Development of Three Slender Wheatgrass Reclamation Varieties

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DEVELOPMENT OF THREE SLENDER WHEATGRASS RECLAMATION VARIETIES

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TABLE OF CONTENTS

LIST OF TABLES

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: slender wheatgrass (*Elymus trachycaulus*, including awnless slender wheatgrass [ssp. *trachycaulus*], awned slender wheatgrass [ssp. *subsecundus*], and broadglumed wheatgrass [ssp. *violaceus*]), alpine bluegrass (*Poa alpina*), 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. Slender wheatgrass was one of the most promising species of these four. It has rapid and good establishment, thus helping to stabilize the soil and prevent erosion. Slender wheatgrass is relatively short-lived and non-competitive. It allows other native plant species from undisturbed areas to invade a reclaimed site. This helps to create a vegetative cover similar to that of the surrounding area.

Ten lines of slender wheatgrass were selected for evaluation in provenance trials at Vegreville, Columbia Icefields, Sunshine Village, and Mountain Park. Data from these trials were used to select seven wheatgrass lines for final evaluation in multilocation trials at Vegreville, Beaverlodge, Columbia Icefields, and Mountain Park. Based on the information collected in these evaluation trials, three reclamation varieties of slender wheatgrass were released by the Alberta Environmental Centre. AEC Highlander slender wheatgrass was released in 1993. It is a mid-elevation variety adapted to elevations as high as 2000 m. AEC Hillcrest awned slender wheatgrass, a lower elevation type (grows best at elevations up to 1800 m) adapted to drier conditions, was released in 1994. This was followed by the release of AEC Mountaineer broadglumed wheatgrass in 1995. AEC Mountaineer is adapted to the highest elevations and grows and produces seed up to elevations of 2200 m. 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 and consequently 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 plants, 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 a research project in 1984. The objective of this project is to select, test, develop, and release 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: slender wheatgrass (*Elymus trachycaulus* (Link) Gould in Shinners), alpine bluegrass (*Poa alpina* L.), 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 three varieties of slender wheatgrass. Slender wheatgrass is a self-pollinated, cool season, perennial bunch grass (Rogler 1973; Hardy BBT Ltd. 1989). It establishes rapidly because of its high germination and vigourous seedlings but is short-lived (Rogler 1973). Slender wheatgrass is native to a large range of environments across North America and there is considerable variation among ecotypes of this species (Hardy BBT Ltd. 1989). Although primarily a bunch grass, small rhizomes are sometimes present. Seed yields are high and seed is relatively easy to thresh and handle.

Three subspecies of slender wheatgrass have been included in our research program. The first subspecies is *E. trachycaulus* ssp. *trachycaulus* or awnless slender wheatgrass. This subspecies has also been referred to as *Agropyron trachycaulum* var. *trachycaulum* (Moss 1983). Awned slender wheatgrass (*E. trachycaulus* ssp. *subsecundus* (Link) Gould) was the second subspecies studied. This species was formerly called *A. trachycaulum* var. *unilaterale* (Cassidy) Malte or *A. subsecundum* (Link) A.S. Hitchc. (Moss 1983). Broadglumed wheatgrass, *E. trachycaulus* ssp. *violaceus* (Horneman) A. & D. Love, was also included as part of the research project. Broadglumed wheatgrass was previously designated as a separate species, *A. violaceum* (Hornem.) Lange (Moss 1983), but has since been included within the slender wheatgrass species.

Awnless slender wheatgrass (or slender wheatgrass) prefers moist to dry sites (Hardy BBT Ltd. 1989) but is less drought tolerant than crested wheatgrass. It is moderately to highly

tolerant of alkaline soil conditions and occurs naturally under a variety of soil nutrient conditions. It is a good colonizing species and is reasonably well adapted to disturbed sites but it is less competitive than many other grasses.

Awned slender wheatgrass (also awned wheatgrass or bearded wheatgrass) is common in moist meadows and open woods (Hardy BBT Ltd. 1989). It is tolerant to low nutrient supplies, alkaline soil conditions, and moderate or low salinity. Awned slender wheatgrass is also relatively shade tolerant and is more drought tolerant than awnless slender wheatgrass.

Broadglumed wheatgrass is adapted to higher elevations and is generally found in montane to alpine slopes and meadows (Moss 1983). It is generally shorter than the other two subspecies.

Research to select and develop varieties of slender wheatgrass was started at AEC in 1984 when plants of slender wheatgrass 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 one variety of each subspecies, research was conducted to determine the most appropriate techniques for growing these varieties for seed production and reclamation.

2 VARIETY DESCRIPTIONS

2.1 AEC Highlander Slender Wheatgrass

AEC Highlander slender wheatgrass, *Elymus trachycaulus* (Link) Gould in Shinners ssp. *trachycaulus*, was released by the Alberta Environmental Centre in 1993 for use in reclaiming and revegetating disturbed sites in the mountains and foothills of Alberta. AEC Highlander is adapted to the short growing seasons of high elevations and can grow rapidly and produce mature seed in short growing seasons.

2.1.1 Origin and Breeding

AEC Highlander was derived from a single plant collected in the Crowsnest Pass region (elevation 2000 m) of southwestern Alberta in 1985. It was part of a collection of slender wheatgrass plants collected from 100 sites in the eastern slopes of the Rocky Mountains. The seed from this plant was designated as line 279 and has been multiplied and tested through successive generations. AEC Highlander 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 Highlander is a self-pollinated perennial bunch grass. The spikes of AEC Highlander are more dense and have more seeds per spike (28 seeds per spike on average) than spikes of Revenue slender wheatgrass (17 seeds per spike on average). The lemmas and glumes are awn-tipped with the lemma awns up to 2 mm long and glume awns up to 1 mm long. Culms of AEC Highlander plants are generally bluish-green. Off-types in this variety include plants with lemma awns longer than 5 mm.

2.1.3 Performance

AEC Highlander produced more seed than Revenue (121 mg plant^{-1} compared to 21 mg plant^{-1}) in mountain trials (Table 1). It matured approximately 3 to 4 wk earlier than Revenue and this is especially important given the very short growing season at higher elevations. At the mountain locations, plants of AEC Highlander were often harvested by late August whereas

Revenue plants did not ripen within the growing season. Above-ground biomass and plant height were also greater for AEC Highlander, although the number of heads produced per plant was similar. AEC Highlander had higher seed yields than Revenue in 4 out of 6 station-years when grown at low elevation sites, Vegreville and Beaverlodge (Table 2). On average, AEC Highlander outyielded Revenue by 14% with a mean seed yield of 994 kg ha^{-1} from small plots. No head smut (*Ustilago bullata* Berk) was observed on plants of AEC Highlander although it was observed on Revenue plants. At the plains sites, AEC Highlander matured approximately two weeks before Revenue.

2.1.4 Utilization

AEC Highlander is primarily for use in reclaiming and revegetating disturbed sites in the mountains and foothills of Alberta up to an elevation of approximately 2000 m. AEC Highlander is also expected to do well outside of this area. The primary advantage the variety has over other varieties of slender wheatgrass is its early maturity. It is capable of growing rapidly and producing mature seed in the short growing seasons found at higher elevations. It may also be useful at more northerly locations where the growing season can be very short. Like all varieties of slender wheatgrass (Crowle 1970; Rogler 1973), AEC Highlander is short-lived (4 to 5 yr) when grown at lower elevations in the prairie area.

2.1.5 Seed Distribution

Breeder seed of AEC Highlander slender wheatgrass will be maintained by the Alberta Environmental Centre, Vegreville, Alberta. The multiplication and distribution of Foundation and Certified seed will be handled by Pickseed Canada, Inc., Box 3230, Sherwood Park Alberta, T8A 2A6.

Table 1. Performance of AEC Highlander and Revenue slender wheatgrass in trials at Columbia Icefields (elevation 1860 m) and Mountain Park (elevation 1800 m). Trials were established using transplants in 1988 at Columbia Icefields and 1989 at Mountain Park.

Location	Year	Variety	Seed Yield (mg/plant)	Number of Heads (no./plant)	Above-ground Biomass (mg/plant)	Plant Height (cm)
Columbia Icefields	1990	AEC Highlander	168	1.7	876	40.7
		Revenue	32	1.6	805	37.4
		SE[†]	24	0.4	200	2.6
Columbia Icefields	1991	AEC Highlander	106	1.3	792	48.5
		Revenue	0	0.7	264	21.8
		SE	15	0.2	101	7.4
Columbia Icefields	1992	AEC Highlander	125	1.2	-	35.4
		Revenue	21	1.2	-	29.8
		SE	36	0.3	-	8.2
Mountain Park	1990	AEC Highlander	232	3.6	1284	40.4
		Revenue	8	0.5	1002	34.5
		SE	29	0.4	130	2.2
Mountain Park	1991	AEC Highlander	24	0.4	470	38.7
		Revenue	5	1.5	517	32.2
		SE	6	0.2	89	2.4
Mountain Park	1992	AEC Highlander	70	1.5	-	41.4
		Revenue	19	2.1	-	29.5
		SE	21	0.3	-	3.3
Mean		AEC Highlander	121	1.6	856	40.8
		Revenue	14	1.3	647	30.9

[†] Standard error based on 44 degrees of freedom.

Table 2. Performance of AEC Highlander and Revenue slender wheatgrass in small plot trials at Vegreville (elevation 640 m) and Beaverlodge (elevation 730 m), Alberta.

Trial	Year Seeded	Year Harvested	Variety	Seed Yield (kg ha^{-1})	Number of Heads (no. m^{-1})	Time to Maturity (days†)	Plant Height (cm)	1000 Seed Weight (g)
First Year of Seed Harvest								
Vegreville	1990	1991	AEC Highlander	1299	264	91	94.0	3.45
			Revenue	906	204	106	97.8	3.68
			SE‡	100	19	0.6	4.0	0.09
Vegreville	1991	1992	AEC Highlander	1321	177	100	75.2	3.26
			Revenue	1242	242	112	90.5	3.69
			SE	118	26	0.5	2.3	0.05
Beaverlodge	1990	1991	AEC Highlander	1415	237	96	96.8	3.44
			Revenue	1102	257	108	97.8	3.54
			SE	75	20	0.7	3.0	0.06
Beaverlodge	1991	1992	AEC Highlander	630	282	98	66.6	3.51
			Revenue	705	434	113	94.0	3.61
			SE	65	22	0.1	2.2	0.05
Second Year of Seed Harvest								
Vegreville	1990	1992	AEC Highlander	902	191	100	81.0	3.62
			Revenue	777	363	111	81.2	3.54
			SE	91	24	1.7	3.1	0.07
Beaverlodge	1991	1992	AEC Highlander	398	200	97	72.8	3.62
			Revenue	513	391	113	90.0	3.49
			SE	51	21	0.0	1.7	0.05
Mean			AEC Highlander	994	225	97	81.0	3.48
			Revenue	874	315	110	91.9	3.59

†Days from April 15 to maturity.
‡Standard error based on 35 degrees of freedom.

2.2 AEC Hillcrest Awned Slender Wheatgrass

The Alberta Environmental Centre released AEC Hillcrest awned slender wheatgrass, *Elymus trachycaulus* ssp. *subsecundus* (Link) Gould, in 1994 for use in reclamation and revegetation in the mountains and foothills of Alberta. This reclamation variety is the first variety of awned slender wheatgrass available in Canada.

2.2.1 Origin and Breeding

AEC Hillcrest (line 299) was derived from a single plant collected in 1985 from a site (elevation 1800 m) near Hillcrest, in the Crowsnest Pass region of southwestern Alberta. It was part of a slender wheatgrass collection from 100 sites in the eastern slopes of the Rocky Mountains. The seed from this plant has been multiplied and tested through successive generations. AEC Hillcrest 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 Hillcrest is a self-pollinated perennial bunch grass. Spikes have long awns with lemma awns 10 to 30 mm long and glume awns 3 to 7 mm long. Culms of AEC Hillcrest plants are generally bluish-green due to the colour of the leaf sheaths. AEC Hillcrest has a stronger blue colour than AEC Highlander slender wheatgrass. Lemmas of AEC Highlander and other slender wheatgrass varieties are awn-tipped. Leaf sheaths are glabrous on upper leaves but pubescent on lower leaves. Off-types in this variety include plants with lemma awns shorter than 5 mm.

2.2.3 Performance

AEC Hillcrest is a different subspecies of slender wheatgrass than either AEC Highlander (*Elymus trachycaulus* ssp. *trachycaulus*) or Revenue (*E. trachycaulus* ssp. *trachycaulus*). Therefore, it is difficult to make direct comparisons among these varieties. In mountain trials, all three varieties provided similar plant cover (Table 3). However, limited data were available on seed yields because it takes three or more years of growth before slender wheatgrass begins to produce seed heads at high elevations. At Mountain Park in 1993, AEC Hillcrest produced

some seed (7.3 mg m^{-1}) while Revenue produced no seed. In 1994, both AEC Hillcrest and Revenue had similar seed yields although most seed from Revenue was immature. Plant height was greatest for AEC Hillcrest, followed by Revenue and AEC Highlander. AEC Hillcrest matured approximately 2 wk earlier than Revenue. In preliminary trials, plants of AEC Hillcrest were often harvested by late August at mountain locations whereas Revenue plants often did not ripen within the growing season. At low elevation prairie sites, seed yields of AEC Hillcrest were lower than those of AEC Highlander and Revenue (Tables 4, 5, 6) although these differences were not always significant. In the first year of seed production, AEC Hillcrest had a mean seed yield of 698 kg ha^{-1} (4 station-years) compared to 1166 kg ha^{-1} for AEC Highlander and 989 kg ha^{-1} for Revenue (Table 4). In the second year of seed production, mean seed yield of AEC Hillcrest was reduced to 490 kg ha^{-1} (Table 5) and seed yields were further reduced in the third year of seed production (Table 6). AEC Hillcrest matured 0 to 7 days earlier than Revenue and 10 to 14 days later than AEC Highlander. No head smut (*Ustilago bullata* Berk) was observed on AEC Hillcrest although it was observed on plants of Revenue.

2.2.4 Utilization

AEC Hillcrest is primarily for use in reclaiming and revegetating disturbed sites in the mountains and foothills of Alberta up to an elevation of approximately 1800 m. AEC Hillcrest tends to be adapted to lower elevations than AEC Highlander but is adapted to higher elevations than Revenue. It is capable of growing rapidly and producing mature seed in the short growing seasons found in the mountains and foothills. Like all varieties of slender wheatgrass (Crowle 1970; Rogler 1973), AEC Hillcrest is short-lived (4 to 5 yr) when grown at lower elevations in the prairie area.

2.2.5 Seed Distribution

Breeder seed of AEC Hillcrest awned slender wheatgrass will be maintained by the Alberta Environmental Centre, Vegreville, Alberta. The multiplication and distribution of Foundation and Certified seed will be handled by Peace Valley Seeds, Ltd., Box 100, Rycroft, Alberta, T0H 3A0.

Table 3. Performance of AEC Hillcrest, AEC Highlander, and Revenue slender wheatgrass 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	1993	AEC Hillcrest	10.8	-[†]	-	-
		AEC Highlander	23.3	-	-	-
		Revenue	32.5	-	-	-
		SE[‡]	4.7	-	-	-
Columbia Icefields	1994	AEC Hillcrest	15.8	-	-	-
		AEC Highlander	45.0	-	-	-
		Revenue	44.2	-	-	-
		SE	7.6	-	-	-
Mountain Park	1993	AEC Hillcrest	49.2	7.3	0.4	37.0
		AEC Highlander	39.2	3.3	0.1	37.0
		Revenue	50.8	0.0	0.5	21.0
		SE	4.1	5.7	0.2	3.7
Mountain Park	1994	AEC Hillcrest	87.5	112.3	1.7	53.0
		AEC Highlander	82.5	18.7	0.3	39.0
		Revenue	89.2	124.8	5.5	37.7
		SE	5.4	36.0	0.8	4.0
Mean		AEC Hillcrest	40.8	59.8	1.1	45.0
		AEC Highlander	47.5	11.0	0.2	38.0
		Revenue	54.2	62.4	3.0	29.4

[†] No or few flowering heads produced.
[‡] Standard error based on 35 degrees of freedom.

