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# THE GENETIC POTENTIAL OF NATIVE ALBERTA GRASSES

by


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## ABSTRACT

A collection of 38 species representing 15 genera of Gramineae was made from the 750 km long region of the Rocky Mountains in Alberta. More than 100 sites with extremely harsh growing conditions were examined for superior specimens. Collection sources ranged in latitude from 49°N to 54°N, in altitude from 900 m to 2400 m, in incline from flat to 40°, and from abandoned coal strip mines to wild ungulate winter ranges.

Growth chamber studies suggest that some genotypes from the Rocky Mountain region possess a neutral photoperiod response for fall flower induction. Hence, the utilization over a wide range of latitudes including the far north and central United States appears to be possible. Transplant studies of grass plants from mountain sources to a common nursery in Edmonton (latitude 53°30'N) have demonstrated genetic variability for some species in the date of seed maturity. Evidence supporting photoperiodic control of flowering was not observed. Transplant studies of native grass plants within the Rocky Mountain region have shown that most species studied have a wide ecological tolerance for survival and ability to flower at different latitudes and altitudes. In general, alpine species were the most widely adaptable species. Of particular note were *Poa interior*, *Poa alpina*, *Trisetum spicatum*, *Festuca saximontana*, and *Agropyron latiglume*. Sub-alpine species which were particularly widely adaptable were *Agropyron*

dasystachyum, *Agropyron trachycaulum*, *Agropyron subsecundum* and *Koeleria cristata*.

Studies on seed yield of collected species have revealed genetic variability which could be exploited in a plant breeding program directed at an economical agricultural seed production of native species. Genetic variability in maturity date was observed in most species within and between collection sources. For agricultural production of seed, it is suggested that accessions with similar growing seasons be bulked to form an even-ripening variety with a broad genetic base. Selection of plants of 11 species outstanding in seed yield, resulted in a progeny with improved seed productivity.

## PREFACE

### THE PROBLEM

Many researchers in the field of reclamation have commented on the unsuitability or complete failure of agronomic varieties of grasses for revegetating disturbed land in harsh environments (Brown and Johnston 1976, Dabbs 1974, Cook et al. 1974, Younkin 1972, Mitchell 1972, Van Cleve 1976, Lesko et al. 1975, Etter 1973, Peterson and Etter 1970). Some of the reasons for the lack of success of introduced grasses have been suggested by these reasearchers. Species of grasses developed for agriculture, and hence maximum productivity, often require repeated fertilizer applications to ensure their continued presence in the nutrient poor conditions common to most disturbed and non-arable land. Fertilization may in turn increase susceptibility to winter kill and snow mold. Other problems include phenologies ill adapted to short growing seasons, lack of winter hardiness or drought hardiness, and a negative impact upon herbivores (Hubbard 1977). Although there are a few adapted agronomic varieties which have overcome these problems in some environments, another problem may arise in that, in the past, introduction of a species has sometimes led to its establishment as a new weed.

Because of such problems, as well as because reclamation sometimes requires that there be a return to natural vegetation, there has been increasing emphasis upon using native species of grasses. Reclamation researchers such as Etter (1973), Brown and Johnston (1976), Klebesadel et al. (1964), Mitchell (1973), Younkin (1972), Aldon and Springfield (1975), and Cook (1976) have all advocated the development of a reliable source of native grass seed for use in revegetating disturbed lands in harsh environments. To date, very little work has been done in Alberta or elsewhere in North America to develop varieties for reclamation of alpine or sub-alpine lands.

The concept of applying principles of agriculture and genetics to plants for reclamation is not new. The Soil Conservation Service (a United States Department of Agriculture Agency) has been in operation for over forty years. The SCS Plant Materials Centers have three functions: (1) to assemble, evaluate, select and increase grasses and legumes for use in soil and water conservation; (2) to determine reliable cultural and management methods for their use; (3) to get proven materials into production by farmers, ranchers and commercial seed growers (Hafenrichter 1968).

More than 15,000 accessions have been screened by the SCS centers in the six Pacific Northwest and Great Basin States resulting in more than forty licensed varieties. The most recent releases are Wytana fourwing saltbush (<u>Atriplex canescens</u>) for use in coal mining reclamation and range revegetation and Goshen prairie sandreed (*Calamovilfa longifolia*) for stabilization and range revegetation on sandy soils.

## SCOPE OF THE STUDY

This study is concerned with the development of a seed source of native grass species for reclamation and wildlife range improvement for the Rocky Mountain region of the Province of Alberta, Canada. Various aspects of the problem have been examined and, as a consequence, the thesis is divided into four units.

1. The Collection of Genetic Resources:

   A survey of naturally occurring grass communities and naturally invading grass species was made and a collection of plant and seed material was assembled. As much genetic diversity as possible was gathered in three summers of collection during 1974-1976.

2. Genecological Studies:

   Transplanting experiments were established to measure the ecological tolerance of various species of native grasses to grow outside the range of their normal habitat. Growth chamber experiments were performed to verify environmental responses of the various ecologically separate accessions. Field observations of the various ecological groups were made at the University of Alberta Field Laboratory at Ellerslie, near Edmonton, Alberta.

3. Genetic Variability in Native Alberta Grasses:
Measurements were made of selected agriculturally important characteristics of various species of native grasses in order to assess their response to a genetic improvement program. Several families of closely related species were examined for their breeding systems and possible methods of genetically improving their agricultural properties were explored.

4. Cytogenetic Studies:
Studies were conducted in association with Dr. R.S. Sadasivaiah of the Department of Genetics, University of Alberta on the cytogenetic relationships of some native Alberta Agropyron species. Information regarding chromosome morphology, evolutionary relationships, interspecific fertility, intergeneric fertility, and chromosomal irregularities was sought and results were published. Unit four contains a summary of results of this published co-authored research.

## ACKNOWLEDGEMENTS

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I am very grateful to Dr. J. Weijer and the members of my supervisory committee who guided me on this study. I would like to acknowledge the contributions of Dr. R.S. Sadasivaiah in the form of unpublished data on genetic variability.

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UNIT ONE

of

THE GENETIC POTENTIAL OF

NATIVE ALBERTA GRASSES

OF THE ROCKY MOUNTAINS

## A. INTRODUCTION

### GENETIC RESOURCES

Fifty-two years ago N.I. Vavilov of the U.S.S.R. Institute of Plant Industry described what are now called geographical centers of genetic diversity of our cultivated plants and their wild relatives (Vavilov 1926). A vast wealth of genetic variation was discovered, including many variants not seen before. These centers made available large quantities of material for genetic, cytogenetic, evolutionary, ecological, and plant breeding studies.

In the years since, natural gene pools have been recognized as sources of new varieties valuable in all aspects of agriculture. With this recognition has also come a deep concern for the preservation of these genetic treasuries (Frankel and Bennett 1970). A new crippling plant pathogen may arise and necessitate the development of resistant varieties. Wild populations often harbour genes for resistance. A new beneficial use for a plant species may be discovered and require the development of new kinds of varieties. Again, wild populations are required to provide genetic diversity. With the disappearance of pristine areas containing the only source of genetic material, the resource may be lost forever.

Alberta occupies a unique geographical location with respect to the ecological distribution of plants. The boreal forest extends into the province from the north. Alpine-arctic communities may be found at higher elevations to the west (Ogilvie 1969), grass communities of the southern Great Plains extend into the province from the south-east (Coupland 1961), and grass communities of the intermoutain region of the United States extend into it from the south-west (Tisdale 1947). The central portion of the province contains the Aspen Parkland, which is undoubtedly the center of distribution for *Festuca scabrella*. No other area in North America contained as much area covered by this species as Alberta in its earlier pristine state (Johnston and Cosby 1966).

The various ice ages that periodically covered most of Canada have undoubtedly played an important role in shaping the genetic resources of plants in Alberta. Genotypes isolated for thousands of years during interglacial periods were brought together by the advancing ice. Once united, they crossed and recombined to produce new forms which competed with the old ones for the land that was laid bare when the ice receded. Evidence of this is the presence of the diploid *Agropyron spicatum*, a grass of the intermountain region, in the tetraploids *Agropyron trachycaulum*, a Great Plains and circumpolar species, and *Agropyron dasystachyum*, a northern and intermediate elevation species (Dewey 1965).

Hawkes (1977) illustrated the importance of wild germplasm in plant breeding, not only for the development of new varieties, but also for their use in hybridization with existing cultivars. Dewey (1976) crossed a wild species of native grass, *Agropyron spicatum*, with a weedy exotic species, *Agropyron repens*, and produced a totally new polyploid and potentially useful forage grass.

Mitchell (1978, p. 112), in Alaska, also found that a good plant collection and much selection are necessary for domestication of a wild grass species. He states:

> 'Native species have demonstrated a high degree of variability in hardiness, disease resistance, and seed producing characteristics. Selection efforts have been necessary to identify individuals or populations that possess appropriate adaptations and agronomic traits for commercial growth and revegetation plantings over wide areas.'

Mitchell has developed a variety of *Poa glauca* for revegetation in the far north. Tundra bluegrass began as a collection of 500 plants, from which 29 were eventually chosen to become a synthetic variety.

In approaching the problem of developing native grasses of Alberta for reclamation in the mountainous areas, an attempt was made to accumulate a large, representative sample of the genetic variability present in the populations of the most common grass species in the Rocky Mountain region of Alberta. This was important, not only to assess the genetic potential of different species in performing the difficult reclamation function over a wide range of environmental conditions, but also to offer the opportunity to utilize a valuable genetic resource in a plant selection program.

MOUNTAIN GRASSLAND COMMUNITIES

Moss (1959), in Flora of Alberta, mentions over 200 species of grass native to Alberta. It is therefore necessary to define exactly which grass associations, species, and ecotypes are under consideration in this study.

THE FESCUE PRAIRIE

The *Festuca scabrella* Association is the major grass community in the area. It occupies the black soil between the clumps of *Populus tremuloides* in the Aspen Parkland region along the foothills and extends into the Rocky Mountain region. It is the most vigorous of the grass communities on the prairies, frequently reaching a height of 2 dm. *Festuca scabrella*, which contributes between 65% and 70% of the biomass, owes it's dominance to its very long life span, resistance to prairie fire, and vigorous growth. Moss (1955) suggests that our very fertile black soil in Alberta is principally due to this grass.

The *Festuca scabrella* Prairie Association has been described by Moss (1944, 1947, 1955), Carbyn (1971), Coupland (1961), Looman (1969), and Hodgkinson (1973). The association includes the grasses in Table 1.1. The mountain valleys are occupied by this particular grass

Table 1.1 Grass species in the *Festuca scabrella* Association.

| | |
|---|---|
| *Festuca scabrella* | Rough fescue |
| *Agropyron dasystachyum* | Northern wheatgrass |
| ~~*Agropyron smithii*~~ | ~~Western wheatgrass~~ |
| *Agropyron trachycaulum* | Slender wheatgrass |
| *Agropyron subsecundum* | Bearded wheatgrass |
| *Stipa spartea curtiseta* | Western porcupine grass |
| *Koeleria cristata* | June grass |
| *Helictotrichon hookeri* | Hookers oatgrass |
| *Danthonia intermedia* | Intermediate oatgrass |
| *Stipa viridula* | Green needlegrass |
| Also in the southern part of the province: | |
| *Danthonia parryi* | Parrys oatgrass |
| *Festuca idahoensis* | Idahoe fescue |

association wherever trees are absent and moisture is adequate. is adequate and trees are absent.

Moss (1944) has noted that, in portions of southern Alberta, *Danthonia parryi* may be co-dominant with *Festuca scabrella*. This is apparently caused by grazing pressure from cattle (Moss and Campbell 1947) and it points to the extreme sensitivity of *Festuca scabrella* to defoliation. Moss (1955) reports that *Danthonia parryi* is replaced by the smaller species *Danthonia intermedia* in the mountain valleys to the west at higher elevations and to the north at greater latitudes.

## THE MIXED PRAIRIE

The *Stipa-Bouteloua* Association is found in the dark brown and brown soil zones to the east of the Fescue Prairie and occupies a drier habitat (Coupland 1961). For this reason it is preclimax to the *Festuca* Association and of possible significance in the mountains where the steep south-facing slopes are too dry to support *Festuca scabrella*. These dry grasslands are important because they are utilized by native ungulates as winter range.

The Mixed Prairie has been described by Clarke (1945), Hubbard (1950), Moss (1955), Watts (1960), and a very thorough analysis of it has been made by Coupland (1961). Coupland divided the Mixed Prairie into five faciations. Three of these faciations contain *Bouteloua gracilis*, a grass not found in the foothills and mountains. Two faciations, namely the *Stipa-Agropyron* Faciation found on intermediate textured soils and the *Agropyron-Koeleria* Faciation found on clay soils, are of possible significance in the mountains of Alberta. The important species are *Stipa spartea curtiseta*, *Stipa comata*, *Agropyron dasystachyum*, *Agropyron smithii*, and *Koeleria cristata*. Together, these species comprise more than 75% of the biomass. *Stipa viridula* is the only other associated grass of any abundance. Coupland (1961) has shown in his studies that *Stipa comata* occupies the warmer and drier habitats while *Stipa spartea curtiseta* has better competitive abilities in the cooler and moister situations.

The *Agropyrons* also occupy relative ecological positions (Coupland 1961). *Agropyron smithii* tends to occupy the warmer or sandier soils while *Agropyron dasystachyum* can be found on the cooler or finer textured soils. In addition, *Agropyron smithii* has a geographical distribution that reaches far south into the Great Plains, while *Agropyron dasystachyum* is distributed throughout the north and only extends south of the U.S. border at higher elevations. The international boundary appears to be a common area where both species can be found in equal frequencies.

Additional information pertinent to the distribution of these two important wheatgrasses comes from studies by Johnston *et al.* (1974). They found that *Agropyron smithii* requires from 120 to 150 days for a growing season in contrast with *Agropyron dasystachyum* which requires fewer than 120 days. If this long growing season is a characteristic requirement of *Agropyron smithii*, then it should not expected in the mountains.

THE PALOUSE PRAIRIE

The *Agropyron-Festuca* Association in southern British Columbia as described by Tisdale (1947) has close affinities with the *Festuca scabrella* Association. The influence of this grassland association is apparent in south-western Alberta through the presence of such intermountain species as *Agropyron spicatum* and *Festuca idahoensis*. The presence of *Stipa columbiana* rather than *Stipa viridula* is another example of the influence of the Palouse Prairie.

THE PEACE RIVER PRAIRIE

Moss (1955) described the grasslands of the Peace River area as the *Agropyron-Stipa* Association and suggested it be considered an eighth association in the grassland formation of North America. This area, close to the northern edge of Alberta's Rocky Mountain region, may influence grassland communities. In addition to most of the species already mentioned, a Peace River Prairie needle grass, *Stipa richardsonii*, is readily found throughout the mountains.

## ALPINE GRASS COMMUNITIES

The number of alpine (treeline and above) grass species is smaller than that of the prairie associations and the synecology less complex. On mountain summits capable of supporting plant life, the following grasses have been reported by Ogilvie (1969) and Moss (1955).

a) *Poa arctica*
b) *Poa alpina*
c) *Phleum alpinum*
d) *Festuca saximontana*
e) *Trisetum spicatum*
f) *Festuca brachyphylla*
g) *Festuca baffinesis*
h) *Agropyron latiglume*
i) *Deschampsia caespitosa*

These alpine grasses have been tied to various alpine communities by Ogilvie (1969) and their environment is indeed rigorous. At Banff, at 3000 m, the frost free period is only 7 days and the growing season may be as short as 45 days.

## ADDITIONAL COMMUNITIES

Stringer (1969) studied the grasslands at low elevations in the national parks of Waterton, Banff and Jasper. He pointed to the close affinities the mountain grasslands had with the large surrounding grass associations. Stringer proposed three new associations for the mountains, two of which, he suggested, could be due to heavy grazing and a complex of environmental factors. These associations are the

Koeleria-Calamagrostis Grasslands found in the Jasper area and the Koeleria-Geum triflorum Grasslands found in the Banff area. The Stipa richardsonii Subalpine Grasslands are found throughout the mountains in small parks surrounded by coniferous forests. Included in this group are also the species Agropyron dasystachyum and Danthonia intermedia.

## B. METHODS AND MATERIALS

### METHOD OF COLLECTION

Plant material was collected in the form of seed during the summer months of 1974 to 1977. Whole plants were collected during 1974 and 1975 only. A method, in which leaves and culms are clipped to 10% of their original height, described by Whalley and Brown (1973) for the collection and transport of native grass plants was unsatisfactory. Rather, another method was used which kept mortality to about 2% and some plants were able to complete production of viable seed the same year as they were collected.

Selected specimens were dug with an adequate amount of root and transported in plastic bags. Water was added to moisten the soil. Survival declined rapidly if plants were kept in bags more than three days. Collection trips were therefore short in duration and transplanting at the nursery at Ellerslie was immediate.

After transplanting, the leaves were sprayed with a wilt-retardant spray[1] which coated the leaves with a harmless plastic, thereby stopping water loss by transpiration. More extreme measures were taken for plants which had lost a large portion of their roots. Plastic bags were placed over the plants thus producing a greenhouse effect in the field. An irrigation system was used when rain was insufficient to keep plants growing vigorously.

Seed material was established by germination in growth chambers in tree seedling containers[2] in early March and transplanted to the field in early June; transplants were either space planted 1 m apart or in rows 1 m apart. This procedure allowed enough time during the growing season for the plants tc produce seeds by the end of the summer. Since grasses seldom set seed the first year when seeded directly into the ground, a year was saved in generation time.

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[1]Wiltproof made by Green Cross Products
[2]Spencer-Lamaire Industries, Edmonton.

