Winterhardiness, Forage Production, and Persistence of Introduced and Native Grasses and Legumes in Southcentral Alaska

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Table of Contents

Summary 4

Introduction 6

- Forage Crops Are Important and Versatile 6
- Why Perennials? 6
- Only Certain Cool-Season Perennial Grasses and Legumes Are Dependably Winterhardy In Alaska 6
- Crop Transfers: Successes and Difficulties 6
- Other Evaluations in Alaska 6
- Objectives and Scope of This Study 7

Experimental Procedures 7

Results and Discussion 7

- Grasses 8
- Legumes 28
- Introduced Legumes 28
- Native Alaskan Legumes 32

Conclusions 33

- Ecotypic Differences Within Species 33
- Latitude-of-Origin and Winter Survival 34
- Winter Climates 34
- Position of Overwintering Plant Parts 35
- Seasonal Distribution of Yields 36
- Pathways of Introductions 37
- The Legume Problem 37
- Taxonomic Note 37

Acknowledgments 37

Literature Cited 37

List of Tables and Figures

Table 1. Seeding-year and subsequent forage yields in Exp. I 9

Table 2. Seeding-year and subsequent forage yields in Exp. II 13

Table 3. Seeding-year and subsequent forage yields in Exp. III 15

Table 4. Seeding-year and subsequent forage yields in Exp. IV 17

Table 5. Common and scientific names of cultivars and strains evaluated and their origins 30

Table 6. Monthly departures from precipitation recorded at the Matanuska Research Farm 35

Figure 1. Comparative winter survival of pumpelly bromegrass, Chinook orchardgrass, and Siberian wildrye (Exp. I) 11

Figure 2. Comparative winter survival of Polar, Regar, and Carlton bromegrasses and arctic wheatgrass (Exp. I) 11
Figure 3. Comparative seeding-year growth and subsequent winter survival of Sherman big bluegrass, Siberian wildrye, Engmo timothy, and Regar meadow bromegrass (Exp. I) 12
Figure 4. Comparative winter survival of Garrison and P-111 creeping foxtails (Exp. II) 20
Figure 5. Third-year growth of violet wheatgrass (Exp. IV) 22
Figure 6. Third-year growth of salt bluegrass (Exp. IV) 24
Figure 7. Third-year growth of bluejoint (Exp. IV) 26
Figure 8. Appearance of native Alaskan legumes—Williams milkvetch, Harrington milkvetch, and alpine sweetvetch 33
Figure 9. Sketches of bunch-type, intermediate, and sod-forming grasses, and species included in each type 36

SUMMARY

This study consisted of four separate field experiments, each of six years duration, conducted at the University of Alaska's Matanuska Research Farm (61.6°N) near Palmer in southcentral Alaska. Objectives were to compare winterhardiness, forage productivity, and general persistence of introduced grass and legume species, strains, and cultivars from various world sources with Alaska-developed cultivars and native Alaskan species.

Twenty-one species of grasses compared (Tables 1 through 4) included eight native to Alaska, four Alaska cultivars, and numerous introduced cultivars and regional strains (one to seven per species) from North America and northern Europe. Legumes included two species of biennial sweetclover and nine species of perennials, six introduced and three native. Each experiment was harvested once near the end of the seeding year and twice annually for five years thereafter.

• All strains evaluated within the following species were inadequately winterhardy for dependable use in this area: orchardgrass (scientific names of species appear in Table 5), tall fescue, meadow fescue, big bluegrass, meadow bromegrass, and reed canarygrass.

• All of the above non-hardy species except reed canarygrass are bunchgrasses, with overwintering tissues relatively exposed to winter stresses. (Information more recent than these experiments has revealed that certain strains of big bluegrass and reed canarygrass from more northern origins than those included in this study are markedly more winterhardy in this area.)

• Grass species marginally winterhardy, or within which individual strains differed widely in hardiness, included timothy, meadow foxtail, creeping foxtail, Russian wildrye, and slender wheatgrass.

• The most winterhardy, productive, and persistent introduced grass cultivars were the northernmost-adapted strains of smooth bromegrass, creeping foxtail, red fescue, and Kentucky bluegrass.

• All of those most winterhardy introductions were rhizomatous, suggesting that this growth characteristic, with the protection afforded by subterranean positioning of overwintering tissues, is advantageous for winter survival of introductions here.

• Alaska cultivars Nugget Kentucky bluegrass, Arctared red fescue, and Polar bromegrass were among the most winterhardy, productive, and persistent cultivars. The relatively cool growing seasons of this area promote continuous, active, season-long growth, circumventing the unproductive mid-season dormancy typical of these species, especially Kentucky bluegrass, when they are grown at more southern latitudes where summer temperatures are considerably higher.

• Native Alaska strains of bluejoint, arctic wheatgrass, violet wheatgrass, and pumpelly bromegrass were extremely winterhardy and were surpassed in forage production only by the three Alaska cultivars (Nugget, Arctared, Polar) and introduced Garrison creeping foxtail.