Table 4. Performance of AEC Hillcrest, AEC Highlander, and Revenue slender wheatgrass in the first year of seed production in small plot trials at Vegreville (elevation 640 m) and Beaverlodge (elevation 730 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 (g)
	Seeded	Harvested						
Vegreville	1990	1991	AEC Hillcrest	787	152	101	95.3	3.70
			AEC Highlander	1299	264	91	94.0	3.45
			Revenue	906	204	106	97.8	3.68
			SE[‡]	100	19	0.6	4.0	0.09
Vegreville	1991	1992	AEC Hillcrest	747	147	106	72.8	3.61
			AEC Highlander	1321	177	100	75.2	3.26
			Revenue	1242	242	112	90.5	3.69
			SE	118	26	0.5	2.3	0.05
Beaverlodge	1990	1991	AEC Hillcrest	919	225	120	102.1	3.60
			AEC Highlander	1415	237	96	96.8	3.44
			Revenue	1102	257	108	97.8	3.54
			SE	75	20	0.7	3.0	0.06
Beaverlodge	1991	1992	AEC Hillcrest	340	217	113	63.4	3.81
			AEC Highlander	630	282	98	66.6	3.51
			Revenue	705	434	113	94.0	3.61
			SE	65	22	0.1	2.2	0.05
Mean			AEC Hillcrest	698	185	110	83.4	3.68
			AEC Highlander	1166	240	96	83.2	3.42
			Revenue	989	284	110	95.0	3.63

[†] Days from April 15 to maturity.
[‡] Standard error based on 35 degrees of freedom.

Table 5. Performance of AEC Hillcrest, AEC Highlander, and Revenue slender wheatgrass in the second year of seed production in small plot trials at Vegreville (elevation 640 m) and Beaverlodge (elevation 730 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 (g)
	Seeded	Harvested						
Vegreville	1990	1992	AEC Hillcrest	419	150	108	77.1	3.70
			AEC Highlander	902	191	100	81.0	3.62
			Revenue	777	363	111	81.2	3.54
			SE[‡]	91	24	1.7	3.1	0.07
Vegreville	1991	1993	AEC Hillcrest	873	143	111	100.9	4.09
			AEC Highlander	1538	163	99	96.4	3.68
			Revenue	1328	239	127	122.4	4.33
			SE	102	29	0.0	3.3	0.07
Beaverlodge	1990	1992	AEC Hillcrest	207	159	113	74.1	3.74
			AEC Highlander	398	200	97	72.8	3.62
			Revenue	513	391	113	90.0	3.49
			SE	51	21	0.0	1.7	0.05
Beaverlodge	1991	1993	AEC Hillcrest	462	101	117	80.1	3.95
			AEC Highlander	765	126	104	81.3	3.26
			Revenue	564	122	117	90.0	3.43
			SE	41	11	0.0	4.9	0.06
Mean			AEC Hillcrest	490	138	112	83.0	3.87
			AEC Highlander	901	170	100	82.9	3.54
			Revenue	795	279	117	95.9	3.70

[†] Days from April 15 to maturity.
[‡] Standard error based on 35 degrees of freedom.

Table 6. Performance of AEC Hillcrest, AEC Highlander, and Revenue slender wheatgrass in the third year of seed production in small plot trials at Vegreville (elevation 640 m) and Beaverlodge (elevation 730 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 (g)
	Seeded	Harvested						
Vegreville	1990	1993	AEC Hillcrest	396	142	112	90.0	3.91
			AEC Highlander	768	174	99	90.8	3.38
			Revenue	573	184	127	97.3	4.12
			SE[‡]	69	46	0.0	3.3	0.12
Vegreville	1991	1994	AEC Hillcrest	217	67	107	84.7	4.36
			AEC Highlander	416	70	103	73.8	3.69
			Revenue	559	223	112	104.6	4.26
			SE	53	14	2.4	2.4	0.21
Beaverlodge	1990	1993	AEC Hillcrest	139	46	117	73.4	3.74
			AEC Highlander	317	64	104	69.8	3.33
			Revenue	304	79	117	80.0	3.47
			SE	21	7	0.0	2.0	0.09
Mean			AEC Hillcrest	251	85	112	82.7	4.00
			AEC Highlander	500	103	102	78.1	3.47
			Revenue	479	162	119	94.0	3.95

[†] Days from April 15 to maturity.
[‡] Standard error based on 35 degrees of freedom.

2.3 AEC Mountaineer Broadglumed Wheatgrass

AEC Mountaineer broadglumed wheatgrass, *Elymus trachycaulus* ssp. *violaceus* (Horneman) A. & D. Love, was developed at the Alberta Environmental Centre, Vegreville, AB and released in 1995. It is the first variety of broadglumed wheatgrass available in Canada. AEC Mountaineer was developed for use in reclaiming and revegetating disturbed sites in the mountains and foothills of Alberta. Its primary advantage over other slender wheatgrass varieties is its ability to grow rapidly and produce mature seed at elevations as high as 2300 m.

2.3.1 Origin and Breeding

AEC Mountaineer (line 144) was derived from a single plant collected in 1984 from a site (elevation 2200 m) south of Kananaskis Country, Alberta. It was part of a slender wheatgrass collection from 100 sites in the eastern slopes of the Rocky Mountains. The seed from this plant has been multiplied and tested through successive generations. AEC Mountaineer 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).

2.3.2 Varietal Characteristics

AEC Mountaineer is a self-pollinated perennial bunch grass with a semi-decumbent growth habit. Plants are 35 to 45 cm tall with glabrous culms and spikes are 8 to 14 cm long. Glumes are broad, scarious-margined and glabrous and have awn tips 1 to 3 mm long. Lemmas are pubescent with awn tips less than 2 mm long. Off-types in this variety include plants with lemma awns greater than 5 mm or plants greater than 55 cm tall with longer, narrower (greater than 15 cm long) spikes.

2.3.3 Performance

AEC Mountaineer broadglumed wheatgrass is a subspecies of slender wheatgrass but it is quite different from other subspecies so it is difficult to compare to other varieties. The superiority of AEC Mountaineer is demonstrated by its performance in mountain trials. AEC Mountaineer produced the most seed at Mountain Park (Table 7). It also outyielded other lines and varieties in preliminary trials at Mountain Park and Columbia Icefields in 1989-1994 (see

Appendix A). AEC Mountaineer matured approximately 3 to 4 wk earlier than other slender wheatgrass types at high elevations. At the mountain sites, it was usually harvested in mid-August while AEC Highlander slender wheatgrass was harvested in late August to early September. Plants of AEC Hillcrest awned slender wheatgrass and Revenue slender wheatgrass were harvested even later or did not mature within the growing season. AEC Mountaineer provided plant cover similar to other varieties at the mountain sites, and was the shortest variety (Table 7). At the plains sites, AEC Mountaineer had lower yields than other varieties (Tables 8, 9, 10) but it maintained its early maturity. In some cases, plants of AEC Mountaineer were harvested as late as AEC Hillcrest or Revenue. This was due to the growth habit of the variety. During the long growing season of lower elevations, plants of AEC Mountaineer generally produce two flushes of heads, one very early, and one later in the season. If spring conditions are dry, the first flush of heads may be very sparse so harvest may be delayed until later in the season to include the second flush. If harvested when the first heads are ripe, AEC Mountaineer matured by the last week of June, approximately 4 wk earlier than AEC Highlander and 5 to 6 wk earlier than AEC Hillcrest and Revenue. AEC Mountaineer was shorter than other varieties of slender wheatgrass and it tended to produce heavier seeds.

2.3.4 Utilization

AEC Mountaineer was developed for reclaiming and revegetating disturbed sites in the mountains and foothills of Alberta. AEC Mountaineer is adapted to higher elevations than either AEC Highlander or AEC Hillcrest and can grow and produce mature seed at elevations up to 2300 m. It may also be useful at more northerly locations where the growing season can be very short. Like all varieties of slender wheatgrass (Crowle 1970; Rogler 1973), AEC Mountaineer is short-lived (4 to 5 yr) when grown at lower elevations in the prairie area.

2.3.5 Seed Distribution

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

Table 7. Performance of AEC Mountaineer, AEC Hillcrest, AEC Highlander, and Revenue slender wheatgrass 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	1993	AEC Mountaineer	25.8	-[†]	-	-
		AEC Hillcrest	10.8	-	-	-
		AEC Highlander	23.3	-	-	-
		Revenue	32.5	-	-	-
		SE[‡]	4.7	-	-	-
Columbia Icefields	1994	AEC Mountaineer	25.0	-	-	-
		AEC Hillcrest	15.8	-	-	-
		AEC Highlander	45.0	-	-	-
		Revenue	44.2	-	-	-
		SE	7.6	-	-	-
Mountain Park	1993	AEC Mountaineer	55.0	41.0	1.0	24.5
		AEC Hillcrest	49.2	7.2	0.4	37.0
		AEC Highlander	39.2	3.3	0.1	37.0
		Revenue	50.8	0.0	0.5	21.0
		SE	4.1	5.7	0.2	3.7
Mountain Park	1994	AEC Mountaineer	97.5	163.2	2.2	24.8
		AEC Hillcrest	87.5	112.3	1.7	53.0
		AEC Highlander	82.5	18.7	0.3	39.0
		Revenue	89.2	124.8	5.5	37.7
		SE	5.4	36.0	0.8	4.0
Mean		AEC Mountaineer	50.8	102.1	1.6	24.6
		AEC Hillcrest	40.8	59.8	1.1	45.0
		AEC Highlander	47.5	11.0	0.2	38.0
		Revenue	54.2	62.4	3.0	29.4

[†] No or few flowering heads produced.
[‡] Standard error based on 35 degrees of freedom.

Table 8. Performance of AEC Mountaineer, AEC Hillcrest, AEC Highlander, and Revenue slender wheatgrass in the first year of seed production in small plot trials at Vegreville (elevation 640 m) and Beaverlodge (elevation 730 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 (g)
	Seeded	Harvested						
Vegreville	1990	1991	AEC Mountaineer	218	80	84	36.7	3.74
			AEC Hillcrest	787	152	101	95.3	3.70
			AEC Highlander	1299	264	91	94.0	3.45
			Revenue	906	204	106	97.8	3.68
			SE[‡]	100	19	0.6	4.0	0.09
Vegreville	1991	1992	AEC Mountaineer	66	151	112	42.5	3.61
			AEC Hillcrest	747	147	106	72.8	3.61
			AEC Highlander	1321	177	100	75.2	3.26
			Revenue	1242	242	112	90.5	3.69
			SE	118	26	0.5	2.3	0.05
Beaverlodge	1990	1991	AEC Mountaineer	1228	406	79	54.9	3.93
			AEC Hillcrest	919	225	120	102.1	3.60
			AEC Highlander	1415	237	96	96.8	3.44
			Revenue	1102	257	108	97.8	3.54
			SE	75	20	0.7	3.0	0.06
Beaverlodge	1991	1992	AEC Mountaineer	202	223	113	37.7	3.47
			AEC Hillcrest	340	217	113	63.4	3.81
			AEC Highlander	630	282	98	66.6	3.51
			Revenue	705	434	113	94.0	3.61
			SE	65	22	0.1	2.2	0.05
Mean			AEC Mountaineer	429	215	97	43.0	3.69
			AEC Hillcrest	698	185	110	83.4	3.68
			AEC Highlander	1166	240	96	83.2	3.42
			Revenue	989	284	110	95.0	3.63

[†] Days from April 15 to maturity.
[‡] Standard error based on 35 degrees of freedom.

Table 9. Performance of AEC Mountaineer, AEC Hillcrest, AEC Highlander, and Revenue slender wheatgrass in the second year of seed production in small plot trials at Vegreville (elevation 640 m) and Beaverlodge (elevation 730 m), Alberta.

Location	Year Seeded	Year Harvested	Variety	Seed Yield (kg ha^{-1})	Number of Heads (no. m^{-1})	Time to Maturity (days[†])	Plant Height (cm)	1000 Seed Weight (g)
Vegreville	1990	1992	AEC Mountaineer	137	97	111	38.7	3.71
			AEC Hillcrest	419	150	108	77.1	3.70
			AEC Highlander	902	191	100	81.0	3.62
			Revenue	777	363	111	81.2	3.54
			SE[‡]	91	24	1.7	3.1	0.07
Vegreville	1991	1993	AEC Mountaineer	477	172	81	52.9	4.30
			AEC Hillcrest	873	143	111	100.9	4.09
			AEC Highlander	1538	163	99	96.4	3.68
			Revenue	1328	239	127	122.4	4.33
			SE	102	29	0.0	3.3	0.07
Beaverlodge	1990	1992	AEC Mountaineer	97	201	76	37.6	3.81
			AEC Hillcrest	207	159	113	74.1	3.74
			AEC Highlander	398	200	97	72.8	3.62
			Revenue	513	391	113	90.0	3.49
			SE	51	21	0.0	1.7	0.05
Beaverlodge	1991	1993	AEC Mountaineer	179	59	54	52.6	4.58
			AEC Hillcrest	462	101	117	80.1	3.95
			AEC Highlander	765	126	104	81.3	3.26
			Revenue	564	122	117	90.0	3.43
			SE	41	11	0.0	4.9	0.06
Mean			AEC Mountaineer	222	132	80	45.4	4.10
			AEC Hillcrest	490	138	112	83.0	3.87
			AEC Highlander	901	170	100	82.9	3.54
			Revenue	795	279	117	95.9	3.70

[†] Days from April 15 to maturity.
[‡] Standard error based on 35 degrees of freedom.

Table 10. Performance of AEC Mountaineer, AEC Hillcrest, AEC Highlander, and Revenue slender wheatgrass in the third year of seed production in small plot trials at Vegreville (elevation 640 m) and Beaverlodge (elevation 730 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 (g)
	Seeded	Harvested						
Vegreville	1990	1993	AEC Mountaineer	57	68	82	34.5	3.52
			AEC Hillcrest	396	142	112	90.0	3.91
			AEC Highlander	768	174	99	90.8	3.38
			Revenue	573	184	127	97.3	4.12
			SE[‡]	69	46	0.0	3.3	0.12
Vegreville	1991	1994	AEC Mountaineer	50	11	99	33.3	3.44
			AEC Hillcrest	217	67	107	84.7	4.36
			AEC Highlander	416	70	103	73.8	3.69
			Revenue	559	223	112	104.6	4.26
			SE	53	14	2.4	2.4	0.21
Beaverlodge	1990	1993	AEC Mountaineer	189	72	54	40.7	4.33
			AEC Hillcrest	139	46	117	73.4	3.74
			AEC Highlander	317	64	104	69.8	3.33
			Revenue	304	79	117	80.0	3.47
			SE	21	7	0.0	2.0	0.09
Mean			AEC Mountaineer	99	50	78	36.2	3.76
			AEC Hillcrest	251	85	112	82.7	4.00
			AEC Highlander	500	103	102	78.1	3.47
			Revenue	479	162	119	94.0	3.95

[†] Days from April 15 to maturity.
[‡] Standard error based on 35 degrees of freedom.

3 DEVELOPMENT OF VARIETIES

3.1 Collection of Plant Material and Initial Selection

Systematic collections of plants of slender wheatgrass were made in 1984 and 1985. These collections were part of a germplasm collection of four species; plants of alpine bluegrass, spike trisetum, and Rocky Mountain fescue, were also collected at the same time. A total of 317 collection sites were used and slender wheatgrass plants were found at 100 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). Slender wheatgrass collection sites varied in elevation from 1000 m to 2500 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 788 plants of slender wheatgrass were transferred to a field nursery with over 98% transplantation success. Initially, 245 plants of slender wheatgrass were selected from the field nursery. Of these, approximately 137 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, 10 lines of slender wheatgrass were selected for further evaluation in provenance trials. These included two lines of broadglumed wheatgrass, three lines of awned slender wheatgrass, and five lines of slender wheatgrass. Because slender wheatgrass is a self-pollinated species, 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 10 selected slender wheatgrass lines at three mountain locations and at Vegreville. These lines included two lines of broadglumed wheatgrass (lines 72, 144), five lines of awnless slender wheatgrass (lines 279, 281, 283, 286, 290), and three lines of awned slender wheatgrass (lines 292, 296, and 299). Two agronomic varieties, Revenue slender wheatgrass and Elbee northern wheatgrass (*Elymus lanceolatus* (Scribner & J.B. Smith) Gould), 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 1988 (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, only three plants per plot were

used due to limited availability of plants. Each transplanted provenance trial consisted of five replicates, 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 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 levels of available nutrients, 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 1992 (Table 11). Lines 72, 144 (AEC Mountaineer), and 279 (AEC Highlander) produced the most seed per plant. Line 279 was also in the top three lines for above-ground biomass. Lines of awnless slender wheatgrass tended to be the tallest while broadglumed wheatgrass and Elbee northern wheatgrass plants were shortest. In the second transplanted provenance trial at Columbia Icefields, the most heads and highest seed yields were observed in 1990 (Table 12). Once again the top three lines for seed yield were 72, 144, and 279. Lines 72 and 144 also produced the most heads per plant.

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 13) were comparable to those of the first transplanted provenance trial at Columbia Icefields (Table 11). Lines 144 and 279 produced the most heads and most seed per plant at Mountain Park (Table 13). Once again, line 279 was in the top three lines for above-ground biomass production.

At Lookout Mountain, the elevation of the site was too high for slender wheatgrass to produce heads during the short growing season. Therefore, only above-ground biomass and plant width data were collected for the transplanted provenance trials at this site (Table 14). Biomass was greater in 1989 than in 1990 (data on biomass were not collected in 1991 or 1993). Plant width appeared to decrease each year, reflecting the poor growth of these plants at this high elevation. No significant differences among lines were observed for biomass or plant width.