## ENVIRONMENTAL DATA

Data on the physical environment from which specimens were taken was gathered according to Bennett's method (Frankel and Bennett 1970). Source locations are listed in the Appendix. Altitude was measured with a Thommen pocket altimeter. Aspect and degree of slope were measured by a Silva compass which had an attached clinometer. Soil samples were taken in many locations for analysis by the Alberta Soil and Feed Testing Laboratory in Edmonton. A description of the nature of the site (eg. winter range of Bighorn Sheep; abandoned coal mine) was also recorded.

## IDENTIFICATION OF SPECIES

Species were identified using Moss (1959) as principal reference but heavy reliance was also placed on Hulten (1968), Hitchcock (1935), Hitchcock and Cronquist (1974), Pohl (1954), Budd (1964), Hubbard (1955), and Campbell et al. (1966). Plants whose identity was in doubt were mounted and advice was sought from the Staff of the University of Alberta Botany Department Herbarium and the Canada Department of Agriculture Biosystematics Research Institute in Ottawa.

## C. RESULTS

### COLLECTION

#### SOURCES

Approximately 150 geographically isolated sites from Waterton National Park north 750 km to Grande Cache were searched for suitable plant material. The Appendix contains a list of sources and their physical descriptions.

#### SPECIES

The collection contains 38 species representing 15 genera. A complete list of species and the number of locations from which each was collected is contained in Table 1.2.

TRANSPLANT MATERIAL

A total of 2,500 plants were dug from their mountain habitats and transplanted to the University of Alberta Genetics Field Laboratory at Ellerslie. The mortality rate at the time of transplanting was less than 2% and the survivors have persisted for three years at the time of writing.

SEED MATERIAL

Nearly 20,000 plants were established at the Ellerslie Farm from seed material collected from mountain localities.

Table 1.2 Species collected from the Alberta Rocky Mountains.

| Genera and their species | Common name |
|---|---|
| *Agropyron spicatum* (Pursh) Scribn. & Smith | bluebunch wheatgrass |
| *Agropyron dasystachyum* (Hook.) Scribn. | northern wheatgrass |
| *Agropyron albicans* Scribn. & Smith | albican wheatgrass |
| *Agropyron riparium* Scribn. & Smith | streambank wheatgrass |
| *Agropyron griffithsii* Scribn. & Smith | Griffiths wheatgrass |
| *Agropyron trachycaulum* (Link) Malte | slender wheatgrass |
| *Agropyron subsecundum* (Link) Hithc. | bearded wheatgrass |
| *Agropyron latiglume* (Scribn. & Smith) Rydb. | alpine wheatgrass |
| *Agrostis scabra* Willd. | hair grass |
| *Bromus pumpellianus* Scribn. | northern brome |
| *Calamagrostis canadensis* (Michx.) Beauv. | marsh reed grass |
| *Calamagrostis purpurescens* R. Br. | purple reed grass |
| *Calamagrostis inexpansa* A. Gray | northern reed grass |
| *Danthonia parryi* Scribn. | Parry oat grass |
| *Danthonia intermedia* Vasey | timber oat grass |
| *Deschampsia atropurpurea* (Wahlenb.) Scheele | mountain hair grass |
| *Deschampsia caespitosa* (L.) Beauv. | tufted hair grass |
| *Elymus canadensis* L. | Canada wildrye |
| *Elymus innovatus* Beal | hairy wildrye |
| *Elymus cinereus* Scribn. & Merr. | giant wildrye |
| *Festuca scabrella* Torr. | rough fescue |
| *Festuca idahoensis* Elmer | bluebunch fescue |
| *Festuca saximontana* Rydb. | alpine fescue |
| *Helictotrichon hookeri* (Scribn.) Henr. | Hookers oat grass |
| *Koeleria cristata* (L.) Pers. | June grass |
| *Oryzopsis hymenoides* (R.& S.) Ricker | Indian ricegrass |
| *Phleum alpinum* L. | alpine timothy |
| *Poa alpina* L. | alpine bluegrass |
| *Poa arctica* R. Br. | arctic bluegrass |
| *Poa canbyi* (Scribn.) Piper | Canby bluegrass |
| *Poa cusickii* Vasey | Cusicks bluegrass |
| *Poa interior* Rydb. | interior bluegrass |
| *Stipa comata* Trin. & Rupr. | spear grass |
| *Stipa spartea curtiseta* Trin. | porcupine grass |
| *Stipa columbiana* Macoun | Columbia needlegrass |
| *Stipa viridula* Trin. | green needlegrass |
| *Stipa richardsonii* Link | Richardson needlegrass |
| *Trisetum spicatum* (L.) Richt. | spike trisetum |

OBSERVATIONS

a. Three wheatgrasses, Agropyron dasystachyum, Agropyron trachycaulum, and Agropyron subsecundum are common or present in most of the grassland areas of the Alberta Rocky Mountain region. In addition, these species are very common pioneer plants in disturbed areas undergoing natural revegetation.

b. Alpine grass species commonly found above the tree line are also very common pioneer species invading disturbed areas in the sub-alpine. Of special note are Festuca saximontana, Poa alpina, and Trisetum spicatum.

c. Only one locality within the mountain regions, the Banff flats, had Stipa viridula. The closely related Stipa columbiana, however, was widespread.

d. Stipa comata was found in only two localities, Jasper National Park along the north side of the Athabasca River and the Kootenay Plains. However, the more moisture-loving Stipa spartea curtiseta was found growing on slopes from Waterton to the Smoky River slopes at Grande Cache.

e. Agropyron smithii was not found in the mountains of Alberta.

f. Festuca scabrella was found in mountain valleys and occasionally on moist slopes but was absent from the drier steep south-facing slopes characteristic of Bighorn Sheep winter range areas.

g. *Festuca idahoensis* was not found further north than the Ya Ha Tinda and even there it was not common.

h. *Koeleria cristata* is a very widespread grass especially on the more xeric sites.

i. Most grass species transplanted from the mountains and grown under ideal conditions of adequate moisture, nutrients and no competition responded by increasing markedly in size. The biggest change, however, was the very large increase in seed production over that observed in the natural state.

D. DISCUSSION

The topography of the mountains creates widely varying micro-climatic environments within very short distances (Billings 1978). South-facing slopes have a higher evaporation and run-off rate, thereby reducing the effect of rainfall amounts. Also, the approximately 50% of yearly moisture which falls as snow does not remain on the steep slopes.

Vegetation density also affects moisture availability. Overgrazed grasslands and disturbed areas have higher evaporation rates due to increased air movement at the soil level (Daubenmire and Colwell 1942). Mountain valleys which run parallel to the direction of the prevailing winds, such as the Jasper and Kootenay Plains, often have so much air movement during the summer months that evaporation rates exceed rainfall amounts.

*Festuca scabrella* requires between 41 and 46 cm of rainfall per year (Best *et al.* 1971). This grass was commonly found in open mountain valleys with moderate winds and grazing pressure such as the Waterton area and the Ya Ha Tinda. Also, *Festuca scabrella* was found to be common in the mountains at the bottom of steep grassy slopes where snow accumulates and where trees are unable to survive winter winds or have been destroyed by fire. Examples include the Kannanaskis, Barnaby Ridge, and Sheep River. This grass was not found as an invader on disturbed lands probably because of its very strict moisture requirements. For this reason, *Festuca scabrella* can be considered a poor candidate as a reclamation species. In addition, its poor record as a seed producer (Johnston and MacDonald 1967) would make seed supplies unreliable and expensive.

The grass species of the Mixed Prairie are preclimax to the Fescue Prairie (Coupland 1961). They would make better candidates ecologically for pioneering vegetation in an environment capable of supporting *Festuca scabrella*. Most of these grasses are present in the *Festuca* Association but do not have the competitive advantage to become dominant except where drier conditions prevail. The sub-alpine areas of the mountains are best described as an ecotone (*sensu* Daubenmire) between the two associations, the dominance of *Festuca scabrella* being determined by grazing intensity, rainfall, incline, aspect, and exposure to wind.

The grass species which occupy the open south facing slopes which are utilized as winter range by elk and sheep appear to belong to two associations. Rangeland slopes in the Rocky Mountain region such as the Smoky River, Rock Lake, Greenock Mountain, Ya Ha Tinda, Grotto Mountain, Pigeon Mountain, Highwood, Barnaby Ridge, and Windsor Ridge are all dominated by the Agropyron and Stipa genera. This composition could be the Stipa-Agropyron Faciation of the Mixed Grass Prairie described by Coupland (1961) for the dark brown soil zone of the central plains, or it could be the Agropyron-Stipa Association described for the Peace River Prairie by Moss (1955). It is impossible without long term grazing exclosures to determine the climax composition of the rangeland slopes.

The most widely found grasses in the xeric environments were Agropyron dasystachyum, Agropyron trachycaulum, Agropyron subsecundum, and Koeleria cristata. Associated with these and often co-dominant were Stipa spartea curtiseta, Stipa columbiana, and Stipa richardsonii and less frequently, Danthonia intermedia.

The most common grass species found on disturbed ground such as abandoned strip mines were alpine species. Frequent finds were Poa alpina, Trisetum spicatum, and Festuca saximontana. It is not clear whether the presence of these species is a result of the lack of better adapted species or whether alpine species are natural pioneers when outside their usual habitat above the tree line. In an historical perspective, it is certainly possible that the ground laid bare by the retreating glaciers of the periodic ice ages was vegetated by alpine-arctic species.

There has been one report on the increase in yield of a native grass when growing conditions are improved. Miltimore (1961) found that Agropyron inerme produced an increase of 400% when fertilized with 450 kg/ha of nitrogen. This fertilizer application was on native range. The present study is significant in showing that a wide range of native grasses have been successfully grown far from their source of ecological adaptation and, in addition, that the seed yield has improved to the point that economical agricultural seed production appears possible for some species. This topic is the subject of the third unit of this manuscript.

## E. CONCLUSIONS

1. Based on their ecological distribution, three wheatgrasses, Agropyron dasystachyum, Agropyron trachycaulum, Agropyron subsecundum, appear to be excellent candidates for use in revegetation in a large number of localities within the mountains of Alberta.
2. Koeleria cristata was found to be a species with a wide ecological tolerance.
3. Several alpine species, Festuca saximontana, Trisetum

spicatum, Poa alpina, are widespread invaders of disturbed ground in sub-alpine areas. They also grow and produce seed at agricultural elevations.

4. Poa interior and Poa cusickii are two native bluegrasses which grow well at agricultural elevations and are common in the Rocky Mountains of Alberta.

# II. GENECOLOGICAL STUDIES

UNIT TWO

of

THE GENETIC POTENTIAL OF

NATIVE ALBERTA GRASSES

OF THE ROCKY MOUNTAINS

## A. INTRODUCTION

There appears to be a widespread, though poorly documented, belief that all native plants are intimately adapted to their environments so that their removal to other locales will be unsuccessful. The exact narrowness of such adaptability has not been well defined. An exception is Schumacher (1975) who has suggested the distance of 240 to 480 km as a range that native grasses can be moved north or south of their site of origin. This was in reference to the Great Plains area of the United States and his distances were based on the trial and error experience of the Soil Conservation Service. Since the Rocky Mountain region of Alberta is some 750 km long in a north-west direction, it is possible that restrictions to movements of some species exist.

If this is in fact the case, then separate varieties of each species will be necessary for each ecological region. Such a requirement would add significantly to the cost of research and development of reclamation varieties of native grasses. Furthermore, ecotypic varieties whose adaptability is restricted to certain latitudes or elevations would not be as simple to use as one variety and seed production would be more expensive because of lower volumes.

PHYSIOLOGICAL BARRIERS

It is possible to speculate on reasons for the inability of plants to survive new environments. Minimum temperatures become lower and growing seasons shorter moving northward on the North American continent. Tolerance to low winter temperatures would certainly be an essential adaptation possessed by ecotypes of species in northern or alpine climes. Such an adaptation would not be essential in ecotypes of the same species from less extreme climates.

A second environmental factor that could pose an ecological barrier to the successful movement of native grasses to new locales is drought. Ecotypes not adapted to the summer drought period experienced on the central portion of the Great Plains areas of North America could not be expected to have a wide ecological tolerance.

The plants in the collection made during the course of this study were chosen from the most extreme climatic regions of their range. Many accessions came from very steep south-facing slopes at high elevations in the Rocky Mountains. Others were chosen from high elevation areas whose soils were drastically disturbed. This was done in the hope that the plant specimens collected would possess extreme tolerance to cold and drought in order that these two environmental factors would not present physiological barriers.

PHENOLOGICAL BARRIERS

Another reason that native plants may not be able to tolerate a move from their site of origin is differences in phenology. Phenology is concerned with periodic biological events in their relation to seasonal climatic changes. Some examples of biological events are the seasonal migration of birds, the hibernation of animals, and the sprouting, flowering, and fall dormancy changes in plants.

The pattern of geographical advance for a given phase in the life cycle of plants, such as the beginning of flowering, is likely to differ among species, and even among different genotypes of the some species. However, many different kinds of plants tend to follow somewhat the same general pattern of geographic progression in the spring for any given developmental phase. This is particularly true of those plants and phases which are responsive to similar environmental factors such as temperature and day length.

Clausen (1940) published information on mean dates of first flowering of clonal transplants for numerous species grown at three different elevations along a latitudinal transect near 38°N in California. His work has shown that long-established native plants of a given species growing at two different climatic extremes are likely to possess contrasting differences in their genetic response to environment. In the area of climatic transition between these two zones of climatic opposites, these native plants tend to possess a genetically controlled response that is intermediate between responses of the plants of that species growing at either of the climatic extremes. In other words, native plant species that cover a wide area of contrasting environments may consist of individuals that change in their genetically controlled response to environment in conformity with the gradient of the environment itself.

Also using the technique of clonal transplants, McMillan (1965) has demonstrated ecotypes within species for several native prairie grasses that possess a north-south gradient for time to flower and shatter. Plants from the colder north did not bloom until the long day season, even when there were prior periods of warm weather. These plants were more adapted for survival in the north where they are less likely to expose their sensitive flowers while the danger of a frost injury exists. They are also able to mature seed in a shorter period of time before the onset of critically cold weather.

Plants of the same species from southern latitudes, which do not possess this long day rapid-maturity response, would soon perish if transferred to northern regions. This fact was demonstrated very clearly by Klebesadel (1972) who found that sub-arctic adapted varieties of Bromus inermis and Poa pratensis were influenced by artificially shortened nyctoperiods (duration of diurnal darkness) in Alaska. Winter survival and subsequent amount of heading were affected negatively. In contrast, mid-temperate adapted varieties of the same species suffered the least winter injury and headed the most after exposure to artificially lengthened nyctoperiods which more closely resemble the diurnal conditions during autumn at its latitude of adaptation. Klebasadel concluded that the number of hours of darkness affects winter survival and heading of grasses the following year.

Pringle et al. (1975) have found that ecotypes of Agropyron trachycaulum derived from far northern latitudes have a reduced capability of producing seed culms in environments with less than continuous light. This characteristic is a partial ecological barrier to the movement of this species, since the reduced reproductive ability would select against its survival.

Other evidence that local populations of widespread species are physiologically different was shown by Olmsted (1944, 1942) with Bouteloua curtipendula, a common American prairie grass. The population was made up of photoperiodic ecotypes with those from North Dakota requiring longer days for flowering than those from Texas. Billings (1971) found a photoperiodic induced flowering response in the arctic-alpine distributed Oxyria digyna.

In Alaska, Hodgson (1966) found not only photoperiodic ecotypes, but also a difference in the development of the inflorescence. Indigenous species initiated inflorescence development in the fall and overwintered in this state with little injury, whereas grasses from more temperate latitudes did not initiate until spring. Hodgson suggested, that for

Arctic regions, a partially developed inflorescence, ready to commence development when favorable spring temperatures occurred, would have a very decided selective advantage.

PURPOSE OF PHOTOPERIODIC AND TRANSPLANT STUDIES

Adaptations to local environments which may restrict movement of widely distributed species have been demonstrated by a number of workers. The experiments in this unit were designed to attempt to answer a very basic question. Are there any ecological barriers, physiological or phenological, which would limit the movement of native Alberta grass species within the Rocky Mountain region of Alberta?

B. METHODS AND MATERIALS

Whole plants of native grass species were dug from many locations in Alberta's Rocky Mountain region and transplanted to experimental plots at Ellerslie during 1974-76. Details concerning collection, planting techniques, and sources of material have been described in Unit I of this manuscript. This material was needed for transplant studies and seed collected from these plants was used for growth chamber and mountain transplant studies.

## GROWTH CHAMBER STUDIES

Growth chamber studies were conducted at the University of Alberta Controlled Environmental Facilities in the Biological Sciences Building. Each chamber has separate controls for temperature, humidity, diurnal temperature change, and photoperiod. Maximum light was 2800 foot candles provided by a mixture of fluorescent and incandescent light bulbs. A diurnal temperature change was maintained. Temperatures were 22°C for 12 daylight hours and were 13°C during night.

Potting soil consisted of 1 part Alberta loam: 1 part perlite: 1 part vermiculite. A very low rate of nitrogen fertilizer was applied bi-monthly to maintain steady growth. Pot size varied (10 to 25 cm) depending on the size of the plant.

### MINIMUM REQUIREMENTS FOR FLOWERING

Since 1974 the various grass species listed in Table 2.3 have been grown in growth chambers. To induce flowering in plants, which had already produced seeds, the following four pre-treatments were applied to potted plants.

1) Six weeks of 12 hour days plus 4 weeks at 4°C in total darkness.
2) Six weeks of 12 hour days.
3) Six weeks of 12 hour days plus 4 weeks at below 0°C (plants buried in snow).
4) Four weeks at 4°C and total darkness.

After pre-treatment, plants were returned to growth chambers with either 12 or 16 hour daylight periods.

