	56.5a	1	110a	10	296b	10
Nugget	91ab	2	366b	2	132bc	5	41.1b	2	99b	9	554a	2

[†]Days from April 15 to maturity.

[‡]Trial 1 was seeded in 1990, Trial 2 was seeded in 1991, and Trial 3 was seeded in 1992.

[§]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 21. Mean performance of selected alpine bluegrass lines in the third year (1994) of seed production in a multilocation trial at Vegreville. The trial was seeded in 1991.

	Survival		Number of Heads		Seed Yield		Plant Height		Time to Maturity		1000 Seed Weight	
Line (n = 6)	%	rank	no. m^{-1}	rank	kg ha^{-1}	rank	cm	rank	days[†]	rank	mg	rank
M1 (1448+1588+1760)	99a[‡]	2	148b	9	39bcd	5	42.6bc	5	82bc	6	437c	9
M2 (907+1003+1214)	94a	7	201b	5	118a	2	40.3bcd	8	68d	3	441c	7
M3 (864+907+1079+1229)	85ab	8	176b	7	56bc	4	35.8d	10	68d	2	468bc	4
907	72b	9	216b	3	73b	3	37.4cd	9	67d	1	437c	8
1003	97a	5	215b	4	147a	1	42.4bc	6	70d	4	502ab	2
1448	98a	3	128b	10	12d	9	43.0b	3	84b	8	467bc	5
1588	99a	2	152b	8	21cd	7	42.8bc	4	83bc	7	459bc	6
1760	98a	4	181b	6	33bcd	6	42.3bc	7	79c	5	472bc	3
Reubens	100a	1	970a	1	21cd	8	76.0a	1	104a	10	276d	10
Nugget	95a	6	231b	2	7d	10	44.1b	2	102a	9	535a	1

[†]Days from April 15 to maturity.

[‡]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

4 AGRONOMY

Unless otherwise indicated, the agronomic practices recommended are suitable for large scale seed production of these alpine bluegrass varieties. Because these varieties were developed for reclamation use, agronomic recommendations for forage and pasture use have not been developed.

4.1 Seeding

4.1.1 Materials and Methods

To evaluate the effect of seeding date on establishment, growth, and yield of alpine bluegrass, trials were seeded at Vegreville in 1991, 1992, and 1993. Trial 1 emerged well but was almost completely winterkilled in the first winter. Therefore, no data were taken from that trial and a third trial was seeded in 1993 to replace it. Alpine bluegrass lines 907 and 1760 (AEC Blueridge) were used in these trials. Four seeding dates were tested: second or third week of May, third or fourth week of June, fourth week of August and the second or third week of October. The trials were set up in randomized complete block designs with four blocks (replicates). A factorial arrangement of treatments was used. Emergence, percent cover, percent winter survival, number of heads produced, seed yield, time to maturity, and plant height were determined for each plot. Data were analyzed using the general linear models procedure of the SAS statistical package (SAS Institute, Inc. 1990).

For other aspects of seeding techniques, much of the information presented was gained through experience in seeding small plots and larger seed increase plots at Vegreville. Although no experiments were conducted to examine alternatives, these techniques represent what has worked well for us and should be applicable to larger field situations.

4.1.2 Results and Discussion

The results of these seeding date trials indicated that alpine bluegrass should be seeded in May. Delaying seeding until June or later resulted in very poor establishment and little or no seed yield in the first year of seed production (Table 22). May seeding gave the best emergence, the best cover, the highest number of heads and the highest seed yield. Plants seeded in May were also tallest but there was no effect on time to maturity. Plants seeded in August or October

did not flower in the first year of seed production. We expected that the October seeded plants would not flower because alpine bluegrass needs one growing season for establishment before seed production. Plants seeded in October did not emerge until the following year so they were in their establishment year while other plants were in the first seed production year. Plants seeded in August did emerge in the year they were seeded but were not large enough to initiate the development of heads. The two alpine bluegrass lines were not significantly different for all data recorded except winter survival where line 1760 survived better than line 907. Previous experience with line 907 has shown that it tends to more susceptible to winterkill than most of the other selected alpine bluegrass lines.

In the second year of seed production, both the May and August seeding dates had good cover values but May-seeded plants still produced the best seed yields (Table 23). Winter survival, number of heads and time to maturity were not significantly affected by time of seeding. Line 1760 matured later than line 907 and had taller plants but otherwise the two lines performed similarly.

When seeding alpine bluegrass, a seeding depth of 1 cm or less gives the best results. A row spacing of 20 to 40 cm is recommended, although for pedigreed seed production, the wider row spacing allows for easier access to remove any off-types. A seeding rate of 2 to 4 kg ha^{-1} may be used, with lower seeding rates for more widely spaced rows.

Conventional seed drills are generally acceptable as long as the depth can be adequately controlled. Alpine bluegrass seed must be mixed with an inert material such as cracked wheat to prevent the seed from bridging in the seeder. Specialized native seed drills with agitators that help prevent bridging may also be useful (Joyce 1993). In some situations, broadcast seeding followed by raking or harrowing may also be acceptable but better results are generally obtained by using seed drills. When broadcasting the seed, use a higher seeding rate.

We do not recommend the application of any fertilizer with the seeding operation. We seed into summerfallow so plant nutrients are generally not lacking. These varieties are adapted to low nutrient situations and the application of fertilizer does not seem to enhance their growth or seed yields. Previous experiments have shown no significant advantage to the use of fertilizer, although these experiments were conducted on summerfallow where soil nutrients may not have been limiting. Lack of response to fertilizer may also be due to the origin of these varieties. They have been derived from plants collected from relatively infertile soils. Such plants are

adapted to low nutrient conditions, and unlike species from high-nutrient environments, they do not respond to additional nutrient inputs (Chapin 1980).

Finally, the most important seeding technique is to be sure to seed into a clean seedbed. Alpine bluegrass is not highly competitive so weeds can provide strong competition and weed control is difficult because no herbicides are registered for use on alpine bluegrass. It is also very important to seed these varieties without a companion crop. Use of a companion crop would delay seed production by an extra year and would severely reduce seed yields.

4.2 Pest Management

Alpine bluegrass can be affected by weeds, insects, and diseases, but the most troublesome problems are created by weeds because of the non-competitive nature of this species. In an attempt to overcome some of the weed problems, an experiment was set up to screen alpine bluegrass seedlings for tolerance to various herbicides. Management techniques for diseases and insects, although less important, have been developed through experience when growing small plot trials and large seed increase plots of these varieties.

4.2.1 Weed Control

4.2.1.1 Materials and Methods

To investigate the tolerance of alpine bluegrass to various herbicides, an indoor experiment was established in 1991. A second, smaller experiment, was set up in 1993. In 1991 the herbicides studied included: bromoxynil/MCPA ester (Buctril M®), dicamba (Banvel®), clopyralid (Lontrel®), clopyralid plus 2,4-D ester, clopyralid plus MCPA ester, diclofop-methyl/bromoxynil (Hoegrass II®), fenoxaprop-ethyl plus MCPA ester plus thifensulfuron methyl (Triumph Plus®), chlorsulfuron (Glean®), 2,4-D/mecoprop/dicamba (Trimex®), and linuron (Lorox DF®). Since undertaking this experiment, Glean has been deregistered for use on crops. In the 1993 experiment, the following additional herbicides were tested: tralkoxydim (Achieve®) plus bromoxynil/MCPA ester (Buctril M®) plus Charge®, bentazon (Basagran®) plus Assist®, tribenuron methyl (Express®) plus 2,4-D ester, fenoxaprop-p-ethyl/bromoxynil/MCPA ester (Laser®), and fenoxaprop-p-ethyl/MCPA ester plus thifensulfuron (Laser DF®). All application rates used in these experiments were based on the recommended rates for forage grass crops

listed in the Guide to Crop Protection in Alberta (Ali 1991; Ali 1993) or the rates listed on the herbicide label.

Alpine bluegrass seedlings were grown in small trays with 10 plants per tray. Greenhouse conditions were set at 22/15°C for day/night temperatures with a 16 hour photoperiod. Herbicides were applied at the 2-leaf and 5-leaf growth stages, using a cabinet sprayer (RIC Spray Chamber, Research Instrument Manufacturing Co. Ltd, Guelph). The sprayer was equipped with an 8001 flat fan nozzle at 275 kpa and 3 km h^{-1}, which is similar to that used in a field sprayer. A randomized complete block design with a factorial arrangement of herbicide treatment and leaf stage was used.

Following spraying, plants were fertilized every two weeks with a 20-20-20 fertilizer solution. These fertilizer applications were used to ensure that observed plant responses were not related to nutrient deficiencies due to the limited amount of soil available in each tray. Seedlings were scored for tolerance to herbicides 1, 5, and 8 wk after herbicide application. A scale of 0 to 9 (as adopted by the Expert Committee on Weeds, 1979) was used; 0 being no tolerance (plant death) and 9 being complete tolerance. Top growth of the plants was harvested after 8 wk and biomass dry weight was recorded. Data were analyzed using the general linear models procedure of SAS (SAS Institute, Inc. 1990) and treatment means were compared to the control using Dunnett's test. A one-sided test was used for score means and a two-sided test was used for biomass means.

4.2.1.2 Results and Discussion

In the first herbicide tolerance trial on potted seedlings of alpine bluegrass, all herbicide treatments except linuron caused a significant decrease in score values one week after treatment at the 2-leaf stage (Table 24). By 8 wk, many treatments had recovered such that above-ground biomass was significantly lower than the control in only five treatments: dicamba (at the highest rate), diclofop-methyl/bromoxynil, chlorsulfuron (at the two rates tested), and 2,4-D/mecoprop/dicamba. The plants treated with linuron had significantly higher biomass than the control. When herbicides were applied at the 5-leaf stage, 11 of the 14 herbicide treatments significantly affected plant score after 1 wk, but by the time above-ground biomass was determined at 8 wk, no treatments were significantly different from the control.

In the second herbicide trial, two herbicide treatments caused a significant decrease in plant scores and above-ground biomass when applied at the 2-leaf stage (Table 25). These treatments were tralkoxydim plus bromoxynil/MCPA ester plus Charge and fenoxaprop-p-ethyl/MCPA ester plus thifensulfuron. Alpine bluegrass seedlings were damaged when sprayed with fenoxaprop-p-ethyl/bromoxynil/MCPA ester at the 2-leaf stage but they later recovered. When plants were sprayed at the five leaf stage there was little effect on plant score but three treatments (tribenuron methyl plus 2,4-D ester, fenoxaprop-p-ethyl/bromoxynil/MCPA ester, and fenoxaprop-p-ethyl/MCPA ester plus thifensulfuron) had significantly lower biomass than the highest value.

These two experiments have indicated possible useful herbicides for weed control in alpine bluegrass, but were conducted indoors on seedlings. Therefore, we do not know what effects these herbicides may have on plants grown under field conditions or on seed yield of alpine bluegrass. Currently, there are no selective herbicides registered for use in alpine bluegrass (Ali 1995). However, spot spraying with glyphosate (eg. Roundup®) can be useful for control of such weeds as quackgrass (*Elytrigia repens*) and Canada thistle (*Cirsium arvense*). These primary noxious weeds can cause problems in seed fields and it is best to avoid these weeds by seeding into a clean seedbed. Preplant applications of glyphosate can also help to control these weeds.

4.2.2 Control of Plant Diseases and Insects

In addition to problems with weeds, alpine bluegrass is susceptible to plant diseases such as powdery mildew (*Erysiphe graminis*) and leaf rust (*Puccinia graminis*) (Martens et al. 1984). In many cases, however, these diseases do not appear until the seed is almost mature or after harvest. They have little effect on seed yield although they may affect plant vigour and therefore seed yield in the following year. Although there are effective fungicides available for controlling powdery mildew and rusts in turfgrass, they are not registered for use in Canada (Martens et al. 1984). Alpine bluegrass may be susceptible to snow mould (Hardy BBT Ltd. 1989) and leaf spot diseases (Martens et al. 1984) but we have not observed any major problems with this disease. We have observed silvertop (or whiteheads) in our seed production plots of alpine bluegrass. The cause of silvertop is uncertain, and it is more common in some years than others. There are no control measures for silvertop in alpine bluegrass.

In our experience, alpine bluegrass has few problems with insect infestations in the field. In some years, however, infestations of spider mites can reduce plant vigour and subsequent seed yields. Fenbutatin oxide (Vendex®) is registered for control of mites in ornamental and nursery crops. There may also be problems with insects such as grasshoppers, cutworms, and wireworms that commonly infest crops (Bolton ca. 1985), but we have not observed any large infestations of these insects.

4.3 Harvesting

Harvesting alpine bluegrass begins in late June. AEC Glacier alpine bluegrass is generally ripe by the last week of June. AEC Blueridge matures later, by the second week of July. In most years, alpine bluegrass will produce a second flush of heads later in the summer but these are too thin to harvest. These late-season heads should be mowed off soon after anthesis so the plants do not expend too much energy to fill the seed.

Alpine bluegrass is highly subject to shattering, more so than other bluegrass species. Direct combining is recommended where possible. Plants should be harvested when the stems and heads are golden and it is possible to remove some seeds from the heads by gently shaking the seed head against the palm of your hand. Seed should be less than 30% moisture when direct combining. We do not recommend swathing before combining because the crop is too short to make a good swath. If swathing is the only alternative, swath in the medium to firm dough stage when seed head moisture content is 45 to 50% (Bolton ca. 1985). The seed heads should be placed in the centre of the swath to help keep shattered seeds on top of the swath. Greater shattering losses can occur if the crop is swathed too close to maturity. Losses can be reduced by swathing in early morning or late evening when humidity is higher. Shattering can also be a problem with direct combining. When combining, a high cylinder speed (1200 to 1400 rpm) and a concave spacing of about 6 mm is recommended (Najda et al. 1994). Use little or no wind over the cleaning shoe. In harvesting other bluegrasses, some seed growers have had success with rotary or axial flow combines (Najda et al. 1994).