In the seeded provenance trial at Columbia Icefields, line 144 clearly outperformed all other lines in terms of seed yield and number of heads produced (Table 15). Lines 72 and 279 also did well. At Lookout Mountain, lines were evaluated only for percent cover (Table 16). As in the transplanted trials at this site, the growing season was too short for slender wheatgrass to flower and produce seed. Lines 286 and 290 had the highest cover values at this site for both trials. Variation in mean cover among years may have been due to different people estimating cover in different years as well as the actual performance of the plants.

At Vegreville, lines 279 and 281 produced the most seed in the transplanted provenance trial (Table 17). Seed yield was higher in the second year than in the first. Although Elbee northern wheatgrass produced the most heads, line 279 had the second highest number of heads. Above-ground plant biomass was similar for all lines, except the two broadglumed wheatgrass lines (lines 72 and 144), which produced significantly less biomass. These two lines were also among the shortest lines. Time to maturity was related to subspecies; lines 72 and 144 matured first, followed by the awnless slender wheatgrass lines, and then the awned slender wheatgrass lines. Elbee matured at about the same time as the awnless slender wheatgrass lines while Revenue matured last. Awned slender wheatgrass lines had the highest seed weights.

In seeded provenance trials at Vegreville, seed yield decreased in the second year of seed production for both trials (Table 18). Lines 281, 286, and 279 produced the greatest seed yields while lines 72 and 144 had the lowest yields. Although it produced the most heads, Revenue had

the sixth highest seed yield. Time to maturity groupings were similar to those for the transplanted provenance trial (Table 17) with broadglumed wheatgrass lines maturing first and awned slender wheatgrass lines and Revenue maturing last (Table 18). Flag leaf lengths were similar for all lines and Elbee but Revenue had significantly longer flag leaves.

Overall, line 279, which was later released as AEC Highlander, performed the best of the selected lines, producing high seed yields in both the mountain and plains sites. Line 144, later released as AEC Mountaineer, had the best overall performance in mountain trials although, like the other broadglumed wheatgrass line, it had low seed yields at lower elevations on the plains. The awned wheatgrass lines, including line 299 which was released as AEC Hillcrest, were intermediate in seed yield at plains sites but did not perform as well at mountain locations. This subspecies seems to be adapted to lower elevations than the other two slender wheatgrass types. In many cases, the selected lines outperformed the check varieties, Elbee northern wheatgrass and Revenue slender wheatgrass. This was especially true at the mountain locations where Elbee and Revenue were poorly adapted to the environmental conditions. Even at the plains locations, some selected lines, including line 279, produced more seed than the checks.

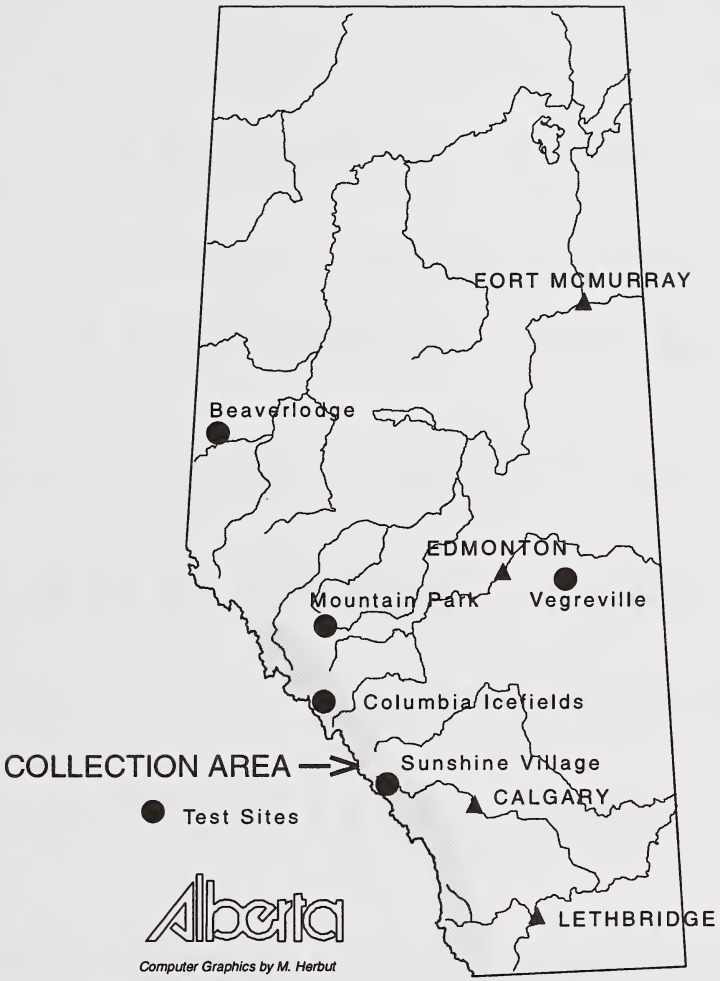

Fig. 1. Collection area and locations used to test selected lines of slender wheatgrass.

Table 11. Performance of selected slender wheatgrass 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 = 60):												
1989	2.7A[†]	1	-	-	-	-	46.1A	1	3.7E	6	3.4A	2
1990	0.9B	2	49AB	2	709A	1	38.7B	2	6.6B	2	4.2A	1
1991	0.6C	4	32B	5	540B	2	38.6B	3	4.5D	5	3.1A	3
1992	0.7BC	3	64A	1	-	-	38.4B	4	5.9BC	3	-	-
1993	0.5C	6	34B	4	-	-	35.3C	6	5.8C	4	-	-
1994	0.6C	5	49AB	3	-	-	35.3C	5	9.8A	1	-	-
LINE[‡]:												
72	1.5b	3	109a	1	499a	10	27.4e	11	6.6ab	4	3.0bcd	8
144	2.3a	1	99ab	3	567a	8	25.8e	12	6.8a	1	3.1bcd	7
279	1.4b	5	100ab	2	798a	3	44.3abc	6	5.9abcd	8	3.5bcd	5
281	0.9bcd	7	57abc	5	602a	6	44.6abc	5	6.6ab	3	3.5bcd	4
283	1.6b	2	89ab	4	810a	2	47.0ab	4	6.1abcd	7	4.3bc	3
286	1.1bc	6	48bcd	6	661a	5	41.8bcd	7	5.2bcd	10	3.1bcd	6
290	0.7cde	8	13cd	8	858a	1	37.7cd	9	6.8a	2	5.0b	2
292	0.4de	10	1d	11	401a	12	50.9a	1	5.5abcd	9	2.0de	11
296	0.3de	11	13cd	7	725a	4	49.8a	2	6.5abc	5	2.6cd	9
299	0.6cde	9	6cd	10	600a	7	47.2ab	3	5.2cd	11	2.1de	10
Revenue	1.5b	4	12cd	9	520a	9	35.3d	10	4.9d	12	7.2a	1
Elbee	0.1e	12	1d	12	452a	11	38.8cd	8	6.4abcd	6	0.4e	12
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 ($P \leq 0.05$).
[‡]Lines 72 and 144 (AEC Mountaineer) are broadglumed wheatgrass; lines 279 (AEC Highlander), 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 (AEC Hillcrest) are awned slender wheatgrass.

Table 12. Performance of selected slender wheatgrass 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 = 48):										
1990	0.5A[†]	1	12A	1	35.3A	1	4.0B	3	3.1A	2
1991	0.1B	4	2B	5	25.5A	3	3.8B	4	4.4A	1
1992	0.2B	2	5B	3	28.6A	2	4.5B	2	-	-
1993	0.1B	5	4B	4	22.8A	4	3.7B	5	-	-
1994	0.2B	3	7B	2	21.9A	5	7.3A	1	-	-
LINE[‡]:										
72	0.7a	2	23a	2	20.7d	9	6.9b	2	1.0b	7
144	0.7a	1	24a	1	23.4bcd	7	5.2c	3	2.2ab	6
279	0.3b	4	15ab	3	35.1bc	4	4.7cd	4	2.6ab	4
281	0.2bc	5	6bc	4	37.6b	2	3.4d	11	2.7ab	3
283	0.1c	6	2c	7	27.0bcd	6	4.4cd	7	-	-
286	0.1c	8	0c	9	36.0b	3	4.6cd	5	2.5ab	5
290	0.0c	9	0c	9	-	-	4.0cd	9	-	-
292	0.0c	9	0c	9	-	-	3.2d	12	-	-
296	0.1c	8	2c	6	56.0a	1	4.4cd	6	4.0ab	2
299	0.1c	7	1c	8	21.0cd	8	3.6cd	10	-	-
Revenue	0.6a	3	5c	5	28.0bcd	5	4.0cd	8	6.5a	1
Elbee	0.0c	9	0c	9	-	-	8.4a	1	-	-
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 ($P \leq 0.05$).

[‡]Lines 72 and 144 (AEC Mountaineer) are broadglumed wheatgrass; lines 279 (AEC Highlander), 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 (AEC Hillcrest) are awned slender wheatgrass.

Table 13. Performance of selected slender wheatgrass 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 = 60):												
1990	1.3A[†]	2	70A	1	644A	1	34.8B	2	5.1C	5	3.8A	2
1991	0.3C	5	5B	5	479B	2	32.3B	4	5.3C	4	4.2A	1
1992	1.3A	1	21B	3	-	-	34.6B	3	8.8B	2	-	-
1993	0.4C	4	6B	4	-	-	28.6C	5	7.4B	3	-	-
1994	0.8B	3	63A	2	-	-	39.7A	1	11.1A	1	-	-
LINE[‡]:												
72	1.2abcd	4	42bcd	5	477bcd	8	24.5d	11	8.1b	2	3.6b	4
144	1.7a	1	70ab	2	490bcd	6	24.0d	12	7.0bc	3	2.6b	12
279	1.5ab	2	89a	1	794a	2	39.8bc	4	5.3bc	11	3.1b	9
281	0.9bcde	6	45bcd	4	674ab	4	35.1c	7	5.8bc	8	3.1b	8
283	0.8cde	7	34bcd	6	644abc	5	38.0bc	5	5.5bc	10	3.8b	3
286	1.1abcd	5	60abc	3	861a	1	40.9bc	3	6.8bc	4	3.9b	2
290	0.5de	8	19cd	7	288d	12	32.4cd	9	5.9bc	6	2.8b	11
292	0.2e	11	8d	10	374cd	11	51.0a	1	5.8bc	9	3.5b	6
296	0.3e	9	9d	9	432bcd	10	37.4bc	6	5.8bc	7	3.4b	7
299	0.2e	12	1d	12	471bcd	9	44.0ab	2	6.0bc	5	3.0b	10
Revenue	1.4abc	3	18cd	8	724ab	3	32.2cd	10	3.8c	12	8.8a	1
Elbee	0.2e	10	2d	11	490bcd	7	34.9c	8	24.5a	1	3.5b	5
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 ($P \leq 0.05$).
[‡]Lines 72 and 144 (AEC Mountaineer) are broadglumed wheatgrass; lines 279 (AEC Highlander), 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 (AEC Hillcrest) are awned slender wheatgrass.

Table 14. Performance of selected slender wheatgrass lines in transplanted provenance trial (established in 1987) at Lookout Mountain (Sunshine Village) in 1989 to 1993.

	Above-ground Biomass		Plant Width	
	mg plant^{-1}	rank	cm	rank
YEAR (n = 60):				
1989	245A[†]	1	-	-
1990	79B	2	2.9A	1
1991	-	-	2.3B	2
1993[‡]	-	-	1.4C	3
LINE[§]:				
72	109a	12	2.3a	7
144	133a	9	2.3a	8
279	174a	4	2.5a	4
281	137a	8	2.5a	3
283	225a	1	2.6a	2
286	211a	2	2.4a	5
290	157a	7	2.7a	1
292	191a	3	1.6a	11
296	174a	6	2.0a	9
299	174a	5	1.8a	10
Revenue	114a	10	1.1a	12
Elbee	112a	11	2.4a	6
n	15		20	

[†]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.

[§]Lines 72 and 144 (AEC Mountaineer) are broadglumed wheatgrass; lines 279 (AEC Highlander), 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 (AEC Hillcrest) are awned slender wheatgrass.

Table 15. Performance of selected slender wheatgrass 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 = 36):												
1989	1.9A[†]	2	-	-	32D	6	31.9B	6	-	-	-	-
1990	1.8A	3	96A	1	38A	5	33.5AB	4	6.0B	2	3.2B	2
1991	1.1A	4	10C	5	46C	4	32.1B	5	4.4C	5	4.2A	1
1992	2.1A	1	86A	2	47BC	3	36.9A	1	4.6C	4	-	-
1993	0.8A	6	17BC	4	54AB	2	35.5AB	2	5.6BC	3	-	-
1994	1.0A	5	55AB	3	56A	1	34.1AB	3	7.5A	1	-	-
LINE[‡]:												
72	1.3b	3	61b	2	27de	11	23.7d	12	6.3a	3	2.3a	8
144	8.2a	1	301a	1	57abcd	4	26.6cd	11	6.4a	2	2.7a	6
279	1.1b	5	56b	3	51abcde	5	40.6abc	6	5.2a	8	3.0a	5
281	0.8b	6	48b	4	45abcde	6	43.1abc	3	6.2a	5	2.5a	7
283	0.7b	8	34b	5	71ab	2	38.2abcd	8	5.6a	6	3.5a	4
286	0.8b	7	10b	8	60abc	3	47.0a	1	6.2a	4	2.0a	9
290	0.3b	11	16b	7	32cde	9	39.6abcd	7	4.9a	10	2.5a	7
292	0.1b	12	1b	11	21e	12	35.0abcd	9	3.6a	12	-	-
296	0.6b	9	26b	6	41bcde	7	41.1abc	4	4.5a	11	2.5a	7
299	0.4b	10	6b	9	39bcde	8	40.7abc	5	5.0a	9	3.7a	3
Revenue	1.2b	4	2b	10	30cde	10	29.3bcd	10	5.4a	7	8.0a	1
Elbee	1.4b	2	0b	12	74a	1	43.7ab	2	7.4a	1	6.0a	2
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 ($P \leq 0.05$).
[‡]Lines 72 and 144 (AEC Mountaineer) are broadglumed wheatgrass; lines 279 (AEC Highlander), 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 (AEC Hillcrest) are awned slender wheatgrass.

Table 16. Performance of selected slender wheatgrass lines in seeded provenance trials (established in 1987 and 1988) at Lookout Mountain (Sunshine Village) in 1989 to 1993.

	Trial 1		Trial 2	
	% cover	rank	% cover	rank
YEAR (n = 48):				
1989	10B[†]	4	14B	2
1990	14B	2	9C	4
1991	34A	1	42A	1
1993[‡]	11B	3	9C	3
LINE[§] (n = 16):				
72	20abc	4	17bc	6
144	21abc	3	21abc	5
279	16abcd	7	22abc	4
281	17abcd	6	22abc	4
283	19abcd	5	23ab	2
286	25a	1	22ab	3
290	25ab	2	28a	1
292	14cd	10	13bc	9
296	15cd	9	13bc	9
299	9d	12	15bc	8
Revenue	11cd	11	12c	10
Elbee	15bcd	8	16bc	7

[†]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.

[§]Lines 72 and 144 (AEC Mountaineer) are broadglumed wheatgrass; lines 279 (AEC Highlander), 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 (AEC Hillcrest) are awned slender wheatgrass.

Table 17. Performance of selected slender wheatgrass 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	g	rank
YEAR (n = 60):														
1988	45B[‡]	2	9.2B	2	64.6	-	50.5	-	23.3	-	89B	1	4.1A	1
1989	71A	1	12.9A	1	-	-	-	-	-	-	98A	2	3.6B	2
LINE[§]:														
72	71bc	3	4.5f	10	44.4b	10	37.2b	9	22.2b	2	74f	1	3.7bcd	7
144	53c	9	4.1f	12	41.1b	11	29.8b	11	18.6b	9	77f	2	3.8bc	6
279	73b	2	20.0a	1	70.8a	5	58.8a	2	21.2b	3	89e	3	3.6cde	8
281	67bc	6	19.1ab	2	73.9a	2	56.4a	4	19.6b	7	92de	4	3.5de	10
283	68bc	5	15.9b	4	73.6a	3	58.0a	3	20.2b	6	95cd	6	3.4e	11
286	66bc	7	17.4ab	3	74.6a	1	53.0a	7	18.8b	8	92de	5	3.5de	9
290	24d	12	4.1f	11	68.0a	7	35.8b	10	16.0b	11	96cd	7	4.6a	2
292	35d	10	10.1cd	6	68.4a	6	56.0a	5	21.0b	4	103b	10	4.6a	1
296	30d	11	8.7de	7	60.4a	9	56.4a	4	17.6b	10	104b	11	4.6a	3
299	54c	8	12.4c	5	61.8a	8	59.2a	1	20.4b	5	102b	9	4.3a	4
Revenue	68bc	4	4.8f	9	-[¶]	-	54.2a	6	20.2b	6	110a	12	3.9b	5
Elbee	94a	1	6.8ef	8	71.2a	4	51.2a	8	69.2a	1	97c	8	3.0f	12
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 ($P \leq 0.05$).