MAXIMUM TOLERANCE FOR FLOWERING

The following experiment was performed to determine if native Alberta grasses could flower under a light regime brought about by a drastic change in latitude. Growth chambers were programmed to simulate the daily light regimes of three different geographical locations in North America. The three locations were at latitude 65°N (Norman Wells), latitude 55°N (Grande Prairie), and latitude 45°N (southern Montana). Table 2.1 has a list of daylight and twilight hours experienced at each location.

Table 2.1 Hours of daylight (d) and twilight (t) in growth chamber flowering studies.[3]

| Duration of Treatment | | Montana lat45°N hr.d/t | Alberta lat55°N hr.d/t | Arctic lat65°N hr.d/t |
|---|---|---|---|---|
| June | 1 to 15 | 15.2/.3 | 16.8/.3 | 21/3 |
| June | 15 to 30 | 15.5/.3 | 17.3/.3 | 22/2 |
| July | 1 to 15 | 15.5/.3 | 17.0/.3 | 22/2 |
| July | 15 to 31 | 15.2/.3 | 17.0/.3 | 20/4 |
| August | 1 to 15 | 14.8/.3 | 16.0/.3 | 18/2 |
| August | 15 to 31 | 14.0/.3 | 15.0/.3 | 16/1 |
| September | 1 to 15 | 13.0/.3 | 14.0/.3 | 15/1 |

Alberta grass species used in this experiment came from the collection described in Unit I. Four plants of each species were cloned by division to produce three specimens for inclusion in the three light regimes.

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[3] Daylight (d) was 2700 foot candles of fluorescent and incandescent light. Twilight (t) was 500 foot candles of incandescent light. Data on hours vs. latitude were taken from Thomas (1953).

Also, control species were included from the Arctic and southern Montana. 'Tundra' bluegrass is a licensed variety of Poa glauca from above the Arctic Circle in Alaska, recommended for tundra reclamation (Mitchell 1978). An unlicensed variety of Festuca arundinacea from the Arctic Circle in Finland was obtained from Golden West Seeds of Calgary. The same firm also supplied an unlicensed variety of Poa alpina which came from Iceland (latitude 65°N). Four native grass species from southern Montana were obtained from R. Brown of Logan, Utah and from C. Strobeck of Edmonton, the collection site being the Beartooth Mountains at an elevation of 3300 m. At least five plants of each check species were cloned and placed in each growth chamber.

## FARM TRANSPLANT STUDIES

Approximately 1500 plants representing 29 species transplanted from different geographical areas of the Rocky Mountains to the Genetics Farm at Ellerslie were used in this study. Table 2.3 contains a list of species studied and their sites of collection. Data on the seed shattering dates of each plant was collected during 1976 under the uniform garden conditions provided at the farm. Spikes from individual plants were harvested as and when they began to shatter. A complete description of the collection sites is contained in the Appendix. The number of plants in each species-source group varied from 3 to 25, depending on the material available.

## MOUNTAIN TRANSPLANT STUDIES

In 1975, a program of field testing native grass species in the mountains was begun to determine if native grass species could be moved to different locations within the Rocky Mountain region of Alberta. One source location was chosen at random for each species in the collection except for two species. Agropyron dasystachyum and Koeleria cristata are cross-pollinated species and since there was no control over inter-pollination between plants from different sources, a province wide mix was used. Transplant sites were chosen throughout the Rocky Mountains of Alberta which represented a wide variety of elevations, latitudes, aspects, soil types and inclines.

To eliminate the variables of seedling establishment (seeding rate, mulches, weather, microtopography, etc.) seeds were germinated in growth chambers, transplanted to containers (41 cc Spencer-Lemaire tree seedling containers in 1976) and planted in mountain test sites in July. Sixteen plants of each species were spaced 25 cm apart in a one square meter plot. No soil amendments of any kind were used. Two parameters were monitored biannually in the following years: (1) plant survival and (2) ability to produce heads. Such characters as height, percent cover and vigour were not recorded because the species used were not of one genotype.

Table 2.2 Species used in mountain transplant studies.

1975 Establishments

| Genera and their species | Source | Elevation |
|---|---|---|
| *Agropyron dasystachyum* | Grotto Mtn. | 1524 m |
| *Deschampsia caespitosa* | Whitehorn Mtn. | 1829 m |
| *Stipa columbiana* | Pigeon Mtn. | 1829 m |
| *Trisetum spicatum* | Mt. Rae | 2286 m |
| *Poa alpina* | Mt. Rae | 2286 m |
| *Festuca saximontana* | Mt.Rae | 2286 m |

1976 Establishments

| Genera and their species | Source | Elevation |
|---|---|---|
| *Apropyron dasystachyum* | Province-wide mix | |
| *Agropyron latiglume* | Peyto Lake | 2286 m |
| *Agropyron trachycaulum* | Banff Flats | 1385 m |
| *Agropyron subsecundum* | Kootenay Plains | 1385 m |
| *Bromus pumpellianus* | Province-wide mix | |
| *Festuca saximontana* | Caw Creek Ridge | 1981 m |
| *Koeleria cristata* | Province-wide mix | |
| *Phleum alpinum* | Peyto Lake | 2286 m |
| *Poa alpina* | Whitehorn Mtn. | 1829 m |
| *Poa interior* | Whistlers Mtn. | 2347 m |
| *Stipa columbiana* | Pigeon Mtn. | 1829 m |
| *Trisetum spicatum* | Mtn. Park Pass | 1981 m |

## C. RESULTS

### GROWTH CHAMBER STUDIES

Results from both growth chamber studies have been combined and are summarized in Table 2.3.

#### MINIMUM REQUIREMENTS FOR FLOWERING

To induce flowering, most Alberta grasses required only 4 weeks at 4°C in total darkness before being returned to the growth chamber. Sixteen hours of light per day vs. 12 hours of light per day had no measurable affect cn the ability of the plants to produce tillers. Exceptions were the members of the genus *Festuca*. A satisfactory method of inducing flowering in growth chambers was not determined for *Festuca scabrella*, *Festuca saximontana*, *Festuca idahoensis* and *Festuca rubra* Boreal.

Other treatments which included a 12 hour photoperiod treatment to simulate fall daylengths were successful only if a period of cold temperatures was included. Photoperiods less than 12 hours per day are generally not experienced in the mountain regions of Alberta since a killing frost is usually experienced before the autumnal equinox. The results of this experiment suggest that photoperiod does not affect flowering but cold temperatures in late season do.

MAXIMUM TOLERANCE FOR FLOWERING

The results presented in Table 2.3 demonstrate that most Alberta grass species were able to flower in the light regimes of latitudes 45°, 55°, and 65°N. The genus *Festuca* contains species which appear to have complex requirements for flowering and none produced seed heads in the latitudinal growth chambers. One fescue species (*Festuca saximontana*) did flower in the constant 16 hour daylight/8 hour night growth chamber for several artificial seasons but not in the latitudinally adjusted growth chambers. It is possible that the clone size was too small, or recovery from the cloning operation was slow, for this species.

Two Arctic species were able to flower only under the simulated light regime of latitude 65°N. The arctic genotype of *Poa alpina* did not flower in any latitudinal chamber.

The Montana genotypes of *Poa alpina*, with the exception of one clone of the total 23, did not produce flowers under any treatment. This single exception was able to flower under all three light regimes. It is possible that genetic variability for the flowering response to daylength exists within the population from the Beartooth Mountains in Montana and is expressed in this specimen. None of the Montana genotypes of

*Deschampsia caespitosa* and *Trisetum spicatum* were able to produce flowers in any of the growth chambers. Five clones of genotypes of *Poa cusickii* from Montana were used in this study and, of these, three clones produced flowers in all three chambers and two did not flower at all.

Table 2.3 Ability of the species studied to have flowering induced in growth chambers with light regimes similar to three locations in North America and of a constant 16 hours of light/8 hours of darkness during a 3 month season.

| | Light Regime | | | |
|---|---|---|---|---|
| Source of Material<br>Genera and their Species | 16 hr.l<br>/8 hr.d | Arctic<br>lat65°N | Alberta<br>lat55°N | Montana<br>lat45°N |
| Alberta Genotypes | | | | |
| Agropyron latiglume | yes | yes. | yes | yes |
| Agropyron dasystachyum | yes | yes | yes | yes |
| Agropyron spicatum | yes | yes | yes | yes |
| Agropyron subsecundum | yes | yes | yes | yes |
| Agropyron trachycaulum | yes | yes | yes | yes |
| Agrostis scabra | yes | yes | yes | yes |
| Calamagrostis purpurescens | no | yes | yes | yes |
| Deschampsia caespitosa | no | yes | yes | yes |
| Festuca rubra Boreal | no | no | no | no |
| Festuca idahoensis | no | no | no | no |
| Festuca saximontana | yes | no | no | no |
| Koeleria cristata | no | no | yes | yes |
| Phleum alpinum | yes | yes | yes | n/a[1] |
| Poa alpina | yes | no | yes | yes |
| Poa interior | yes | yes | yes | yes |
| Poa cusickii | yes | yes | yes | yes |
| Stipa comata | yes | yes | yes | yes |
| Stipa columbiana | yes | yes | yes | yes |
| Stipa spartea curtiseta | yes | yes | yes | yes |
| Trisetum spicatum | yes | yes | yes | no |
| Arctic Genotypes | | | | |
| Festuca arundinacea | n/a | yes | no | no |
| Poa alpina | n/a | no | no | no |
| Poa glauca Tundra | n/a | yes | no | no |
| Montana Genotypes | | | | |
| Deschampsia caespitosa | n/a | no | no | no |
| Poa alpina | n/a | no | no | no |
| Poa cusickii | n/a | yes | yes | yes |
| Trisetum spicatum | n/a | no | no | no |

[1]data not available

FARM TRANSPLANT STUDIES

Data on the date of shattering of approximately 1500 plants representing 29 species (collected from different geographical areas) grown in Ellerslie are given in Table 2.4. The shattering date indicates that one or more plants from that geographical source began to shatter seed on that day.

The observed variations in the number of days to ripen seeds can be divided into three types.

1. Intra-plant variations: Some species such as *Stipa columbiana* and *Phleum alpinum* have an indeterminate tillering habit in which seed heads ripen one at a time throughout the growing season so that there is no single day on which the majority of the seeds can be harvested. Dates indicate when peak ripening periods occurred. Most other native species have a less severe type of indeterminate tillering habit in which the heads may ripen for a period of a few days to several weeks.
2. Inter-plant variations within a geographical area: Most of the species show a great deal of variation within a geographical area with respect to the date on which shattering begins. For example, plants of *Koeleria cristata* collected from Cat Creek shattered on July 12, 19, 27 and August 18. This population contained the earliest and latest ripening plants of the species in the collection. Other species which displayed a wide range of shattering dates included *Agropyron*

trachycaulum, *Poa alpina*, *Agropyron dasystachyum*. Most species had variable shattering dates within a collection source which differed by about 2 to 3 weeks.

3. Inter-geographical variations: The shattering date varies between different sources for some species and not for others. For example, all plants of *Festuca scabrella* collected from Waterton in southern Alberta to Caw Creek Ridge north of Grande Cache ripened seed on July 9. Most other species showed a less remarkable synchronization. Differences occurred in the growing season between the sources of most of the species but these are generally no greater than the differences observed within each collection source. For example, plants of *Poa alpina* shattered seed on July 9, 19, and August 18 in the plots from Barnaby Ridge (49°N) and similarly those from Pyramid Lake (53°N) shattered on July 9, 19, and August 18. There appears to be no consistent correlation between shattering date and collection source or latitude of sources.

Table 2.4 Shattering dates in 1976 at Ellerslie

| Genera and Species | Source | Dates Harvested |
|---|---|---|
| Trisetum spicatum | Peyto Lake | June 16, 17, 18 |
| | Whitehorn | June 29 |
| | Mt. Rae | June 29 |
| | Grassy Mtn. | July 12, 20 |
| | Mtn. Park Pass | July 19 |
| | Sunshine | July 19, Aug. 6, 20 |
| | Coal Valley | Aug. 6 |
| Phleum alpinun | Cat Creek | June 30, July 5 |
| | Fortress Mtn. | July 12 |
| | Cat Creek | July 12, Aug. 18 |
| | Barnaby Ridge | July 12, Aug. 18 |
| | Sunshine | July 16, Aug. 20 |
| | Caw Creek | Aug. 20 |
| Festuca saximontana | Grassy Mtn. | July 6 |
| | Sunshine | July 6 |
| | Mt. Rae | July 9, 13, 19 |
| | Barnaby Ridge | July 19 |
| | Pyramid Lake | July 19 |
| | Coal Valley | July 20 |
| Poa alpina | Grassy Mtn. | July 7, Aug. 19 |
| | Mtn. Park | July 7, Aug. 6, 20 |
| | Coal Valley | July 7, Aug. 6 |
| | Caw Creek | July 8, Aug. 6 |
| | Snow Creek | July 8, Aug. 6 |
| | Sunshine | July 8, 19, Aug. 6, 18 |
| | Pyramid Lake | July 9, 19, Aug. 18 |
| | Ribbon Creek | July 9, 19 |
| | Barnaby Ridge | July 9, 19, Aug. 18 |
| | Forget-Me-Not Mtn. | July 9, 13 |
| | Highwood House | July 9 |
| | Clearwater | July 19 |
| Festuca scabrella | Beauvais | July 9 |
| | Waterton | July 9 |
| | Stavely sub-stn. | July 9 |
| | Clearwater | July 9 |
| | Ya Ha Tinda | July 9 |
| | Cat Creek | July 9 |
| | Porcupine Hills | July 9 |
| | Whaleback Ridge | July 9 |
| | Snow Creek | July 9 |
| | Caw Creek Ridge | July 9 |
| Poa cusickii | Highwood House | July 12 |
| | Forget-Me-Not Mtn. | July 13 |
| Poa interior | Whistlers Mtn. | June 27, Aug. 8 |

Table 2.4 Harvest dates in 1976 at Ellerslie.

| Genus and Species | Source | Dates Harvested |
|---|---|---|
| *Koeleria cristata* | Cat Creek | July 12,19,27, Aug. 18 |
| | Sheep River | July 12,27, Aug 18 |
| | Athabasca Ranch | July 12,19,27 |
| | Waterton | July 19 |
| | Ya Ha Tinda | July 19,27 |
| | Yarrow Creek | July 19 |
| | Beauvais Lake | July 19 |
| | Pincher Ridge | July 19 |
| | Drywood Creek | July 19 |
| | Mt. Stearn | July 19,27 |
| | Snow Creek | July 19,27 |
| | Ram Mtn. | July 19 |
| | Devona Lookout | Aug. 20 |
| *Agropyron latiglume* | Mtn. Park | July 13,19,22, Aug 6,20 |
| | Caw Creek | July 16, Aug. 6,19 |
| *Festuca idahoensis* | Waterton | July 13,15,19 |
| | Windsor Ridge | July 14,15,19 |
| | Stavely sub-stn. | July 15,19 |
| | Porcupine Hills | July 15 |
| *Agrostis scabra* | Grassy Mtn. | July 15, Aug. 20 |
| *Agropyron trachycaulum* | Grassy Mtn. | July 15,20, Aug. 6,19 |
| | Barnaby Ridge | July 15,20,22,Aug. 19 |
| | Mtn. Park | July 16,20, Aug. 6,19 |
| | Mt. Stearn | July 20,28, Aug. 5,19 |
| | Kootenay Plains | July 28, Aug. 5,19 |
| | Clearwater | July 28 |
| | Greenock Mtn. | July 28, Aug. 5 |
| | Athabasca Ranch | Aug. 19 |
| | Waterton | Aug. 5,19 |
| | Porcupine Hills | Aug. 5,19 |
| *Agropyron subsecundum* | Kootenay Plains | July 28, Aug. 5,19 |
| | Clearwater | July 28, Aug. 5,19 |
| | Rock Lake | July 28, Aug. 5,19 |
| | Ram River Falls | July 28, Aug. 5,19 |
| | Greenock Mtn. | Aug. 5,19 |
| | Athabasca Ranch | Aug. 5,19 |
| | Cat Creek | Aug. 5,19 |
| | Smoky River | Aug. 5,19 |

Table 2.4 Harvest dates in 1976 at Ellerslie.

| Genus and Species | Source | Dates Harvested |
|---|---|---|
| *Helictotrichon hookeri* | Sheep River | July 15 |
| | Waterton | July 15 |
| | Porcupine Hills | July 15 |
| *Stipa richardsonii* | Pyramid Lake | July 16, Aug. 6 |
| | Cat Creek | July 16, Aug. 5 |
| | Porcupine Hills | July 16 |
| | Grassy Mtn. | July 16, Aug. 6 |
| *Stipa comata* | Kootenay Plains | July 16,20,28, Aug. 5 |
| | Greenock Mtn. | July 20,28, Aug. 5 |
| *Stipa spartea* | Greenock Mtn. | July 20, Aug. 5 |
| | Porcupine Hills | July 23 |
| *Stipa columbiana* | Barnaby Ridge | July 16,21,28 |
| | Cat Creek | July 21,28 |
| | Rock Lake | July 21,28 |
| | Greenock Mtn. | July 21,28 |
| | Pigeon Mtn. | July 20,28, Aug. 7, 18, 31 |
| *Calamagrostis purpurescens* | Athabasca Ranch | July 16, Aug. 5 |
| | Plateau Mtn. | July 16 |
| | Clearwater | July 16, Aug. 6 |
| | Kootenay Plains | July 16 |
| | Brule Lake | July 16 |
| | Mtn. Park Pass | July 20, Aug. 20 |
| *Danthonia intermedia* | Smoky River | July 19 |
| *Danthonia parryii* | Porcupine Hills | July 19 |
| *Agropyron albicans* | Kootenay Plains | July 21,23,27, Aug. 3 |
| | Smoky River | July 26, Aug. 20 |
| | Brule Lake | Aug. 3, 18 |
| | Greenock Mtn. | Aug. 3, 18 |

Table 2.4 Harvest dates in 1976 at Ellerslie.

| Genus and Species | Source | Dates Harvested |
|---|---|---|
| Agropyron spicatum | Yarrow Creek | July 21, Aug. 3 |
| | Cat Creek | July 21,23, Aug. 3,18 |
| | Windsor Ridge | July 23, Aug. 3 |
| | Waterton | Aug. 3 |
| Agropyron dasystachyum | Ya Ha Tinda | July 23, 26, Aug. 5 |
| | Smoky River | July 26, Aug. 5,20 |
| | Mt. Stearn | July 26, Aug. 3 |
| | Cat Creek | July 26 |
| | Porcupine Hills | July 27, Aug. 5 |
| | Sheep River | July 27, Aug. 5 |
| | Kootenay Plains | Aug. 3 |
| | Waterton | Aug. 4 |
| | Athabasca Ranch | Aug. 5 |
| | Disaster Point | Aug. 5 |
| | Devona Lookout | Aug. 5 |
| Agropyron riparium | Smoky River | Aug. 20 |
| | Kootenay Plains | Aug. 3 |
| | Cat Creek | Aug. 3 |
| Bromus pumpellianus | Disaster Point | July 28 |
| | Athabasca Ranch | July 28 |
| | Rock Lake | July 28 |
| | Kootenay Plains | July 28 |
| | Cat Creek | July 28 |
| | Fortress Mtn. | July 28 |
| Elymus innovatus | Ribbon Creek | Aug. 5 |
| | Ya Ha Tinda | Aug. 5 |
| | Ram Mtn. | Aug. 5 |
| | Coal Valley | Aug. 5 |

## MOUNTAIN TRANSPLANT STUDIES

Percent mean survival and percent of survivors flowering were compared to determine what, if any, changes were taking place with time in the past 3 years of observations. The results are shown in Table 2.5.