Following harvest, all seed must be dried using aeration with or without heat (maximum air temperature of 38°C; Najda et al. 1994). This is especially true for seed that has been direct-combined because it will generally have a higher moister content. It is best to dry the seed to a moisture content of 10 to 12% for long term storage. Seed cleaning can be completed in most

seed cleaning plants. Use as little wind as possible when cleaning to minimize the amount of seed lost.

4.4 Post-Harvest Management

After harvesting, the fields are often mowed to remove any remaining stems. This won't be necessary if the swather or combine cuts low enough. After mowing, the straw is baled and removed from the field. Removing harvest residue from the seed field reduces disease problems and increases light penetration, which stimulates the plants to produce more tillers (Najda et al. 1994). If the alpine bluegrass plants produce more seed heads after harvest, these are mowed while still green. In Kentucky and Canada bluegrass seed fields, burning the field in the spring to reduce the effects of disease and insects is recommended (Bolton ca. 1985).

Even with good management, alpine bluegrass stands will survive for only four to five years on the plains. The use of nitrogen fertilizer to extend the life of the stand has been recommended for other bluegrasses (Bolton ca. 1985). However, past experiments on alpine bluegrass showed no response to nitrogen fertilizer application.

Table 22. Effect of seeding date on the performance of two lines of alpine bluegrass in the first year of seed production in small plot trials (seeded in 1992 and 1993) at Vegreville.

	Emergence (no. plants m^{-1})	Cover (%)	Winter Survival (%)	Number of Heads (no. m^{-1})	Seed Yield (kg ha^{-1})	Time to Maturity (days†)	Plant Height (cm)
LINE (n = 32):							
907	29 A‡	51 A	94 B	40 A	55 A	75 A	24.3A
1760	22 A	49 A	99 A	55 A	48 A	81 A	27.1A
DATE OF SEEDING (n = 16):							
May	58 a	79 a	90 b	169 a	201 a	78 a	34.9a
June	5 c	35 c	98 a	22 b	3 b	76 a	24.1b
August	23 b	57 b	100 a	0 b	0 b	-	9.4c
October	15 bc	7 d	100 a	0 b	0 b	-	26.7b

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). For emergence, n = 16 for line means and n = 8 for seeding date means.

Table 23. Effect of seeding date on the performance of two lines of alpine bluegrass in the second year (1994) of seed production in a small plot trial at Vegreville. The trial was seeded in 1992.

	Cover (%)	Winter Survival (%)	Number of Heads (no. m^{-1})	Seed Yield (kg ha^{-1})	Time to Maturity (days[†])	Plant Height (cm)
LINE (n = 16):						
907	30 A[‡]	76 A	165 A	36 A	70 B	26.5B
1760	38 A	70 A	191 A	31 A	77 A	32.3A
DATE OF SEEDING (n = 8):						
May	54 a	88 a	236 a	64 a	75 a	34.7a
June	11 b	79 a	137 a	21 b	72 a	28.0b
August	52 a	71 a	194 a	32 b	73 a	29.8ab
October	14 b	54 a	137 a	16 b	72 a	24.7b

[†]Days from April 15 to maturity.
[‡]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 24. Effect of 14 herbicide treatments on potted plants of common alpine bluegrass when applied at the 2-leaf and 5-leaf stages of growth in a greenhouse trial.

Herbicide	Rate (kg a.i. ha^{-1})	Applied at 2-leaf Stage				Applied at 5-leaf Stage			
		Plant Score[†]			Above-ground Biomass (g plant^{-1})	Plant Score			Above-ground Biomass (g plant^{-1})
		at 1 wk	at 5 wk	at 8 wk		at 1 wk	at 5 wk	at 8 wk	
Control		9.0	9.0	9.0	0.95	9.0	9.0	9.0	1.59
Bromoxynil/MCPA ester	0.55	7.8*	8.8	8.2	1.11	9.0	8.2	9.0	1.53
Dicamba	0.15	5.2*	8.2	8.5	0.93	7.0*	9.0	9.0	1.72
Dicamba	0.27	5.0*	6.8*	9.0	0.87	7.0*	8.8	8.8	1.63
Dicamba	0.4	5.0*	6.5*	7.8*	0.71*	6.5*	7.8*	8.8	1.51
Clopyralid	0.2	7.2*	8.2	8.2	0.99	7.5*	8.8	9.0	1.61
Clopyralid	0.3	6.8*	7.8*	8.5	0.95	7.0*	8.8	8.8	1.49
Clopyralid + 2,4-D ester	0.2 + 0.5	6.5*	9.0	8.8	0.93	7.8*	8.5	9.0	1.59
Clopyralid + MCPA ester	0.2 + 0.5	6.0*	8.2	8.8	0.82	7.5*	9.0	8.8	1.33
Diclofop-methyl/bromoxynil	0.07	5.5*	7.2*	8.0*	0.60*	6.5*	9.0	9.0	1.46
Fenoxaprop-ethyl + MCPA ester + thifensulfuron methyl	0.2 + 0.42 + 0.006	4.8*	6.0*	8.2	0.77	6.5*	8.8	8.8	1.40
Chlorsulfuron	0.011	7.2*	3.8*	5.5*	0.36*	8.2	7.2*	8.8	1.39
Chlorsulfuron	0.022	6.5*	2.8*	4.5*	0.21*	7.8*	7.5*	8.8	1.47
2,4-D/mecoprop/dicamba	1.694	5.5*	4.0*	7.2*	0.39*	7.2*	8.0*	8.8	1.33
Linuron	0.2	9.0	9.0	8.8	1.16*	8.5	8.2	9.0	1.54

*Indicates a mean significantly different from the control as determined by Dunnett's test ($P \leq 0.05$). A one-sided test was used for score values and a two-sided test was used for biomass values.

[†]Score was estimated visually using a scale of 0 to 9; 0 being no tolerance (plant death) and 9 being complete tolerance.

Table 25. Effect of five herbicide treatments on potted plants of common alpine bluegrass when applied at the 2-leaf and 5-leaf stages of growth in a greenhouse trial.

Herbicide	Rate (kg a.i. ha^{-1})	Applied at 2-leaf Stage				Applied at 5-leaf Stage			
		Plant Score[†]			Above-ground Biomass (g $plant^{-1}$)	Plant Score			Above-ground Biomass (g $plant^{-1}$)
		at 1 wk	at 5 wk	at 8 wk		at 1 wk	at 5 wk	at 8 wk	
Control		9.0	9.0	9.0	0.31	-[‡]	-	-	-
Tralkoxydim + bromoxynil /MCPA ester + Charge®	0.25 + 0.55 + 0.5%	3.8*	5.2*	6.8*	0.19*	8.3	9.0	9.0	0.52
Bentazon + Assist®	1.08 + 1%	7.0	8.2	9.0	0.36	8.5	8.8	9.0	0.59
Tribenuron methyl + 2,4-D ester	0.0075 + 0.5	7.0	8.5	9.0	0.28	8.2	8.8	9.0	0.49*
Fenoxaprop-p-ethyl /bromoxynil/MCPA ester	0.585	3.8*	8.8	9.0	0.28	8.5	9.0	9.0	0.50*
Fenoxaprop-p-ethyl/MCPA ester + thifensulfuron	0.458 + 0.015	5.0*	5.2*	7.5*	0.24*	7.7	8.3	8.7	0.44*

*Indicates a mean significantly different from the control as determined by Dunnett's test ($P \leq 0.05$). A one-sided test was used for score values and a two-sided test was used for biomass values.

[†]Score was estimated visually using a scale of 0 to 9; 0 being no tolerance (plant death) and 9 being complete tolerance.

[‡]No control was included for plants sprayed at the 5-leaf stage due to an error in experimental setup. For Dunnett's test, Bentazon was used as a 'control' because plants were unaffected by this herbicide at the 2-leaf or 5-leaf stage.

5 MANAGEMENT PRACTICES FOR USE IN RECLAMATION

Disturbed sites at high elevations provide very harsh environments for plant establishment and growth. Revegetating such sites requires the development of techniques specifically suited to overcome such problems as short growing seasons, moisture stress, and shallow, infertile soils. Selection of species and varieties adapted to these conditions can help to overcome these problems. Techniques used for establishing native plants are also important. Brown et al. (1976) recommended that alpine disturbances be seeded in late fall. However, no data were presented to support this recommendation. Fall seeding mimics natural seeding because most native plants drop their seed by fall. Fall seeding also ensures that the seed can take full advantage of the moisture available after snowmelt in the spring. The use of soil amendments and fertilizers to improve plant stands for reclamation has also been investigated with varying results. More research is required to determine appropriate methods for establishment and maintenance of alpine bluegrass when grown for reclaiming disturbed sites at high elevations.

5.1 Species/Variety Selection

Adaptation is important when selecting plant species and varieties within species for reclaiming and revegetating a disturbed site. By choosing species/varieties that are adapted to the conditions found at a particular site, the chances of successful revegetation are greatly improved (Thornburg 1982; Brown and Chambers 1989). The short growing seasons characteristic of high elevations limit the number of plant species that can be successfully grown at such sites.

Alpine bluegrass is adapted to alpine and subalpine regions (Moss 1983) and is common on dry and moist slopes, meadows, and rocky areas (Hardy BBT Ltd. 1989). It is a good candidate for revegetation in alpine areas (Hardy BBT Ltd. 1990) because it is an active colonizer species on virtually all disturbed sites in alpine environments including bare soils, acidic mine spoils, talus slopes, and alluvial sites (Hardy BBT Ltd. 1989). Alpine bluegrass is rated high for palatability and is grazed by both domestic animals and wildlife. Its high root:shoot ratio is important for soil building but it is not very effective for control of surface runoff. Alpine bluegrass is less susceptible to trampling than other alpine species and has been observed to thrive on trampled soil.

AEC Blueridge alpine bluegrass is adapted to elevations as high as 2500 m. AEC Glacier is also adapted to high elevations, but seems to do better at slightly lower elevations, up to 2400 m. Observations made in field trials at plains sites indicate that AEC Glacier is more drought tolerant than AEC Blueridge. Although these varieties are pure lines, they were developed to be included in mixtures of several species/varieties and were not intended to be seeded in monoculture on reclaimed sites.

When reclaiming a disturbed site, we recommend that a mixture of native plant species and varieties (when available) be used. A seed mixture is likely to contain species adapted to the many different microsites found at one reclamation site. Alpine bluegrass makes a good addition to any mixture because it has good establishment and grows well on a wide range of soils. Because of its non-competitive nature, alpine bluegrass will allow other native plant species from surrounding undisturbed areas to invade a reclaimed site. This will help to create a more natural plant community.

5.2 Seeding, Establishment, and Stand Maintenance

5.2.1 Materials and Methods

An experiment was designed to evaluate the time of seeding (fall versus spring) and the use of peat moss on emergence, growth, and reproduction of common alpine bluegrass under reclamation conditions at high elevations. Trials were established at Columbia Icefields (elevation 1860 m) and Mountain Park (elevation 1800 m) at sites with little or no topsoil. A randomized complete block design with factorial arrangement of seeding date and soil amendment (peat moss versus no peat moss) was used. Each trial consisted of three replicates. Trial 1 was seeded in September 1990 and June 1991. Trial 2 was seeded in September 1991 and June 1992. For plots receiving the peat moss treatment, approximately 500 g of peat moss (equivalent to 2500 kg ha^{-1}) were added and incorporated to a depth of about 30 cm. Data on plant emergence and percent cover were recorded and analyzed using the general linear models procedure of SAS (SAS Institute Inc. 1990). For plots at Mountain Park, where plants flowered, data on number of heads, seed yield, plant height, and plant width were also recorded.

A small trial to examine fall versus spring seeding of alpine bluegrass was also established at Columbia Icefields in September 1989 and June 1990. A randomized complete

block design with three replicates was used for this trial but no peat moss amendments were included. Emergence and percent cover data were recorded and analyzed using SAS.

5.2.2 Results and Discussion

At Columbia Icefields, seeding alpine bluegrass in the fall improved emergence compared to seeding in the spring (Table 26). However, at Mountain Park, seeding date had no effect on emergence. Percent cover at both sites was unaffected by seeding date. Similar results were obtained in an earlier trial at Columbia Icefields where seeding date did not affect emergence or cover (Table 27). Although cover was unaffected by seeding date, plants seeded in fall at Mountain Park, produced more seed heads and higher seed yields than those seeded in spring (Table 26). This supports the recommendation of Brown et al. (1976) to seed alpine disturbances in the fall.

The use of peat moss clearly improved emergence and plant cover of alpine bluegrass in our trials at Columbia Icefields and Mountain Park (Table 26). Number of heads and seed yield at Mountain Park also increased with the addition of peat moss. Soils at both sites were very poor and soil nutrient analyses indicated that there was no nitrogen available for plant growth. The application of peat moss not only provided a source of nutrients but it also helped to alleviate some of the physical problems of the soil. At Columbia Icefields especially, the soil forms a very hard crust when dry, thus impeding the emergence of grass seedlings. The addition of peat moss to the soil improved soil conditions, reducing the crusting and cementation problem. Brown et al. (1978) also reported that applications of organic matter such as peat moss, manure, or straw (at rates of 2000 to 4000 kg ha^{-1}) greatly enhanced plant growth and development at high elevation reclamation sites. The addition of topsoil or mulches, if available, is also desirable (Brown et al. 1976; Takyi 1984; Ziemkiewicz 1984; Hardy BBT Ltd. 1990).