[§]Lines 72 and 144 (AEC Mountaineer) are broadglumed wheatgrass; lines 279 (AEC Highlander), 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 (AEC Hillcrest) are awned slender wheatgrass.

[¶]Revenue was cut and removed early because of head smut infection.

Table 18. Performance of selected slender wheatgrass lines in seeded provenance trials at Vegreville in 1988, 1989, and 1990.

	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	g	rank	cm	rank
TRIAL AND YEAR[‡] (n = 48):														
S1 1988	338A[§]	1	57.6A	1	424	-	-	-	88D	1	4.1	3	-	-
S1 1989	212C	3	43.4C	3	-	-	57.6B	2	102A	4	4.1	1	-	-
S2 1989	280B	2	57.2B	2	-	-	52.7B	3	100B	3	4.1	2	-	-
S2 1990	84D	4	12.3D	4	-	-	70.4A	1	97C	2	-	-	8.4	-
LINE[¶]:														
72	199cdef	8	14.4d	12	399abc	8	34.1d	12	72f	1	3.6f	11	7.0b	10
144	166defg	9	16.3cd	11	281c	11	39.8cd	11	88e	2	4.1e	6	7.2b	9
279	284abc	4	63.6a	3	433abc	5	63.2ab	6	95d	4	3.8ef	9	8.2b	4
281	304ab	2	66.9a	1	509a	2	63.2ab	8	95d	5	3.9ef	7	7.7b	6
283	256abcd	6	61.8a	4	485ab	3	60.9ab	9	96d	6	3.8ef	10	8.0b	5
286	282abc	5	64.2a	2	470ab	4	64.6ab	5	94d	3	3.9ef	8	7.5b	8
290	98g	12	18.0cd	10	346bc	9	50.7bc	10	102bc	9	4.8bc	3	6.6b	11
292	126fg	11	36.1bcd	8	342bc	10	68.8a	2	107b	11	5.3a	1	8.2b	3
296	150efg	10	38.0bc	7	433abc	6	66.2ab	4	107b	10	5.0ab	2	-	-
299	226bcde	7	52.8ab	5	424abc	7	66.5ab	3	102bc	8	4.5cd	4	7.6b	7
Revenue	345a	1	52.6ab	6	-[#]	-	74.0a	1	113a	12	4.1de	5	13.2a	1
Elbee	297abc	3	23.8cd	9	524a	1	63.2ab	7	97cd	7	3.0g	12	8.9b	2
n	16		16		4		12		16		12		4	

[†]Days from April 15 to maturity.

[‡]Trial S1 was seeded in 1987 and S2 was seeded in 1988.

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

[¶]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[#]Revenue was cut down early because of head smut infection.

3.3 Multilocation Trials

3.3.1 Materials and Methods

Seven lines of slender wheatgrass, 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 slender wheatgrass selections included three broadglumed wheatgrass lines (lines 137, 144, and M1), two awnless slender wheatgrass lines (lines 279 and M2), and two awned wheatgrass lines (lines 299 and M3). Line M1 was a mixture of lines 137 and 144, M2 consisted of lines 279, 281, and 286, and M3 was mixture of lines 292, 296, and 299. Revenue slender wheatgrass was used as a check variety in all trials.

Multilocation trials were seeded in 1990 and 1991 at Vegreville, Beaverlodge (elevation 730 m), Columbia Icefields, and Mountain Park (Fig. 1). 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 20 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 determined 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 all 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, there were limited data available because it usually takes three or more years before slender wheatgrass plants begin to flower and set seed. At the Columbia Icefields site, plants in Trial 1 (seeded in 1990) did not produce seed heads until 1994. 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 young. Mean percent cover in this trial was only 17% in 1993 (Table 19). In Trial 1, percent cover ranged from only 23% in 1993 to 80% in 1992. Because cover estimates are subjective, some of the variation among years may be due to different people estimating cover values. Lines M1 and 279 had the highest mean cover values. At this site, Revenue had the highest mean seed yield in 1994 but many of its seeds were very green when harvested in mid-September. Lines M3 and M1 also produced some seed, but variability was so high that there were no significant differences for seed yield. Plant width was similar for all lines and Revenue.

At Mountain Park, where environmental conditions were less harsh, seed was harvested from Trial 1 in 1992 to 1994 and from Trial 2 in 1994. Percent cover values (Table 20) were higher than those observed at Columbia Icefields (Table 19). The broadglumed wheatgrass lines had the highest mean cover values while awned slender wheatgrass lines had the lowest although all lines had mean cover values of 45% or greater (Table 20). Once again, high variability made it difficult to detect differences in seed yield, although line 144 produced the most seed. Broadglumed wheatgrass lines had the shortest and widest plants while awned wheatgrass plants were the tallest.

In the first year of seed production (second year of growth) at the plains locations , winter survival was 99% or greater for all trials except Trial 1 at Vegreville in 1991 (Table 21). The 1990/91 winter seemed to be more severe than 1991/92 winter at Vegreville, possibly due to the early arrival of snow in October. First year seed yields ranged from 348 kg ha^{-1} at Beaverlodge, Trial 2, to 1086 kg ha^{-1} at Beaverlodge, Trial 1. The low yields in Trial 2 at Beaverlodge were due to a hail storm which damaged plants and caused some premature shattering of seed. The number of heads produced was similar for both trials at Beaverlodge, and these values were significantly higher than those for the Vegreville trials. Line 279 had the best seed yields (mean of 1166 kg ha^{-1}), followed by line M2, both awnless slender wheatgrass. These two lines yielded higher than Revenue, the check variety, which had the third highest yields. Lines of broadglumed wheatgrass had the lowest yields (255 to 429 kg ha^{-1}). The number of heads followed the same general trend except that Revenue had the most heads. Revenue generally produced smaller spikes than the selected awnless slender wheatgrass lines and therefore produced fewer seeds per spike. Revenue also produced the tallest plants, followed by the awned wheatgrass lines. Plants of broadglumed wheatgrass were the shortest and they also matured the earliest. Awned wheatgrass and Revenue matured last. All lines matured earlier in 1991 than in 1992. Seed weight was similar for all lines and Revenue and for all locations although awned wheatgrass tended to have the heaviest seeds while awnless slender wheatgrass had the lightest seeds.

In the second year of seed production, winter survival was high (greater than 90%) for all locations and lines (Table 22). Seed yields were reduced for Trial 1 at both sites compared to the first year of seed production. In Trial 2, however, second year seed yields were higher than those in the first year. This may reflect the better moisture conditions in 1993 compared to 1992. In addition, hail reduced yields in the first year of Trial 2 at Beaverlodge (Table 21) and in the second year of Trial 1 at Beaverlodge (Table 22). Among lines, the trend was similar to that observed in the first year with the awnless slender wheatgrass lines yielding the highest (901 to 960 kg ha^{-1}) and broadglumed wheatgrass lines with the poorest yields (222 to 317 kg ha^{-1}). Revenue had the highest number of heads but was only third highest for seed yield. Plant height and time to maturity values showed similar trends among lines as were observed in the first year. Broadglumed wheatgrass was the earliest and awned wheatgrass and Revenue were

latest. For seed weights, awnless slender wheatgrass had the lightest seeds while broadglumed and awned wheatgrass had seeds of similar weights.

The third year of seed production showed some decrease in survival for the broadglumed wheatgrass lines but all other lines had very high survival values (Table 23). Seed yields were reduced compared to the second year of seed production. For example, in Trial 1 at Vegreville, mean seed yield in 1993 was 394 kg ha^{-1} (Table 23) compared to 483 kg ha^{-1} in 1992 (Table 22) and 695 kg ha^{-1} in 1991 (Table 21). Among lines, awnless slender wheatgrass lines still had the highest yields while broadglumed wheatgrass yields were very low (68 to 104 kg ha^{-1}) (Table 23). Trends in number of heads produced were similar to previous years with Revenue producing the most heads. The same groupings of lines were observed for plant height, time to maturity and seed weights as had been observed in previous years.

Of the single lines, line 279 clearly outperformed all lines and Revenue at the plains sites. This line was released as AEC Highlander slender wheatgrass. At mountain sites, line 279 did not perform as well as it had in the provenance trials but it still appeared to be well adapted to higher elevations. Line 144, released as AEC Mountaineer, was the best line at high elevations although it did not produce large seed yields at plains sites. However, the amount of seed produced was adequate for providing large amounts of seed for reclamation purposes. Line 299, released at AEC Hillcrest, was intermediate between these two lines, at both the mountain sites and plains sites. It performed well at both high and low elevations, although it was not the best performer at any site.

In our breeder seed plots, which were harvested with a combine as opposed to hand harvesting of small plot trials, average seed yield for AEC Highlander slender wheatgrass was 832 kg ha^{-1}. For AEC Hillcrest awned slender wheatgrass, mean seed yield was 317 kg ha^{-1}, and average seed yield on breeder seed plots of AEC Mountaineer broadglumed wheatgrass was 180 kg ha^{-1}. These seed yields were lower than those recorded from small plot trials because some seed was lost due to shattering when combining the fields. Yields observed on breeder seed plots will more closely approximate those to be expected on larger seed fields of these varieties.

Table 19. Mean performance of selected slender wheatgrass 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
TRIAL AND YEAR (n = 48):										
Trial 1 - 1991[†]	51 B[‡]	2	-	-	-	-	-	-	-	-
Trial 1 - 1992	80 A	1	-	-	-	-	-	-	-	-
Trial 1 - 1993	23 CD	5	-	-	-	-	-	-	-	-
Trial 1 - 1994	32 C	4	0.1	-	4.5	-	30.5	-	5.3	-
Trial 2 - 1992	45 B	3	-	-	-	-	-	-	-	-
Trial 2 - 1993	17 D	6	-	-	-	-	-	-	-	-
LINE:										
M1 (137+144)[§]	46 a	1	0.1a	3	0.7a	3	31.0a	2	5.7a	4
137	39 bc	6	0.0a	4	0.0a	4	-	-	3.8a	8
144	42 abc	4	0.0a	4	0.0a	4	-	-	4.0a	7
M2 (279+281+286)	40 abc	5	0.0a	4	0.0a	4	-	-	6.0a	3
279	45 ab	2	0.0a	4	0.0a	4	-	-	4.2a	6
M3 (292+296+299)	38 bc	7	0.2a	2	4.3a	2	25.5a	3	6.5a	2
299	37 c	8	0.0a	4	0.0a	4	-	-	5.5a	5
Revenue	44 abc	3	0.7a	1	30.7a	1	40.0a	1	6.7a	1
n	36		6		6		6		6	

[†]Trial 1 was seeded in 1990 and Trial 2 was seeded in 1991.
[‡]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).
[§]M1, 137, and 144 are broadglumed wheatgrass; M2 and 279 are awnless slender wheatgrass; M3 and 299 are awned slender wheatgrass.

Table 20. Mean performance of selected slender wheatgrass 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
TRIAL AND YEAR (n = 48):										
Trial 1 - 1991[†]	70B[‡]	3	0.3C	4	-	-	-	-	-	-
Trial 1 - 1992	56C	4	0.8B	2	6.0B	3	32.9AB	3	4.7C	3
Trial 1 - 1993	47D	5	0.3C	3	7.9B	2	26.6B	4	3.9D	4
Trial 1 - 1994	90A	1	1.5A	1	75.3A	1	38.7A	1	9.6A	1
Trial 2 - 1992	37E	7	-	-	-	-	-	-	-	-
Trial 2 - 1993	37E	6	-	-	-	-	-	-	-	-
Trial 2 - 1994	74B	2	0.2C	5	2.7B	4	35.0AB	2	6.0B	2
LINE:										
M1 (137+144)[§]	66a	1	0.3b	4	13.5a	5	21.0d	8	6.5a	4
137	62ab	2	0.1b	7	11.2a	7	31.7bc	6	6.7a	2
144	66a	1	0.8b	2	51.8a	1	23.9cd	7	6.8a	1
M2 (279+281+286)	60abc	3	0.2b	5	15.1a	4	39.0ab	3	6.5a	3
279	56bc	5	0.1b	7	5.8a	8	38.5ab	4	5.8b	5
M3 (292+296+299)	45d	7	0.2b	6	12.6a	6	39.4ab	2	5.3bc	7
299	55c	6	0.6b	3	33.0a	3	46.6a	1	5.6bc	6
Revenue	57bc	4	2.7a	1	40.6a	2	34.8b	5	5.0c	8
n	36		30		24		24		24	

[†]Trial 1 was seeded in 1990 and Trial 2 was seeded in 1991.
[‡]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).
[§]M1, 137, and 144 are broadglumed wheatgrass; M2 and 279 are awnless slender wheatgrass; M3 and 299 are awned slender wheatgrass.

Table 21. Mean performance of selected slender wheatgrass lines in the first year of seed production in multilocation trials at Vegreville and Beaverlodge.

	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	g	rank
LOCATION (n = 48):												
Vegreville Trial 1 - 1991[‡]	83 B[§]	3	155 B	4	695 B	2	74.5B	2	92 D	1	3.6B	2
Vegreville Trial 2 - 1992	99 A	2	160 B	3	680 B	3	66.6C	3	106 B	3	3.5B	4
Beaverlodge Trial 1 - 1991	100 A	1	276 A	1	1086 A	1	84.0A	1	97 C	2	3.7A	1
Beaverlodge Trial 2 - 1992	100 A	1	253 A	2	348 C	4	59.6D	4	109 A	4	3.5B	3
LINE (n = 24):												
M1 (137+144)[¶]	93 a	7	184 a	7	388 cd	7	47.0c	7	95 c	2	3.6bc	6
137	95 a	6	188 a	5	255 d	8	47.5c	6	94 c	1	3.6abc	5
144	92 a	8	215 a	4	429 cd	6	42.9c	8	96 bc	4	3.7ab	2
M2 (279+281+286)	97 a	5	245 a	2	1079 a	2	82.1b	5	96 bc	3	3.3c	8
279	97 a	3	240 a	3	1166 a	1	83.2b	4	96 bc	3	3.4bc	7
M3 (292+296+299)	97 a	4	148 a	8	614 bcd	5	88.2ab	2	111 a	7	3.9a	1
299	98 a	2	185 a	6	698 bc	4	83.4b	3	110 ab	6	3.7ab	3
Revenue	98 a	1	284 a	1	989 ab	3	95.0a	1	110 ab	5	3.6abc	4

[†]Days from April 15 to maturity.
[‡]Trial 1 was seeded in 1990 and Trial 2 was seeded in 1991.
[§]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).
[¶]M1, 137, and 144 are broadglumed wheatgrass; M2 and 279 are awnless slender wheatgrass; M3 and 299 are awned slender wheatgrass.

Table 22. Mean performance of selected slender wheatgrass lines in the second year of seed production in multilocation trials at Vegreville and Beaverlodge.

	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	g	rank
LOCATION (n = 48):												
Vegreville Trial 1 - 1992[‡]	93 B[§]	3	163 B	3	483 B	2	65.1BC	3	108 A	4	3.7C	4
Vegreville Trial 2 - 1993	100 A	1	176 B	2	1014 A	1	88.2A	1	99 B	3	4.1A	1
Beaverlodge Trial 1 - 1992	95 B	2	213 A	1	248 C	4	63.9C	4	95 C	2	3.8C	3
Beaverlodge Trial 2 - 1993	100 A	1	93 C	4	464 B	3	71.6B	2	90 D	1	4.0B	2
LINE (n = 24):												
M1 (137+144)[¶]	92 b	8	120 b	8	301 bc	7	47.0c	7	80 b	1	4.1ab	2
137	95 ab	6	130 b	7	317 bc	6	50.0c	6	81 b	2	4.2a	1
144	94 ab	7	132 b	6	222 c	8	45.5c	8	80 b	1	4.1ab	3
M2 (279+281+286)	99 a	2	180 b	2	960 a	1	83.5b	3	100 ab	3	3.5c	8
279	99 a	3	170 b	3	901 a	2	82.9b	5	100 ab	3	3.5c	7
M3 (292+296+299)	99 a	4	142 b	4	452 b	5	89.7ab	2	113 a	5	4.1ab	4
299	98 a	5	138 b	5	490 b	4	83.0b	4	112 a	4	3.9abc	5
Revenue	99 a	1	279 a	1	795 a	3	95.9a	1	117 a	6	3.7bc	6

[†]Days from April 15 to maturity.
[‡]Trial 1 was seeded in 1990 and Trial 2 was seeded in 1991.
[§]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).
[¶]M1, 137, and 144 are broadglumed wheatgrass; M2 and 279 are awnless slender wheatgrass; M3 and 299 are awned slender wheatgrass.

Table 23. Mean performance of selected slender wheatgrass lines in the third year of seed production in multilocation trials at Vegreville and Beaverlodge.