Table 2.5 Results of mountain transplant studies according to year of transplanting and year data taken.

| | Year Established | | | |
|---|---|---|---|---|
| Year Data Taken | 1975 % Survs | 1975 % Flwrs | 1976 % Survs | 1976 % Flwrs |
| 1976 | 87±19 | 56±39 | | |
| 1977 | 81±18 | 67±31 | 88±18 | 31±39 |
| 1978 | 79±29 | 73±40 | 80±25 | 49±41 |
| No. of Plants | 528 | | 1,920 | |
| No. of Sites | 4 | | 12 | |

The trend of the results suggests that survival is decreasing slightly with time. Most of the decrease can be attributed to external disturbance unrelated to climatic adaptation to the environment. For example, all of the plants of <u>Poa interior</u> were selectively grazed and destroyed by elk at the Johnston Creek site. Death and decrease in flowers by grazing was also evident at the Highwood Pass and Kootenay Plains sites. The percent of plants which are flowering shows a definite upward trend as plants become older and better established.

The soil environment may play a role in the survival and ability to flower of the species. The results of soil analyses at some of the test sites are given in Table 2.6.

Table 2.6 Soil analyses for mountain test sites. Numbers refer to available major plant nutrients nitrogen (N), phosphorus (P), and potassium (K) expressed in kg/ha in the top 15-24 cm of soil. Relative acidity of the soil is expressed as pH.

| Test Site | N | P | K | pH |
|---|---|---|---|---|
| Grassy Mountain | 2 | 24 | 105 | 5.8 |
| Snow Creek Pass | 3 | 31 | 266 | 7.6 |
| Bighorn Dam | 4 | 1 | 83 | 8.4 |
| Cuthead Creek | 4 | 11 | 147 | 8.2 |
| Mountain Park | 1 | 2 | 85 | 7.5 |
| Key | low 0-20 | low 0-30 | low 0-150 | normal 6-7.5 |

The results of soil analyses at some of the sites reveal that low nutrients levels are common, although the pH varies from acidic (pH=5.8) to alkaline (pH=8.4). Close examination of the rates of survival and ability to flower of the various species indicates a tolerance for low nutient levels and for a wide range of soil acidity levels. Data on the percentage of plants surviving and the percentage of survivors that flowered after transplanting to mountain test sites are contained in Tables 2.7 to 2.19. Each species was returned to a suitable test site of approximately the same elevation and latitude as its collection source in addition to a a wide range of other elevations and latitudes. Generally high survival rates for all species and the ability of some species to flower at many sites appear to indicate that the most important factors regulating survival and ability tc flower are probably (1) the species and (2) the weather conditions. Tolerance to low temperatures and drought hardiness are suggested as possible traits possessed by those species which are able to survive and flower at the many test sites.

Table 2.7 Percent surviving and percent survivors flowering after transplanting to mountain test sites of 1975 transplants of *Agropyron dasystachyum* from Grotto Mtn. (el. 1524 m, lat. 51° 3'N) and 1976 transplants from an open-pollinated multi-latitudinal mix as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site el. 1341 m, lat. 52° 0'N | 32 | 97 | 3 | 75&76 |
| Caw Creek Ridge el. 1981 m, lat. 54° 4'N | 32 | 75 | 0 | 75&76 |
| Mt. Stearn Sheep Range el. 1128 m, lat. 53°49'N | 16 | 81 | 23 | 76 |
| Cuthead Creek Roadbed el. 1853 m, lat. 51°20'N | 16 | 19 | 33 | 76 |
| Grassy Mtn. Coal Mine el. 1829 m, lat. 49°42'N | 16 | 81 | 0 | 76 |
| Highwood Pass Roadbed el. 2206 m, lat. 50°23'N | 16 | 75 | 33 | 75 |
| Johnston Creek Corral el. 1969 m, lat. 51°15'N | 16 | 62 | 0 | 76 |
| Maligne Canyon Roadbed el. 1981 m, lat. 52°50'N | 16 | 94 | 0 | 76 |
| Marmot Basin Ski Area el. 2237 m, lat. 52°47'N | 16 | 88 | 0 | 76 |
| Mountain Park Coal Mine el. 1798 m, lat. 52°56'N | 16 | 100 | 0 | 76 |
| Racehorse Creek Coal el. 1981 m, lat. 49°4[illegible]'N | 32 | 69 | 73 | 75&76 |
| Snow Creek Pass Coal el. 2200 m, lat. 51°38'N | 16 | 88 | 0 | 76 |
| Tent Mtn. Coal Mine el. 2073 m, lat. 49°34'N | 16 | 94 | 0 | 76 |
| Totals of 13 Sites | 256 | 76 | 11 | |

Table 2.8 Percent surviving and percent survivors flowering after transplanting to mountain test sites for 1975 transplants of *Poa alpina* from Mt. Rae (el. 2286 m, lat. 50°37'N) and for 1976 transplants from Whitehorn Mtn. (el. 1829 m, lat. 51°27'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site<br>el. 1341 m, lat. 52° 0'N | 32 | 100 | 85 | 75&76 |
| Caw Creek Ridge<br>el. 1981 m, lat. 54° 4'N | 32 | 97 | 93 | 75&76 |
| Cuthead Creek Roadbed<br>el. 1853 m, lat. 51°20'N | 16 | 100 | 100 | 76 |
| Grassy Mtn. Coal Mine<br>el. 1829 m, lat. 49°42'N | 16 | 81 | 15 | 76 |
| Highwood Pass Roadbed<br>el. 2206 m, lat. 50°23'N | 16 | 100 | 100 | 75 |
| Johnston Creek Corral<br>el. 1969 m, lat. 51°15'N | 16 | 100 | 100 | 76 |
| Marmot Basin Ski Area<br>el. 2237 m, lat. 52°47'N | 16 | 100 | 88 | 76 |
| Mountain Park Coal Mine<br>el. 1798 m, lat. 52°56'N | 16 | 94 | 100 | 76 |
| Racehorse Creek Coal<br>el. 1981 m, lat. 49°48'N | 16 | 100 | 100 | 76 |
| Snow Creek Pass Coal<br>el. 2200 m, lat. 51°38'N | 16 | 69 | 64 | 76 |
| Tent Mtn. Coal Mine<br>el. 2073 m, lat. 49°34'N | 16 | 100 | 94 | 76 |
| Totals of 11 Sites | 208 | 96 | 86 | |

Table 2.9 Percent surviving and percent survivors flowering after transplanting to mountain test sites for 1975 transplants of *Trisetum spicatum* from Mt. Rae (el. 2286 m, lat. 50°37'N) and 1976 transplants from Mtn. Park Pass (el. 1981 m, lat. 52°53'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site<br>el. 1341 m, lat. 52° 0'N | 32 | 91 | 90 | 75&76 |
| Caw Creek Ridge<br>el. 1981 m, lat. 54° 4'N | 32 | 84 | 68 | 75&76 |
| Mt. Stearn Sheep Range<br>el. 1128 m, lat. 53°49'N | 16 | 100 | 19 | 76 |
| Cuthead Creek Roadbed<br>el. 1853 m, lat. 51°20'N | 16 | 19 | 100 | 76 |
| Grassy Mtn. Coal Mine<br>el. 1829 m, lat. 49°42'N | 16 | 87 | 78 | 76 |
| Highwood Pass Roadbed<br>el. 2206 m, lat. 50°23'N | 16 | 100 | 87 | 75 |
| Johnston Creek Corral<br>el. 1969 m, lat. 51°15'N | 16 | 75 | 0 | 76 |
| Maligne Canycn Roadbed<br>el. 1981 m, lat. 52°50'N | 16 | 100 | 100 | 76 |
| Marmot Basin Ski Area<br>el. 2237 m, lat. 52°47'N | 16 | 50 | 25 | 76 |
| Mountain Park Coal Mine<br>el. 1798 m, lat. 52°56'N | 16 | 56 | 100 | 76 |
| Racehorse Creek Coal<br>el. 1981 m, lat. 49°48'N | 16 | 69 | 100 | 76 |
| Snow Creek Pass Coal<br>el. 2200 m, lat. 51°38'N | 16 | 44 | 0 | 76 |
| Tent Mtn. Coal Mine<br>el. 2073 m, lat. 49°34'N | 16 | 88 | 71 | 76 |
| Totals of 13 Sites | 240 | 74 | 68 | |

Table 2.10 Percent surviving and percent survivors flowering after transplanting to mountain test sites for Festuca saximontana from Caw Creek Ridge (el. 1981 m, lat. 54°4'N) and 1975 transplants from Mt. Rae (el. 2286 m, lat. 50°37'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site el. 1341 m, lat. 52° 0'N | 32 | 70 | 73 | 75&76 |
| Caw Creek Ridge el. 1981 m, lat. 54° 4'N | 32 | 94 | 100 | 75&76 |
| Grassy Mtn. Coal Mine el. 1829 m, lat. 49°42'N | 16 | 44 | 14 | 76 |
| Highwood Pass Roadbed el. 2206 m, lat. 50°23'N | 16 | 25 | 0 | 75 |
| Johnston Creek Corral el. 1969 m, lat. 51°15'N | 16 | 94 | 14 | 76 |
| Marmot Basin Ski Area el. 2237 m, lat. 52°47'N | 16 | 100 | 100 | 76 |
| Mountain Park Coal Mine el. 1798 m, lat. 52°56'N | 16 | 88 | 100 | 76 |
| Racehorse Creek Coal el. 1981 m, lat. 49°48'N | 16 | 44 | 43 | 76 |
| Snow Creek Pass Coal el. 2200 m, lat. 51°38'N | 16 | 69 | 100 | 76 |
| Tent Mtn. Coal Mine el. 2073 m, lat. 49°34'N | 16 | 13 | 100 | 76 |
| Totals of 10 Sites | 192 | 70 | 73 | |

Table 2.11 Percent surviving and percent survivors flowering after transplanting to mountain test sites for *Koeleria cristata* from an open-pollinated mix as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site el. 1341 m, lat. 52° 0'N | 16 | 100 | 56 | 76 |
| Caw Creek Ridge el. 1981 m, lat. 54° 4'N | 16 | 100 | 81 | 76 |
| Mt. Stearn Sheep Range el. 1128 m, lat. 53°49'N | 16 | 100 | 31 | 76 |
| Cuthead Creek Roadbed el. 1853 m, lat. 51°20'N | 16 | 31 | 80 | 76 |
| Grassy Mtn. Coal Mine el. 1829 m, lat. 49°42'N | 16 | 100 | 6 | 76 |
| Johnston Creek Corral el. 1969 m, lat. 51°15'N | 16 | 44 | 0 | 76 |
| Maligne Canyon Roadbed el. 1981 m, lat. 52°50'N | 16 | 100 | 25 | 76 |
| Marmot Basin Ski Area el. 2237 m, lat. 52°47'N | 16 | 100 | 0 | 76 |
| Mountain Park Coal Mine el. 1798 m, lat. 52°56'N | 16 | 100 | 19 | 76 |
| Racehorse Creek Coal el. 1981 m, lat. 49°48'N | 16 | 75 | 83 | 76 |
| Snow Creek Pass Coal el. 2200 m, lat. 51°38'N | 16 | 88 | 0 | 76 |
| Tent Mtn. Coal Mine el. 2073 m, lat. 49°34'N | 16 | 100 | 38 | 76 |
| Totals of 12 Sites | 192 | 86 | 38 | |

Table 2.12 Percent surviving and percent survivors flowering after transplanting to mountain test sites for Bromus pumpellianus from an open-pollinated mix as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site el. 1341 m, lat. 52° 0'N | 16 | 94 | 7 | 76 |
| Caw Creek Ridge el. 1981 m, lat. 54° 4'N | 16 | 100 | 0 | 76 |
| Mt. Stearn Sheep Range el. 1128 m, lat. 53°49'N | 16 | 88 | 0 | 76 |
| Cuthead Creek Roadbed el. 1853 m, lat. 51°20'N | 16 | 44 | 0 | 76 |
| Grassy Mtn. Coal Mine el. 1829 m, lat. 49°42'N | 16 | 75 | 0 | 76 |
| Johnston Creek Corral el. 1969 m, lat. 51°15'N | 16 | 81 | 0 | 76 |
| Maligne Canycn Roadbed el. 1981 m, lat. 52°50'N | 16 | 100 | 0 | 76 |
| Marmot Basin Ski Area el. 2237 m, lat. 52°47'N | 16 | 94 | 0 | 76 |
| Mountain Park Coal Mine el. 1798 m, lat. 52°56'N | 16 | 100 | 0 | 76 |
| Racehorse Creek Coal el. 1981 m, lat. 49°48'N | 16 | 81 | 7 | 76 |
| Snow Creek Pass Coal el. 2200 m, lat. 51°38'N | 16 | 81 | 0 | 76 |
| Tent Mtn. Coal Mine el. 2073 m, lat. 49°34'N | 16 | 100 | 0 | 76 |
| Totals of 12 Sites | 192 | 85 | 10 | |

Table 2.13 Percent surviving and percent survivors flowering after transplanting to mountain test sites for *Poa interior* from Whistlers Mtn. (el. 2347 m, lat. 52°50'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site el. 1341 m, lat. 52° 0'N | 16 | 100 | 100 | 76 |
| Caw Creek Ridge el. 1981 m, lat. 54° 4'N | 16 | 100 | 100 | 76 |
| Mt. Stearn Sheep Range el. 1128 m, lat. 53°49'N | 16 | 88 | 93 | 76 |
| Cuthead Creek Roadbed el. 1853 m, lat. 51°20'N | 16 | 44 | 29 | 76 |
| Grassy Mtn. Coal Mine el. 1829 m, lat. 49°42'N | 16 | 37 | 88 | 76 |
| Johnston Creek Corral el. 1969 m, lat. 51°15'N | 16 | 0 | 0 | 76 |
| Maligne Canyon Roadbed el. 1981 m, lat. 52°50'N | 16 | 100 | 100 | 76 |
| Marmot Basin Ski Area el. 2237 m, lat. 52°47'N | 16 | 100 | 100 | 76 |
| Mountain Park Coal Mine el. 1798 m, lat. 52°56'N | 16 | 100 | 94 | 76 |
| Racehorse Creek Coal el. 1981 m, lat. 49°48'N | 16 | 63 | 80 | 76 |
| Snow Creek Pass Coal el. 2200 m, lat. 51°38'N | 16 | 100 | 69 | 76 |
| Tent Mtn. Coal Mine el. 2073 m, lat. 49°34'N | 16 | 88 | 100 | 76 |
| Totals of 12 Sites | 192 | 81 | 87 | |

Table 2.14 Percent surviving and percent survivors flowering after transplanting to mountain test sites for <u>Phleum alpinum</u> from Peyto Lake (el. 2286 m, lat. 51°42'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site<br>el. 1341 m, lat. 52° 0'N | 16 | 94 | 80 | 76 |
| Caw Creek Ridge<br>el. 1981 m, lat. 54° 4'N | 16 | 94 | 87 | 76 |
| Mt. Stearn Sheep Range<br>el. 1128 m, lat. 53°49'N | 16 | 94 | 100 | 76 |
| Cuthead Creek Roadbed<br>el. 1853 m, lat. 51°20'N | 16 | 94 | 100 | 76 |
| Grassy Mtn. Coal Mine<br>el. 1829 m, lat. 49°42'N | 16 | 38 | 17 | 76 |
| Johnston Creek Corral<br>el. 1969 m, lat. 51°15'N | 16 | 19 | 0 | 76 |
| Maligne Canyon Roadbed<br>el. 1981 m, lat. 52°50'N | 16 | 100 | 94 | 76 |
| Marmot Basin Ski Area<br>el. 2237 m, lat. 52°47'N | 16 | 100 | 44 | 76 |
| Mountain Park Coal Mine<br>el. 1798 m, lat. 52°56'N | 16 | 100 | 31 | 76 |
| Racehorse Creek Coal<br>el. 1981 m, lat. 49°48'N | 16 | 63 | 100 | 76 |
| Snow Creek Pass Coal<br>el. 2200 m, lat. 51°38'N | 16 | 75 | 0 | 76 |
| Tent Mtn. Coal Mine<br>el. 2073 m, lat. 49°34'N | 16 | 88 | 21 | 76 |
| Totals of 12 Sites | 192 | 76 | 56 | |