When seeding alpine bluegrass at reclamation sites, it is important to seed shallowly (no more than 1 cm deep). Site preparation should include removing any weeds because alpine bluegrass is not highly competitive. Loosening the soil surface by ripping, rototilling, harrowing, or raking is also beneficial (Brown et al. 1976; Hardy BBT Ltd. 1990). If the site is easily accessible, it may be possible to use conventional farm seed drills (an inert carrier such as cracked wheat must be added to the seed to improve seed flow). In most cases, however, it will be necessary to broadcast the seed either by hand or by using equipment mounted on all terrain

vehicles. Hydroseeding is another useful alternative if the equipment is available (Hardy BBT Ltd. 1990). Raking or harrowing the seed after broadcasting is necessary to facilitate contact between the seed and soil. When broadcasting the seed, it is necessary to double the seeding rate of that recommended for seed drills (Thornburg 1982) so seeding rates should be approximately 4 to 8 kg ha^{-1}.

Some researchers (Brown et al. 1976, 1978; Brown and Chambers 1989) recommend the use of fertilizers at the time of seeding, although large quantities and repeated yearly applications may not be necessary (Brown et al. 1984). High rates of fertilization may favour species adapted to high nutrient conditions and reduce the rates of natural colonization and succession (Chapin 1980; Brown and Chambers 1989). Fertilizers may also encourage the growth of weeds (Thornburg 1982) and other non-native species. Therefore, we do not recommend the use of fertilizer when seeding alpine bluegrass at reclamation sites. Instead, the addition of topsoil (Ziemkiewicz 1984) and mulches (Takyi 1984) has been shown to improve establishment of native grasses on abandoned mine sites in Alberta.

Once plants are established, repeated applications of fertilizer may be necessary to maintain an adequate stand of native plants (Brown et al. 1978; Reeder and McGinnies 1989). In contrast, Schuman et al. (1991) reported that a single large application of nitrogen fertilizer can be used to supply adequate nitrogen for the revegetated plant community. With repeated applications, a sharp decline in site productivity occurs when fertilizer applications are discontinued (Brown and Chambers 1989). To avoid this decline, it may be better to use little or no fertilizer or only organic soil amendments (such as peat moss) so that native plant populations are allowed to build up slowly.

Table 26. Effect of seeding date and the use of peat moss as a soil amendment on common alpine bluegrass in small plot trials at Columbia Icefields and Mountain Park.

	Columbia Icefields		Mountain Park					
	Emergence (no. plants m^{-1})	Cover (%)	Emergence (no. plants m^{-1})	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
Time of Seeding								
Fall	46 A[†]	6.1 A	25 A	18.1 A	1.8A	29.0A	18.4A	3.3A
Spring	25 B	5.8 A	35 A	15.0 A	0.2B	5.0B	22.0A	2.5A
Soil Amendment								
With peat moss	51 a	9.8 a	38 a	28.6 a	1.7a	28.7a	20.6a	3.8a
Without peat moss	20 b	2.2 b	22 b	4.5 b	0.3b	5.3b	16.5a	2.0a
n	12	18	12	30	6	6	6	6

[†]Means within columns and within main effects followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

Table 27. Effect of seeding date on the emergence and percent cover of common alpine bluegrass in a small plot trial at Columbia Icefields.

Time of Seeding	Emergence (no. plants m^{-1})	Cover (%)
Fall	5.2 a[†]	1.8 a
Spring	2.2 a	2.5 a
n	3	6

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).

6 CONCLUSIONS

The release of AEC Blueridge alpine bluegrass and AEC Glacier alpine bluegrass will provide easily accessible sources of native grass seed adapted for reclaiming disturbed sites in the mountains and foothills. These varieties are well adapted to the short growing seasons characteristic of higher elevations. AEC Blueridge is adapted to the highest elevations while AEC Glacier is adapted to slightly lower elevations. AEC Glacier appears to be more drought tolerant than AEC Blueridge and it produced more seed at plains sites during dry growing seasons. Although these varieties were released as pure lines, we recommend that they be incorporated into seed mixtures containing other native plant species and varieties to maximize genetic and species diversity and improve the likelihood of obtaining a good plant cover in any one location. Mixtures of several species have a better chance of some species being adapted to the conditions found in individual microsites within a large reclamation project.

When growing these alpine bluegrass varieties for seed production, seed into a clean seedbed using rates of 2 to 4 kg ha^{-1}. Seeding in May will give the best results. Place seed a maximum of 1 cm deep and use row spacings of 20 to 40 cm. The application of fertilizer is generally not necessary. Weed control is difficult because there are no recommended selective herbicides for alpine bluegrass. Pre-plant and spot spraying with glyphosate may be necessary to control quackgrass, Canada thistle, and other weeds. Alpine bluegrass should be harvested by direct combining to minimize shattering losses. At Vegreville, AEC Glacier alpine bluegrass is harvested in late June while AEC Blueridge is generally harvested in the second week of July.

At high elevations, reclamation plantings of alpine bluegrass should be seeded in late fall to take maximum advantage of spring snowmelt. The use of additional topsoil, mulches, or organic matter such as peat moss or manure is beneficial to successful establishment of alpine bluegrass on reclamation sites. Fertilizer applications are not necessary although they may improve plant growth and cover.

In addition to these alpine bluegrass varieties, the Alberta Environmental Centre has also developed and released three slender wheatgrass varieties: AEC Highlander slender wheatgrass (released in 1993), AEC Hillcrest awned slender wheatgrass (released in 1994), and AEC Mountaineer broadglumed wheatgrass (released in 1995). Slender wheatgrass is adapted to lower elevations than alpine bluegrass although broadglumed wheatgrass grows well and

produces seed up to elevations of 2300 m. Slender wheatgrass establishes rapidly to provide a quick cover on reclamation sites so it is a useful addition to reclamation seed mixes.

Cooperative research with Wild Rose Consulting Inc. has also led to the development and release of common seed of a native legume species, *Astragalus alpinus* (Smreciu 1993). This native legume is adapted to the mountains and foothills and its release provides an important source of native legume seed for inclusion in reclamation seed mixes.

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APPENDIX A
PERFORMANCE OF ALPINE BLUEGRASS LINES IN INDIVIDUAL PROVENANCE TRIALS

Table A.1. Performance of selected alpine bluegrass lines in transplanted provenance trial 1 at Columbia Icefields in 1989. The trial was established in 1988.

Line	Number of Heads (no. plant^{-1})	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	11.3cd[†]	3.8k	4.8c	1.5a
752	19.2b	5.8jk	6.6bc	2.1a
864	3.4e	11.4defg	6.2bc	1.3a
907	5.3cde	11.6def	6.4bc	1.3a
1001	1.5e	8.0hij	6.4bc	1.6a
1003	1.6e	6.8ij	5.8bc	1.4a
1079	6.5cde	12.8cde	7.6ab	1.6a
1207	4.2de	8.8ghi	5.8bc	1.5a
1214	5.7cde	7.2ij	5.9bc	1.5a
1229	6.1cde	14.4c	6.2bc	1.6a
1245	4.1de	13.8cd	5.6bc	1.3a
1267	4.3de	10.8efg	7.6ab	1.5a
1448[‡]	-	-	-	-
1588	3.2e	10.0fgh	5.4bc	1.6a
1760	3.8de	9.2fghi	7.2b	1.2a
Reubens	12.7bc	30.6a	9.4a	2.3a
Nugget	35.8a	20.4b	7.6ab	1.8a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.
[‡]At the time of planting there were no plants of line 1448 for this trial.

Table A.2. Performance of selected alpine bluegrass in transplanted provenance trial 1 at Columbia Icefields in 1990. The trial was established in 1988.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Above-ground Biomass (mg plant^{-1})	Wt. Heads/ Total Wt. (%)	Harvest Index (Wt.Seed/Total) (%)	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	4.2c[†]	35.0bcde	459cde	11.7ab	5.3abc	20.2cdef	5.4e	1.4a
752	10.2a	74.0a	1194ab	14.3a	5.8ab	21.2cdef	8.7bcd	1.6a
864	0.9f	3.0e	333de	0.4f	0.1e	25.3abcd	7.5cde	2.1a
907	1.3f	5.0de	400de	2.1def	0.8de	22.7bcde	7.3cde	0.9a
1001	0.4f	0.3e	454cde	0.0f	0.0e	22.5bcde	7.9cde	1.5a
1003	0.4f	0.0e	456cde	0.0f	0.0e	18.8def	6.1de	1.3a
1079	0.4f	1.0e	823abcde	0.0f	0.0e	20.0def	9.8abc	1.5a
1207	1.7ef	8.0de	304e	1.0ef	0.4de	19.5def	6.6de	1.1a
1214	2.1cdef	11.5cde	534cde	3.8cdef	1.9cde	22.4bcde	6.5de	1.2a
1229	1.8def	17.5cde	632bcde	3.5cdef	2.0cde	28.0ab	7.8cde	1.7a
1245	1.1f	5.2de	442cde	3.2def	1.9cde	23.6bcde	6.8de	1.5a
1267	0.5f	5.5de	803abcde	1.1ef	0.7de	18.3ef	8.7bcd	0.9a
1448[‡]	-	-	-	-	-	-	-	-
1588	3.8cde	44.5abc	930abcd	6.4bcdef	2.5bcde	24.8abcde	7.4cde	1.8a
1760	4.3c	52.0ab	1357a	7.9abcde	4.1abcd	26.6abc	9.7abc	2.2a
Reubens	7.8b	76.5a	1030abc	10.0abc	6.6a	30.6a	12.0a	2.7a
Nugget	4.1cd	38.7bcd	1277a	8.3abcd	4.7abc	15.6f	10.8ab	1.6a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.

[‡]At the time of planting there were no plants of line 1448 for this trial.

Table A.3. Performance of selected alpine bluegrass in transplanted provenance trial 1 at Columbia Icefields in 1991. The trial was established in 1988.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Above-ground Biomass (mg plant^{-1})	Wt. Heads/ Total Wt. (%)	Harvest Index (Wt.Seed/Total) (%)	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	4.0b[†]	11.0cd	469cde	5.4de	2.1b	17.9abc	4.1bc	1.0bcde
752	6.3a	30.2a	604abcd	12.9b	5.2a	21.4ab	5.2bc	1.2bcde
864	0.4c	0.2d	188e	1.5ef	0.2c	15.1bcde	3.5c	1.0bcde
907	0.1c	0.0d	245de	0.0f	0.0c	4.5de	4.4bc	0.4de
1001	0.1c	0.8d	311cde	0.6f	0.2c	4.7de	3.9bc	0.2e
1003	0.0c	0.0d	189e	0.0f	0.0c	-	3.5c	-
1079	0.1c	0.0d	407cde	0.0f	0.0c	6.5cde	5.5bc	0.5cde
1207	0.1c	0.2d	279cde	0.1f	0.1c	7.0cde	4.1bc	0.3e
1214	0.2c	0.0d	155e	0.0f	0.0c	13.7bcde	4.5bc	0.5cde
1229	1.0c	6.4cd	503bcde	2.2def	1.7bc	16.6bcd	4.2bc	1.2cde
1245	0.4c	4.2d	318cde	5.3de	1.6bc	17.9abc	4.1bc	1.5bc
1267	0.1c	0.0d	521bcde	0.0f	0.0c	3.4e	6.0bc	0.4de
1448[‡]	-	-	-	-	-	-	-	-
1588	3.6b	10.2cd	623abc	10.4bc	1.3bc	24.2ab	3.9bc	1.4bcd
1760	2.8b	17.6bc	846ab	6.5cd	1.8bc	26.0ab	5.8bc	1.7ab
Reubens	6.8a	23.8ab	919a	17.9a	2.9b	29.4a	10.4a	2.6a
Nugget	0.7c	5.4d	388cde	2.6def	1.1bc	8.3cde	6.4b	0.6cde

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 5 for all means.

[‡]At the time of planting there were no plants of line 1448 for this trial.

Table A.4. Performance of selected alpine bluegrass in transplanted provenance trial 1 at Columbia Icefields in 1992. The trial was established in 1988.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	5.5bc[†]	66.8bc	12.2de	6.0c
752	9.9a	110.5ab	16.6bcde	7.0c
864	0.9e	5.9c	21.0abcd	5.8c
907	1.7de	20.0c	18.6abcd	5.6c
1001	0.8e	26.4c	17.8abcd	5.6c
1003	0.2e	7.3c	9.8de	4.8c
1079	0.6e	42.7bc	16.8bcde	6.4c
1207	0.5e	7.0c	12.2de	5.4c
1214	0.8e	24.9c	13.0cde	6.0c
1229	2.3de	57.9bc	24.4ab	6.0c
1245	2.0de	25.6c	25.6ab	5.2c
1267	1.1e	19.4c	20.0abcd	6.4c
1448[‡]	-	-	-	-
1588	2.6de	144.1a	19.8abcd	6.8c
1760	3.6cd	45.3bc	23.6abc	7.2c
Reubens	6.2b	20.3c	28.6a	12.0b
Nugget	1.2e	11.7c	6.0e	19.4a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.
[‡]At the time of planting there were no plants of line 1448 for this trial.