	Survival		Number of Heads		Seed Yield		Plant Height		Time to Maturity		1000 Seed Weight	
	%	rank	no. m^{-1}	rank	kg/ha	rank	cm	rank	days[†]	rank	g	rank
LOCATION (n = 48):												
Vegreville Trial 1 - 1993[‡]	96 A[§]	2	134 A	1	394 A	1	70.7A	1	99 B	2	3.7A	3
Vegreville Trial 2 - 1994	69 B	3	68 B	2	245 B	2	66.7AB	2	104 A	3	3.9A	2
Beaverlodge Trial 1 - 1993	97 A	1	59 B	3	216 B	3	63.1B	3	90 C	1	3.9A	1
LINE (n = 16):												
M1 (137+144)[¶]	65 a	6	36 a	7	71 c	7	40.0c	6	78 b	3	4.0a	3
137	67 a	5	32 a	8	68 c	8	39.6c	7	77 b	1	3.9a	4
144	65 a	7	48 a	6	104 c	6	36.4c	8	78 b	2	3.8a	6
M2 (279+281+286)	100 a	1	122 a	2	502 a	1	77.1b	4	102 ab	4	3.4a	8
279	99 a	2	94 a	3	467 ab	2	76.5b	5	102 ab	4	3.5a	7
M3 (292+296+299)	98 a	3	80 a	4	258 bc	4	86.1ab	2	114 a	6	4.3a	1
299	97 a	4	78 a	5	232 c	5	81.8ab	3	112 a	5	4.0a	2
Revenue	100 a	1	160 a	1	467 ab	3	93.5a	1	118 a	7	3.9a	5

[†]Days from April 15 to maturity.
[‡]Trial 1 was seeded in 1990 and Trial 2 was seeded in 1991.
[§]Means within columns followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$).
[¶]M1, 137, and 144 are broadglumed wheatgrass; M2 and 279 are awnless slender wheatgrass; M3 and 299 are awned slender wheatgrass.

4 AGRONOMY

Unless otherwise indicated, the agronomic practices recommended are suitable for large scale seed production of these slender wheatgrass 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 slender wheatgrass, trials were seeded at Vegreville in 1991 and 1992. Common broadglumed wheatgrass, and lines 279 (AEC Highlander slender wheatgrass) and 299 (AEC Hillcrest awned slender wheatgrass) 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. Unfortunately, an early snowfall in 1991 prevented the seeding of the October plots in the first trial. 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 from each line were analyzed separately 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

For broadglumed wheatgrass, seeding in May gave the best results. Emergence was highest for the May seeding date, probably due to favourable moisture conditions (Table 24). However, percent cover in the first year of seed production (second year of growth) was not significantly different among treatments. Winter survival was also not affected by seeding date. The number of heads produced and seed yield were significantly higher for the May seeding date.

Very little seed was produced on plants seeded in August and plants seeded in October did not flower in the first year. This is to be expected since slender wheatgrass generally 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 all other plants were in the first seed production year. Delaying seeding also tended to delay time to maturity, possibly due to a thinner stand. As expected, plant height was unaffected.

In the second year of seed production, no significant differences were observed for seeding date of broadglumed wheatgrass (Table 25). However, seed yields for the October date were very low (44 kg ha^{-1}) even though this was essentially the first year of seed production for plants seeded in October.

Seeding date had a significant effect on emergence of AEC Highlander (Table 24). Seeding in May gave the best emergence, although this was not significantly different from emergence in June-seeded plots. Emergence in the October seeding date was very low (only 9 plants m^{-1}). Percent cover in the first year of seed production had similar trends while winter survival was not affected by seeding date. Plants seeded in May produced the most heads and highest seed yields. Once again, plants seeded in October did not produce any heads during their first year. Time to maturity was significantly delayed by delayed seeding in the previous year. Even plant height was affected; plants seeded in August were shorter than those seeded in May or June.

In the second year of seed production, the effect of seeding date on AEC Highlander was still clearly visible. Plots seeded in October had lower percent cover, number of heads, and seed yields than all other plots (Table 25). However, there were no significant differences among the May, June, and August seeding dates. Winter survival, time to maturity and plant height were not affected by seeding date.

For AEC Hillcrest, both May and June seeding dates were appropriate. Emergence was similar for these two dates and significantly higher than emergence in the August or October seeding dates (Table 24). Percent cover and winter survival in the first year of seed production were unaffected by seeding date. For number of heads produced and seed yield, values for May and June seeding dates were not significantly different and these were considerably higher than the values for August and October. Plants seeded in October did not flower in the first year of seed production. Time to maturity was unaffected by seeding date.

All data except seed yield of AEC Hillcrest were not affected by seeding date in the second year of seed production (Table 25). However, plants seeded in October still produced significantly lower seed yields than those seeded earlier.

Overall, for all three slender wheatgrass varieties released by AEC, seeding in May gave the best results. In some cases, it may be possible to delay seeding until early or mid-June with minimal effects but the later the seeding date, the lower the subsequent seed yields. Dormant seeding in October so plants will emerge the following year did not give good results. Not only did this delay seed production for a full year, but emergence, cover, and seed yields were also reduced.

When seeding any of the three slender wheatgrass types, a seeding depth of approximately 1 to 2 cm 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 4 to 12 kg ha^{-1} may be used, with lower seeding rates for more widely spaced rows (Bolton ca. 1985).

Conventional seed drills are generally acceptable as long as the depth can be adequately controlled. Specialized native seed drills are available (Joyce 1993) but these are not necessary for slender wheatgrass. In some situations, broadcast seeding followed by raking or harrowing may also be acceptable but better results are 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 growth or seed yield. 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 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 seed into a clean seedbed. Slender wheatgrass, and especially broadglumed wheatgrass, is not highly competitive so weeds can provide strong competition. Weed control is difficult because of a limited number of herbicides

recommended for use on slender wheatgrass. Quackgrass (*Elytrigia repens*) is an especially troublesome weed because seeds of this species are impossible to remove from seed lots of slender wheatgrass. It is also very important to seed these varieties without a companion crop. Use of a companion crop would severely reduce seed yields and may even delay seed production by an extra year.

4.2 Pest Management

Slender wheatgrass 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. This is especially true for broadglumed wheatgrass. In an attempt to overcome some of the weed problems, an experiment was set up to screen broadglumed wheatgrass seedlings for tolerance to various herbicides. Management techniques for diseases and insects, although less important, have been developed through experience in 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 broadglumed wheatgrass 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.

Broadglumed wheatgrass seedlings were grown in small trays with 10 plants per tray. Greenhouse conditions were set at 22/15°C for day/night temperature 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 2 wk 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 for growth. 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. The general linear models procedure of SAS (SAS Institute, Inc. 1990) was used to analyze the data. Treatment means were compared to the control using a one-sided Dunnett's test for score means and a two-sided Dunnett's test for biomass means.

4.2.1.2 Results and Discussion

In the first herbicide tolerance trial on potted seedlings of broadglumed wheatgrass, most herbicide treatments caused a significant decrease in score values one week after treatment at the 2-leaf stage (Table 26). Only bromoxynil/MCPA ester, diclofop-methyl/bromoxynil, chlorsulfuron, and linuron did not adversely affect the plants at the first evaluation. By 8 wk, many treatments had recovered such that above-ground biomass was significantly lower than the control in only five treatments: dicamba (at three rates), 2,4-D/mecoprop/dicamba, and linuron. When herbicides were applied at the 5-leaf stage, the broadglumed wheatgrass plants were better able to tolerate their effects. After one week, only four treatments had significantly lower scores than the control: dicamba (at the two higher rates), clopyralid plus 2,4-D ester, and 2,4-D/mecoprop/dicamba. After 8 wk, these treatments, except the clopyralid plus 2,4-D ester treatment, had less biomass than the control.

In the second trial, the selected herbicide treatments had little effect on broadglumed wheatgrass at either the 2-leaf or 5-leaf stage of application (Table 27). The only treatment that was significantly different from the control was the tribenuron methyl plus 2,4-D ester treatment when evaluated 1 wk after application at the 2-leaf stage. Plants in this treatment later recovered.

These two experiments have indicated possible useful herbicides for weed control in broadglumed wheatgrass 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 broadglumed wheatgrass. Most of the herbicides tested have not been registered for use on slender wheatgrass so they cannot be used for weed control in this crop.

Herbicides registered for use on slender wheatgrass include bromoxynil plus MCPA (Buctril M®), bromoxynil (Pardner®), dicamba (Banvel®), clopyralid (Lontrel®), and tralkoxydim (Achieve®) (Ali 1995). In addition, 2,4-D and MCPA are registered for use on established grasses. Our experiments show that even though they are registered for slender wheatgrass, there could be some problems in using dicamba and clopyralid (when applied early) on the broadglumed wheatgrass subspecies. However, these are only preliminary evaluation trials so no recommendations can yet be made. When selecting herbicides for use on slender wheatgrass, use the above recommended chemicals or other chemicals recommended for use on slender wheatgrass according to the pesticide label.

An important consideration for seed production of slender wheatgrass is the control of quackgrass (*Elytrigia repens*). This primary noxious weed can be a big problem in seed fields. It is difficult to control and seed of quackgrass is impossible to clean out of slender wheatgrass seed. Therefore, it is very important that the seed field is free of quackgrass before seeding. Preplant applications of glyphosate (eg. Roundup®) can help to control this weed. If patches of quackgrass appear later, then spot applications of glyphosate can be used.

4.2.2 Control of Plant Diseases and Insects

In addition to problems with weeds, slender wheatgrass is susceptible to some plant diseases. Varieties such as Revenue slender wheatgrass are susceptible to head smut (*Ustilago bullata* Berk) and we observed head smut on Revenue in our research plots. AEC Highlander, AEC Hillcrest, and AEC Mountaineer appeared to be tolerant to head smut as we did not observe any smut on plants of these varieties in our test plots or seed increase plots. Slender wheatgrass

is resistant to stem and stripe rust (Hardy BBT Ltd. 1989). However, all varieties of slender wheatgrass, including those released by AEC, are susceptible to leaf rust (*Puccinia graminis*), char spot (*Cheilaria agrostis*) and other leaf spot diseases (Martens et al. 1984). 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. Such effects appear to be minimal.

In our experience, slender wheatgrass appears to have few problems with insect infestations in the field. In some years, there may 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 slender wheatgrass begins in early July for broadglumed wheatgrass. AEC Mountaineer is generally ripe by the first or second week of July. AEC Highlander slender wheatgrass ripens by the fourth week of July, while AEC Hillcrest awned slender wheatgrass matures in early August. In some years, AEC Mountaineer broadglumed wheatgrass may also produce a second flush of heads that ripens in late August. If there is a thin stand, we generally mow the second flush of heads before they ripen so the plants do not expend energy filling the seeds. In some years when moisture conditions are favourable, good seed yields can be obtained by harvesting this second flush. However, allowing the plants to produce two seed crops in one year may reduce their vigour such that winter survival and seed yields the following year may be severely reduced. Generally, broadglumed wheatgrass produces only two good seed crops, either in separate years or in one year if weather conditions are favourable. It may be advantageous to harvest both flushes in some years when seed yields are high due to favourable weather conditions.

Slender wheatgrass, especially broadglumed wheatgrass, is highly subject to shattering so 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. For direct combining, the cutter bar should be set as high as possible to avoid taking in too much green material. If swathing prior to combining, swathing in the medium to firm

dough stage when seed head moisture content is 40 to 45% is recommended (Najda et al. 1994). 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 10 to 13 mm is recommended (Najda et al. 1994). Use very little or no wind over the cleaning shoe. For awned slender wheatgrass, we have been using a regular cylinder, although a spike-tooth cylinder or rotary combine may work better. Blocking off the front holes of the concave so that seed is in contact with the cylinder longer may also help to remove some of the awns.

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, although 15% moisture may be acceptable for seed stored in sacks (Holzworth et al. 1990). Seed cleaning can be done in most seed cleaning plants. Use as little wind as possible when cleaning to reduce the amount of seed loss. For AEC Hillcrest awned slender wheatgrass, use of de-awning machines is necessary because seeding is impossible unless the awns have been removed. De-awning may also be beneficial to remove the awn tips found on the seed of AEC Highlander slender wheatgrass.

4.4 Post-Harvest Management

After harvesting, fields are often mowed to remove tall standing straw. This will be necessary if the swather or combine cuts high to reduce problems associated with threshing large amounts of straw with the seed heads. 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 slender wheatgrass plants produce more seed heads after harvest, these are mowed while still green unless there are enough heads to make it worthwhile to combine the field a second time (broadglumed wheatgrass only).

Even with good management, slender wheatgrass stands will survive for only four to five years on the plains (Rogler 1973). The use of nitrogen fertilizer to extend the life of a stand of

slender wheatgrass has been recommended for other varieties (Bolton ca. 1985). However, past experiments on three year old stands of slender wheatgrass showed no response to nitrogen fertilizer application (Darroch 1993).

Table 24. Effect of seeding date on the performance of three lines of slender wheatgrass in the first year of seed production in small plot trials at Vegreville.

Month Seeded	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)
Common Broadglumed Wheatgrass							
May	53 a‡	85 a	100	241 a	340 a	91 a	44.0a
June	42 b	90 a	100	104 b	104 b	112 a	46.5a
August	34 b	78 a	100	15 b	10 b	120 a	47.9a
October	34 b	71 a	100	0 b	0 b	-	-
AEC Highlander							
May	55 a	92 a	100	178 a	561 a	100 c	66.2a
June	39 ab	84 ab	100	105 b	345 b	109 b	69.1a
August	27 b	78 b	100	26 c	76 c	122 a	55.7b
October	9 c	40 c	100	0 c	0 c	-	-
AEC Hillcrest							
May	54 a	91 a	100	101 a	230 a	123 a	61.0b
June	48 a	84 a	100	92 a	190 a	118 a	72.3a
August	34 b	79 a	100	29 b	57 b	131 a	58.7b
October	19 c	80 a	100	0 b	0 b	-	-

†Days from April 15 to maturity.

‡Means within columns and within lines followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 8 for all means except October means where n = 4 (weather conditions prevented the October seeding in the first trial).

Table 25. Effect of seeding date on the performance of three lines of slender wheatgrass in the second year of seed production in small plot trials at Vegreville.

Month Seeded	Cover (%)	Winter Survival (%)	Number of Heads (no. m^{-1})	Seed Yield (kg ha^{-1})	Time to Maturity (days†)	Plant Height (cm)
Common Broadglumed Wheatgrass						
May	85 a‡	89 a	171 a	161 a	99 a	50.6a
June	80 a	84 a	144 a	173 a	103 a	51.0a
August	91 a	95 a	169 a	166 a	99 a	58.3a
October	81 a	82 a	141 a	44 a	116 a	57.6a
AEC Highlander						
May	94 a	100	264 a	1058 a	103	102.6a
June	83 a	100	270 a	1002 a	103	98.5a
August	96 a	100	242 a	1009 a	103	98.3a
October	64 b	100	87 b	417 b	103	99.4a
AEC Hillcrest						
May	90 a	99 a	253 a	547 a	114 a	102.8a
June	84 a	100 a	188 a	476 a	113 a	97.4a
August	95 a	100 a	245 a	444 a	114 a	101.0a
October	91 a	99 a	133 a	278 b	116 a	105.9a

†Days from April 15 to maturity.

‡Means within columns and within lines followed by the same letter are not significantly different by Duncan's new multiple range test ($P \leq 0.05$). n = 8 for all means except October means where n = 4 (weather conditions prevented the October seeding in the first trial).