Table 2.15 Percent surviving and percent survivors flowering after transplanting to mountain test sites for *Agropyron subsecundum* from Kootenay Plains (el. 1385 m, lat. 52°0'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site el. 1341 m, lat. 52° 0'N | 16 | 81 | 36 | 76 |
| Caw Creek Ridge el. 1981 m, lat. 54° 4'N | 16 | 62 | 30 | 76 |
| Mt. Stearn Sheep Range el. 1128 m, lat. 53°49'N | 16 | 94 | 73 | 76 |
| Cuthead Creek Roadbed el. 1853 m, lat. 51°20'N | 16 | 75 | 17 | 76 |
| Grassy Mtn. Coal Mine el. 1829 m, lat. 49°42'N | 16 | 88 | 29 | 76 |
| Johnston Creek Corral el. 1969 m, lat. 51°15'N | 16 | 50 | 0 | 76 |
| Maligne Canycn Roadbed el. 1981 m, lat. 52°50'N | 16 | 100 | 12 | 76 |
| Marmot Basin Ski Area el. 2237 m, lat. 52°47'N | 16 | 94 | 7 | 76 |
| Mountain Park Coal Mine el. 1798 m, lat. 52°56'N | 16 | 88 | 21 | 76 |
| Racehorse Creek Coal el. 1981 m, lat. 49°48'N | 16 | 75 | 100 | 76 |
| Snow Creek Pass Coal el. 2200 m, lat. 51°38'N | 16 | 88 | 0 | 76 |
| Tent Mtn. Coal Mine el. 2073 m, lat. 49°34'N | 16 | 94 | 27 | 76 |
| Totals of 12 Sites | 192 | 81 | 33 | |

Table 2.16 Percent surviving and percent survivors flowering after transplanting to mountain test sites for *Agropyron latiglume* from Peyto Lake (el. 2286 m, lat. 51°42'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Caw Creek Ridge el. 1981 m, lat. 54° 4'N | 16 | 100 | 100 | 76 |
| Cuthead Creek Roadbed el. 1853 m, lat. 51°20'N | 16 | 94 | 73 | 76 |
| Grassy Mtn. Coal Mine el. 1829 m, lat. 49°42'N | 16 | 88 | 36 | 76 |
| Johnston Creek Corral el. 1969 m, lat. 51°15'N | 16 | 88 | 88 | 76 |
| Marmot Basin Ski Area el. 2237 m, lat. 52°47'N | 16 | 100 | 6 | 76 |
| Mountain Park Coal Mine el. 1798 m, lat. 52°56'N | 16 | 100 | 56 | 76 |
| Snow Creek Pass Coal el. 2200 m, lat. 51°38'N | 16 | 88 | 0 | 76 |
| Tent Mtn. Coal Mine el. 2073 m, lat. 49°34'N | 16 | 94 | 33 | 76 |
| Totals of 8 Sites | 128 | 83 | 49 | |

Table 2.17 Percent surviving and percent survivors flowering after transplanting to mountain test sites for *Deschampsia caespitosa* from Whitehorn Mtn. (el. 1829 m, lat. 51°27'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Highwood Pass Roadbed el. 2206 m, lat. 50°23'N | 16 | 88 | 100 | 75 |
| Caw Creek Ridge el. 1981 m, lat. 54° 4'N | 16 | 94 | 88 | 75 |
| Totals of 2 Sites | 32 | 91 | 93 | |

Table 2.18 Percent surviving and percent survivors flowering after transplanting to mountain test sites for *Stipa columbiana* from Pigeon Mtn. (el. 1829 m, lat. 51°1'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Bighorn Dam Site el. 1341 m, lat. 52° 0'N | 32 | 69 | 68 | 75&76 |
| Caw Creek Ridge el. 1981 m, lat. 54° 4'N | 16 | 0 | 0 | 76 |
| Mt. Stearn Sheep Range el. 1128 m, lat. 53°49'N | 16 | 69 | 73 | 76 |
| Cuthead Creek Roadbed el. 1853 m, lat. 51°20'N | 16 | 94 | 7 | 76 |
| Highwood Pass Roadbed el. 2206 m, lat. 50°23'N | 16 | 69 | 82 | 75 |
| Maligne Canycn Roadbed el. 1981 m, lat. 52°50'N | 16 | 94 | 27 | 76 |
| Totals of 6 Sites | 112 | 66 | 54 | |

Table 2.19 Percent surviving and percent survivors flowering after transplanting to mountain test sites for *Agropyron trachycaulum* from Banff Flats (el. 1385 m, lat. 51°12'N) as of August 1978.

| Site | Plants | % Survs | % Flwrs | Year Est. |
|---|---|---|---|---|
| Mt. Stearn Sheep Range el. 1128 m, lat. 53°49'N | 16 | 100 | 100 | 76 |
| Maligne Canycn Roadbed el. 1981 m, lat. 52°50'N | 16 | 100 | 25 | 76 |
| Racehorse Creek Coal el. 1981 m, lat. 49°48'N | 16 | 94 | 100 | 76 |
| Totals of 3 Sites | 48 | 98 | 75 | |

## D. DISCUSSION

### GROWTH CHAMBER STUDIES

The results obtained in this study suggest that populations of native grass species collected from different geographical regions of Alberta's Rocky Mountains are similar with regard to their requirements for flowering. Most grass species used in the study flowered after only four weeks of treatment at 4°C in total darkness. This is in marked contrast with many cool season grass species in North America which have been investigated (Olmsted 1944, Pringle et al. 1975, Klebasadel 1971, Hodgson 1966, Cooper and Calder 1964, Canode et al. 1977, Rotsettis 1972, Dorvrat 1966). These researchers found that most grasses required a decreasing photoperiod during the late growing season to induce flowering the following season. Moreover, the number of hours in the photoperiod and the rate of change as the days shorten is often important, although these specific conditions vary between species and genotypes depending on the latitude.

The results obtained from growth chamber experiments, which drastically altered the photoperiod normally experienced by Alberta grass species, adds further evidence that some of the species lack the light requirement for flowering and rely solely on a period of cold for induction. Such a wide tolerance for latitudinal change was not evident from the response of the genotypes from Montana and Arctic sources.

It is possible to speculate on the reason why the grass genotypes from the mountain areas have a different response. None of the researchers studying photoperiod response used species or genotypes from alpine sources. Also, the intermediate location of Alberta between latitude 65° and 45° in a location with short growing seasons and extremes in climatic conditions may be significant. It is probable that alpine environments have such short growing seasons and widely variable growing conditions (shading from mountains, late and early blizzards, snowhollows, etc.) that a photoperiodic response for flowering is a luxury enjoyed only by plants occupying climatically more predictable environments.

Most of the Alberta Rocky Mountain native grass species flowered readily under a wide range of photoperiods. From a practical point of view, this is a most useful finding. It means that these species may be utilized over a wide range of latitudes, as are most commercial agronomic and horticultural grass varieties. The large scale seed production of a widely adapted variety would make the marketing of reclamation varieties derived from native grasses economically feasible.

## FARM TRANSPLANT STUDIES

Plants transplanted from many different latitudes in Alberta to a single location at Edmonton displayed a range of growth patterns. Some species, irrespective of the source latitude, ripened seed on the same day while other species possessed more irregular growth patterns. In most cases it appeared that the origin of the material had no apparent influence on the length of growing season. Differences in daylength exist between the northern and southern ends of the study area which could influence the spring initiation of flowering (see Table 2.20).

Table 2.20 Hours of daylight at two locations in Alberta.*

| Date | Porcupine Hills latitude 50°N | Grande Prairie latitude 55°N |
|---|---|---|
| May 1 | 14.6 | 14.1 |
| May 15 | 15.4 | 16.1 |
| June 1 | 15.9 | 16.7 |
| June 15 | 16.4 | 17.4 |
| July 1 | 16.1 | 17.1 |
| July 15 | 16.0 | 17.0 |
| August 1 | 15.2 | 16.0 |

Although photoperiods differ at the different sources of material, it appears from the data on harvest dates that all genotypes, regardless of source, begin growth and flower initiation at the same time and that variation in the growing season is due to genetic variability in rate of flower production rather than a photoperiod regulated flower

*from Thomas (1953)

initiation. This information adds further support to the results of growth chamber studies which concluded that Alberta genotyes from the mountains possess a neutral photoperiod response for flower induction in the fall.

One of the species, Poa interior, has displayed a most unusual reproductive pattern in that, two complete seed crops are produced in a single season under field conditions. The first crop ripens about the end of June (see Table 2.4) and a second crop about six weeks later. This pattern of seed production was repeated during each of the test years 1976, 1977, and 1978. Under growth chamber conditions, potted plants of this species continued to produce seed without interruption in intervals of two to three months. The light regime was 16 hours of light per day and a cold or short day period was not included. This result suggests that Poa interior does not require an external stimulus to induce, initiate and develop flowers.

Inter-plant variations pose a particularly difficult harvest problem in that some species exhibit a broad ripening period. Phleum alpinum and Stipa columbiana are two such species in which tillers are produced sequentially during flowering. This period may extend, for example for Stipa columbiana during a mild fall, from late July until late September. Little genetic variation of this trait was visually apparent among the accessions of this species and the possibility of improving this undesirable habit through selection seems remote.

Most other species showed varying degrees of inter-plant variation with regard to shattering date which differs greatly from plant to plant and presents an opportunity for improvement of the agronomic quality of the species. Plants which exhibit a "tight" harvest period could be grouped with other members of their species which have a similar growing season. Thus the loss due to shattering is minimized and seed quality not reduced by the presence of unripe seed.

## MOUNTAIN TRANSPLANT STUDIES

The survival rate of established native grass plants transplanted to different localities in the mountains was high. At the end of the 1978 growing season 80% were alive and 51% had flowered. The analysis of variance of survival of species is as follows.

Table 2.21 Analysis of variance of % mean survival of mountain transplants.

| Source | S.S. | M.S. | D.F. | F |
|---|---|---|---|---|
| Between species | 9159.5 | 763.3 | 12 | 1.331 |
| Within species | 5962.5 | 573.2 | 104 | |

The F value is not significant (P=.21) and differences between the ability of the various species to survive a wide variety of environments when transplanted are minimal. This suggests that seedling establishment is the most important problem in the successful utilization of native species. Most sites selected were either devoid of or sparsely populated with native pioneer plants and the ease with which the transplanted grasses survived suggests that the lack of pioneer vegetation could be due to early seedling mortality. Another reason for lack of vegetation on the disturbed sites is lack of a seed sources. Observations of these plots in subsequent years should give a better indication of how long native species can survive in disturbed soils.

Differences in the ability of the species to flower in different localities are apparent. The analysis of variance is as follows.

Table 2.22 Analysis of variance of percent mean flowering cf mountain transplants.

| Source | S.S. | M.S. | D.F. | F |
|---|---|---|---|---|
| Between Species | 85535 | 7127 | 12 | 6.478 |
| Within Species | 112229 | 1100 | 102 | *** |

Some species were more successful ($P<0.001$) in flowering than others. In general, the alpine species, whether they were collected from an alpine locality or not, were the most succesful species to flower. These results may be significant in defining an area of adaptation of native species in the Rocky Mountain region of Alberta. In this regard, alpine grasses appear to be excellent pioneer species for all elevations of the Rocky Mountain region.

In the 1920's Gote Turesson of Sweden began some studies, now considered to be classic experiments, using the technique of transplanting plant material to uniform environments. He found that local populations were adapted to a specific type of environment and possessed similar adaptive characteristics. Turesson used the term ecotype to describe such locally and similarly adapted populations. While each local population within an ecotype varies somewhat within and between local populations, they have greater similarities to each other than they do to populations from other ecotypes of the same species.

Although longer term results are necessary to make definite conclusions, there does appear to be a trend suggesting that plants from different locales can be moved successfully within the mountain regions of Alberta. If this trend continues in subsequent years of plot observation it would then appear that almost every one of the grass species found in different locales of Alberta's Rocky Mountain region belong to a single ecotype, widely adaptable to many different habitats. The lack of a photoperiod flowering response would further substantiate this conclusion.

E. CONCLUSIONS

Growth chamber studies have demonstrated that native Alberta grasses from the Rocky Mountains appear to have a neutral photoperiod response for flower induction. This was confirmed by the ability of most species to flower under light regimes characteristic of localities far removed from their source of collection. Harvest date studies have shown that a great deal of genetic variability exists in natural populations with regard to the number of days to ripen seeds. However, it does not appear to be influenced by the latitude of the source. This variability does pose a problem to economical seed production because a single ripening day does not arise when the majority of the population can be harvested. However, this problem can probably be solved by a plant selection program which groups plants with similar growing seasons.

Mountain transplant studies have demonstrated that most of the mountain genotypes of Alberta grasses collected in this study can be successfully moved substantial distances from their site of origin without loss in viability or flowering ability. However, since a rigorous selection procedure was employed to chose unusually robust and reproductively superior specimens, these conclusions may not apply to the population as a whole.

From a practical stand point, these conclusions seem to suggest that a single variety of each grass species suitable for reclamation could be developed for use in a wide range of mountaincus environments. However, to ensure a wide range of adaptability and to avoid the dangers of a monoculture, a multiline variety of each species composed of improved genotypes from several locales is desirable.

The following species were found to be superior in their ability to survive and flower in a wide variety of environments in the Rocky Mountain region of Alberta:

1) *Poa alpina*
2) *Poa interior*
3) *Festuca saximontana*
4) *Trisetum spicatum*
5) *Agropyron latiglume*

Also excellent for elevations below treeline were:

6) *Agropyron dasystachyum*
7) *Agropyron trachycaulum*
8) *Agropyron subsecundum*
9) *Koeleria cristata*

III. GENETIC VARIABILITY

UNIT THREE

of

THE GENETIC POTENTIAL OF

NATIVE ALBERTA GRASSES

OF THE ROCKY MOUNTAINS

A. INTRODUCTION

The principles of genetics and modern breeding methods apply equally to the improvement of grasses for reclamation as they do to other crops. However, the evaluation procedures for reclamation grasses may be much more complex because of interactions between plant and environment as well as between plant and grazing animals. In addition, characteristics desirable for efficient agricultural seed production may be at odds with those for reclamation. For example, low shattering of inflorescences at harvest time is important in maximizing yield but could render the variety less able to reseed itself in a reclamation situation. Even ripening of seed within the variety is also an efficient agricultural characteristic but would undoubtedly be a disadvantageous feature of a wild population. A highly competitive strain is advantageous in agriculture where weeds are a constant problem. However, reclamation in harsh climates usually requires great effort to achieve any sort of ground cover and the ultimate objective of returning the disturbance to natural vegetation may be hampered by a highly competitive reclamation cover which does not yield to invading native species. Longevity, tolerance to low soil fertility and short growing season are not characteristics of prime importance for agricultural forage grasses but are in demand in reclamation.

In order to develop varieties for whatever purpose, a plant breeder must have, in the gene pool with which he is working, an adequate amount of genetic variability. Although variability has been extensively studied in annual crops such as cereal grains, the domestication and breeding of perennial grasses is, by comparison, a more recent event. Breeding of grasses began around the turn of the century and the number of generations or cycles of establishment are only 10 or 20 for the earliest varieties of Bromus inermis and Agropyron cristatum (Knowles 1969). Most grass breeding work is directed towards introduced species from other regions of the world.

There are only three varieties of grass licensed for commercial production in Canada that are native to North America. This is unfortunate since information is almost completely lacking on the genetic variability, breeding systems, evclutionary development, and population dynamics on native species which are virtually on our doorstep in vast areas of grasslands.

There are five varieties of the native species Phalaris arundinacea on the market. Most were derived from native collections, although the most recent release was produced at Beaverlodge, Alberta, from a four-clone synthetic comprised cf one from Saskatchewan, one from Minnesota and two from Russia (Ellott 1970). The other varieties were derived from very small seed lots or from single plants

(Hanson 1970).

A variety of *Agropyron riparium* called 'Sodar' is available in Canada and is significant to this study because of its close relationship to *Agropyron dasystachyum* (Dewey 1965). It was developed at the Plant Materials Center, Soil Conservation Service at Pullman Washington, and was derived from the best plant out of eleven collected from a single location (Hanson 1972).

Only one species in the present study has been previously examined in Canada and licensed for production. *Agropyron trachycaulum* var. Revenue was developed at Saskatoon for use on saline soils in the black and dark brown soil zones of western Canada (Crowle 1970). It resulted from the seed of a single plant, although a total of 750 plants were screened over a 10 year period.

As a result of the limited number of native species which have been examined by plant breeders in Canada, very little published information is available on the extent of genetic variability within wild populations of native grasses. An exception is a study by Johnston *et al.* (1974) who studied *Agropyron smithii* (not included in the present study). Four hundred and sixty-eight plants were transplanted to a nursery in Lethbridge and examined for a wide range of agronomically important characters. A significant amount of variability for characters such as seed yield, forage yield, colour, days to maturity, and fertile florets per head, was reported. Of note was the fact that approximately 10% of the plants collected were later discovered, on the basis of chromosome count differences and shorter growing season evidence, to be Agropyron dasystachyum. Apparently, genetic variation in morphology is present in Agropyron dasystachyum to the extent that even experienced researchers encounter taxonomic difficulties.

The study by Johnston and his co-workers demonstrated an adequate amount of genetic variability in agronomic characters to be present in Agropyron smithii to make genetic improvement feasible. The purpose of this section of the present study is to examine the collection of native grass species (transplanted from the various sources in the Rocky Mountains of Alberta) for genetic variability and to assess the possibilities for their genetic improvement.