Table A.5. Performance of selected alpine bluegrass in transplanted provenance trial 1 at Columbia Icefields in 1993. The trial was established in 1988.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	6.0a[†]	27.4abcd	16.9bc	4.8cd
752	6.1a	41.9ab	19.6ab	7.9bc
864	0.6d	5.9def	21.6ab	5.8bcd
907	1.9bcd	25.8abcde	22.3ab	4.8cd
1001	0.9d	18.9bcdef	25.6a	5.0cd
1003	0.4d	6.5def	25.0a	4.4d
1079	0.7d	8.7def	19.6ab	6.0bcd
1207	0.2d	1.7ef	22.0ab	4.4d
1214	0.7d	7.1def	23.1ab	5.6bcd
1229	1.3cd	15.4cdef	24.0a	5.4bcd
1245	0.9d	11.5def	23.5ab	5.2bcd
1267	1.7bcd	37.4abc	23.3ab	6.0bcd
1448[‡]	-	-	-	-
1588	1.8bcd	15.4cdef	25.9a	5.4bcd
1760	3.3b	43.5a	26.7a	8.2b
Reubens	2.6bc	0.0f	23.2ab	13.0a
Nugget	0.9d	3.1def	12.5c	11.2a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 5 for all means.
[‡]At the time of planting there were no plants of line 1448 for this trial.

Table A.6. Performance of selected alpine bluegrass in transplanted provenance trial 1 at Columbia Icefields in 1994. The trial was established in 1988.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	5.5b[†]	58.4bc	15.0cde	9.6cde
752	9.4a	83.0b	13.6de	12.4bcd
864	1.7defgh	26.0c	16.8bcde	7.4e
907	1.4defgh	34.8c	16.8bcde	8.4de
1001	0.8fgh	21.2c	17.8abcd	7.4e
1003	0.7gh	8.8c	18.5abcd	7.8e
1079	0.9fgh	28.4c	16.4bcde	9.0cde
1207	0.8fgh	12.8c	17.0bcde	7.8e
1214	1.0efgh	19.8c	14.0de	7.6e
1229	2.5defg	49.4bc	22.0ab	10.8bcde
1245	1.3defgh	28.2c	21.2abc	9.0cde
1267	1.7defgh	49.2bc	19.4abcd	10.6cde
1448[‡]	-	-	-	-
1588	3.5bcd	83.6b	22.8ab	11.4bcde
1760	5.2bc	147.6a	23.6a	12.8abc
Reubens	3.1cdef	21.6c	20.6abc	14.6ab
Nugget	3.3bcde	32.6c	10.6e	16.4a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 5 for all means.
[‡]At the time of planting there were no plants of line 1448 for this trial.

Table A.7. Performance of selected alpine bluegrass in transplanted provenance trial 2 at Columbia Icefields in 1990. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	1.2bcd[†]	10.8a	15.0de	3.1bc	0.6b
752	1.9abcd	10.1a	12.7e	2.5c	1.0b
864	2.7abc	4.3a	16.0cde	3.0bc	0.5b
907	0.6cd	5.1a	19.0abcde	3.0bc	1.2b
1001	0.5cd	4.8a	19.3abcd	4.0bc	0.7b
1003	1.4bcd	20.1a	23.5ab	4.5b	1.3b
1079	0.7cd	9.0a	21.0abcd	4.0bc	0.8b
1207	1.7abcd	8.7a	20.1abcd	4.3b	0.8b
1214	2.9ab	20.7a	17.3bcde	3.5bc	0.9b
1229	0.0d	0.0a	-	3.0bc	-
1245	0.7cd	5.3a	20.8abcd	4.0bc	0.9b
1267	1.0bcd	12.2a	22.5abc	3.5bc	1.0b
1448	0.7cd	4.6a	20.0abcd	3.5bc	1.0b
1588	1.4bcd	10.4a	20.0abcd	3.5bc	0.8b
1760[‡]	-	-	-	-	-
Reubens	3.5a	21.4a	25.5a	8.0a	2.6a
Nugget	2.0abcd	0.0a	6.0f	3.5bc	1.0b

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 4$ for all means.
[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.8. Performance of selected alpine bluegrass in transplanted provenance trial 2 at Columbia Icefields in 1991. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	2.5a[†]	7.0a	12.6a	2.0b	0.9bc
752	1.5a	14.5a	12.8a	2.0b	0.7c
864	0.3a	1.0a	10.8a	2.0b	0.5c
907	1.0a	11.5a	17.2a	2.0b	1.7ab
1001	0.1a	0.8a	20.5a	2.4b	1.0bc
1003	0.1a	0.3a	14.5a	2.1b	0.5c
1079	0.3a	2.3a	18.0a	2.3b	1.3bc
1207	0.6a	0.5a	12.6a	2.4b	0.8bc
1214	0.5a	0.5a	15.8a	2.8b	0.5c
1229	0.0a	0.0a	-	2.5b	-
1245	0.0a	0.0a	-	2.1b	-
1267	0.0a	0.0a	-	2.3b	-
1448	0.6a	1.5a	23.0a	2.5b	1.0bc
1588	1.1a	1.0a	19.5a	2.8b	0.8bc
1760[‡]	-	-	-	-	-
Reubens	1.9a	1.8a	21.7a	9.3a	2.5a
Nugget	0.0a	0.0a	-	3.0b	-

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.
[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.9. Performance of selected alpine bluegrass in transplanted provenance trial 2 at Columbia Icefields in 1992. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	3.3a[†]	12.9a	10.5a	2.8b
752	1.9ab	5.1a	7.8a	2.8b
864	1.2b	3.7a	3.8a	3.0b
907	0.2b	0.5a	2.8a	2.5b
1001	0.1b	2.1a	4.3a	3.8b
1003	0.0b	0.0a	-	3.0b
1079	0.0b	0.0a	-	2.8b
1207	0.0b	0.0a	-	3.0b
1214	0.0b	0.0a	-	3.8b
1229	0.0b	0.0a	-	4.0b
1245	0.0b	0.0a	-	2.8b
1267	0.0b	0.0a	-	3.0b
1448	0.8b	3.0a	8.3a	3.8b
1588	0.6b	2.5a	11.8a	3.5b
1760[‡]	-	-	-	-
Reubens	1.1b	0.6a	9.8a	9.3a
Nugget	0.0b	0.0a	-	4.0b

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.
[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.10. Performance of selected alpine bluegrass in transplanted provenance trial 2 at Columbia Icefields in 1993. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	1.4a[†]	6.5a	12.9a	3.0b
752	0.3b	2.5a	10.5a	3.0b
864	0.1b	0.0a	3.0a	3.3b
907	0.1b	1.0a	5.0a	3.8b
1001	0.2b	0.0a	-	3.3b
1003	1.4a	0.0a	5.3a	3.5b
1079	0.1b	0.0a	5.0a	2.8b
1207	0.0b	0.0a	-	3.0b
1214	0.0b	0.0a	-	3.3b
1229	0.0b	0.0a	-	3.0b
1245	0.1b	0.3a	6.3a	3.0b
1267	0.3b	10.5a	6.5a	3.5b
1448	0.0b	0.0a	-	4.0b
1588	0.0b	0.0a	-	3.8b
1760[‡]	-	-	-	-
Reubens	0.2b	0.0a	4.0a	8.0a
Nugget	0.0b	0.0a	-	7.0a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.
[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.11. Performance of selected alpine bluegrass in transplanted provenance trial 2 at Columbia Icefields in 1994. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	1.4a[†]	5.8a	6.3a	6.3a
752	1.5a	7.5a	7.8a	6.3a
864	0.1c	0.0a	7.0a	4.8a
907	0.5bc	2.3a	7.7a	4.8a
1001	0.0c	0.0a	-	4.3a
1003	0.1c	0.3a	7.0a	4.3a
1079	0.0c	0.0a	-	4.3a
1207	0.0c	0.0a	-	4.3a
1214	0.0c	0.0a	-	4.7a
1229	0.0c	0.0a	-	5.0a
1245	0.2c	1.3a	14.0a	5.0a
1267	0.0c	0.0a	-	5.3a
1448	0.3bc	3.3a	21.0a	7.0a
1588	1.0ab	13.8a	18.0a	7.0a
1760[‡]	-	-	-	-
Reubens	0.0c	0.0a	-	6.0a
Nugget	0.0c	0.0a	-	5.0a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.
[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.12. Performance of selected alpine bluegrass lines in seeded provenance trial at Columbia Icefields in 1989. The trial was seeded in 1987.

Line	Cover (%)	Number of Heads (no. m^{-1})	Plant Height (cm)
745	13.7a[†]	5.8a	12.1ab
752	10.7a	5.2a	4.8ab
864	15.3a	3.2a	11.9ab
907	21.7a	21.3a	7.9ab
1001	26.7a	0.0a	-
1003	20.3a	0.4a	8.3ab
1079	4.0a	0.0a	-
1207	5.7a	2.8a	6.2ab
1214	25.3a	21.0a	14.4ab
1229	25.0a	26.0a	8.2ab
1245	4.0a	0.0a	-
1267	31.7a	2.5a	16.6a
1448	21.7a	14.3a	9.5ab
1588	28.7a	1.5a	9.1ab
1760	28.0a	2.8a	8.5ab
Reubens	15.0a	3.8a	13.3ab
Nugget	21.7a	1.5a	6.1ab

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 3 for all means.

Table A.13. Performance of selected alpine bluegrass in seeded provenance trial at Columbia Icefields in 1990. The trial was established in 1987.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	12.7a[†]	17.0a	109b	15.3bcde	4.7a	1.2a
752	18.7a	21.0a	218b	13.3de	2.8a	1.2a
864	21.0a	13.2a	108b	20.7abcd	4.3a	1.5a
907	17.7a	14.8a	104b	17.5abcde	4.5a	1.3a
1001	33.3a	43.3a	72b	24.5a	6.5a	1.5a
1003	27.7a	8.0a	141b	23.3abc	4.7a	1.2a
1079	7.7a	6.0a	89b	25.0a	3.0a	1.0a
1207	15.3a	6.8a	99b	23.5abc	3.2a	0.8a
1214	27.7a	10.5a	102b	21.7abcd	7.3a	1.2a
1229	23.3a	41.0a	6b	15.0cde	5.0a	1.5a
1245	3.7a	1.2a	19b	15.3bcde	2.7a	1.7a
1267	33.3a	32.2a	570a	23.0abc	5.0a	1.7a
1448	25.0a	11.5a	157b	24.0abc	4.0a	1.0a
1588	34.3a	29.5a	142b	21.0abcd	5.3a	1.5a
1760	28.3a	11.8a	80b	22.0abcd	4.0a	1.3a
Reubens	41.7a	15.8a	145b	24.3ab	7.0a	2.7a
Nugget	33.3a	8.3a	65b	11.7e	5.3a	1.2a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 3 for all means.

Table A.14. Performance of selected alpine bluegrass in seeded provenance trial at Columbia Icefields in 1991. The trial was established in 1987.

Line	Cover (%)	Number of Heads ($no.m^{-1}$)	Seed Yield ($mg\ m^{-1}$)	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	16.7bc[†]	21.0a	33.7ab	15.8a	3.2b	1.3a
752	13.3bc	15.3abc	47.7a	14.8a	3.8b	0.8a
864	15.0bc	2.3d	2.3c	13.2a	2.3b	1.7a
907	23.3abc	5.7cd	19.3bc	12.0a	1.5b	1.0a
1001	45.0ab	1.3d	3.3c	11.2a	2.3b	1.2a
1003	20.7abc	1.3d	7.3bc	12.2a	1.7b	0.7a
1079	8.3c	3.7d	12.7bc	7.0a	1.2b	0.3a
1207	15.0bc	9.0bcd	17.7bc	6.2a	1.5b	0.5a
1214	19.0bc	4.7d	8.3bc	19.2a	2.5b	0.8a
1229	29.0abc	2.7d	7.7bc	8.5a	1.3b	0.2a
1245	6.3c	0.3d	0.0c	1.3a	2.3b	0.2a
1267	31.7abc	2.7d	10.0bc	14.0a	3.0b	0.5a
1448	22.3abc	2.0d	4.3c	14.5a	4.2b	0.5a
1588	40.0abc	5.3cd	7.3bc	21.3a	3.3b	0.8a
1760	31.7abc	3.3d	6.7bc	15.0a	3.7b	0.8a
Reubens	53.3a	17.0ab	0.0c	22.7a	4.5b	2.7a
Nugget	28.3abc	4.3d	44.7a	15.7a	8.7a	1.3a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 3 for all means.

Table A.15. Performance of selected alpine bluegrass in seeded provenance trial at Columbia Icefields in 1992. The trial was established in 1987.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{1})	Plant Height (cm)	Plant Width (cm)
745	15.0a[†]	24.0a	28.3ab	6.0f	3.3a
752	15.0a	18.7ab	32.0ab	6.0f	3.3a
864	16.7a	1.3c	0.0b	15.5bcde	2.7a
907	13.3a	0.5c	0.0b	13.0cdef	4.0a
1001	33.3a	4.5bc	61.0a	21.0ab	4.5a
1003	18.3a	1.3c	3.0b	14.5bcde	3.3a
1079	6.7a	0.5c	0.0b	16.0bcde	2.0a
1207	13.3a	0.0c	0.0b	-	4.0a
1214	13.3a	0.0c	0.0b	-	3.3a
1229	22.3a	2.5c	3.0b	20.0abc	2.5a
1245	8.3a	4.0bc	17.0ab	9.0ef	3.0a
1267	33.3a	0.3c	5.0ab	15.0bcde	4.0a
1448	22.3a	7.7bc	37.5ab	25.0a	3.7a
1588	36.7a	9.0abc	15.7ab	18.3abcd	6.0a
1760	27.3a	7.0bc	18.5ab	18.5abcd	3.0a
Reubens	50.0a	14.0abc	22.7ab	16.3bcde	5.3a
Nugget	28.3a	1.3c	21.0ab	11.5def	9.0a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 3 for all means.