Table 26. Effect of 14 herbicide treatments on potted plants of common broadglumed wheatgrass 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	1.09	9.0	9.0	9.0	1.96
Bromoxynil/MCPA ester	0.55	8.5	8.5	9.0	0.91	9.0	9.0	9.0	1.84
Dicamba	0.15	4.2*	4.0*	6.2*	0.66*	9.0	8.0*	8.5*	1.83
Dicamba	0.27	4.0*	3.2*	6.0*	0.53*	8.0*	7.0*	8.0*	1.68*
Dicamba	0.4	4.0*	2.8*	4.5*	0.35*	7.5*	6.8*	8.2*	1.70*
Clopyralid	0.2	7.2*	6.5*	7.8*	1.14	8.5	8.5	9.0	1.82
Clopyralid	0.3	8.0*	6.8*	8.0	1.07	8.8	8.5	8.8	1.91
Clopyralid + 2,4-D ester	0.2 + 0.5	5.5*	6.8*	7.2*	0.96	7.8*	8.0*	8.5*	1.86
Clopyralid + MCPA ester	0.2 + 0.5	6.5*	6.0*	8.0	1.08	8.8	8.5	9.0	1.84
Diclofop-methyl/bromoxynil	0.07	9.0	8.8	8.8	1.01	8.8	9.0	9.0	1.78
Fenoxaprop-ethyl + MCPA ester + thifensulfuron methyl	0.2 + 0.42 + 0.006	7.8*	8.5	8.8	1.09	8.5	9.0	9.0	1.76
Chlorsulfuron	0.011	8.5	8.5	8.8	1.02	8.8	8.8	8.5*	1.75
Chlorsulfuron	0.022	8.5	8.8	9.0	1.19	9.0	9.0	9.0	1.76
2,4-D/mecoprop/dicamba	1.694	4.2*	3.8*	7.0*	0.48*	8.0*	8.0*	9.0	1.68*
Linuron	0.2	8.2	8.8	8.0	0.82*	9.0	9.0	9.0	1.74

*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 27. Effect of five herbicide treatments on potted plants of common broadglumed wheatgrass 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	0.41	-[‡]	-	-	-
Tralkoxydim + bromoxynil /MCPA ester + Charge®	0.25 + 0.55 + 0.5%	8.8	8.8	9.0	0.41	9.0	9.0	9.0	0.59
Bentazon + Assist®	1.08 + 1%	8.8	9.0	9.0	0.44	9.0	9.0	9.0	0.59
Tribenuron methyl + 2,4-D ester	0.0075 + 0.5	7.8*	8.8	9.0	0.41	9.0	9.0	9.0	0.54
Fenoxaprop-p-ethyl /bromoxynil/MCPA ester	0.585	8.0	9.0	9.0	0.38	9.0	9.0	9.0	0.57
Fenoxaprop-p-ethyl/MCPA ester + thifensulfuron	0.458 + 0.015	8.2	9.0	9.0	0.40	9.0	9.0	9.0	0.57

*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 been investigated with varying results. More research is required to determine appropriate methods for establishment and maintenance of slender wheatgrass when grown for reclaiming disturbed sites at high elevations.

5.1 Species/Variety Selection

When selecting plant species and varieties within species for reclaiming and revegetating a disturbed site, it is important to consider the adaptation of the species/variety. 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.

Slender wheatgrass is adapted to a wide range of environments (Hardy BBT Ltd. 1989) and is suitable for use in alpine reclamation (Hardy BBT Ltd. 1990). It is common in moist and semi-arid ranges, open woods, boreal forest, subalpine, and subarctic regions and has been found at elevations as high as 2600 m in Alberta (Hardy BBT Ltd. 1989). Slender wheatgrass is reasonably tolerant to shade and salinity and prefers moist to dry sites. It is well adapted to colonizing disturbed sites. Awned slender wheatgrass is tolerant to low nutrient supplies, alkaline soil conditions, and moderate or low salinity (Hardy BBT Ltd. 1989). Awned slender wheatgrass is also relatively shade tolerant and is more drought tolerant than awnless slender wheatgrass.

AEC Mountaineer broadglumed wheatgrass is adapted to the highest elevations of all of the slender wheatgrass varieties. It can grow and produce seed up to elevations of 2300 m. AEC

Hillcrest awned slender wheatgrass is adapted to lower elevations (as high as 1800 m) and will do best in the foothills region. AEC Highlander slender wheatgrass is the mid-elevation variety; it does best at elevations up to 2000 m. These elevation limitations are only rough guidelines for the range of adaptation of these varieties. Other factors such as latitude, slope, aspect, and moisture conditions must also be considered. Of these three varieties, AEC Hillcrest is probably the most drought tolerant, followed by AEC Highlander.

AEC Highlander, AEC Hillcrest, and AEC Mountaineer were developed to be included in seed mixtures and were not intended to be seeded in monoculture on reclaimed sites. We recommend that a mixture of native plant species and varieties (when available) be used to revegetate disturbed areas. A seed mixture will have species adapted to the many different microsites found at one reclamation site. Slender wheatgrass makes a good addition to any mixture because it has rapid and good establishment, thus helping to stabilize the soil and prevent erosion (Hardy BBT Ltd. 1989). Because it is relatively short-lived, slender wheatgrass depends on natural reseeding to perpetuate a stand. When used in mixtures, slender wheatgrass will be dominant at first but will eventually become secondary. This allows other native plant species from surrounding undisturbed areas to invade the disturbed site. Eventually, a site reclaimed with native plants including slender wheatgrass will look similar to surrounding areas, thus helping to restore ecosystem integrity.

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 broadglumed wheatgrass 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). Few plants in these trials flowered by 1994 so no other data were available.

A small trial to examine fall versus spring seeding was also established at Columbia Icefields in September 1989 and June 1990. A randomized complete block design with three replicates was also used for this trial. No peat moss amendments were included. Emergence and percent cover data were recorded and analyzed using SAS.

5.2.2 Results and Discussion

At both Columbia Icefields and Mountain Park, seeding broadglumed wheatgrass in the fall improved emergence compared to seeding in the spring (Table 28). Similar results were obtained in an earlier trial at Columbia Icefields (Table 29). However, this initial advantage was not maintained as percent cover was not significantly different at either site (Tables 28, 29). There was some indication that percent cover was higher for fall-seeded plots (Table 28) and, in some years, this difference was significant. This supports the recommendation of Brown et al. (1976) to seed alpine disturbances in the fall so seed can take advantage of the moisture available during spring snowmelt. Other slender wheatgrass subspecies and varieties would probably also benefit from fall seeding when trying to establish plants at high elevations.

The use of peat moss clearly improved emergence and plant cover of broadglumed wheatgrass in our trials at Columbia Icefields and Mountain Park (Table 28). 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 slender wheatgrass at reclamation sites, it is important to seed shallowly (no more than 1 to 2 cm deep). Site preparation should include removing any weeds because

slender wheatgrass 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. 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 8 to 24 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 slender wheatgrass at reclamation sites.

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. Although slender wheatgrass is moderately tolerant to grazing (Hardy BBT Ltd. 1989), restricting grazing for several growing seasons will help to create a well-established plant stand under alpine conditions (Brown et al. 1978).

Table 28. Effect of seeding date and the use of peat moss as a soil amendment on the emergence and percent cover of common broadglumed wheatgrass in small plot trials at Columbia Icefields and Mountain Park.

	Emergence (no. plants m^{-1})		Cover (%)	
	Columbia Icefields (n = 12)	Mountain Park (n = 12)	Columbia Icefields (n = 18)	Mountain Park (n = 30)
Time of Seeding				
Fall	55 A[†]	57 A	52 A	64 A
Spring	31 B	37 B	46 A	56 A
Soil Amendment				
With peat moss	55 a	55 a	58 a	74 a
Without peat moss	31 b	39 b	40 b	46 b

[†]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 29. Effect of seeding date on the emergence and percent cover of common broadglumed wheatgrass in a small plot trial at Columbia Icefields.

Time of Seeding	Emergence (no. plants m^{-1})	Cover (%)
Fall	70 a[†]	63 a
Spring	27 b	66 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 Highlander slender wheatgrass, AEC Hillcrest awned slender wheatgrass, and AEC Mountaineer broadglumed wheatgrass will provide easily accessible sources of slender wheatgrass 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 Mountaineer is adapted to the highest elevations (up to elevations of 2300 m) while AEC Hillcrest is adapted to the lowest elevations (up to elevations of 1800 m) of these three reclamation varieties. Of the three, AEC Highlander, the mid-elevation variety, has the highest seed yields when grown at low elevation, plains sites. 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. By using mixtures of several species, there is a better chance that some species will be adapted to the conditions found in individual microsites within a large reclamation project.

When growing these slender wheatgrass varieties for seed production, seed into a clean seedbed using rates of 4 to 12 kg ha^{-1}. Seeding in May will give the best results. Seeding depths of 1 to 2 cm and row spacings of 20 to 40 cm are recommended. The application of fertilizer is generally not necessary. Weed control can be accomplished using recommended herbicides. Spot spraying with glyphosate may be necessary to control quackgrass. Seed of these varieties may be harvested by direct combining or by swathing followed by combining. At Vegreville, AEC Mountaineer broadglumed wheatgrass is harvested in early July; AEC Highlander slender wheatgrass is ripe by the fourth week of July, and AEC Hillcrest awned slender wheatgrass is harvested in early August.

At high elevations, reclamation plantings of slender wheatgrass 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 slender wheatgrass on reclamation sites. Fertilizer applications are not necessary although they may improve plant growth and cover.

In addition to slender wheatgrass varieties, the Alberta Environmental Centre has also developed and released two reclamation varieties of alpine bluegrass: AEC Blueridge (released

in 1994) and AEC Glacier (released in 1995). Alpine bluegrass is adapted to higher elevations than slender wheatgrass and provides 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 *Astragalus alpinus* (Smreciu 1993). This native legume species is adapted to the mountains and foothills and its release provides an important source of native legume seed for reclamation seed mixes.

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APPENDIX A

PERFORMANCE OF SLENDER WHEATGRASS LINES IN INDIVIDUAL PROVENANCE TRIALS

Table A.1. Performance of selected wheatgrass 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)
72	2.1bcde[‡]	30.3e	3.8a	2.7a
144	4.0abc	32.0de	3.2a	3.4a
279	3.1abcd	51.8ab	4.0a	2.5a
281	1.7de	47.4abc	4.0a	1.9a
283	4.3ab	56.9a	3.6a	2.7a
286	3.1abcd	45.7abc	3.4a	2.8a
290	2.8bcd	42.2bcd	4.2a	7.2a
292	1.8cde	54.3a	4.0a	3.0a
296	1.1de	51.4ab	3.4a	2.4a
299	2.9abcd	52.1ab	3.4a	2.9a
Revenue	5.1a	47.1abc	3.6a	6.3a
Elbee	0.4e	36.2cde	3.8a	1.2a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.2. Performance of selected wheatgrass lines 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)
72	1.4abc[‡]	22.9c	427a	3.4bc	1.0cd	25.8c	7.0a	3.0b
144	2.0a	100.0ab	693a	23.4a	15.8a	26.2c	7.5a	2.8b
279	1.7ab	168.5a	876a	10.7b	8.0b	40.7b	5.4a	3.6b
281	0.8bcd	45.3bc	592a	4.2bc	3.0bcd	43.8b	7.0a	4.6b
283	1.9ab	138.5a	1101a	9.6b	6.6bc	45.0ab	5.8a	4.5b
286	1.0abcd	58.7bc	752a	5.9bc	4.1bcd	40.8b	5.5a	4.1b
290	0.2d	0.0c	963a	0.0c	0.0d	41.2b	8.0a	3.9b
292	0.0d	0.0c	475a	0.0c	0.0d	-	6.6a	-
296	0.1d	0.0c	733a	0.0c	0.0d	53.0a	7.2a	3.8b
299	0.4d	27.0c	924a	2.9bc	2.2bcd	44.0b	6.7a	3.2b
Revenue	1.6abc	31.5bc	805a	6.7bc	3.0bcd	37.4b	6.4a	8.3a
Elbee	0.0d	0.0c	581a	0.0c	0.0d	-	6.1a	-

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.3. Performance of selected wheatgrass lines 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)
72	0.9bc[‡]	9.8c	576abc	1.9cd	1.6bc	30.4abc	5.5a	3.3bcd
144	1.9a	76.4ab	549abc	15.5ab	11.7a	25.5abc	5.2a	3.0bcd
279	1.3b	105.6a	792a	18.4a	13.3a	48.5a	4.4a	4.3abc
281	0.7cdef	36.0bc	640ab	7.3cd	5.0bc	40.3ab	4.9a	4.0abc
283	0.8bcd	37.6bc	614ab	6.6cd	4.5bc	44.9ab	4.6a	5.6ab
286	0.5cdef	45.0bc	610ab	9.0bc	6.3b	32.4abc	4.2a	2.5bcd
290	0.3cdef	46.6bc	754a	9.4bc	6.2b	31.6abc	4.0a	3.6bcd
292	0.1ef	0.0c	328bc	0.0d	0.0c	22.4bc	5.1a	1.1cd
296	0.2def	22.0c	718a	3.9cd	2.4bc	25.7abc	5.2a	2.4bcd
299	0.1ef	0.0c	313bc	0.0d	0.0c	8.8c	3.6a	0.6d
Revenue	0.7bcde	0.0c	264c	5.1cd	0.0c	21.8bc	3.5a	7.0a
Elbee	0.0f	0.0c	323bc	0.0d	0.0c	-	4.3a	-

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.4. Performance of selected wheatgrass lines 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)
72	1.3a[‡]	139.2ab	19.8bc	4.8a
144	1.2ab	62.2bcd	19.8bc	5.2a
279	1.2ab	124.7abc	35.4abc	6.4a
281	0.9abc	107.3abcd	43.0ab	6.4a
283	1.2ab	177.4a	50.8a	7.2a
286	0.9abc	87.1abcd	42.6ab	6.0a
290	0.5abc	8.5cd	16.6bc	6.2a
292	0.1bc	5.7d	8.8c	4.6a
296	0.2abc	35.7bcd	32.0abc	6.6a
299	0.2abc	4.4d	16.6bc	5.6a
Revenue	1.2ab	21.3cd	29.8abc	6.0a
Elbee	0.0c	0.0d	-	6.2a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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.5. Performance of selected wheatgrass lines 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)
72	2.1a[‡]	119.6a	29.6cde	7.5a
144	2.2a	134.6a	26.6de	6.3a
279	0.5b	40.0b	37.8abcd	6.6a
281	0.4b	36.8b	43.0ab	5.2a
283	0.4b	33.1b	42.7ab	5.4a
286	0.5b	32.9b	40.0abc	4.8a
290	0.1b	6.4b	36.0abcde	6.7a
292	0.1b	0.0b	31.0bcde	5.8a
296	0.1b	6.8b	46.0a	6.0a
299	0.0b	0.0b	-	5.0a
Revenue	0.1b	1.4b	25.0e	4.9a
Elbee	0.0b	0.0b	-	4.9a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.6. Performance of selected wheatgrass lines 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)
72	1.6a[‡]	254.3a	22.8b	11.2abc
144	2.1a	122.6b	25.0b	13.6a
279	0.9b	60.8b	43.0a	8.6abcd
281	0.9b	59.9b	41.0a	12.4abc
283	0.8b	59.4b	39.8a	10.0abcd
286	0.3bc	17.7b	39.3a	7.6bcd
290	0.1c	2.3b	28.0b	11.8abc
292	0.0c	0.0b	-	7.0cd
296	0.0c	0.0b	-	10.8abc
299	0.0c	0.0b	-	6.8cd
Revenue	0.4bc	8.1b	39.0a	5.2d
Elbee	0.1c	1.4b	44.0a	12.8ab

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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.7. Performance of selected wheatgrass lines 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)
72	0.5cd[‡]	8.5bc	24.0a	5.0a	1.0c
144	0.8bc	33.3ab	28.0a	4.5a	2.3bc
279	1.2b	47.8a	37.3a	3.8a	2.3bc
281	0.8bc	25.9abc	42.3a	2.5a	2.7bc
283	0.0d	0.0c	-	3.5a	-
286	0.2d	0.0c	36.0a	4.4a	2.5bc
290	0.0d	0.0c	-	3.5a	-
292	0.0d	0.0c	-	3.3a	-
296	0.2d	9.7bc	56.0a	4.5a	4.0ab
299	0.0d	0.0c	-	4.8a	-
Revenue	1.9a	16.1bc	31.0a	3.3a	5.5a
Elbee	0.0d	0.0c	-	5.3a	-

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.8. Performance of selected wheatgrass lines 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)
72	0.1b[‡]	1.5b	8.0a	3.8b	0.5a
144	0.6a	17.0a	20.1a	2.0b	1.6a
279	0.2b	7.0b	15.1a	3.6b	1.6a
281	0.0b	0.0b	-	3.0b	-
283	0.0b	0.0b	-	3.5b	-
286	0.0b	0.0b	-	3.6b	-
290	0.0b	0.0b	-	2.9b	-
292	0.0b	0.0b	-	2.8b	-
296	0.0b	0.0b	-	4.0b	-
299	0.0b	0.0b	-	2.5b	-
Revenue	0.5a	0.8b	18.1a	3.0b	7.5a
Elbee	0.0b	0.0b	-	11.0a	-

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.9. Performance of selected wheatgrass lines 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)
72	1.0a[‡]	31.4a	12.0b	5.0b
144	0.8a	13.4b	16.0ab	4.8b
279	0.2bc	15.5b	26.8ab	4.8b
281	0.2c	5.3b	15.3ab	3.3b
283	0.0c	0.0b	-	4.5b
286	0.0c	0.0b	-	4.3b
290	0.0c	0.0b	-	3.8b
292	0.0c	0.0b	-	2.8b
296	0.0c	0.0b	-	3.8b
299	0.0c	0.0b	-	3.8b
Revenue	0.7ab	7.4b	29.0a	2.8b
Elbee	0.0c	0.0b	-	10.8a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.10. Performance of selected wheatgrass lines 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 Width (cm)
72	0.0b[‡]	0.0b	4.5a
144	1.1a	46.5a	4.8a
279	0.0b	0.0b	5.1a
281	0.0b	0.0b	3.3a
283	0.0b	0.0b	4.0a
286	0.0b	0.0b	3.8a
290	0.0b	0.0b	3.9a
292	0.0b	0.0b	3.0a
296	0.0b	0.0b	4.0a
299	0.0b	0.0b	2.3a
Revenue	0.0b	0.0b	3.0a
Elbee	0.0b	0.0b	3.1a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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.11. Performance of selected wheatgrass lines 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)
72	1.3a[‡]	52.3a	20.0a	13.0a
144	0.3b	11.3b	15.5a	10.0ab
279	0.2b	6.8b	34.0a	6.3b
281	0.0b	0.0b	-	4.8b
283	0.3b	7.5b	27.0a	7.0b
286	0.0b	0.0b	-	6.8b
290	0.0b	0.0b	-	5.8b
292	0.0b	0.0b	-	4.7b
296	0.0b	0.0b	-	5.8b
299	0.2b	1.5b	21.0a	4.8b
Revenue	0.1b	0.5b	24.0a	8.0ab
Elbee	0.0b	0.0b	-	13.3a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.12. Performance of selected wheatgrass lines in seeded provenance trial at Columbia Icefields in 1989. The trial was seeded in 1987.