## B. METHODS AND MATERIALS

### BREEDING SYSTEM

The breeding system of the various native grass species was determined in growth chamber studies by growing plants in pots and bagging emerging heads in glazine envelopes. Growth chamber facilities have been described in Unit II. Tillers were staked to prevent stems from breaking and the envelopes were tapped periodically to ensure pollination. Four pots of each species with 1 plant per pot were used and at least two heads on each plant were bagged. Species were scored as being obligate cross-pollinators when viable seeds could not be found in bagged heads but were present on unbagged heads. Those plants which produced only a few seeds in bagged heads but many seeds on unbagged heads were classified as facultative cross-pollinators. A few species produced equal quantities of seed on both bagged and unbagged heads and these were classified as self-pollinators.

SHATTERING DATE

In 1975, a single harvest day was selected when most of the plants of each species were shattering and the seed from individual plants was collected. It was apparent at the time that much seed was being lost because some plants had already shattered while others were still green. This substantially reduced the average yield of the species and gave an erroneous measure of the yield of some plants which were post or premature at the time of harvest.

To rectify this situation in 1976, the same plants were harvested as and when each plant or part of each plant was in the shattering stage. Thus the total seed yield was recovered. A comparison was then made of the seed yield of the same plants harvested in 1975 on a single harvest date with those harvested in 1976 on individual shattering dates to determine losses due to uneven ripening.

SEED YIELD

Data on the seed yield and number of tillers was collected from approximately 1,000 plants representing 10 species of native grasses transplanted from various sources in the mountains to the nursery at Ellerslie. Individual plants were harvested by hand as they ripened and were threshed by hand with rub bars and mats. Seed was cleaned with a New Brunswick Seed Blower and weight of seed was recorded in grams. Information on each plant has not been recorded here because of the large volume of data. Instead, seed yield and number of tillers has been reported as the mean obtained from each collection source and the variation found within each source described by the standard deviation of each mean. The number of plants of each species from the various sources varied according to the availability of material.

Based on the results obtained in 1976 on seed yield and appearance (as well as pollen fertility studies, R.S. Sadasivaiah, unpublished data) of the population transplanted from mountain sources to Ellerslie, plants were selected for increase in 1977. One hundred and sixty-nine plants representing 18 species were picked for characteristics of superior disease resistance, vigour, uniformity of maturity within the plant, and seed yield. Seed from these selected plants were germinated in growth chambers in late winter and transplanted to the Ellerslie nursery in late spring. One hundred and fifty of the most vigorous seedlings of each line were established 1 m apart in 150 m rows. Seed was harvested and yield data collected as described above. The large number of plants in this nursery (26,000) did not allow individual harvesting of each plant. Rather, the plants of each line were bulked and a mean weight per plant calculated. Studies were concentrated primarily on 4 Agropyron species, specifically Agropyron dasystachyum, Agropyron trachycaulum, Agropyron subsecundum, and Agropyron latiglume. From these results, an analysis was made of the variation of mean yield within and between collection sources of the very best plants chosen from the original population.

## STATISTICAL ANALYSES

Statistical analyses of data were accomplished with the aid of the MTS computer in the Computing Services Department at the University of Alberta. A programed package was used for calculating means, variances, analyses of variance, and Pearson Correlation Coefficients. Significance of the results of statistical test is indicated by asterisks. A single asterisk (*) indicates a probability of <0.05, a double asterisk (**) <0.01 and a triple asterisk (***) means P<0.001.

The experimental design for the 1976 seed yield studies was as follows. The experimental units in this study were individual plants of native grasses found growing at various different locations in the Rocky Mountain region of Alberta from latitude 49°N to latitude 54°N. The number of experimental units (plants) varied according the availabilty of material from 1 to 60 and the number of source locations varied up to 16 for a single species (a complete description of each location examined is contained in the appendix). The treatment applied to the experimental units in this study was the translocation of each plant from the source locations in the mountains to a single location in a nursery at Ellerslie, near Edmonton, Alberta at latitude 53°N. Seed yield and number of tillers of the transplants was monitored in the years 1975, 1976 and 1978 under the nursery conditions. The following environmental factors, which might affect these two traits, were either eliminated or minimized by transplanting and maintaining the plants in a common nursery.

a. elevation

b. rainfall

c. competition from other plants

d. decrement by grazing animals

e. average annual temperature

f. length of growing season

g. severe winter temperatures

h. large differences in soil fertility

It was hoped that this procedure, by minimizing different environmental factors, would allow genetic differences between plants to become apparent. All environmental factors, however, were not eliminated. In order to achieve this, plants collected from mountain locations would have had to be grown for one to two years to increase their size, cloned by division and then re-established in a randomized and replicated experimental plot at the nursery location. This would have required at minimum of four years and therefore was not carried out. Although the exact contribution of local environmental factors, such as soil and micro-climatic conditions, to the yield results cannot be determined under the limitations of the experimental design, it is assumed that it is small in comparison to that contributed by differences in genotype. The primary purpose of the experiment was to select obviously superior plants to be tested under more ridgid conditions.

The amount of variation in seed yield and number of tillers between plants (from genetic sources as well as nursery field sources) was measured by the mean and variance of each species-source combination. The possibility of significant differences between sources for each species was measured by an analysis of variance test.

## C. RESULTS

### BREEDING SYSTEM

Results of self-fertilization experiments using glazine bags to determine the breeding system of plants growing in growth chambers are presented in Table 3.1.

Table 3.1 Ability of 19 species representing 11 genera of Alberta native grasses to produce seeds from enforced self-pollination.

| GENERA AND THEIR SPECIES | SEED SET | DEGREE |
|---|---|---|
| *Agropyron dasystachyum* | no | |
| *Agropyron latiglume* | yes | good |
| *Agropyron trachycaulum* | yes | good |
| *Agropyron subsecundum* | yes | good |
| *Agropyron spicatum* | no | |
| *Agrostis scabra* | yes | good |
| *Bromus pumpellianus* | no | |
| *Calamagrostis purpurescens* | yes | poor |
| *Deschampsia caespitosa* | yes | poor |
| *Elymus canadensis* | yes | good |
| *Festuca saximontana* | yes | poor |
| *Festuca idahoensis* | no | |
| *Koeleria cristata* | no | |
| *Poa alpina* | yes | poor |
| *Phleum alpinum* | yes | poor |
| *Poa interior* | no | |
| *Poa cusickii* | yes | poor |
| *Stipa columbiana* | yes | good |
| *Stipa comata* | yes | poor |
| *Stipa spartea curtiseta* | no | |

## SHATTERING DATE

Observations on the date of shattering of the plants of native grass species grown at Ellerslie during 1975 to 1978 indicate that each plant possesses a unique growing pattern. Each species has a general period of several days to several weeks during the summer when shattering occurs, but variability in the harvest date exists between plants. Shattering dates of the various species for 1976 are contained in Table 2.4 of Unit II.

The following table gives an indication of the effect of harvesting each species on a single day in 1975 when the majority of the plants appeared ripe as oppossed to harvesting each plant separately when ripe in 1976. A correlation of seed yield of each plant has been calculated to minimize the effect of weather and age of the plants.

Table. 3.2 Average seed yield (g) of the same plants harvested on a single date for each species in 1975 and on individual ripening dates for each plant in 1976 together with the Pearson Correlation Coefficient.

| GENERA AND THEIR SPECIES | N | 1975 | 1976 | COEF |
|---|---|---|---|---|
| *Agropyron spicatum* | 31 | 1.9 | 5.0 | 0.29 |
| *A. dasystachyum* | 100 | 7.1 | 10.2 | 0.10 |
| *A. trachycaulum* | 20 | 4.3 | 15.6 | 0.12 |
| *Festuca idahoensis* | 64 | 4.7 | 8.4 | -0.43 |
| *Koeleria cristata* | 62 | 3.8 | 5.4 | 0.34 |
| *Trisetum spicatum* | 8 | 0.2 | 1.2 | 0.36 |

Observations on the date of shattering of the 150 plants of the 169 selected lines revealed that the progeny of each selected parent had, in almost all cases, a very uniform growing season. Consequently, it was possible to harvest all progeny of each line on a single harvest day. Variation was still apparent between lines, however, and dates of harvest were stretched to almost two weeks for some species.

SEED YIELD

The tables on the following pages contain data on various aspects of seed yield collected during 1975 to 1978. Measurements on two characteristics of reproductive capacity, number of tillers and weight of seeds, have been used in correlation, analysis of variance, and genetic improvement studies.

Table 3.3 Pearson Correlation Coefficients between the number of tillers and yield of 15 species of native grass in 1976 at Ellerslie.

| GENERA AND THEIR SPECIES | N | COEF | *SIG |
|---|---|---|---|
| *Agropyron dasystachyum* | 248 | 0.89 | *** |
| *Agropyron subsecundum* | 64 | 0.93 | *** |
| *Agropyron spicatum* | 51 | 0.53 | *** |
| *Agropyron trachycaulum* | 109 | 0.89 | *** |
| *Agropyron latiglume* | 53 | 0.86 | *** |
| *Agrostis scabra* | 16 | 0.69 | *** |
| *Elymus innovatus* | 20 | 0.58 | ** |
| *Elymus canadensis* | 4 | 0.91 | * |
| *Festuca idahoensis* | 99 | 0.86 | *** |
| *Festuca scabrella* | 29 | 0.77 | *** |
| *Festuca saximontana* | 94 | 0.78 | *** |
| *Koeleria cristata* | 88 | 0.83 | *** |
| *Poa alpina* | 120 | 0.66 | *** |
| *Phleum alpinum* | 58 | 0.66 | *** |
| *Trisetum spicatum* | 67 | 0.49 | *** |

Table 3.4. Mean number of tillers/plant in 1976 of *Agropyron dasystachyum*

| SOURCE | N | SUM | MEAN | VARIANCE | SUM [illegible] |
|---|---|---|---|---|---|
| Athabasca Ranch | 10 | 415.00 | 41.50 | 979.61 | 8816.50 |
| Brule Lake | 4 | 315.00 | 78.75 | 1784.25 | 5352.75 |
| Cat Creek | 32 | 1471.00 | 45.97 | 1410.93 | 43738.97 |
| Devona Lookout | 1 | 1.00 | 1.00 | 0.00 | 0.00 |
| Disaster Point | 4 | 136.00 | 34.00 | 1108.67 | 3316.00 |
| Drywood Creek | 4 | 341.00 | 85.25 | 1788.92 | 5366.75 |
| Greenock Mtn. | 7 | 164.00 | 23.43 | 207.29 | 1243.71 |
| Kootenay Plains | 37 | 2576.00 | 69.62 | 1145.52 | 41238.70 |
| Mt. Stearn | 28 | 3812.00 | 136.14 | 9151.16 | 247081.43 |
| Pincher Ridge | 4 | 388.00 | 97.00 | 4772.67 | 14318.00 |
| Porcupine Hills | 20 | 471.00 | 23.55 | 305.63 | 5806.95 |
| Sheep River | 20 | 1488.00 | 74.40 | 4359.74 | 82834.80 |
| Smoky River | 22 | 434.00 | 19.73 | 177.45 | 3726.36 |
| Spionkop Ridge | 3 | 99.00 | 33.00 | 1033.00 | 2066.00 |
| Waterton | 21 | 976.00 | 46.48 | 1665.16 | 33303.24 |
| Ya Ha Tinda | 32 | 3004.00 | 93.87 | 5307.15 | 164521.50 |
| Total | 249 | 16091.00 | 64.62 | 3899.33 | 662741.70 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 304292.85 | 15 | 20286.19 | 7.13 |
| Within Groups | 662741.67 | 233 | 2844.38 | *** |

Table 3.5 Mean seed yield (g)/plant in 1976 of *Agropyron dasystachyum*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Athabasca Ranch | 10 | 88.63 | 8.86 | 59.42 | 534.74 |
| Brule Lake | 4 | 79.23 | 19.81 | 114.25 | 342.74 |
| Cat Creek | 32 | 179.05 | 5.60 | 29.47 | 913.55 |
| Devona Lookout | 1 | 0.06 | 0.06 | 0.00 | 0.00 |
| Disaster Point | 14 | 28.66 | 7.16 | 50.51 | 151.54 |
| Drywood Creek | 4 | 45.40 | 11.35 | 32.77 | 98.32 |
| Greenock Mtn. | 7 | 25.31 | 3.62 | 5.12 | 30.73 |
| Kootenay Plains | 38 | 484.21 | 12.74 | 52.94 | 1958.93 |
| Mt. Stearn | 28 | 635.06 | 22.68 | 267.09 | 7211.55 |
| Pincher Ridge | 4 | 60.15 | 15.04 | 282.49 | 847.46 |
| Porcupine Hills | 20 | 9.96 | 0.50 | 0.53 | 10.13 |
| Sheep River | 20 | 166.56 | 8.33 | 70.55 | 1340.56 |
| Smoky River | 21 | 56.70 | 2.70 | 3.31 | 66.21 |
| Spionkop Ridge | 3 | 10.44 | 3.48 | 4.94 | 9.87 |
| Waterton | 25 | 246.73 | 9.87 | 57.22 | 1373.18 |
| Ya Ha Tinda | 32 | 456.53 | 14.27 | 137.30 | 4256.15 |
| Totals | 253 | 2572.68 | 10.17 | 115.72 | 19145.67 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 10015.80 | 15 | 667.72 | 8.27 |
| Within Groups | 19145.67 | 237 | 80.78 | *** |

Table 3.6 Mean number of tillers/plant in 1976 of *Poa alpina*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Barnaby Ridge | 7 | 169.00 | 24.14 | 317.81 | 1906.85 |
| Caw Creek Ridge | 5 | 70.00 | 14.00 | 130.50 | 522.00 |
| Coal Valley | 19 | 1152.00 | 60.63 | 1912.13 | 34418.42 |
| Grassy Mtn. | 23 | 1112.00 | 48.35 | 206.69 | 4547.22 |
| Mountain Park | 20 | 1753.00 | 87.65 | 4771.92 | 90666.55 |
| Pyramid Lake | 4 | 232.00 | 58.00 | 38.67 | 116.00 |
| Snow Creek Pass | 20 | 469.00 | 23.45 | 433.31 | 8232.95 |
| Sunshine | 22 | 805.00 | 36.59 | 436.35 | 9163.32 |
| Totals | 120 | 5762.00 | 48.02 | 1757.41 | 149573.32 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 59558.65 | 7 | 8508.38 | 6.37 |
| Within Groups | 149573.31 | 112 | 1335.48 | *** |

Table 3.7 Mean seed yield (g)/plant in 1976 of *Poa alpina*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Barnaby Ridge | 7 | 13.56 | 1.94 | 4.72 | 28.3074 |
| Caw Creek Ridge | 5 | 2.88 | 0.58 | 0.65 | 2.62 |
| Coal Valley | 19 | 48.57 | 2.55 | 1.67 | 30.15 |
| Grassy Mtn. | 23 | 174.22 | 7.57 | 8.60 | 189.11 |
| Mountain Park | 20 | 127.06 | 6.35 | 12.74 | 242.10 |
| Pyramid Lake | 4 | 15.74 | 3.94 | 2.01 | 6.02 |
| Snow Creek Pass | 20 | 37.43 | 1.87 | 7.58 | 144.08 |
| Sunshine | 24 | 53.06 | 2.21 | 2.31 | 53.25 |
| Totals | 122 | 472.52 | 3.87 | 11.52 | 695.61 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 698.15 | 7 | 99.74 | 6.34 |
| Within Groups | 695.61 | 114 | 6.10 | *** |

Table 3.8 Mean number of tillers/plant in 1976 of <u>Trisetum spicatum</u>.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Cat Creek | 8 | 360.00 | 45.00 | 1022.86 | 7160.00 |
| Coal Valley | 21 | 301.00 | 14.33 | 113.33 | 2266.67 |
| Grassy Mtn. | 18 | 213.00 | 11.83 | 199.44 | 3390.50 |
| Mtn. Park Pass | 5 | 662.00 | 132.40 | 6566.80 | 26267.20 |
| Sheep River | 3 | 83.00 | 27.67 | 44.33 | 88.67 |
| Sunshine | 12 | 327.00 | 27.25 | 730.02 | 8030.25 |
| Totals | 67 | 1946.00 | 29.05 | 1705.65 | 47203.28 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 65369.58 | 5 | 13073.91 | 16.89 |
| Within Groups | 47203.28 | 61 | 773.82 | *** |

Table 3.9 Mean seed yield (g)/plant in 1976 of <u>Trisetum spicatum</u>.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Cat Creek | 8 | 34.76 | 4.34 | 65.66 | 459.60 |
| Coal Valley | 21 | 7.53 | 0.36 | 0.06 | 1.16 |
| Grassy Mtn. | 18 | 11.13 | 0.62 | 0.42 | 7.14 |
| Mtn. Park Pass | 5 | 19.25 | 3.85 | 6.35 | 25.40 |
| Sheep River | 3 | 3.67 | 1.22 | 0.59 | 1.17 |
| Sunshine | 12 | 6.57 | 0.55 | 0.44 | 4.89 |
| Totals | 67 | 82.91 | 1.24 | 9.69 | 499.38 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 140.21 | 5 | 28.04 | 3.42 |
| Within Groups | 499.38 | 61 | 8.19 | *** |