Table A.16. Performance of selected alpine bluegrass in seeded provenance trial at Columbia Icefields in 1993. The trial was established in 1987.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
745	29.7bcd[†]	4.2a	12.5a	10.0a	4.7a
752	18.3bcd	4.2a	19.8a	12.3a	4.2a
864	8.3cd	0.0d	0.0a	-	2.8a
907	28.3bcd	0.2cd	1.0a	5.3a	2.8a
1001	55.0ab	0.0d	0.0a	-	3.5a
1003	33.0bcd	0.5cd	5.2a	7.3a	3.3a
1079	5.0d	0.2cd	2.0a	8.0a	2.2a
1207	16.0cd	0.3cd	7.0a	7.3a	2.3a
1214	26.3bcd	0.2cd	1.7a	8.0a	3.3a
1229	30.0bcd	0.0d	0.0a	-	1.3a
1245	4.0d	0.0d	0.0a	-	2.8a
1267	33.3bcd	0.5cd	3.3a	6.3a	5.3a
1448	28.3bcd	0.8cd	8.3a	5.0a	3.0a
1588	50.0abc	3.5ab	19.5a	21.0a	5.0a
1760	38.0bcd	2.2bc	14.5a	18.3a	3.2a
Reubens	53.3ab	2.0bcd	0.0a	15.0a	4.0a
Nugget	83.3a	0.2cd	0.0a	3.7a	4.8a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 3 for all means.

Table A.17. Performance of selected alpine bluegrass in seeded provenance trial at Columbia Icefields in 1994. The trial was established in 1987.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
745	30.0bc[†]	3.0bc	9.2b	8.7efg	4.3a
752	21.7bc	4.8ab	34.7b	7.0fg	5.5a
864	8.3bc	0.0c	0.0b	-	4.0a
907	8.3bc	0.2c	33.2b	15.0abcdef	3.0a
1001	18.3bc	0.3c	4.0b	12.0cdefg	5.0a
1003	15.0bc	0.0c	0.0b	-	3.3a
1079	1.7c	0.0c	0.0b	-	2.0a
1207	3.3c	0.2c	1.0b	18.0abcde	3.5a
1214	18.3bc	0.2c	0.3b	13.0bcdef	3.5a
1229	30.0bc	0.2c	17.2b	22.0ab	3.0a
1245	3.3c	0.3c	0.3b	3.0g	4.0a
1267	50.0ab	0.2c	0.7b	10.0cdefg	5.7a
1448	30.0bc	3.0bc	65.3ab	23.5a	8.5a
1588	53.3ab	6.8a	124.3a	18.7abcd	5.7a
1760	8.3bc	2.8bc	48.0ab	19.0abc	6.0a
Reubens	33.3bc	0.2c	3.8b	24.0a	8.5a
Nugget	80.0a	0.3c	3.8b	9.0defg	9.3a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 3 for all means.

Table A.18. Performance of selected alpine bluegrass lines in transplanted provenance trial at Mountain Park in 1990. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Wt. Heads/ Total Wt. (%)	Harvest Index (Wt.Seed/Total) (%)	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	6.1ab[†]	57.9ab	21.3a	11.9a	17.0de	4.7c	1.3bcd
752	5.3abc	40.3bc	18.0ab	10.5ab	16.6def	3.7c	1.0cd
864	1.5e	5.7d	3.5c	0.8c	18.6de	4.7c	0.9cd
907	0.3e	0.5d	1.6c	0.1c	15.5ef	4.5c	1.1cd
1001	0.1e	0.0d	0.0c	0.0c	21.0bcd	4.7c	1.0cd
1003	0.7e	5.3d	2.4c	1.4c	23.5bc	5.6c	1.1cd
1079	0.2e	0.0d	0.0c	0.0c	20.0cde	4.9c	0.5d
1207	3.4d	19.6cd	6.9bc	2.5c	17.8de	5.4c	1.3bcd
1214	4.5bcd	36.0bc	14.3abc	6.9abc	19.4cde	5.4c	1.2cd
1229	0.6e	6.4d	2.1c	1.3c	25.3ab	5.3c	1.0cd
1245	0.6e	1.8d	0.1c	0.1c	20.5cd	4.9c	1.3bcd
1267	0.4e	0.7d	0.0c	0.0c	19.7cde	5.2c	1.2cd
1448	0.6e	5.8d	1.0c	0.5c	25.0b	5.8c	2.0b
1588	3.5d	40.1bc	21.5a	11.6a	23.2bc	5.7c	1.4bc
1760[‡]	-	-	-	-	-	-	-
Reubens	6.6a	77.5a	8.8abc	3.7bc	29.2a	11.5a	3.2a
Nugget	3.9cd	41.3bc	18.0ab	11.0ab	12.6f	8.7b	1.5bc

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 5 for all means.

[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.19. Performance of selected alpine bluegrass lines in transplanted provenance trial at Mountain Park in 1991. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Above-ground Biomass (mg plant^{-1})	Wt. Heads/ Total Wt. (%)	Harvest Index (Wt.Seed/Total) (%)	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	4.2ab[†]	26.6a	221bcde	33.9a	12.3a	14.8abc	2.4b	1.1a
752	3.3b	8.2b	149cde	22.7b	5.1b	13.3bc	2.5b	1.0a
864	0.3c	0.2b	151cde	0.7c	0.1b	15.7abc	3.0b	1.2a
907	0.1c	0.0b	197cde	0.1c	0.0b	15.0abc	2.0b	0.5a
1001	0.2c	0.0b	327abc	0.1c	0.0b	11.8c	3.1b	0.8a
1003	0.2c	0.0b	406ab	0.0c	0.0b	15.5abc	3.1b	1.5a
1079	0.4c	0.8b	339abc	2.9c	0.2b	12.8c	3.0b	1.3a
1207	0.8c	0.4b	191cde	1.3c	0.1b	11.5c	2.8b	0.9a
1214	1.2c	4.2b	314abcd	6.3c	1.1b	15.6abc	3.0b	1.0a
1229	0.2c	3.0b	322abcd	5.8c	0.8b	16.3abc	3.1b	0.8a
1245	0.1c	0.0b	81e	0.2c	0.0b	17.5abc	2.4b	1.5a
1267	0.2c	0.0b	251bcde	1.2c	0.0b	16.5abc	3.0b	0.8a
1448	0.8c	0.0b	128de	0.4c	0.0b	17.8abc	3.0b	1.2a
1588	0.9c	3.4b	273abcde	7.0c	0.7b	21.0a	3.1b	1.3a
1760[‡]	-	-	-	-	-	-	-	-
Reubens	4.9a	7.8b	442a	9.6c	1.7b	20.8ab	10.2a	1.9a
Nugget	0.8c	4.4b	221bcde	3.6c	1.4b	10.8c	3.5b	0.9a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 5 for all means.

[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.20. Performance of selected alpine bluegrass in transplanted provenance trial 2 at Mountain Park in 1992. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	1.8cd[†]	4.1a	9.8bcd	2.8c
752	2.1cd	8.9a	9.0cd	2.8c
864	0.8d	3.7a	5.8d	2.2c
907	1.6cd	18.6a	13.6abcd	3.0c
1001	1.3cd	6.3a	12.2bcd	3.0c
1003	1.8cd	75.0a	17.2abcd	4.4c
1079	1.0d	27.3a	16.4abcd	4.2c
1207	3.4abc	40.0a	19.4abc	3.8c
1214	4.3ab	49.8a	22.0ab	4.2c
1229	1.4cd	11.6a	14.4abcd	3.8c
1245	2.4bcd	27.0a	10.4bcd	4.6c
1267	1.0d	6.0a	8.5cd	4.2c
1448	1.1d	10.2a	16.3abcd	3.7c
1588	1.2cd	11.4a	9.0cd	3.6c
1760[‡]	-	-	-	-
Reubens	5.0a	11.2a	24.8a	19.0a
Nugget	1.5cd	15.4a	8.4cd	12.4b

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.
[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.21. Performance of selected alpine bluegrass in transplanted provenance trial at Mountain Park in 1993. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	0.4a[†]	1.7a	10.5cd	3.4b
752	0.6a	2.5a	11.7cd	3.6b
864	0.3a	0.4a	12.0bcd	3.8b
907	0.4a	2.3a	14.0abcd	4.6b
1001	0.4a	6.0a	18.0ab	4.4b
1003	0.9a	14.9a	19.0a	5.4b
1079	0.1a	1.7a	18.0ab	5.2b
1207	1.0a	7.1a	20.1a	4.0b
1214	1.5a	15.1a	16.5abc	5.0b
1229	0.2a	2.0a	19.0a	4.0b
1245	2.3a	40.2a	20.3a	6.0b
1267	0.0a	0.0a	-	5.2b
1448	0.4a	1.3a	19.3a	5.7b
1588	0.4a	5.6a	20.3a	5.0b
1760[‡]	-	-	-	-
Reubens	1.7a	0.3a	18.8a	22.9a
Nugget	1.1a	3.3a	9.4d	22.0a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.
[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.22. Performance of selected alpine bluegrass in transplanted provenance trial at Mountain Park in 1994. The trial was established in 1989.

Line	Number of Heads (no. plant^{-1})	Seed Yield (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	0.3ab[†]	2.4a	6.3bc	3.4b
752	0.6ab	10.4a	11.7abc	3.6b
864	0.3b	4.4a	2.4c	3.8b
907	0.3b	16.8a	14.0ab	4.6b
1001	0.4ab	5.2a	10.8abc	4.4b
1003	0.9ab	50.6a	15.2ab	5.4b
1079	0.1b	9.0a	7.2bc	5.2b
1207	1.0ab	11.2a	16.1ab	4.0b
1214	1.5ab	58.6a	16.5ab	5.0b
1229	0.2b	10.6a	7.6bc	4.0b
1245	2.3a	122.4a	8.1bc	6.0b
1267	0.0b	18.3a	-	5.2b
1448	0.3ab	1.8a	9.6abc	4.3b
1588	0.4ab	9.4a	12.2abc	5.0b
1760[‡]	-	-	-	-
Reubens	1.7ab	13.2a	18.8a	22.9a
Nugget	1.1ab	2.0a	9.4abc	22.0a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.
[‡]At the time of planting there were no plants of line 1760 for this trial.

Table A.23. Performance of selected alpine bluegrass lines in transplanted provenance trial at Sunshine Village in 1989. The trial was established in 1987.

Line	Number of Heads (no. plant^{-1})	Above-ground Biomass (mg plant^{-1})	Plant Height (cm)	Flag Leaf Length (cm)
745	3.1ab[†]	324a	6.6d	1.6cdef
752	3.5a	397a	7.0d	2.9abc
864	3.0abc	440a	15.3ab	1.1ef
907	0.3d	204a	8.5d	1.0f
1001	1.4abcd	470a	13.9abc	2.1cdef
1003	1.1bcd	394a	10.2cd	1.7cdef
1079	1.4abcd	390a	11.4bcd	1.4def
1207	1.4abcd	286a	10.3cd	1.8cdef
1214	1.5abcd	360a	9.1d	1.3ef
1229	2.1abcd	326a	17.9a	1.3def
1245	1.9abcd	313a	15.6ab	1.9cdef
1267	0.3d	376a	7.7d	0.8f
1448	1.6abcd	463a	17.3a	3.5ab
1588	1.1bcd	318a	18.0a	2.7bcd
1760	2.1abcd	390a	16.0ab	4.0a
Reubens	1.1bcd	265a	17.5a	4.0a
Nugget	0.8cd	495a	15.0ab	2.5bcde

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.

Table A.24. Performance of selected alpine bluegrass lines in transplanted provenance trial at Sunshine Village in 1990. The trial was established in 1987.

Line	Number of Heads (no. plant^{-1})	Wt. Heads/ Total Wt. (%)	Plant Height (cm)	Plant Width (cm)	Flag Leaf Length (cm)
745	5.8a[†]	33.5a	4.8c	5.8a	1.7bc
752	5.5a	26.5ab	5.7bc	4.9a	1.4bcd
864	2.4b	18.5bcd	12.6a	5.2a	1.1bcd
907	1.4b	15.7bcde	10.1abc	3.7a	0.8cd
1001	1.5b	16.1bcd	8.5abc	5.5a	1.1bcd
1003	1.0b	12.5cde	6.1bc	4.1a	0.9bcd
1079	1.2b	14.2cde	6.2bc	6.9a	0.8cd
1207	1.9b	19.5bcd	6.6bc	4.1a	1.7bc
1214	2.0b	16.7bcd	7.5abc	5.1a	1.4bcd
1229	1.2b	13.2cde	12.5a	4.5a	1.1bcd
1245	1.8b	14.7bcde	8.6abc	4.8a	0.8cd
1267	0.9b	9.4de	8.9abc	5.4a	0.9bcd
1448	2.6b	24.2abc	11.1ab	6.4a	2.8a
1588	2.6b	15.1bcde	10.6abc	6.1a	1.3bcd
1760	2.1b	15.7bcde	11.2ab	5.6a	1.8b
Reubens	1.5b	3.9e	8.0abc	5.5a	0.5d
Nugget	1.9b	12.2cde	11.0ab	6.8a	1.9b

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.

Table A.25. Performance of selected alpine bluegrass lines in transplanted provenance trial at Sunshine Village in 1991. The trial was established in 1987.

Line	Number of Heads (no. plant^{-1})	Plant Height (cm)
745	1.8ab[†]	5.0e
752	2.9a	5.0e
864	1.4bc	10.0abc
907	0.2c	8.0bcde
1001	0.4bc	8.4bcd
1003	0.4bc	7.8cde
1079	0.5bc	8.5bcd
1207	0.2c	6.8de
1214	0.4bc	7.3cde
1229	0.2c	10.3abc
1245	0.6bc	8.0bcde
1267	0.4c	8.4bcd
1448	1.8ab	13.0a
1588	0.9bc	10.4abc
1760	1.2bc	11.0ab
Reubens	0.7bc	11.0ab
Nugget	0.0c	-

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 5$ for all means.