Line[†]	Cover (%)	Number of Heads (no. m^{-1})
72	13.7bc[‡]	0.7a
144	41.7abc	18.3a
279	37.0abc	0.0a
281	22.0bc	0.0a
283	51.7ab	0.0a
286	46.7ab	0.0a
290	18.3bc	0.0a
292	7.3c	0.0a
296	36.7abc	6.5a
299	20.3bc	0.0a
Revenue	13.7bc	2.5a
Elbee	70.0a	16.7a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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 wheatgrass lines in seeded provenance trial at Columbia Icefields in 1990. The trial was seeded 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)
72	11.7d[‡]	0.8b	14.7b	22.0a	6.7a	1.0a
144	50.0abcd	11.0a	712.7a	25.5a	6.7a	3.0a
279	46.0abcd	2.3b	110.7b	36.5a	6.5a	2.5a
281	31.7bcd	0.7b	50.3b	31.0a	3.7a	3.0a
283	66.7ab	2.7b	95.7b	40.0a	5.3a	3.5a
286	56.7abc	0.5b	43.3b	29.0a	6.0a	2.0a
290	25.0cd	0.3b	27.3b	45.0a	6.2a	3.0a
292	11.0d	0.0b	0.0b	-	3.0a	-
296	38.3abcd	1.0b	7.5b	39.5a	5.5a	2.5a
299	32.7bcd	0.8b	1.9b	35.0a	3.7a	3.5a
Revenue	17.7d	1.3b	0.0b	26.5a	10.7a	5.3a
Elbee	73.3a	0.0b	0.0b	45.0a	8.0a	6.0a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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 wheatgrass lines in seeded provenance trial at Columbia Icefields in 1991. The trial was seeded 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)
72	31.7bc[‡]	0.7b	14.0a	14.2a	5.7a	2.0b
144	55.0ab	7.7a	44.7a	27.5a	4.0a	2.5b
279	53.3ab	0.3b	0.0a	12.0a	4.5a	1.3b
281	50.0abc	1.0b	27.0a	14.8a	9.3a	0.7b
283	75.0a	0.0b	2.7a	-	3.3a	-
286	60.0ab	0.0b	0.0a	-	5.0a	-
290	31.7bc	0.7b	30.7a	14.2a	3.3a	0.7b
292	22.3bc	0.0b	0.0a	-	3.5a	-
296	45.0abc	0.0b	0.0a	-	2.7a	-
299	33.3bc	1.0b	0.0a	24.8a	3.5a	2.5b
Revenue	13.3c	1.7b	0.0a	20.8a	2.7a	7.2a
Elbee	83.3a	0.0b	0.0a	-	5.0a	-

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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 wheatgrass lines in seeded provenance trial at Columbia Icefields in 1992. The trial was seeded in 1987.

Line[†]	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
72	30.0bc[‡]	2.3b	60.0a	21.5a	4.7a
144	58.3ab	13.3a	272.0a	26.0a	6.0a
279	51.7abc	2.7b	126.3a	44.3a	3.3a
281	55.0ab	0.3b	146.0a	49.0a	4.3a
283	63.3a	1.0b	51.3a	36.0a	4.3a
286	66.7a	0.7b	1.5a	60.0a	5.0a
290	41.7abc	0.7b	28.0a	35.5a	3.3a
292	23.3c	0.0b	0.0a	-	4.0a
296	46.7abc	0.0b	0.0a	-	5.0a
299	38.3abc	0.7b	13.0a	47.0a	4.0a
Revenue	21.7c	4.0b	14.0a	32.0a	3.5a
Elbee	70.0a	0.0b	0.0a	-	7.3a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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 wheatgrass lines in seeded provenance trial at Columbia Icefields in 1993. The trial was seeded in 1987.

Line[†]	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
72	40.0abc[‡]	1.0a	33.5b	19.3a	5.7a
144	65.0abc	3.5a	172.0a	26.3a	7.7a
279	61.7abc	0.3a	0.0b	14.7a	5.0a
281	36.7abc	0.2a	0.0b	12.0a	4.0a
283	85.0a	0.2a	0.0b	14.0a	6.5a
286	75.0ab	3.3a	0.0b	17.3a	8.8a
290	20.0c	0.0a	0.0b	-	5.0a
292	53.3abc	0.2a	4.3b	13.7a	3.7a
296	26.7bc	0.0a	0.0b	-	4.0a
299	48.3abc	0.0a	0.0b	-	7.7a
Revenue	50.0abc	0.0a	0.0b	-	3.7a
Elbee	85.0a	0.3a	0.0b	12.7a	6.0a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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 wheatgrass lines in seeded provenance trial at Columbia Icefields in 1994. The trial was seeded in 1987.

Line[†]	Cover (%)	Number of Heads (no. m^{-1})	Seed Yield (mg m^{-1})	Plant Height (cm)	Plant Width (cm)
72	33.3a[‡]	2.8ab	180.5ab	26.3a	8.7a
144	73.3a	4.8a	304.7a	26.7a	7.7a
279	53.3a	0.7b	44.2b	39.5a	7.5a
281	73.3a	2.8ab	83.3b	49.0a	9.7a
283	83.3a	0.2b	21.2b	37.0a	8.3a
286	56.7a	0.0b	0.0b	-	6.5a
290	53.3a	0.0b	0.0b	-	6.7a
292	8.3a	0.2b	1.3b	29.0a	4.0a
296	53.3a	0.3b	30.0b	41.0a	6.0a
299	58.3a	0.0b	0.0b	-	6.3a
Revenue	63.3a	0.0b	0.0b	-	6.0a
Elbee	63.3a	0.0b	0.0b	-	11.0a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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 wheatgrass 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})	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)
72	0.5de[‡]	15.7de	506de	1.5e	0.9c	25.0d	5.4a	3.2b
144	2.6ab	170.3ab	728cde	22.9a	16.3a	28.4cd	5.4a	3.2b
279	3.7a	232.3a	1284a	19.5ab	14.8a	40.4ab	4.4a	3.4b
281	2.2bc	164.1abc	966abc	12.7bcd	9.4b	39.3ab	5.4a	3.1b
283	1.4cd	70.8cde	784bcde	6.7cde	4.8bc	31.3bcd	4.5a	3.8b
286	1.8bc	105.4bcd	899abcd	6.8cde	4.7bc	36.2abc	5.6a	3.9b
290	0.4de	18.9de	338e	0.0e	0.0c	32.2bcd	4.6a	3.0b
292	0.0e	0.0e	380e	0.0e	0.0c	-	4.3a	-
296	0.6de	29.2de	514cde	4.3de	3.3bc	35.0abc	4.8a	3.5b
299	0.2de	0.0e	530cde	0.0e	0.0c	43.3a	6.1a	3.0b
Revenue	0.5de	7.9de	1002ab	16.0abc	0.0c	34.5abcd	4.5a	8.3a
Elbee	0.3de	3.8de	490de	0.0e	0.0c	40.0ab	7.5a	4.0b

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.19. Performance of selected wheatgrass 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)
72	0.7b[‡]	0.4b	452bc	0.7a	0.1c	23.8cde	4.9b	3.9b
144	0.2bc	1.8b	361bc	0.7a	0.4bc	19.3e	4.2b	1.0b
279	0.4bc	24.4a	470bc	5.6a	3.9a	38.7ab	4.1b	2.5b
281	0.2bc	0.0b	484bc	6.1a	0.0c	34.3abcd	4.9b	3.2b
283	0.3bc	0.0b	560b	0.0a	0.0c	35.9abc	3.9b	3.9b
286	0.6bc	22.6a	871a	3.8a	2.4ab	38.6ab	4.8b	4.0b
290	0.1c	2.2b	224c	1.0a	0.6bc	21.5de	2.6b	2.0b
292	0.1c	0.0b	369bc	0.0a	0.0c	47.0a	4.9b	3.5b
296	0.1c	0.0b	369bc	6.9a	0.0c	42.5ab	4.7b	3.0b
299	0.0c	0.0b	413bc	0.0a	0.0c	-	4.8b	-
Revenue	1.5a	4.8b	517bc	11.0a	0.5bc	32.3bcde	2.6b	9.9a
Elbee	0.1c	0.0b	611b	0.0a	0.0c	21.0de	16.1a	2.5b

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.20. Performance of selected wheatgrass lines in transplanted provenance trial 1 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)
72	2.1b[‡]	1.8a	23.0d	7.2b
144	3.2a	23.6a	22.8d	6.0b
279	1.5bc	70.0a	41.4bc	5.6b
281	0.9c	25.8a	41.0bc	6.6b
283	1.2bc	38.5a	51.5ab	5.6b
286	1.4bc	58.5a	41.8bc	7.4b
290	0.8c	0.0a	-	4.0b
292	0.6c	17.3a	60.0a	6.2b
296	0.6c	0.0a	32.0cd	7.4b
299	0.5c	0.0a	-	7.0b
Revenue	2.1b	18.62a	29.5cd	4.6b
Elbee	0.5c	0.0a	-	37.8a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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.21. Performance of selected wheatgrass lines in transplanted provenance trial 1 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)
72	1.0ab[‡]	19.0a	26.6a	6.8bc
144	1.1a	17.9a	20.6a	6.4bc
279	0.6abc	17.1a	34.5a	5.2bc
281	0.3c	0.1a	25.3a	5.3bc
283	0.2c	4.2a	35.5a	6.2bc
286	0.5abc	16.0a	38.5a	6.4bc
290	0.6abc	0.0a	26.0a	14.5ab
292	0.0c	0.0a	-	5.9bc
296	0.1c	0.0a	36.0a	5.3bc
299	0.0c	0.0a	-	4.7c
Revenue	0.4bc	0.0a	23.8a	3.0c
Elbee	0.0c	0.0a	-	20.9a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.

[‡]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.22. Performance of selected wheatgrass lines in transplanted provenance trial 1 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)
72	1.7a[‡]	170.8a	23.6abc	16.2b
144	1.7a	138.6ab	26.0abc	13.0bc
279	1.4ab	100.6abc	42.6ab	7.2cd
281	0.8abc	35.8bc	29.6abc	7.0cd
283	0.8abc	56.4bc	17.8bc	7.2cd
286	1.3abc	98.2abc	48.8a	9.8bcd
290	0.6abc	68.6abc	17.8bc	4.8d
292	0.3bc	21.6c	19.4bc	7.6cd
296	0.2bc	16.2c	9.8c	7.0cd
299	0.1c	6.8c	9.2c	7.6cd
Revenue	1.5ab	45.8bc	24.8abc	5.2d
Elbee	0.1c	2.4c	8.4c	40.4a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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.23. Performance of selected wheatgrass lines in transplanted provenance trial at Sunshine Village in 1989 to 1993. The trial was established in 1987.

	Above-ground Biomass (mg plant^{-1})		Plant Width (cm)		
Line[†]	1989	1990	1990	1991	1993[‡]
72	145a[§]	80a	3.4a	2.4ab	1.2a
144	186a	79a	3.0a	2.4ab	1.4a
279	236a	111a	3.1a	2.8a	0.8a
281	170a	103a	3.7a	2.2ab	1.7a
283	356a	94a	2.5a	3.7a	1.5a
286	332a	89a	2.9a	2.8a	1.6a
290	224a	90a	3.7a	3.2a	1.1a
292	385a	37a	2.2a	1.5ab	1.1a
296	276a	71a	3.3a	1.6ab	1.2a
299	278a	69a	2.6a	1.4ab	1.4a
Revenue	188a	54a	1.9a	0.4b	1.0a
Elbee	160a	63a	2.4a	2.7ab	2.2a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]No data were collected in 1992 due to an early snowfall.
[§]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 wheatgrass lines in seeded provenance trial 1 at Sunshine Village in 1989 to 1993. The trial was established in 1987.

Line[†]	Cover %			
	1989	1990	1991	1993[‡]
72	7.5cd[§]	15.0b	45.0abcd	12.5a
144	18.8ab	7.5b	52.5ab	5.0a
279	10.0cd	10.0b	37.5abcde	5.0a
281	6.3cd	15.0b	32.5abcde	15.0a
283	15.0abc	11.3b	35.0abcde	13.8a
286	8.8cd	25.0a	50.0abc	16.3a
290	11.3cd	13.8b	57.5a	16.3a
292	6.3cd	15.0b	23.8cde	10.0a
296	6.3cd	13.8b	25.0bcde	13.8a
299	5.0d	10.0b	16.3e	5.0a
Revenue	5.0d	15.0b	15.0e	10.0a
Elbee	20.0a	13.8b	20.0de	6.3a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]No data were collected in 1992 due to an early snowfall.
[§]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.25. Performance of selected wheatgrass lines in seeded provenance trial 2 at Sunshine Village in 1989 to 1993. The trial was established in 1988.

Line[†]	Cover %			
	1989	1990	1991	1993[‡]
72	11.3a[§]	10.0a	32.5bcde	11.7a
144	16.3a	7.5a	50.0bcde	10.0a
279	20.0a	6.3a	55.0abc	6.3a
281	13.8a	11.3a	52.5abcd	10.0a
283	12.5a	9.5a	60.0ab	8.8a
286	17.5a	12.0a	50.0bcde	10.0a
290	15.0a	7.5a	80.0a	10.0a
292	12.5a	6.3a	27.5cde	7.5a
296	10.0a	11.3a	22.5de	10.0a
299	12.5a	12.5a	25.0cde	10.0a
Revenue	11.3a	8.8a	20.0e	8.8a
Elbee	13.8a	8.8a	27.5cde	11.7a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]No data were collected in 1992 due to an early snowfall.
[§]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.26. Performance of selected wheatgrass 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 $^{-1}$)	Above-ground Biomass (g plant^{-1})	Time to Maturity (days[‡])	1000 Seed Wt. (g)
72	46.1bc[§]	2.7d	44.4b	73e	3.9cd
144	51.1ab	3.9d	41.1b	73e	4.3bc
279	55.2ab	14.4a	70.8a	81d	3.7d
281	45.9bc	15.8a	73.9a	87cd	3.7d
283	54.9ab	13.4a	73.6a	90c	3.7d
286	54.3ab	14.6a	74.6a	88cd	3.6d
290	32.7cd	5.8bcd	68.0a	92bc	5.0a
292	26.3d	7.7b	68.4a	101a	5.0a
296	27.9d	7.4b	60.4a	102a	4.6ab
299	38.8cd	8.3b	61.8a	100ab	4.6ab
Revenue[¶]	-	-	-	-	-
Elbee	63.6a	7.0bc	71.2a	90c	3.2e

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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.
[¶]Revenue was cut and removed early because of head smut infection.

Table A.27. Performance of selected wheatgrass 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. (g)	Plant Height (cm)	Plant Width (cm)
72	95.3b[§]	6.3gh	74g	3.5cd	37.3b	22.3b
144	55.2cde	4.3gh	82f	3.4d	29.8b	18.6b
279	91.4b	25.6a	97e	3.5cd	58.8a	21.2b
281	88.1b	22.3ab	97e	3.2d	56.4a	19.6b
283	81.4bc	18.4bc	100d	3.2d	58.0a	20.3b
286	77.0bc	20.3bc	97e	3.4d	53.0a	18.8b
290	8.8f	1.3h	102cd	4.1ab	35.8b	16.0b
292	44.1de	12.5de	104bc	4.3ab	56.0a	21.0b
296	31.4ef	9.9ef	105b	4.5a	56.4a	17.6b
299	68.4bcd	16.5cd	104bc	4.1ab	59.2a	20.4b
Revenue	68.5bcd	4.8gh	110a	3.9bc	54.3a	20.3b
Elbee	124.9a	6.5fg	104bc	2.7e	51.2a	62.2a

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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.28. Performance of selected wheatgrass lines in seeded provenance trial 1 at Vegreville in 1988. The trial was seeded in 1987.