Table 3.10 Mean number of tillers/plant in 1976 of *Festuca saximontana*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Barnaby Ridge | 4 | 60.00 | 15.00 | 82.00 | 246.00 |
| Cat Creek | 5 | 164.00 | 32.80 | 229.70 | 918.80 |
| Clearwater R. | 4 | 96.00 | 24.00 | 390.00 | 1170.00 |
| Mountain Park | 3 | 362.00 | 120.67 | 1500.33 | 3000.67 |
| Porcupine Hills | 8 | 32.00 | 4.00 | 14.00 | 98.00 |
| Pyramid Lake | 2 | 64.00 | 32.00 | 242.00 | 242.00 |
| Snow Creek Pass | 18 | 200.00 | 11.11 | 126.93 | 2157.77 |
| Stavely Station | 5 | 57.00 | 11.40 | 136.80 | 547.20 |
| Caw Creek | 18 | 558.00 | 31.00 | 140.82 | 2394.00 |
| Ya Ha Tinda | 27 | 1419.00 | 52.56 | 2420.79 | 62940.67 |
| Totals | 94 | 3012.00 | 32.04 | 1359.03 | 73715.11 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 52674.719 | 9 | 5852.75 | 6.67 |
| Within Groups | 73715.11 | 84 | 877.56 | *** |

Table 3.11 Mean seed yield (g)/plant in 1976 of *Festuca saximontana*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Barnaby Ridge | 4 | 1.68 | 0.42 | 0.34 | 1.03 |
| Cat Creek | 5 | 22.98 | 4.60 | 0.59 | 2.38 |
| Clearwater R. | 4 | 7.69 | 1.92 | 1.62 | 4.90 |
| Mountain Park | 3 | 11.86 | 3.95 | 1.86 | 3.71 |
| Porcupine Hills | 8 | 3.08 | 0.38 | 0.08 | 0.56 |
| Pyramid Lake | 2 | 7.05 | 3.52 | 0.36 | 0.36 |
| Snow Creek Pass | 18 | 16.00 | 0.90 | 0.83 | 14.13 |
| Stavely Station | 5 | 3.16 | 0.63 | 0.35 | 1.42 |
| Caw Creek | 18 | 45.09 | 2.50 | 3.02 | 51.32 |
| Ya Ha Tinda | 27 | 169.45 | 6.28 | 32.62 | 848.07 |
| Totals | 94 | 288.04 | 3.06 | 15.40 | 927.85 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 504.03 | 9 | 56.00 | 5.07 |
| Within Groups | 927.85 | 84 | 11.05 | *** |

Table 3.12 Mean number of tillers/plant in 1976 of *Koeleria cristata*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Athabasca Ranch | 4 | 268.00 | 67.00 | 2422.00 | 7266.00 |
| Cat Creek | 8 | 694.00 | 86.75 | 5860.50 | 41023.50 |
| Devona Lookout | 1 | 3.00 | 3.00 | 0.00 | 0.00 |
| Disaster Point | 1 | 11.00 | 11.00 | 0.00 | 0.00 |
| Drywood Creek | 9 | 1788.00 | 198.67 | 15702.50 | 125620.00 |
| Mt. Stearn | 11 | 1707.00 | 155.18 | 9440.36 | 94403.63 |
| Pincher Ridge | 4 | 498.00 | 124.50 | 4453.67 | 13361.00 |
| Ram Mtn. | 9 | 155.00 | 17.22 | 307.69 | 2461.56 |
| Sheep River | 8 | 1127.00 | 140.87 | 3523.27 | 24662.88 |
| Snow Creek Pass | 3 | 9.00 | 3.00 | 3.00 | 6.00 |
| Waterton | 7 | 348.00 | 49.71 | 1188.90 | 7133.43 |
| Waterton Flats | 5 | 408.00 | 81.60 | 9319.80 | 37279.20 |
| Ya Ha Tinda | 12 | 328.00 | 27.33 | 917.15 | 10088.67 |
| Yarrow Creek | 6 | 748.00 | 124.67 | 6475.07 | 32375.33 |
| Totals | 88 | 8092.00 | 91.95 | 8347.81 | 395681.20 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 330578.62 | 13 | 25429.12 | 4.76 |
| Within Groups | 395681.19 | 74 | 5347.04 | *** |

Table 3.13 Mean seed yield (g)/plant in 1976 of *Koeleria cristata*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Athabasca Ranch | 4 | 18.35 | 4.59 | 34.02 | 102.05 |
| Cat Creek | 8 | 39.00 | 4.87 | 16.76 | 117.33 |
| Devona Lookout | 1 | 0.28 | 0.28 | 0.00 | 0.00 |
| Disaster Point | 1 | 0.43 | 0.43 | 0.00 | 0.00 |
| Drywood Creek | 9 | 87.12 | 9.68 | 32.41 | 259.25 |
| Mt. Stearn | 11 | 122.91 | 11.17 | 25.64 | 256.40 |
| Pincher Ridge | 4 | 34.44 | 8.61 | 18.48 | 55.43 |
| Ram Mtn. | 9 | 10.40 | 1.16 | 1.31 | 10.51 |
| Sheep River | 8 | 62.20 | 7.77 | 28.69 | 200.86 |
| Snow Creek Pass | 3 | 1.29 | 0.43 | 0.18 | 0.35 |
| Waterton | 7 | 21.39 | 3.06 | 4.45 | 26.71 |
| Waterton Flats | 5 | 27.36 | 5.47 | 36.69 | 146.77 |
| Ya Ha Tinda | 12 | 22.04 | 1.84 | 2.80 | 30.85 |
| Yarrow Creek | 6 | 30.80 | 5.13 | 7.07 | 35.35 |
| Totals | 88 | 478.01 | 5.43 | 26.93 | 1241.88 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 1101.09 | 13 | 84.70 | 5.05 |
| Within Groups | 1241.88 | 74 | 16.78 | *** |

Table 3.14 Mean number of tillers/plant in 1976 of *Phleum alpinum*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Caw Creek Ridge | 36 | 601.00 | 16.69 | 132.96 | 4653.64 |
| Sunshine | 24 | 838.00 | 34.92 | 494.43 | 11371.83 |
| Totals | 60 | 1439.00 | 23.98 | 352.66 | 16025.47 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 4781.51 | 1 | 4781.51 | 17.31 |
| Within Groups | 16025.47 | 58 | 276.30 | *** |

Table 3.15 Mean seed yield (g)/plant in 1976 of *Phleum alpinum*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Caw Creek Ridge | 35 | 26.73 | 0.76 | 0.49 | 16.56 |
| Sunshine | 23 | 37.39 | 1.63 | 0.92 | 20.32 |
| Totals | 58 | 64.12 | 1.11 | 0.83 | 36.88 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 10.31 | 1 | 10.31 | 15.66 |
| Within Groups | 36.88 | 56 | 0.66 | *** |

Table 3.16 Mean number of tillers/plant in 1976 of *Agropyron subsecundum*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Cat Creek | 18 | 492.00 | 27.33 | 409.29 | 6958.00 |
| Clearwater R. | 18 | 766.00 | 42.56 | 1120.03 | 19040.44 |
| Porcupine Hills | 5 | 112.00 | 22.40 | 347.30 | 1389.20 |
| Smoky River | 14 | 334.00 | 23.86 | 662.29 | 8609.71 |
| Waterton Flats | 10 | 738.00 | 73.80 | 5428.40 | 48855.60 |
| Totals | 65 | 2442.00 | 37.57 | 1626.50 | 84852.96 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 19242.98 | 4 | 4810.74 | 3.40 |
| Within Groups | 84852.96 | 60 | 1414.22 | * |

Table 3.17 Mean seed yield (g)/plant in 1976 of *Agropyron subsecundum*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Cat Creek | 18 | 128.96 | 7.16 | 36.73 | 624.41 |
| Clearwater R. | 17 | 243.17 | 14.30 | 149.93 | 2398.88 |
| Porcupine Hills | 5 | 7.39 | 1.48 | 1.51 | 6.04 |
| Smoky River | 14 | 138.37 | 9.88 | 104.31 | 1355.97 |
| Waterton Flats | 10 | 209.73 | 20.97 | 374.79 | 3373.12 |
| Totals | 64 | 727.62 | 11.37 | 153.42 | 7758.42 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 1907.08 | 4 | 476.77 | 3.63 |
| Within Groups | 7758.419 | 59 | 131.50 | * |

Table 3.18 Mean number of tillers/plant in 1976 of *Agropyron trachycaulum*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Athabasca Ranch | 36 | 781.00 | 130.17 | 3558.57 | 17792.83 |
| Barnaby Ridge | 16 | 1341.00 | 83.81 | 4916.30 | 73744.44 |
| Grassy Mtn. | 25 | 1921.00 | 76.84 | 1354.14 | 32499.36 |
| Greenock Mtn. | 9 | 470.00 | 52.22 | 2460.19 | 19681.56 |
| Kootenay Plains | 12 | 515.00 | 42.92 | 984.63 | 10830.91 |
| Mountain Park | 16 | 613.00 | 38.31 | 635.83 | 9537.44 |
| Mt. Stearn | 2 | 146.00 | 73.00 | 648.00 | 648.00 |
| Ram River Falls | 4 | 96.00 | 24.00 | 304.67 | 914.00 |
| Rock Lake | 11 | 816.00 | 74.18 | 2124.76 | 21247.64 |
| Smoky River | 8 | 150.00 | 18.75 | 171.07 | 1197.50 |
| Totals | 109 | 6849.00 | 62.83 | 2461.47 | 188093.68 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 77745.35 | 9 | 8638.37 | 4.55 |
| Within Groups | 188093.68 | 99 | 1899.94 | *** |

Table 3.19 Mean seed yield (g)/plant in 1976 of *Agropyron trachycaulum*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Athabasca Ranch | 6 | 216.90 | 36.15 | 280.62 | 1403.09 |
| Barnaby Ridge | 16 | 287.60 | 17.97 | 331.30 | 4969.45 |
| Grassy Mtn. | 25 | 513.80 | 20.55 | 85.79 | 2058.99 |
| Greenock Mtn. | 9 | 165.29 | 18.37 | 311.62 | 2492.10 |
| Kootenay Plains | 12 | 149.17 | 12.43 | 78.02 | 858.17 |
| Mountain Park | 16 | 96.36 | 6.02 | 22.97 | 344.51 |
| Mt. Stearn | 3 | 27.11 | 9.04 | 36.09 | 72.18 |
| Ram River Falls | 4 | 21.95 | 5.49 | 16.99 | 50.98 |
| Rock Lake | 11 | 176.71 | 16.06 | 167.37 | 1673.74 |
| Smoky River | 8 | 62.11 | 7.76 | 32.69 | 228.83 |
| Totals | 109 | 1716.10 | 15.61 | 184.21 | 14152.94 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 5926.04 | 9 | 658.45 | 4.65 |
| Within Groups | 14152.94 | 100 | 141.53 | *** |

Table 3.20 Mean number of tillers/plant in 1976 of *Agropyron latiglume*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Barnaby Ridge | 2 | 23.00 | 11.50 | 12.50 | 12.50 |
| Caw Creek Ridge | 24 | 2327.00 | 96.958 | 2751.61 | 63286.96 |
| Mountain Park | 24 | 1089.00 | 45.37 | 2849.11 | 65529.62 |
| Snow Creek Pass | 3 | 24.00 | 8.00 | 25.00 | 50.00 |
| Totals | 53 | 3463.00 | 65.34 | 3424.10 | 128879.08 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 49220.80 | 3 | 16406.94 | 6.24 |
| Within Groups | 128879.08 | 49 | 2630.18 | ** |

Table 3.21 Mean seed yield (g)/plant in 1976 of *Agropyron latiglume*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Barnaby Ridge | 2 | 1.88 | 0.94 | 0.72 | 0.72 |
| Caw Creek Ridge | 24 | 128.30 | 5.35 | 14.44 | 332.09 |
| Mountain Park | 24 | 55.99 | 2.33 | 4.83 | 111.19 |
| Snow Creek Pass | 3 | 2.43 | 0.81 | 0.11 | 0.23 |
| Totals | 53 | 188.60 | 3.56 | 11.41 | 444.23 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 149.09 | 3 | 49.70 | 5.48 |
| Within Groups | 444.23 | 49 | 9.07 | ** |

Table 3.22 Mean number of tillers/plant in 1976 of <u>Festuca idahoensis</u>.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Grassy Mtn. | 3 | 66.00 | 22.00 | 793.00 | 1586.00 |
| Porcupine Hills | 13 | 479.00 | 36.85 | 3446.64 | 41359.69 |
| Stavely Station | 4 | 215.00 | 53.75 | 485.58 | 1456.75 |
| Waterton | 57 | 5201.00 | 91.25 | 8525.37 | 477420.56 |
| Windsor Ridge | 22 | 2642.00 | 120.09 | 5297.42 | 111245.82 |
| Totals | 99 | 8603.00 | 86.90 | 7224.32 | 633068.82 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 74914.17 | 4 | 18728.54 | 2.78 ** |
| Within Groups | 633068.82 | 94 | 6734.77 | |

Table 3.23 Mean seed yield (g)/plant in 1976 of <u>Festuca idahoensis</u>.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Grassy Mtn. | 3 | 1.04 | 0.35 | 0.18 | 0.35 |
| Porcupine Hills | 13 | 29.06 | 2.23 | 16.64 | 199.70 |
| Stavely Station | 4 | 13.04 | 3.26 | 1.95 | 5.84 |
| Waterton | 57 | 312.83 | 5.49 | 32.03 | 1793.39 |
| Windsor Ridge | 22 | 109.54 | 4.98 | 13.20 | 277.13 |
| Totals | 99 | 465.51 | 4.70 | 25.08 | 2276.41 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 181.24 | 4 | 45.31 | 1.87 |
| Within Groups | 2276.41 | 94 | 24.22 | |

Table 3.24 Mean yield (g/plant) of parents in 1976 and selected progeny in 1978 of various species for the entire working population.

| SPECIES | 76 MEAN | VARIANCE | 78 MEAN | VARIANCE |
|---|---|---|---|---|
| *Agropyron latiglume* | 3.56 | 11.41 | 0.71 | 0.24 |
| *A. dasystachyum* | 10.17 | 115.72 | 8.85 | 10.44 |
| *A. trachycaulum* | 15.61 | 184.21 | 28.98 | 254.57 |
| *A. subsecundum* | 11.37 | 153.42 | 15.20 | 85.40 |
| *A. spicatum* | 5.00 | 21.25 | 9.83 | 14.49 |
| *Trisetum spicatum* | 1.24 | 9.69 | 4.27 | 6.41 |
| *Koeleria cristata* | 5.43 | 26.93 | 17.48 | 3.14 |
| *Phleum alpinum* | 1.11 | 0.83 | 3.89 | 0.42 |
| *Poa alpina* | 3.87 | 11.52 | 10.13 | 7.83 |
| *Festuca idahoensis* | 4.70 | 25.08 | 6.38 | 22.19 |
| *Festuca saximontana* | 3.06 | 15.40 | 8.19 | 131.90 |

Table 3.25 Mean seed yield (g)/plant in 1978 of *Agropyron dasystachyum*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Athabasca Ranch | 2 | 17.08 | 8.54 | 38.96 | 38.96 |
| Brule Lake | 3 | 16.28 | 5.43 | 3.00 | 5.99 |
| Cat Creek | 1 | 8.62 | 8.63 | 0.00 | 0.00 |
| Kootenay Plains | 4 | 27.19 | 6.80 | 2.74 | 8.23 |
| Mt. Stearn | 9 | 98.30 | 10.92 | 12.88 | 103.08 |
| Sheep River | 5 | 40.16 | 8.03 | 6.40 | 25.59 |
| Ya Ha Tinda | 8 | 75.64 | 9.46 | 6.38 | 44.63 |
| Totals | 32 | 283.29 | 8.85 | 10.44 | 226.49 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 97.15 | 6 | 16.19 | 1.79 |
| Within Groups | 226.49 | 25 | 9.06 | |

N= Number of Parental Lines.

Table 3.26 Mean seed yield (g/plant) in 1978 of *Agropyron trachycaulum*.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Check: Revenue | 1 | 53.54 | 53.54 | 0.00 | 0.00 |
| Barnaby Ridge | 3 | 85.92 | 28.64 | 87.69 | 175.39 |
| Grassy Mtn. | 8 | 221.07 | 27.63 | 21.10 | 147.71 |
| Mountain Park | 4 | 35.35 | 8.84 | 3.49 | 10.46 |
| Smoky River | 2 | 40.54 | 20.27 | 302.05 | 302.05 |
| Sheep River | 1 | 39.64 | 39.64 | 0.00 | 0.00 |
| Waterton | 3 | 161.47 | 53.82 | 176.54 | 353.09 |
| Totals | 22 | 637.53 | 28.98 | 254.57 | 988.69 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 4357.31 | 6 | 726.22 | 11.02 |
| Within Groups | 988.69 | 15 | 65.91 | *** |

N=Number of Parental Lines

Table 3.27 Mean seed yield (g/plant) in 1978 of <u>Agropyron subsecundum</u>.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Athabasca Ranch | 1 | 33.07 | 33.07 | 0.00 | 0.00 |
| Cat Creek | 3 | 15.24 | 5.08 | 0.60 | 1.19 |
| Greenock Mtn. | 3 | 87.89 | 29.30 | 3.77 | 17.55 |
| Kootenay Plain | 6 | 58.28 | 9.71 | 47.03 | 235.13 |
| Rock Lake | 4 | 60.02 | 15.01 | 6.00 | 17.97 |
| Smoky River | 3 | 53.79 | 17.93 | 1.08 | 2.15 |
| Waterton Flats | 1 | 10.94 | 10.94 | 0.00 | 0.00 |
| Totals | 21 | 319.22 | 15.20 | 85.40 | 264.00 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 1443.99 | 6 | 240.66 | 12.76 |
| Within Groups | 264.00 | 14 | 18.86 | *** |

Table 3.28 Mean seed yield (g)/plant in 1978 of <u>Agropyron latiglume</u>.

| SOURCE | N | SUM | MEAN | VARIANCE | SUM SQS |
|---|---|---|---|---|---|
| Caw Creek Ridge | 6 | 3.43 | 0.57 | 0.15 | 0.77 |
| Mountain Park | 4 | 3.62 | 0.90 | 0.39 | 1.16 |
| Totals | 10 | 7.05 | 0.71 | 0.24 | 1.93 |

Analysis of Variance

| SOURCE OF VARIATION | SUM SQS | D.F. | MEAN SQ | F |
|---|---|---|---|---|
| Between Groups | 0.27 | 1 | 0.27 | 0.32 |
| Within Groups | 1.93 | 8 | 0.24 | |

N= Number of Parental Lines

## D. DISCUSSION

### BREEDING SYSTEM

Isolation of heads in bags may introduce the possibility of creating environmental conditions adverse to seed production. However, since some species set equal quantities of seed on bagged and unbagged heads, this possibility seems remote. Failure to set seed in isolation is an almost certain indication that the species is cross-pollinated. The reverse is not necessarily the case because cross pollinated species may be self-fertile. In addition, self-pollinated species whose mode of breeding is maintained largely by flower morphology, may be capable of occasional cross-pollination.