Table A.26. Performance of selected alpine bluegrass lines in transplanted provenance trial at Sunshine Village in 1993. The trial was established in 1987.

Line	Number of Heads (no. plant^{-1})	Above-ground Biomass (mg plant^{-1})	Plant Height (cm)	Plant Width (cm)
745	0.9a[†]	119a	9.0a	4.2a
752	1.4a	109a	9.0a	4.0a
864	0.7a	97a	10.2a	4.2a
907	0.9a	133a	11.4a	4.6a
1001	0.8a	147a	10.6a	4.0a
1003	0.7a	98a	8.6a	4.8a
1079	0.8a	114a	12.2a	5.0a
1207	0.9a	99a	9.0a	5.8a
1214	1.1a	82a	7.6a	6.2a
1229	0.8a	97a	7.6a	4.0a
1245	0.7a	89a	9.5a	4.0a
1267	0.7a	106a	11.0a	3.9a
1448	0.8a	131a	11.8a	4.8a
1588	0.9a	127a	9.0a	4.2a
1760	1.0a	107a	9.2a	5.4a
Reubens	1.2a	40a	8.5a	3.5a
Nugget	0.6a	64a	8.5a	5.0a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 5 for all means.

Table A.27. Performance of selected alpine bluegrass lines in seeded provenance trial I at Sunshine Village in 1989 to 1993. The trial was established in 1987.

Line	Cover (%)				Number of Heads (no. m^{-1})		Plant Height (cm)
	1989	1990	1991	1993	1991	1993	1993
745	7.5c[†]	7.0a	70.0a	30.0a	0.5a	3.9a	9.5a
752	7.5c	12.0a	77.5a	17.5a	0.5a	0.8a	3.8a
864	7.5c	13.3a	31.3a	51.3a	0.0a	6.0a	8.5a
907	32.5ab	18.8a	72.5a	17.5a	0.8a	3.1a	4.0a
1001	48.8a	8.3a	75.0a	30.0a	0.3a	4.4a	9.5a
1003	33.8ab	9.0a	75.0a	23.8a	0.8a	1.3a	2.5a
1079	33.8ab	8.8a	75.0a	13.8a	0.0a	3.6a	12.4a
1207	18.8bc	8.3a	80.0a	25.0a	1.5a	3.0a	8.9a
1214	11.3bc	14.5a	35.0a	15.0a	0.5a	1.5a	8.9a
1229	16.3bc	12.5a	60.0a	28.8a	0.0a	3.4a	11.9a
1245	15.0bc	12.5a	50.0a	31.3a	0.0a	2.0a	9.8a
1267	50.0a	16.3a	77.5a	8.8a	0.5a	0.6a	3.3a
1448	23.8bc	5.3a	87.5a	5.0a	0.0a	0.3a	2.3a
1588	12.5bc	15.0a	62.5a	38.8a	0.5a	4.1a	6.1a
1760	25.0bc	10.0a	75.0a	23.8a	0.5a	4.3a	9.3a
Reubens	8.8c	14.5a	30.0a	26.3a	0.0a	3.0a	4.8a
Nugget	6.3	14.5a	57.5a	25.0a	0.0a	6.5a	7.8a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 4 for all means.

Table A.28. Performance of selected alpine bluegrass lines in seeded provenance trial 2 at Sunshine Village in 1989 to 1993. The trial was established in 1988.

Line	Cover (%)				Number of Heads (no. m^{-1})
	1989	1990	1991	1993	1993
745	10.0a[†]	10.0d	45.0abcde	16.3a	2.8a
752	10.0a	8.3d	67.5a	17.5a	0.8a
864	8.8a	8.3d	30.0bcde	16.3a	0.4a
907	10.0a	10.8d	33.8bcde	12.5a	1.6a
1001	16.3a	32.5ab	57.5abc	36.3a	1.9a
1003	15.0a	15.0dc	41.3abcde	25.0a	3.1a
1079	10.0a	13.8dc	27.5cde	13.8a	0.3a
1207	6.3a	38.8a	15.0e	25.0a	0.4a
1214	8.8a	10.0d	26.3cde	21.3a	1.5a
1229	11.3a	15.0dc	50.0abcd	17.5a	1.3a
1245	10.0a	30.0abc	32.5bcde	31.3a	2.0a
1267	8.8a	10.0d	26.3cde	25.0a	2.9a
1448	12.5a	12.5d	67.5a	16.3a	1.1a
1588	7.5a	12.0d	60.0ab	15.0a	0.0a
1760	8.8a	8.8d	40.0abcde	11.3a	2.1a
Reubens	7.5a	30.0abc	16.3e	33.8a	0.0a
Nugget	7.5a	20.0bcd	23.8de	31.3a	0.0a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 4 for all means.

Table A.29. Performance of selected alpine bluegrass lines in transplanted provenance trial at Vegreville in 1988. The trial was established in 1987.

Line	Number of Heads (no. plant^{-1})	Seed Yield (g plant $^{-1}$)	Time to Maturity (days †)	1000 Seed Wt. (mg)	Above-ground Biomass (g plant $^{-1}$)
745	100.4ab‡	1.7bc	86ab	431bcde	24.2ef
752	130.0a	1.4bc	87a	374de	22.1f
864	46.9cdef	2.4abc	63gh	398de	43.4bcd
907	28.8def	1.8bc	62h	383de	27.6def
1001	22.9f	3.9abc	70efg	440bcde	35.7cdef
1003	38.9cdef	3.7abc	69fgh	453abcd	36.7bcdef
1079	34.4cdef	3.7abc	66fgh	492abc	39.4bcde
1207	39.1cdef	2.0bc	72def	405de	33.1cdef
1214	26.1ef	1.4bc	71def	397de	34.6cdef
1229	25.5ef	2.1abc	65fgh	390de	41.4bcd
1245	20.9f	0.3c	68fgh	355e	38.0bcdef
1267	40.2cdef	4.0abc	65fgh	530a	37.6bcdef
1448	48.4cdef	4.0abc	81abc	411cde	68.7a
1588	79.8bcd	4.9ab	76cde	406de	49.7bc
1760	77.6bcde	5.9a	77cd	432bcde	52.7b
Reubens	140.2a	3.4abc	80bc	417cde	46.0bc
Nugget	82.0bc	3.3abc	81abc	504ab	38.5bcdef

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 5 for all means.

Table A.30. Performance of selected alpine bluegrass lines in transplanted provenance trial at Vegreville in 1989. The trial was established in 1987.

Line	Number of Heads (no. plant^{-1})	Seed Yield (g plant $^{-1}$)	Time to Maturity (days †)	1000 Seed Wt. (mg)	Plant Height (cm)
745	102.2bc‡	3.6a	81bcde	400c	19.7c
752	115.9b	2.6a	84bc	468bc	26.8bc
864	26.4d	1.5a	73f	435c	26.3bc
907	41.9cd	3.2a	72f	438c	29.4ab
1001	27.9d	3.1a	80bcde	526ab	28.4ab
1003	40.8cd	4.1a	78cdef	566a	30.2ab
1079	23.6d	2.7a	77def	542ab	31.8ab
1207	38.4cd	1.5a	80bcde	474bc	26.8bc
1214	49.6bcd	2.3a	79bcde	432c	28.4ab
1229	7.7d	0.4a	76ef	430c	23.8bc
1245	14.5d	0.4a	79bcde	413c	26.7bc
1267	22.2d	2.4a	78cdef	545ab	29.0ab
1448	40.1cd	2.2a	80bcde	428c	31.6ab
1588	43.6cd	1.9a	85b	523c	28.8ab
1760	34.9cd	1.9a	83bcd	474bc	31.0ab
Reubens	222.5a	5.2a	94a	433c	36.3a
Nugget	69.9bcd	2.1a	94a	565a	25.5bc

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 5 for all means.

Table A.31. Performance of selected alpine bluegrass lines in seeded provenance trial 1 at Vegreville in 1988. The trial was established in 1987.

Line	Number of Heads (no. m^{-1})	Seed Yield (g m^{-1})	Above-ground Biomass (g m^{-1})	Time to Maturity (days†)	1000 Seed Wt. (mg)
745	256abcd‡	4.3c	139f	82a	398f
752	417ab	5.1c	181f	84a	401f
864	217cd	11.0abc	196ef	60d	419ef
907	230bcd	10.2abc	215ef	60d	428def
1001	189cd	19.7ab	240ef	63cd	501bc
1003	203cd	19.9ab	297bcde	63cd	485bcd
1079	182d	20.0ab	278cdef	61d	528ab
1207	213cd	12.0abc	186ef	66c	405f
1214	198cd	12.3abc	200ef	64cd	429def
1229	153d	11.3abc	219ef	60d	424ef
1245	155d	7.5bc	269def	62cd	427def
1267	119d	13.5abc	256ef	62cd	496bc
1448	368abc	23.3a	394bcd	71b	467cde
1588	425a	19.5ab	418b	73b	428def
1760	445a	23.7a	410bc	73b	429def
Reubens	-	-	565a	80a	-
Nugget	269abcd	8.3bc	408bc	84a	575a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 4$ for all means.

Table A.32. Performance of selected alpine bluegrass lines in seeded provenance trial 1 at Vegreville in 1989. The trial was established in 1987.

Line	Number of Heads (no. m^{-1})	Seed Yield (g m^{-1})	Time to Maturity (days†)	1000 Seed Wt. (mg)	Plant Height (cm)
745	-	-	-	-	13.0c
752	32d‡	0.5e	85b	350g	29.5b
864	54d	3.0de	69cd	408efg	30.5ab
907	97d	7.3cde	68d	463cdef	36.0ab
1001	77d	6.7cde	74cd	563ab	34.3ab
1003	104d	10.4c	74cd	583a	38.3a
1079	37d	3.6de	71cd	528abc	33.3ab
1207	251c	8.2cd	74cd	442def	32.8ab
1214	152c	6.0cde	75c	452cdef	32.3ab
1229	108d	7.4cde	73cd	492bcd	36.8ab
1245	63d	3.4de	74cd	477cde	35.8ab
1267	37d	5.3cde	73cd	565ab	35.0ab
1448	37d	2.5de	75c	450def	36.0ab
1588	75d	5.3cde	75c	482cde	36.0ab
1760	76d	6.3cde	75c	505bcd	38.0a
Reubens	1096a	36.3a	96a	390fg	35.0ab
Nugget	528b	18.9b	89b	595a	35.8ab

†Days from April 15 to maturity.
‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 4 for all means.

Table A.33. Performance of selected alpine bluegrass lines in seeded provenance trial 2 at Vegreville in 1990. The trial was established in 1989.

Line	Number of Heads (no. m^{-1})	Seed Yield (g m^{-1})	Time to Maturity (days[†])	Plant Height (cm)	Flag Leaf Length (cm)
745	557a[‡]	36.9a	87b	30.0ab	6.1ab
752	15c	0.3b	87b	18.1f	3.6de
864	108c	11.5b	64f	27.6bcd	4.2bcde
907	13c	0.4b	81bcd	19.7def	4.2bcde
1001	23c	0.2b	84bc	19.2ef	4.1cde
1003	11c	0.7b	80bcd	20.5def	4.4bcde
1079	2c	0.1b	80bcd	18.3f	3.6e
1207	81c	7.0b	74de	21.2cdef	3.5e
1214	78c	3.6b	72e	22.1cdef	4.3bcde
1229	8c	0.2b	83bc	23.1bcdef	5.1abcde
1245	56c	4.3b	83bc	22.0cdef	3.4e
1267	3c	0.2b	80bcd	20.3def	6.0ab
1448	163bc	9.3b	80bcd	29.0bc	5.7abc
1588	103c	5.4b	78cde	25.8bcdef	5.5abcd
1760	126c	10.6b	76cde	27.0bcde	4.8bcde
Reubens	312b	2.9b	96a	36.4a	5.3abcde
Nugget	667a	27.6a	88b	21.3cdef	6.9a

[†]Days from April 15 to maturity.

[‡]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 4 for all means.

Table A.34. Performance of selected alpine bluegrass lines in seeded provenance trial 2 at Vegreville in 1990. The trial was established in 1989.

Line	Number of Heads (no. m^{-1})	Seed Yield (g m^{-1})	Time to Maturity (days†)	1000 Seed Wt. (mg)	Plant Height (cm)	Flag Leaf Length (cm)
745	-	-	-	-	-	-
752	-	-	-	-	-	-
864	62b‡	2.2b	72g	321c	30.9b	3.4ef
907	40b	2.0b	74fg	452ab	29.3b	3.7ef
1001	21b	1.8b	84c	454ab	31.0b	4.0def
1003	24b	2.1b	76ef	446ab	29.5b	5.2bcd
1079	7b	0.3b	77ef	437ab	30.5b	6.3ab
1207	81b	4.1b	75fg	356c	32.9b	3.1f
1214	116b	6.0b	74fg	352c	32.8b	3.1f
1229	29b	1.1b	77ef	379bc	34.7b	4.2cdef
1245	51b	2.3b	77ef	357c	30.8b	3.6ef
1267	22b	0.8b	84c	322c	29.7b	6.8a
1448	90b	5.1b	80de	354c	31.6b	5.3bc
1588	71b	3.0b	81cd	350c	31.3b	4.9cd
1760	119b	6.8b	80de	353c	30.5b	5.3bc
Reubens	979a	15.7a	98a	250d	46.4a	5.4bc
Nugget	107b	4.6b	88b	503a	28.9b	4.4cde

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 4$ for all means.

APPENDIX B
PERFORMANCE OF ALPINE BLUEGRASS LINES IN INDIVIDUAL MULTILOCATION TRIALS

Table B.1. Performance of selected alpine bluegrass lines in multilocation trial 1 at Columbia Icefields in 1991. The trial was seeded in 1990.