Line[†]	Number of Heads (no. m^{-1})	Seed Yield (g m^{-1})	Above-ground Biomass (g $plant^{-1}$)	Time to Maturity (days [‡])	1000 Seed Wt. (g)
72	294bcd[§]	17.9f	399abc	61f	3.4de
144	335abc	29.8ef	281c	73e	3.8cd
279	401ab	78.5bc	433abc	88d	3.7cd
281	410ab	87.7ab	509a	88d	3.8cd
283	472a	107.9a	485ab	88d	3.6d
286	426ab	91.7ab	471ab	88d	3.7cd
290	208cd	31.6e	347bc	90c	4.9ab
292	164d	41.7e	341bc	102a	5.2a
296	245cd	45.8de	433abc	102a	5.1a
299	266cd	63.7cd	423abc	96b	4.5b
Revenue[¶]	-	-	-	-	-
Elbee	430ab	30.2ef	524a	90c	3.2e

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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.
[¶]Revenue was cut and removed early because of head smut infection.

Table A.29. Performance of selected wheatgrass lines in seeded provenance trial 1 at Vegreville in 1989. The trial was seeded in 1987.

Line†	Number of Heads (no. m^{-1})	Seed Yield (g m^{-1})	Plant Height (cm)	Time to Maturity (Days ‡)	1000 Seed Wt. (g)
72	135cde§	9.7d	30.8c	74e	3.7e
144	102de	7.7d	26.3c	100cd	4.4bcd
279	317a	79.9a	67.3a	100cd	4.1cde
281	298ab	74.7a	66.8a	100cd	3.9de
283	183bcd	53.6b	64.3a	101cd	3.9e
286	219abc	61.1ab	67.8a	97d	3.9de
290	55e	7.9d	46.3b	111a	4.5bc
292	145cde	43.0bc	67.0a	110ab	5.0a
296	115cde	41.6bc	66.3a	113a	4.8ab
299	238abc	52.4b	69.8a	108abc	4.7ab
Revenue	339a	45.4bc	68.8a	115a	4.1cde
Elbee	326a	26.2cd	50.3b	103bcd	2.9f

†Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
‡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.30. Performance of selected wheatgrass lines in seeded provenance trial 2 at Vegreville in 1989. The trial was seeded in 1987.

Line†	Number of Heads (no. m^{-1})	Seed Yield (g m^{-1})	Plant Height (cm)	Time to Maturity (days ‡)	1000 Seed Wt. (g)
72	168d§	15.8d	36.0c	81f	3.8c
144	166d	21.4cd	42.5c	86e	4.1c
279	335bc	85.0a	55.5ab	97d	3.7c
281	351bc	77.1a	53.8ab	100cd	4.0c
283	277c	71.0ab	51.5b	100cd	3.8c
286	409b	92.6a	55.3ab	100cd	3.9c
290	114d	29.9cd	55.0ab	108b	4.8b
292	126d	45.0bc	52.0ab	115a	5.6a
296	-	-	-	-	-
299	296c	77.2a	55.8ab	103c	4.2c
Revenue	539a	86.7a	61.8a	115a	4.1c
Elbee	295c	27.7cd	60.5ab	101cd	2.9d

†Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
‡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.31. Performance of selected wheatgrass lines in seeded provenance trial 2 at Vegreville in 1990. The trial was seeded in 1988.

Line[†]	Number of Heads (no. m^{-1})	Seed Yield (g m^{-1})	Plant Height (cm)	Time to Maturity (days[‡])	Flag Leaf Length (cm)
72	-	-	40.0d	-	7.0b
144	3.3c[§]	0.1c	50.5d	94c	7.2b
279	84.1ab	10.8bc	67.0c	94c	8.2b
281	109.7ab	15.1ab	69.1c	94c	7.7b
283	93.4ab	14.9ab	66.9c	94c	8.0b
286	77.0bc	11.7abc	70.7c	94c	7.5b
290	4.5c	0.3c	50.9d	100b	6.6b
292	76.9bc	16.2ab	87.3ab	102b	8.2b
296	0.5c	0.0c	-	101b	-
299	102.1ab	17.7ab	74.1c	100b	7.6b
Revenue	158.0a	25.9a	91.5a	109a	13.2a
Elbee	140.6ab	11.3bc	78.9bc	95c	8.9b

[†]Lines 72 and 144 are broadglumed wheatgrass; lines 279, 281, 283, 286, and 290 are awnless slender wheatgrass; lines 292, 296, and 299 are awned slender wheatgrass.
[‡]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 SLENDER WHEATGRASS LINES IN INDIVIDUAL MULTILOCATION TRIALS

Table B.1. Performance of selected wheatgrass lines in multilocation trial 1 at Columbia Icefields in 1991 to 1994. The trial was seeded in 1990.

Line	Emergence (no. plants m^{-1})	Cover (%)				Seed Yield (mg m^{-1}) 1994
		1991	1992	1993	1994	
M1 (137+144)[†]	46bcd[‡]	55a	93a	32a	37a	0.7a
137	39d	49a	76a	16b	32a	0.0a
144	55abc	55a	83a	26ab	25a	0.0a
M2 (279+281+286)	56ab	54a	75a	21ab	30a	0.0a
279	46bcd	52a	85a	23ab	45a	0.0a
M3 (292+296+299)	46bcd	46a	75a	20ab	26a	4.3a
299	43cd	48a	82a	11b	16a	0.0a
Revenue	67a	52a	74a	32a	44a	30.7a

[†]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[‡]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 wheatgrass lines in multilocation trial 2 at Columbia Icefields in 1991 to 1993. The trial was seeded in 1991.

Line	Emergence (no. plants m^{-1})	Cover (%)	
		1992	1993
M1 (137+144)[†]	35b[‡]	45a	17a
137	34b	42a	19a
144	34b	47a	18a
M2 (279+281+286)	44ab	43a	14a
279	47ab	50a	16a
M3 (292+296+299)	39b	45a	17a
299	55a	47a	18a
Revenue	54a	43a	17a

[†]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.
[‡]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 wheatgrass 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 (137+144)[†]	44bc[‡]	75a	0.0b
137	43bc	73ab	0.0b
144	38c	75a	0.0b
M2 (279+281+286)	46bc	75a	0.1b
279	49b	63bc	0.0b
M3 (292+296+299)	37c	61c	0.2b
299	45bc	69abc	0.2b
Revenue	63a	68abc	1.7a

[†]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[‡]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 wheatgrass 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 (137+144)[†]	68a[‡]	0.1b	0.0a	21.0b	5.7a
137	58ab	0.0b	0.0a	-	5.0a
144	66a	0.8b	3.2a	22.5b	5.8a
M2 (279+281+286)	57abc	0.2b	15.2a	44.0a	5.2a
279	44bc	0.0b	1.0a	-	4.0a
M3 (292+296+299)	41c	0.2b	0.0a	26.0b	3.7a
299	55abc	0.4b	12.7a	43.3a	4.7a
Revenue	58ab	4.4a	15.9a	34.2ab	3.5a

[†]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[‡]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 wheatgrass 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 (137+144)[†]	53a[‡]	0.2b	8.3b	12.0a	4.2a
137	45abc	0.0b	0.0b	-	4.9a
144	55a	1.0a	41.0a	24.5a	3.9a
M2 (279+281+286)	47abc	0.2b	3.7b	21.0a	4.3a
279	39bc	0.1b	3.3b	37.0a	3.7a
M3 (292+296+299)	34c	0.1b	0.0b	34.0a	3.7a
299	49ab	0.4ab	7.2b	37.0a	3.6a
Revenue	51ab	0.5ab	0.0b	21.0a	2.8a

[†]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.
[‡]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 wheatgrass 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 (137+144)†	95ab‡	1.0b	46.0a	27.0c	10.2a
137	95ab	0.4b	45.0a	31.7bc	10.0a
144	98a	2.2b	163.2a	24.8c	10.8a
M2 (279+281+286)	92ab	0.8b	41.7a	40.6abc	10.0a
279	82ab	0.3b	18.7a	39.0abc	9.5a
M3 (292+296+299)	78b	0.4b	50.5a	43.2ab	8.8a
299	88ab	1.7b	112.3a	53.0a	9.5a
Revenue	89ab	5.5a	124.8a	37.7abc	7.7a

†Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

‡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 wheatgrass lines in multilocation trial 2 at Mountain Park in 1991 to 1994. The trial was seeded in 1991.

Line	Emergence (no. plants m^{-1})	Cover (%)		
		1992	1993	1994
M1 (137+144)[†]	54cd[‡]	42a	42a	86a
137	64abc	42a	46a	78ab
144	46d	41a	46a	82ab
M2 (279+281+286)	60bc	30b	34a	85a
279	66ab	35ab	39a	90a
M3 (292+296+299)	54cd	29b	24a	48c
299	63bc	37ab	32a	57bc
Revenue	74a	39a	32a	63abc

[†]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[‡]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 wheatgrass 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 (g)
M1 (137+144)[‡]	72bc[§]	48c	252d	40.8c	82de	3.5bcd
137	82abc	77c	120d	45.7c	82e	3.4cd
144	67c	80c	218d	36.7c	84d	3.7ab
M2 (279+281+286)	87ab	272a	1185ab	85.0b	91c	3.3d
279	89a	264a	1299a	94.0ab	91c	3.5bcd
M3 (292+296+299)	89a	147b	792c	100.5a	102b	3.8a
299	90a	152b	787c	95.3ab	101b	3.7abc
Revenue	91a	204b	906bc	97.8a	106a	3.7abc

[†]Days from April 15 to maturity.

[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[§]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 wheatgrass 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 (g)
M1 (137+144)[‡]	86c[§]	105c	238bc	40.5b	111a	3.6bcd
137	88bc	98c	95c	43.6b	112a	3.8ab
144	88c	97c	137bc	38.7b	111a	3.7bc
M2 (279+281+286)	97a	166bc	846a	79.8a	100b	3.4d
279	96a	191b	902a	81.0a	100b	3.6bcd
M3 (292+296+299)	96ab	138bc	388b	78.8a	111a	3.9a
299	94abc	150bc	419b	77.1a	109a	3.7bc
Revenue	98a	363a	777a	81.2a	111a	3.5cd

[†]Days from April 15 to maturity.

[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[§]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 wheatgrass lines in multilocation trial 1 at Vegreville in 1993. 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 (g)
M1 (137+144)[‡]	91b[§]	49b	67c	41.4c	82d	3.7bc
137	89b	36b	53c	34.9c	82d	3.6bcd
144	88b	68b	57c	34.5c	82d	3.5cd
M2 (279+281+286)	100a	278a	786a	83.6b	99c	3.2d
279	100a	175ab	768a	90.8ab	99c	3.4cd
M3 (292+296+299)	100a	141ab	452b	93.2ab	112b	4.2a
299	98a	142ab	396b	90.0ab	112b	3.9ab
Revenue	100a	184ab	573ab	97.3a	127a	4.1a

[†]Days from April 15 to maturity.
[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.
[§]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.11. Performance of selected wheatgrass 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 (g)
M1 (137+144)[‡]	99b[§]	126bc	74c	50.8c	105bc	3.5b
137	99b	126bc	114c	45.8cd	103c	3.5b
144	99b	151bc	66c	42.5d	112a	3.6ab
M2 (279+281+286)	100a	207ab	1394a	79.4b	100d	3.3c
279	100a	177abc	1321a	75.2b	100d	3.3c
M3 (292+296+299)	100a	108c	482b	75.5b	112a	3.7a
299	100a	147bc	747b	72.8b	106b	3.6ab
Revenue	100a	242a	1242a	90.5a	112a	3.7a

[†]Days from April 15 to maturity.

[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[§]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 wheatgrass 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 (g)
M1 (137+144)[‡]	100a[§]	142a	725bc	59.1de	81d	4.3abc
137	100a	176a	791bc	63.5d	81d	4.4a
144	100a	172a	477c	52.9e	81d	4.3abc
M2 (279+281+286)	100a	173a	1602a	100.7bc	99c	3.8d
279	100a	163a	1538a	96.4c	99c	3.7d
M3 (292+296+299)	100a	198a	778bc	109.8b	111b	4.1bc
299	100a	143a	873b	100.9bc	111b	4.1c
Revenue	100a	239a	1328a	122.4a	127a	4.3ab

[†]Days from April 15 to maturity.
[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.
[§]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 wheatgrass 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 (g)
M1 (137+144)[‡]	20b[§]	9c	7c	34.9d	101bc	3.7bc
137	27b	12c	12c	35.8d	96c	3.6bc
144	22b	11c	50c	33.3d	99c	3.4c
M2 (279+281+286)	100a	78b	473a	77.1c	103bc	3.6bc
279	98a	70b	416a	73.8c	103bc	3.7bc
M3 (292+296+299)	95a	72b	224b	89.6b	112a	4.3a
299	94a	67b	217b	84.7b	107ab	4.4a
Revenue	100a	223a	559a	104.6a	112a	4.3ab

[†]Days from April 15 to maturity.

[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[§]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 wheatgrass lines in multilocation trial 1 at Beaverlodge 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 (g)
M1 (137+144)[‡]	100a[§]	333b	1114bc	57.5b	79d	4.0a
137	100a	326b	706d	58.8b	79d	4.1a
144	100a	407a	1228ab	54.9b	79d	3.9a
M2 (279+281+286)	100a	266c	1359a	99.3a	96c	3.4c
279	100a	237c	1415a	96.8a	96c	3.4bc
M3 (292+296+299)	100a	158d	848d	104.5a	118a	4.0a
299	100a	225c	919cd	102.1a	120a	3.6b
Revenue	100a	257c	1102bc	97.8a	108b	3.5bc

[†]Days from April 15 to maturity.

[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[§]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 wheatgrass lines in multilocation trial 1 at Beaverlodge 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 (g)
M1 (137+144)[‡]	82d[§]	179c	45b	39.3d	76c	3.9abc
137	92b	188bc	53b	41.1d	76c	3.9ab
144	87c	201bc	97b	37.6d	76c	3.8bc
M2 (279+281+286)	100a	254b	549a	73.4c	97b	3.6de
279	100a	200bc	398a	72.8c	97b	3.6de
M3 (292+296+299)	100a	135c	169b	82.5b	113a	4.0a
299	100a	159c	207b	74.0c	113a	3.7cd
Revenue	100a	391a	513a	90.0a	113a	3.5e

[†]Days from April 15 to maturity.
[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.
[§]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 wheatgrass lines in multilocation trial 1 at Beaverlodge in 1993. 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 (g)
M1 (137+144)[‡]	93b[§]	54bc	137b	44.0d	54c	4.4ab
137	92b	50c	134b	46.5d	54c	4.5a
144	92b	72ab	189b	40.7d	54c	4.3ab
M2 (279+281+286)	100a	61abc	343a	72.8bc	104b	3.2d
279	100a	64abc	317a	69.8c	104b	3.3d
M3 (292+296+299)	99a	47c	163b	77.9ab	117a	4.2b
299	100a	46c	139b	73.4bc	117a	3.7c
Revenue	100a	79a	304a	80.0a	117a	3.5d

[†]Days from April 15 to maturity.

[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[§]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 wheatgrass 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 (g)
M1 (137+144)[‡]	100a[§]	229bc	112c	38.9d	113a	3.3d
137	100a	222bc	79c	39.8d	113a	3.3d
144	100a	223bc	202bc	37.7d	113a	3.5bc
M2 (279+281+286)	100a	236bc	377b	64.6c	98b	3.4cd
279	100a	282b	630a	66.6bc	98b	3.5bc
M3 (292+296+299)	100a	178c	335b	72.1b	113a	3.9a
299	100a	217bc	340b	63.4c	113a	3.8a
Revenue	100a	434a	705a	94.0a	113a	3.6b

[†]Days from April 15 to maturity.

[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.

[§]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 wheatgrass 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 (g)
M1 (137+144)[‡]	100a[§]	55c	198c	49.0b	54c	4.7ab
137	100a	58c	293c	51.7b	54c	4.8a
144	100a	59c	179c	52.6b	54c	4.6b
M2 (279+281+286)	100a	129a	775a	80.2a	104b	3.2f
279	100a	126ab	765a	81.3a	104b	3.3ef
M3 (292+296+299)	100a	95b	474b	87.6a	117a	4.2c
299	100a	101ab	462b	80.1a	117a	4.0d
Revenue	100a	122ab	564b	90.0a	117a	3.4e

[†]Days from April 15 to maturity.
[‡]Lines M1, 137, and 144 are broadglumed wheatgrass; lines M2 and 279 are awnless slender wheatgrass; lines M3 and 299 are awned slender wheatgrass.
[§]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.

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	1988	-	-	-	-	-	-	-	-	5.0	3.4	-6.8	-8.0
maximum air	1989	-10.7	-12.2	-5.4	-0.4	-	-	-	-	-	-	-	-
temperature (°C)													
Average monthly	1988	-	-	-	-	-	-	-	-	-1.7	-2.5	-6.8	-13.4
minimum air	1989	-17.5	-20.9	-14.1	-7.3	-	-	-	-	-	-	-	-
temperature (°C)													

[†]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.