The results of enforced self-pollination studies presented in Table 3.1 indicate that there are species which are self-incompatible, as well as some which are completely self-fertile. The self-pollinated nature of Agropyron trachycaulum, Agropyron subsecundum, Agropyron latiglume, Elymus canadensis, and the cross-pollinated nature of Agropyron dasystachyum, Agropyron spicatum, and Bromus pumpellianus have been reported elsewhere by numerous authors and concurrence of results obtained in the present study lends credence to the observations on the remaining, unreported species.

The breeding system inherent in a species is important in a genetic improvement program because breeding methods are different for cross- and self-pollinated species. In addition, with cross-pollinated species, great care must be taken that contamination from undesirable genotypes does not take place. Studies by Knowles (1968) have suggested minimum distances that are required for genetically isolating cross-pollinating species under field conditions.

## SHATTERING DATE

Table 2.4 contains the shattering dates of transplants from the mountains when grown at Edmonton in 1976. The observations indicate that, for some species in the collection, a great deal of variability exists within species and within collection sources. For example, as much as a month difference exists between the time that the first and last plant of *Koeleria cristata* from Cat Creek began to shatter. Such lack of synchronization can seriously depress agricultural seed yields.

Table 3.2 contains seed yield figures for production of the same plants when harvested on a single date in 1975 and on individual shattering dates in 1976. Since yield generally increases during the first several years of establishment for forage grasses and because weather conditions may have played a part in these two years, a correlation has been calculated between the yields of each plant for both years. Correlations ranged from 0.10 for *Agropyron dasystachyum* to 0.43 for *Festuca idahoensis*. Plants which were harvested when shattering in both years showed a consistency in performance, while those whose seed had shattered or was not ripe at harvest in 1975, showed a dramatic increase in seed yield. These results are reflected in the overall average increase in yield for all the species studied. In order to solve this agricultural seed production problem, plants from different sources, which have similar shattering dates, should be bulked to form an even-ripening variety with a broad genetic background.

SEED YIELD

It is expected that a high degree of correlation should be present between the number of tillers on a plant and its seed yield. The data in Table 3.3 do not support this. The correlation coefficients range from a high of 0.93 for *Agropyron subsecundum* to a low of 0.53 for *Agropyron spicatum*. The self-pollinated species, *Agropyron trachycaulum*, *Agropyron subsecundum*, *Agropyron latiglume*, and *Elymus canadensis* have generally higher correlations than the cross-pollinated species, *Agropyron spicatum* and *Elymus innovatus*, although *Agropyron dasystachyum* is an exception. This lack of high correlation is a reflection of the number of plants in the species population which appear to have good potential for seed production on the basis of tillers but are sterile. Some of the reasons for sterility in the Agropyrons have been determined by R.S. Sadasivaiah of this laboratory. A plant, originally identified as Agropyron subsecundum, was later found to be a completely sterile intergeneric hybrid between Agropyron subsecundum and Elymus innovatus. In the population of Agropyron dasystachyum from the Porcupine Hills, a high frequency of sterile plants was found to be due to the formation of unreduced gametes which led to the formation of hexaploids (Sadasivaiah et al. 1977b).

In order to avoid the presence of unproductive plants, it is important to rogue sterile individuals and, in addition, ensure that species capable of crossing, are sufficiently separated in the field.

Data on the number of tillers and mean yield of 10 species of native grasses are presented in Tables 3.4 to 3.20. Results on these species, transplanted from the mountains, reveal the presence of genetic variability for these two agronomic characteristics within and between sources. In some cases, the variance was very large indicating a geat deal of variability. All analyses of variance, except mean yield for Festuca idahoensis, indicated that highly significant differences exist between the collection sources. For example, the population of Agropyron dasystachyum from the Porcupine Hills (referred to above) had an average of 23.55 tillers, a number about one-half that of the population mean, 64.62. The average seed yield of 0.50, however, was substantially below the population mean of 10.17. The presence of sterile plants contributed to the low productivity and high variability in the Porcupine Hills plants. The exceptional case of Festuca idahoensis could be due to the cross-pollinated nature of this species, the restriction of collection sources to southern Alberta, and the presence of plants with good combining ability from each source.

The significant differences in yield and number of tillers, do not demonstrate genetic isolation for these characters between sources. The number of plants and the method of sampling cannot allow such a conclusion. As explained in Unit 1, plants were often dug from their sources during times when viable seeds could not be detected, and transplanted to Edmonton. This method allowed the inclusion of sterile plants. Furthermore, since exceptionally robust specimens were sought, intergeneric and interspecific hybrids displaying heterosis undoubtedly attracted attention. Variations of the soil in the nursery probably added somewhat to the variation in seed yields. In order to eliminate the effect of soil on seed yield, the single plants would have had to be cloned in order that a fully replicated and randomized experiment was established. This proceedure would have added at least two years to the time required for the experiment and thus was not done.

Dewey (numerous publications), Collins (1965), and

Allderdice (1965) have reported natural and synthetic intergeneric and interspecific hybrids in the Agropyrons. Varying frequencies of similar hybrids have been detected and studied in the natural population of this collection (Sadasivaiah et al. 1978).

The selection of fertile and higher yielding plants for seed production has resulted in a modest increase in yield for most species (Table 3.24). Seed production generally increases with age during the first several years of establishment. Since the 1978 data is on plants in their first year of production, the increases are significant when compared to the yield obtained from the population in 1976 which were comprised of older plants. The variance has decreased in selected lines in all species (Table 3.24).

The selected progeny of *Agropyron dasystachyum* produced seed yields which resulted in a lack of significant difference between collection sources (Table 3.25). Some sources for this species were eliminated during selection, and the inclusion of only the best plants from the remaining sources has resulted in lower standard deviations within each source and a lack of significant difference between sources (see Table 3.5).

The selected progenies of *Agropyron subsecundum*, *Agropyron latiglume*, and *Agropyron trachycaulum* showed significant yield differences between sources. Since these species are self-pollinated, each line is expected to breed true and retain the characteristic yield performance of the parents. Nevertheless, variation within sources has decreased as measured by the variance indicating genetic improvement in this trait of the population.

E. CONCLUSIONS

The breeding system of 19 species of native grasses, including 12 previously unreported, has been determined. Investigations on seed yield and harvest date have revealed the presence of genetic variability within and between sources of collection. The selection of outstanding individual plants from the wild population has resulted in progeny with characteristics more conducive to economical agricultural seed production. This selected population may now be further tested for environmentally important traits necessary for reclamation in harsh climates.

IV. CYTOGENETIC STUDIES

UNIT FOUR

of

THE GENETIC POTENTIAL OF

NATIVE ALBERTA GRASSES

OF THE ROCKY MOUNTAINS

In conjunction with the studies described in this thesis, cytogenetic investigations to facilitate the plant breeding work are being conducted in association with Dr. R.S. Sadasivaiah of the Department of Genetics, University of Alberta. Information regarding chromosome numbers, evolutionary relationships, interspecific fertility, intergeneric fertility, and chromosomal irregularities is being sought at this early stage of the plant development program in order to avoid some of the problems which have plagued plant breeders in the past and have caused costly delays.

Chromosome number of various species was determined in root tip cells using the Feulgen squash technique. The procedure for staining and examining karyotypes has been described by Sadasivaiah and Rajhathy (1968). Meiosis studies were conducted by fixing immature spikes in Carnoy's solution (6 parts of 95% ethanol: 3 parts of choroform: 1 part of glacial acetic acid) and staining according to Sadasivaiah and Rajhathy (1968). Chromosome pairing was studied at metaphase I, and irregularities were studied at anaphase I and later if present.

A naturally occurring intergeneric hybrid was identified by cytomorphological studies as being derived from a cross between Elymus innovatus (2n=4x=28) and Agropyron subsecundum (2n=4x=28). Morphology of the hybrid was intermediate between the two parents but the plant was completely sterile. Hybrids were very robust and possessed the vigorous creeping root habit of the *Elymus* parent. Chromosome pairing was highly irregular with univalents ranging from 14 to 28 per cell. The presence of bivalents (0 to 7) was interpreted to be due to the homeologous relationship existing between the genomes of *E. innovatus* and *A. subsecundum*.

Although *Agropyron dasystachyum* normally occurs as an allotetraploid (2n=4x=28), several plants from the Porcupine Hills in southern Alberta were determined by cytological investigations to be hexaploid (2n=6x=42). Plants thus affected were indistinquishable from the normal tetraploid *A. dasystachyum* plants on the basis of morphology except for a high degree of sterility. Pollen staining studies using 1% acetocarmine revealed a high percentage of aborted pollen grains. Percent pollen sterility for the hexaploid plants ranged from 13.5 to 69.3 while that of normal tetraploid plants from the same source ranged from 1.1 to 9.1. On the basis of chromosome pairing studies, it was concluded that the naturally occurring hexaploids originated as a result of fertilization between unreduced and normal gametes of *A. dasystachyum*.

Detailed results of these jointly researched cytogenetic studies have been prepared and presented in the following papers or reports:

Sadasivaiah, R.S., D.G. Walker, and J. Weijer. 1977. Research Report on Breeding Native Grasses. Proceedings of the Twenty-fourth Grass Breeders Work Planning Conference, Tifton, Georgia. p. 20.

Sadasivaiah, R.S., D.G. Walker, and J. Weijer. 1978. Breeding native grass species for range improvement in Alberta. Proceedings of the First International Rangeland Congress. (in press).

Sadasivaiah, R.S., D.G. Walker, and J. Weijer. 1978. Origin and meiotic behaviour of hexaploid northern wheatgrass (*Agropyron dasystachyum*). Proceedings of the XIV International Congress of Genetics, Moscow. (in press).

Sadasivaiah, R.S., D.G. Walker, and J. Weijer. 1978. Cytomorphological studies on some natural intergeneric hybrids between *Elymus innovatus* and *Agropyron subsecundum*. Proceedings of the XIV International Congress of Genetics, Moscow. (in press).

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# APPENDIX

# Source Description of Grass Germplasm Accessions

| Name of Source | Lat. & Long. | Alt. (m) | Slope & Aspect | Description of Site |
|---|---|---|---|---|
| Athabasca Ranch | 53°23' 117°40' | 914 | 26-38° south | Elk winter range |
| Banff Flats | 51°12' 115°32' | 1385 | flat | airport & railway |
| Barnaby Ridge | 49°20' 114° 6' | 1716 | 30° west | Bighorn winter range |
| Beauvais Lake | 49°24' 114° 6' | 1676 | flat | Elk winter range |
| Bragg Creek | 50°56' 114°36' | 1372 | 30° south | Foothills Natural Area |
| Brule Lake | 53°14' 117°53' | 975 | steep south | Bighorn winter range |
| Cameron Lake | 49° 2' 114° 3' | 1676 | steep south | open forest |
| Cat Creek | 50°24' 114°42' | 1585 | steep south | range of Elk and Bighorns |
| Caw Creek Ridge | 54° 4' 119°22' | 1981 | flat | oil well site 1970 |
| Clearwater River | 51°53' 115°45' | 1524 | flat | subalpine meadow |
| Coal Valley | 53° 3' 116°40' | 1402 | flat | coal strip mine |
| Devona Lookout | 53°10' 118° 1' | 1378 | 30° south west | lookout tower |
| Disaster Point | 53° 9' 117°57' | 1219 | steep south west | Bighorn winter range |

Source Description of Grass Germplasm Accessions

| Name of Source | Lat. & Long. | Alt. (m) | Slope & Aspect | Description of Site |
|---|---|---|---|---|
| Drywood Creek | 49°15' 114° 3' | 1524 | steep south | Bighorn winter range |
| Elpoca Mtn. | 50°39' 114°56' | 2134 | flat | wind blown hilltop |
| Forget-Me-Not Mtn. | 50°45' 114°47' | 2167 | 30° south | alpine meadow |
| Gibralter Mtn. | 50°36' 114°49' | 1981 | flat | disturbed roadside |
| Grassy Mtn. | 49°42' 114°25' | 1798 | 38° north | coal strip mine |
| Greenock Mtn. | 53° 5' 118° 4' | 1045 | 30° south | Bighorn winter range |
| Grotto Mtn. | 51° 3' 115°15' | 1524 | 35° south | Bighorn winter range |
| Highwood House | 50°23' 114°39' | 1676 | 27° south | Elk/Bighorn winter range |
| Highwood Pass | 50°35' 114°59' | 2206 | flat | roadside |
| Kootenay Plains | 52° 0' 116°18' | 1372 | flat | sandy banks N. Sask. River |
| Lake Minnewanka | 51°12' 115°30' | 1524 | flat | open forest meadows |
| Marmot Basin | 52°47' 118° 6' | 2225 | steep east | ski hill |
| Mountain Park | 52°56' 117°16' | 1743 | 38° north east | coal slag 25 years old |

Source Description of Grass Germplasm Accessions

| Name of Source | Lat. & Long. | Alt. (m) | Slope & Aspect | Description of Site |
|---|---|---|---|---|
| Mountain Park Pass | 52°53' 117°14' | 1981 | flat | alpine picnic site |
| Mt. Rae | 50°37' 114°54' | 2286 | flat windblown | exploration trail |
| Mt. Stearn | 53°49' 119°13' | 1219 | steep south | Bighorn winter range |
| Nihahi Ridge | 50°47' 114°56' | 1981 | flat | roadside |
| Parkers Ridge | 52°11' 117° 5' | 2134 | mountain ridge | Mtn. Goat range |
| Peyto Lake | 51°42' 116°30' | 2286 | 38° north east | alpine meadows |
| Pigeon Mtn. | 51° 1' 115°14' | 1829 | 35° north west | ski hill & Bighorn range |
| Pincher Ridge | 49°16' 114° 8' | 1829 | 38° | Bighorn winter range |
| Plateau Mtn. | 50°15' 114°31' | 2286 | windblown hilltop | exploration oil site |
| Porcupine Hills | 49°53' 113°59' | 1527 | 20° south | Elk range & forestry reserve |
| Pyramid Lake | 52°55' 118° 4' | 1103 | 20° south west | forest clearing |
| Ram Mountain | 52°21' 115°47' | 2060 | 30° south | Bighorn Range |
| Ram River Falls | 52° 5' 115°50' | 1585 | flat | open meadows & roadside |
| Ramparts Creek | 51°59' 116°47' | 1445 | flat | roadside ditch |

Source Description of Grass Germplasm Accessions

| Name of Source | Lat. & Long. | Alt. (m) | Slope & Aspect | Description of Site |
| --- | --- | --- | --- | --- |
| Ribbon Creek | 50°56' 115°11' | 1737 | steep south east | abandoned coal strip mine |
| Rock Lake | 53°28' 118°16' | 1676 | steep south | Bighorn winter range |
| Savanna Creek | 50° 9' 114°27' | 1829 | | roadside |
| Sheep River | 50°39' 114°38' | 1676 | 34° south | Bighorn winter range |
| Smoky River | 54° 1' 119°6' | 1372 | 38° south | high river bank slopes |
| Snow Creek Pass | 51°38' 115°51' | 2237 | 40° south west | roadside & alpine meadow |
| Spionkop Ridge | 49°13' 114° 2' | 1829 | steep south | Bighorn winter range |
| Spray Lakes | 50°53' 115°25' | 1402 | flat | roadside |
| Stavely sub-station | 50°10' 113°51' | 1384 | rolling foothills | research station |
| Sulphur Mtn. | 51° 9' 115°35' | 2285 | steep north east | disturbed alpine tundra |
| Sunshine | 51°4' 115°48' | 2286 | 45° south | ski area alpine meadows |
| Tent Mountain | 49°34' 114°4' | 2073 | shallow north east | 25 year old coal slag |
| Vermillion Lakes | 51°11' 115°38' | 1524 | 35° south | Bighorn winter range |

Source Description of Grass Germplasm Accessions

| Name of Source | Lat. & Long. | Alt. (m) | Slope & Aspect | Description of Site |
|---|---|---|---|---|
| Waterton Badlands | 49°6' 113°52' | 1372 | 20° south | undisturbed native prairie |
| Waterton Flats | 49° 4' 113°53' | 1219 | flat | dry roadside |
| Whaleback Ridge | 49°54' 114°10' | 1311 | 20° east | Elk winter range |
| Whistlers Mtn. | 52°50' 118° 9' | 2347 | flat windswept | alpine tundra |
| Whitehorn Mtn. | 51°27' 116° 8' | 1829 | 35° south west | ski area |
| Windsor Ridge | 49°17' 114°16' | 1829 | 35° south west | Bighorn winter range |
| Ya Ha Tinda | 51°45' 115°37' | 1585 | steep south | Elk/Bighorn winter range |
| Yarrow Creek | 49°12' 114° 2' | 1981 | 35° south | Bighorn winter range |