Line	Emergence (no. plants m^{-1})	Cover (%)
M1 (1448+1588+1760)	121a[†]	48.3a
M2 (907+1003+1214)	80a	36.7ab
M3 (864+907+1079+1229)	61a	24.2bc
907	86a	35.0ab
1003	98a	43.3ab
1448	86a	41.7ab
1588	95a	39.2ab
1760	110a	47.5ab
Reubens	105a	27.5abc
Nugget	73a	8.3c

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 6$ for all means.

Table B.2. Performance of selected alpine bluegrass lines in multilocation trial 1 at Columbia Icefields in 1992. The trial was seeded in 1990.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
M1 (1448+1588+1760)	77.5a[†]	0.8a	2.8a	21.5ab	3.2a
M2 (907+1003+1214)	70.0a	0.4a	5.4a	18.2bc	3.7a
M3 (864+907+1079+1229)	79.2a	1.1a	9.4a	16.5c	3.2a
907	63.3a	1.4a	17.1a	16.0c	2.7a
1003	84.2a	0.6a	5.9a	20.0abc	3.3a
1448	74.2a	1.2a	12.9a	23.3a	3.7a
1588	70.0a	1.1a	8.7a	21.8ab	3.5a
1760	81.7a	0.6a	4.6a	21.0ab	3.2a
Reubens	60.8a	0.7a	1.2a	21.0ab	4.0a
Nugget	14.2b	0.0a	0.0a	-	2.7a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.3. Performance of selected alpine bluegrass lines in multilocation trial 1 at Columbia Icefields in 1993. The trial was seeded in 1990.

Line	Cover (%)	Number of Heads (no. m^{-1})
M1 (1448+1588+1760)	11.7a[†]	-
M2 (907+1003+1214)	20.8a	0.8a
M3 (864+907+1079+1229)	10.8a	0.7a
907	13.3a	0.5a
1003	17.5a	-
1448	12.5a	0.5a
1588	15.0a	0.8a
1760	17.5a	-
Reubens	14.2a	-
Nugget	2.8a	-

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.4. Performance of selected alpine bluegrass lines in multilocation trial 1 at Columbia Icefields in 1994. The trial was seeded in 1990.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
M1 (1448+1588+1760)	48.3ab[†]	0.0a	0.0a	-	6.2a
M2 (907+1003+1214)	68.3a	0.8a	10.5a	17.0a	3.7b
M3 (864+907+1079+1229)	34.2b	0.6a	17.7a	22.0a	3.8b
907	38.3ab	0.3a	6.7a	16.5a	3.2b
1003	53.3ab	0.0a	0.0a	-	3.3b
1448	43.3ab	0.3a	6.3a	23.0a	5.3ab
1588	51.7ab	0.7a	10.7a	21.7a	6.7a
1760	45.0ab	0.2a	4.3a	20.0a	6.3a
Reubens	20.8bc	0.1a	0.5a	17.0a	5.2ab
Nugget	4.2c	0.0a	0.0a	-	3.3b

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.5. Performance of selected alpine bluegrass lines in multilocation trial 2 at Columbia Icefields in 1991, 1992 & 1993. The trial was seeded in 1991.

Line	Emergence (no. plants m^{-1})	Cover (%)	
		1992	1993
M1 (1448+1588+1760)	29a[†]	31.7abc	1.0a
M2 (907+1003+1214)	21a	19.2bc	1.3a
M3 (864+907+1079+1229)	35a	52.5a	0.5a
907	34a	48.3a	0.5a
1003	45a	45.0ab	1.0a
1448	34a	40.0abc	4.5a
1588	27a	40.0abc	1.0a
1760	42a	46.7a	1.2a
Reubens	30a	15.0c	0.2a
Nugget	27a	14.2c	0.2a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.6. Performance of selected alpine bluegrass lines in multilocation trial 1 at Mountain Park in 1991. The trial was seeded in 1990.

Line	Emergence (no. plants m^{-1})	Cover (%)	Number of Heads (no. m^{-1})
M1 (1448+1588+1760)	35bcd[†]	33.3a	0.1b
M2 (907+1003+1214)	37abcd	24.2ab	0.0b
M3 (864+907+1079+1229)	24cd	9.2c	0.0b
907	25bcd	13.3bc	0.0b
1003	60a	30.8a	0.0b
1448	38abcd	30.0a	0.0b
1588	35bcd	28.3a	0.0b
1760	49ab	33.3a	0.0b
Reubens	41abc	28.7a	3.5a
Nugget	15d	11.2bc	0.0b

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.7. Performance of selected alpine bluegrass lines in multilocation trial 1 at Mountain Park in 1992. The trial was seeded in 1990.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
M1 (1448+1588+1760)	15.8ab[†]	1.2b	7.0a	21.2a	3.8a
M2 (907+1003+1214)	15.0abc	1.1b	10.0a	18.5a	2.8a
M3 (864+907+1079+1229)	9.3cd	1.1b	9.4a	17.5a	2.7a
907	10.3bcd	1.1b	9.3a	16.0a	2.5a
1003	18.3a	0.6b	10.8a	19.3a	2.7a
1448	16.7ab	2.3b	30.2a	21.5a	4.0a
1588	20.0a	2.8b	30.0a	16.8a	3.5a
1760	20.0a	2.4b	34.3a	20.8a	3.0a
Reubens	18.3a	5.6a	12.3a	23.8a	4.0a
Nugget	6.7d	0.2b	5.6a	-	3.3a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 6$ for all means.

Table B.8. Performance of selected alpine bluegrass lines in multilocation trial 1 at Mountain Park in 1993. The trial was seeded in 1990.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
M1 (1448+1588+1760)	19.2bc[†]	2.3a	22.3abc	19.8a	3.5a
M2 (907+1003+1214)	25.0ab	3.0a	19.1abc	18.7a	2.8a
M3 (864+907+1079+1229)	15.0c	1.5a	11.9bc	17.0a	3.8a
907	15.8c	2.8a	41.1a	16.8a	4.7a
1003	24.2ab	0.4a	3.7c	15.3a	3.3a
1448	26.7ab	2.5a	22.8abc	20.4a	4.5a
1588	25.8ab	2.2a	13.9bc	18.4a	4.0a
1760	32.5a	4.1a	33.8ab	19.3a	4.0a
Reubens	27.5ab	3.2a	0.0c	19.6a	4.8a
Nugget	12.0c	0.5a	0.0c	14.5a	2.8a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.9. Performance of selected alpine bluegrass lines in multilocation trial 1 at Mountain Park in 1994. The trial was seeded in 1990.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
M1 (1448+1588+1760)	40.8abc[†]	2.5c	46.8bcd	21.2b	4.5a
M2 (907+1003+1214)	60.0a	8.2a	120.5ab	19.7bc	5.0a
M3 (864+907+1079+1229)	14.2c	3.3c	47.3bcd	14.0cd	4.7a
907	23.3bc	5.5abc	55.5bcd	16.0bcd	4.3a
1003	50.8ab	4.5abc	74.0bcd	18.2bcd	4.5a
1448	39.2abc	5.3abc	95.7bc	20.8b	6.8a
1588	38.3abc	3.4bc	57.5bcd	19.2bcd	7.2a
1760	56.7a	7.6ab	174.2a	18.7bcd	7.2a
Reubens	40.8abc	3.7bc	23.2cd	28.0a	5.3a
Nugget	10.8c	1.3c	5.8d	13.0d	5.5a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 6$ for all means.

Table B.10. Performance of selected alpine bluegrass lines in multilocation trial 2 at Mountain Park in 1991, 1992 & 1993. The trial was seeded in 1991.

Line	Emergence (no. plants m^{-1})	Cover (%)		Number of Heads (no. m^{-1})
		1992	1993	1993
M1 (1448+1588+1760)	74a[†]	13.0ab	13.3a	-
M2 (907+1003+1214)	50a	7.5abc	12.8a	1.5a
M3 (864+907+1079+1229)	46a	5.0c	10.7a	-
907	72a	6.3bc	12.5a	0.5a
1003	72a	12.5ab	20.0a	-
1448	55a	10.8abc	15.8a	-
1588	75a	13.3a	19.2a	0.5a
1760	45a	11.7abc	20.0a	1.0a
Reubens	89a	10.8abc	17.0a	2.0a
Nugget	86a	7.7abc	12.3a	-

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.11. Performance of selected alpine bluegrass lines in multilocation trial 2 at Mountain Park in 1994. The trial was seeded in 1991.

Line	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
M1 (1448+1588+1760)	38.3a[†]	1.6a	34.0a	21.7a	3.7a
M2 (907+1003+1214)	24.2a	0.8a	15.0a	18.8a	3.2a
M3 (864+907+1079+1229)	15.8a	1.3a	12.8a	15.5a	2.8a
907	28.3a	0.3a	4.2a	10.7a	2.8a
1003	40.8a	1.0a	16.7a	15.0a	5.6a
1448	22.5a	0.9a	18.2a	19.8a	4.0a
1588	37.5a	1.7a	30.3a	19.0a	3.3a
1760	36.7a	3.4a	70.7a	20.8a	4.5a
Reubens	24.2a	4.3a	19.2a	18.6a	6.0a
Nugget	23.3a	0.3a	2.2a	11.0a	3.7a

[†]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.12. Performance of selected alpine bluegrass lines in multilocation trial 1 at Vegreville in 1991. The trial was seeded in 1990.

Line	Survival (%)	Number of Heads (no. m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	81ab‡	295bc	224ab	32.2cd	78de	521a
M2 (907+1003+1214)	64bc	125def	83de	30.3cd	78e	507ab
M3 (864+907+1079+1229)	52c	80ef	46e	29.8d	74f	527a
907	52c	47f	26e	26.3e	70g	500ab
1003	72abc	84ef	108cde	30.2d	78e	536a
1448	87a	250cd	181bc	33.5bc	80cd	477b
1588	77ab	244cd	156bcd	30.7cd	80c	475b
1760	83ab	231cde	155bcd	30.5cd	79cde	516ab
Reubens	74abc	560a	234ab	52.5a	99a	374c
Nugget	61bc	431ab	282a	36.0b	87b	537a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.13. Performance of selected alpine bluegrass lines in multilocation trial 1 at Vegreville in 1992. The trial was seeded in 1990.

Line	Survival (%)	Number of Heads (no. m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	51c‡	108b	12b	38.1b	83c	494abc
M2 (907+1003+1214)	88ab	231b	48b	35.3bc	76d	424bc
M3 (864+907+1079+1229)	43c	144b	25b	34.0bc	72de	478abc
907	61bc	160b	36b	32.2c	68e	382c
1003	68abc	171b	75b	37.5bc	73d	553a
1448	42c	74b	3b	36.4bc	83c	537ab
1588	50c	156b	18b	32.2c	83c	528ab
1760	35c	127b	17b	34.2bc	82c	510ab
Reubens	100a	1820a	228a	46.2a	103a	449abc
Nugget	64bc	255b	18b	35.0bc	95b	554a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). $n = 6$ for all means.

Table B.14. Performance of selected alpine bluegrass lines in multilocation trial 2 at Vegreville in 1992. The trial was seeded in 1991.

Line	Survival (%)	Number of Heads (no. m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	89bc‡	264c	109d	30.3de	83c	542b
M2 (907+1003+1214)	94abc	197c	217b	32.8cd	72de	514b
M3 (864+907+1079+1229)	87c	227c	207bc	32.2cde	71e	499b
907	88c	213c	253b	29.2e	69e	455b
1003	96ab	179c	393a	34.6bc	74d	548b
1448	94abc	264c	63d	31.4cde	85c	539b
1588	96ab	290c	108d	29.4de	85c	522b
1760	95ab	254c	124cd	30.2de	85c	561b
Reubens	100a	892a	207bc	39.5a	103a	498b
Nugget	92abc	482b	75d	36.8ab	96b	696a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.15. Performance of selected alpine bluegrass lines in multilocation trial 2 at Vegreville in 1993. The trial was seeded in 1991.

Line	Survival (%)	Number of Heads (no. m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	99a‡	126c	139b	36.2d	74c	563b
M2 (907+1003+1214)	91ab	165c	323a	41.5b	71d	566b
M3 (864+907+1079+1229)	83ab	173c	157b	41.2b	71d	568b
907	76b	162c	119b	39.7bc	71d	557b
1003	100a	157c	298a	40.1bc	72d	615a
1448	98a	146c	68b	37.4cd	75c	555b
1588	99a	157c	73b	32.8e	75c	546b
1760	100a	179c	118b	35.6d	75c	580ab
Reubens	100a	1502a	288a	69.0a	116a	231c
Nugget	99a	405b	325a	42.7b	96b	584ab

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.16. Performance of selected alpine bluegrass lines in multilocation trial 2 at Vegreville in 1994. The trial was seeded in 1991.

Line	Survival (%)	Number of Heads (no m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	99a‡	148b	39bcd	42.6bc	82bc	437c
M2 (907+1003+1214)	94a	201b	118a	40.3bcd	68d	441c
M3 (864+907+1079+1229)	85ab	176b	56bc	35.8d	68d	468bc
907	72b	216b	73b	37.4cd	67d	437c
1003	97a	215b	147a	42.4bc	70d	502ab
1448	98a	128b	12d	43.0b	84b	467bc
1588	99a	152b	21cd	42.8bc	83bc	459bc
1760	98a	181b	33bcd	42.3bc	79c	472bc
Reubens	100a	970a	21cd	76.0a	104a	276d
Nugget	95a	231b	7d	44.1b	102a	535a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.17. Performance of selected alpine bluegrass lines in multilocation trial 3 at Vegreville in 1993. The trial was seeded in 1992.

Line	Survival (%)	Number of Heads (no m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	100a‡	276c	476cd	35.6cd	82c	483cd
M2 (907+1003+1214)	100a	382bc	919ab	34.6d	76d	506bc
M3 (864+907+1079+1229)	100a	332bc	838b	41.0b	71e	502bc
907	100a	442b	1031a	35.7cd	67e	478cd
1003	100a	346bc	1072a	37.7bcd	71e	531b
1448	100a	301c	547c	38.3bcd	82c	467de
1588	100a	274c	553c	34.9cd	82c	442e
1760	100a	301c	613c	36.8bcd	82c	465de
Reubens	100a	660a	351d	61.7a	115a	226f
Nugget	100a	601a	538c	39.4bc	98b	578a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.18. Performance of selected alpine bluegrass lines in multilocation trial 3 at Vegreville in 1994. The trial was seeded in 1992.

Line	Survival (%)	Number of Heads (no m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	93ab‡	106b	22d	36.5c	87c	497a
M2 (907+1003+1214)	98a	152b	82ab	33.9cd	78d	510a
M3 (864+907+1079+1229)	95a	124b	23d	33.0cd	73d	478a
907	86b	131b	29cd	30.3d	73d	476a
1003	98a	152b	102a	36.5c	73d	533a
1448	99a	418b	20d	37.8c	87c	496a
1588	98a	147b	42bcd	36.2c	87c	458a
1760	98a	144b	60bcd	37.9c	87c	456a
Reubens	100a	1060a	55bcd	62.0a	104a	311b
Nugget	100a	383b	69abc	47.5b	95b	514a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.19. Performance of selected alpine bluegrass lines in multilocation trial 2 at Beaverlodge in 1992. The trial was seeded in 1991.

Line	Survival (%)	Number of Heads (no m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	100a‡	136b	56b	29.4b	75c	553bc
M2 (907+1003+1214)	100a	116b	52b	25.3cde	75c	565abc
M3 (864+907+1079+1229)	100a	161b	63b	25.7cde	75c	517bcd
907	100a	180b	85b	24.6de	75c	468cd
1003	100a	154b	87b	27.6bcd	75c	578ab
1448	100a	150b	28b	30.5b	75c	553bc
1588	100a	214b	64b	28.3bc	75c	498bcd
1760	100a	196b	56b	29.3b	82b	556bc
Reubens	100a	420a	238a	42.2a	97a	429d
Nugget	98a	101b	45b	23.8e	97a	658a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.20. Performance of selected alpine bluegrass lines in multilocation trial 2 at Beaverlodge in 1993. The trial was seeded in 1991.

Line	Survival (%)	Number of Heads (no m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	72cde‡	152c	194bc	31.7b	68c	474b
M2 (907+1003+1214)	79bcd	145c	252ab	30.6b	68c	522ab
M3 (864+907+1079+1229)	62de	123c	205bc	31.4b	68c	460b
907	69cde	168c	198bc	30.0b	68c	488b
1003	88abc	132c	338a	31.6b	68c	499b
1448	66de	145c	214bc	31.6b	68c	489b
1588	58e	169c	115c	29.1b	68c	490b
1760	73cde	182c	242abc	32.5b	68c	488b
Reubens	100a	1146a	166bc	39.6a	117a	243c
Nugget	96ab	292b	152bc	36.3a	104b	583a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 6 for all means.

Table B.21. Performance of selected alpine bluegrass lines in multilocation trial 3 at Plamondon in 1993. The trial was seeded in 1992.

Line	Survival (%)	Number of Heads (no m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	100a‡	97c	73cd	35.4b	83b	265a
M2 (907+1003+1214)	100a	174b	160a	34.1bc	76c	257a
M3 (864+907+1079+1229)	100a	115bc	82bcd	33.3bc	76c	251a
907	100a	116bc	70cd	31.8bc	76c	238a
1003	100a	72c	142ab	33.8bc	76c	263a
1448	100a	103bc	68cd	36.3b	83b	269a
1588	100a	118bc	77bcd	32.3bc	83b	240a
1760	100a	125bc	108abc	32.9bc	83b	252a
Reubens	100a	361a	107abc	48.3a	92a	127b
Nugget	100a	68c	25d	30.2c	92a	261a

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 4 for all means.

Table B.22. Performance of selected alpine bluegrass lines in multilocation trial 3 at Plamondon in 1994. The trial was seeded in 1992.

Line	Survival (%)	Number of Heads (no m^{-1})	Seed Yield (kg ha^{-1})	Plant Height (cm)	Time to Maturity (days†)	1000 Seed Weight (mg)
M1 (1448+1588+1760)	100a‡	431b	120bcd	47.0b	83b	589ab
M2 (907+1003+1214)	100a	384b	398a	44.9b	76c	513c
M3 (864+907+1079+1229)	100a	312b	190bc	44.0b	76c	584abc
907	100a	413b	233b	41.9b	76c	514c
1003	100a	340b	396a	43.3b	76c	584abc
1448	100a	426b	44d	46.3b	83b	614a
1588	100a	346b	39d	43.0b	83b	581abc
1760	100a	484b	202bc	43.0b	83b	527bc
Reubens	100a	785a	101cd	70.6a	109a	224d
Nugget	100a	530b	53d	43.9b	109a	529bc

†Days from April 15 to maturity.

‡Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 4 for all means.

APPENDIX C

METEOROLOGICAL DATA FOR RESEARCH SITES

Table C.1. Meteorological data for Vegreville, Alberta, 1988 - 1994.

	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly maximum air temperature (°C)	1988	-9.1	-3.0	6.2	13.1	20.9	23.3	22.6	22.0	16.9	12.4	-1.0	-5.1
	1989	-6.0	-10.8	-4.9	11.5	17.3	21.5	24.0	21.9	17.4	10.8	0.3	-5.2
	1990	-5.4	-5.6	2.9	9.6	18.0	22.3	22.3	22.3	19.7	8.5	-3.2	-10.9
	1991	-8.5	1.5	0.3	3.2	18.0	20.4	24.8	26.9	18.7	6.1	-1.8	-5.5
	1992	-3.7	-4.4	6.3	12.0	15.7	22.7	22.3	22.1	14.9	10.0	0.6	-12.8
	1993	-10.3	-6.7	2.9	9.6	18.6	20.2	20.6	21.0	16.8	10.4	-0.1	-1.4
	1994[†]	-15.7	-16.1	-3.0	12.2	18.5	18.7	23.7	20.9	19.5	10.6	-2.2	-10.7
Average monthly minimum air temperature (°C)	1988	-19.1	-15.0	-6.5	-1.8	5.3	10.6	9.9	8.8	4.1	-1.6	-9.1	-13.0
	1989	-17.0	-21.9	-15.6	-2.3	2.6	8.5	11.0	10.3	4.2	-2.3	-8.0	-14.1
	1990	-14.2	-19.6	-6.2	-1.3	3.4	8.0	9.7	9.2	4.3	-4.1	-13.6	-22.7
	1991	-18.6	-8.1	-11.5	-1.4	3.8	8.2	9.2	10.9	3.9	-6.1	-11.8	-15.7
	1992	-15.0	-13.8	-4.2	-0.4	2.8	8.7	8.5	6.4	1.6	-3.6	-7.3	-23.4
	1993	-22.6	-17.6	-6.9	4.4	6.9	9.0	7.7	3.3	-4.3	-10.9	-13.9	-13.9
	1994[†]	-20.2	-21.7	-4.5	3.9	10.5	13.7	15.8	13.2	9.5	0.7	-8.3	-17.0
Total monthly precipitation (mm)	1988	4.5	13.5	25.9	15.0	23.0	135.2	31.2	132.8	43.7	1.7	7.5	21.5
	1989	25.0	8.0	7.5	4.5	45.9	77.4	65.0	101.3	39.6	16.6	20.0	15.0
	1990	5.3	19.0	8.5	8.1	17.1	56.4	120.0	82.4	14.5	4.4	21.0	7.5
	1991	0.0	13.0	5.0	41.4	58.1	44.3	22.6	44.4	10.4	37.4	2.0	10.5
	1992	10.0	11.0	0.5	20.2	42.2	21.6	69.6	35.4	13.8	8.7	1.0	19.5
	1993	5.0	2.5	14.0	54.0	35.4	54.6	98.3	54.6	21.8	0.0	6.5	2.0
	1994	36.5	2.5	6.0	0.0	67.6	97.2	64.2	82.0	17.2	17.0	18.0	6.0

[†]Means were calculated without weekend values for air temperature which were not available in 1994.

Table C.2. Meteorological data for Beaverlodge, Alberta, 1990 - 1993.

	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly maximum air temperature (°C)	1990	-6.3	-4.6	5.7	9.4	15.9	19.6	23.1	22.3	19.2	6.2	-6.6	-8.8
	1991	-6.9	1.4	-0.5	13.0	17.7	18.5	22.4	24.0	17.9	6.0	-1.3	-3.0
	1992	-0.6	-5.3	7.8	11.1	15.4	21.9	22.2	22.5	12.1	7.6	1.4	-11.4
	1993	-7.5	-3.4	4.3	10.4	18.4	19.8	18.9	20.1	17.2	11.6	2.1	0.3
Average monthly minimum air temperature (°C)	1990	-14.5	-17.6	-5.1	-2.6	3.5	7.0	9.4	9.3	5.4	-2.3	-14.7	-20.4
	1991	-17.4	-6.7	-10.8	-0.3	3.7	7.2	8.2	10.2	5.5	-3.6	-11.6	-11.1
	1992	-9.9	-12.0	-3.5	-0.9	2.7	9.6	8.7	8.1	2.0	-1.9	-6.0	-20.0
	1993	-19.4	-12.5	-5.6	-0.5	6.0	7.4	8.6	7.9	4.2	0.5	-7.2	-8.1
Total monthly precipitation (mm)	1990	46.5	10.9	7.6	9.5	44.2	189.9	58.7	45.5	16.6	18.6	67.0	54.0
	1991	7.4	2.0	9.8	15.0	44 .0	90.1	28.1	54.8	28.5	20.0	30.0	43.0
	1992	20.5	20.5	12.5	16.9	26.8	45.3	57.6	49.7	80.0	5.3	11.2	27.7
	1993	12.4	5.4	6.1	25.2	15.3	134.0	79.4	81.0	23.2	21.3	2.5	24.5

Table C.3. Meteorological data for Columbia Icefields, Jasper National Park, Alberta, 1988-1994.

	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly maximum air temperature (°C)	1988	-[†]	-	-	-	-	14.5	15.2	14.9	12.5	-	-	-
	1989	-	-	-	-	-	-	21.6	14.8	12.3	5.9	-1.5	2.9
	1990	-0.2	-5.2	7.4	-	-	-	-	-	-	-	-	-
	1991	1.8	2.8	4.7	5.7	13.2	14.2	14.3	15.9	-	-	-	-
	1992	-	-	-	7.6	9.2	16.5	15.6	16.4	-	-	-	-
	1993	-	-	-	-	13.2	16.5	19.0	17.2	12.6	-	-2.7	-2.7
	1994	-2.2	-6.4	2.9	6.2	10.2	14.2	19.0	17.2	14.4	4.6	-4.7	-5.5
Average monthly minimum air temperature (°C)	1988	-	-	-	-	-	5.0	5.0	4.1	0.9	-	-	-
	1989	-	-	-	-	-	-	7.2	4.5	0.8	-2.9	-10.2	-6.7
	1990	-11.5	-14.5	-10.1	-	-	-	-	-	-	-	-	-
	1991	-5.0	-7.3	-7.1	-5.3	1.4	1.7	1.5	3.7	-	-	-	-
	1992	-	-	-	-0.5	-0.4	4.9	9.6	3.7	-	-	-	-
	1993	-	-	-	-	5.3	6.1	4.3	2.4	0.7	-5.3	-12.9	-12.3
	1994	-11.4	-18.9	-10.8	-4.8	-0.1	2.6	6.1	4.3	3.8	-5.0	-12.8	-14.5

[†]Gaps in the weather data were due to problems with downloading data to tapes, especially during the winter months.

Table C.4. Meteorological data for Mountain Park, Alberta, 1991-1994.

	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly maximum air temperature (°C)†	1991	-	-	-	-	-	-	-	-	12.1	20.8	-1.6	-1.0
	1992	-2.0	2.3	5.7	5.7	-	-	-	19.0	15.1	-	-	-
	1993	-	-	-	-	-	-	-	-	9.2	9.9	2.1	-1.1
	1994	1.2	4.8	5.1	5.9	10.8	-	-	-	-	-	-	-
Average monthly minimum air temperature (°C)†	1991	-	-	-	-	-	-	-	-	-0.4	-0.9	-10.5	-9.4
	1992	-10.2	-9.7	-7.0	-5.5	-	-	-	5.7	1.1	-	-	-
	1993									2.6	1.9	-5.7	-6.2
	1994	-	-	-	-	-1.3	-5.3	-3.9	-4.7	-3.1	-4.7	-7.8	-8.1

†The data set for this site is incomplete because of problems with downloading data to tapes, especially during the winter months. For some months, means are based on less than the total number of days in the month.

Table C.5. Meteorological data for Lookout Mountain, Sunshine Village Ski Resort in Banff National Park, Alberta, 1988 and 1989[†].

	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly maximum air temperature (°C)	1988	-	-	-	-	-	-	-	-	5.0	3.4	-6.8	-8.0
	1989	-10.7	-12.2	-5.4	-0.4	-	-	-	-	-	-	-	-
Average monthly minimum air temperature (°C)	1988	-	-	-	-	-	-	-	-	-1.7	-2.5	-6.8	-13.4
	1989	-17.5	-20.9	-14.1	-7.3	-	-	-	-	-	-	-	-

[†]Meteorological data for this site is incomplete because it was difficult to maintain a weather station at the site and the station was removed in spring 1989.