• Native Alaska strains of Siberian wildrye, polargrass, salt bluegrass, and slender wheatgrass also were extremely winterhardy but were somewhat lower in total 6-year forage yield than the other native species because (a) native Siberian wildrye and slender wheatgrass were relatively short-lived; they would have rated higher in 2- to 4-year tests but produced little forage in the last years of these 6-year experiments as their stands gradually deteriorated, and (b) polargrass and salt bluegrass, species favored by abundant soil moisture, produced forage at less than full potential due to below-normal precipitation during five of the nine years during these experiments.

• The proportion of total annual forage yield in the first and second harvests each year was influenced by four major factors: (a) date of cuttings, especially the first, which determines the relative length of the growth period prior to each cutting, (b) occurrence of winter injury which reduced first-cutting yields because plants produced less herbage while they were recovering from injury, (c) early-season moisture deficits that sometimes markedly reduced first cuttings, and (d) the inherent growth characteristics of the several grass species.

• Concerning factor (d) above, approximate proportions of total annual yield in first and second cuttings, respectively, of the very winterhardy strains were: Kentucky bluegrass ½:½; Polar bromegrass, Arctared red fescue, and Garrison creeping foxtail ⅔:⅓; and seven native Alaskan grasses (pumpelly brome, bluejoint, polargrass, Siberian wildrye, and slender, arctic, and violet wheatgrasses) ¾:¼.

• Legumes included in the four experiments (a total of 25 plantings) generally compared unfavorably in winter survival and/or as forage producers with the most winterhardy and productive grasses. All seedings of the perennials alsike clover (2), sainfoin (3), red clover (1), and cicer milkvetch (1) invariably winterkilled totally the first winter.

• The introduced legume cultivars Vernal alfalfa and Erector and Arctic sweetclover winterkilled totally the first winter except for Arctic surviving with 29% stand in one experiment.

• Of three alfalfa strains, an Alaska line of the yellow-flowered Siberian type was the most winterhardy, surviving in all three experiments where included, until stands were terminated with an herbicide; however, forage yields were generally mediocre.

• Native Alaskan legumes (alpine sweetvetch, Williams and Harrington milkvetch) survived winters well but produced little forage. This deficiency suggests that their good winterhardiness and N-fixing attributes suit them better for revegetation purposes than as forages.

• The dominant factor contributing to generally poor winter survival of most perennial grasses and legumes introduced from more southern latitudes is believed to be their poor adaptation to subarctic winter-hardening conditions during late summer and early autumn, and therefore failure to develop timely freeze tolerance to their full genetic capacity. Those introduced grasses and legumes ordinarily survive winters well in their more southern areas of adaptation but are deficiently winterhardy at the high latitude of Alaska's Matanuska Valley where winter temperatures generally are no more severe, and sometimes less so, than occur at their lower-latitude origins.

• Future potentially useful plant introductions to Alaska from other north-latitude areas should travel directly from origin to Alaska to maintain intact the genetic constitution that confers optimal adaptation to northern climatic effects and patterns. To first culture such introductions for a time at lower latitudes selects away from and discards genetic/physiologic elements critical to north-latitude adaptation.

• Several plant introductions possessing optimal adaptation for the variable and transitional coastal/continental climate of southcentral Alaska have derived from other circumpolar sources such as Iceland and northern Norway that experience relatively analogous winter climates (and reciprocal transfers have been equally successful). Extension of this logic suggests that, for ideal winterhardiness and adaptation to the quite different continental-type winter climate of interior Alaska, introduced plant strains ideally should be sought in other large, north-latitude land masses where similar continental climatic patterns prevail.

• These results summarizing winterhardiness, adaptation, and persistence of numerous grass and legume ecotypes, regional strains, and cultivars, grown for forage in Alaska, should be helpful not only to farmers and ranchers but also to individuals selecting plant materials for various non-farm uses wherein adapted perennial plant cover is required.

Introduction

Forage Crops Are Important and Versatile

Forages provide the dominant portion of the feed base for livestock agriculture in Alaska as elsewhere. Because of this importance, an assured supply of forage must be produced or purchased to be available when needed to meet year-around feeding requirements. Forages are utilized in various ways, including fresh consumption as pasture or green-chop, in preserved forms including hay (baled or loose), haylage, silage, and as compressed wafers and cubes.

The choice of perennial forage species to be grown, as well as choice of the specific cultivars (varieties) within a species, involve crucial decisions for Alaska growers, for many forages that grow well elsewhere are not dependably winterhardy in Alaska. Moreover, one cannot simply rely entirely on what is available from seed suppliers, for some Alaska seed merchants unfortunately continue to stock and sell seed of crops poorly adapted to Alaska conditions.

Why Perennials?

Both annual and perennial forages can contribute materially to the total livestock feeding needs on Alaska farms and ranches. Several considerations govern the amounts of each to be grown. Utilization of dependably winterhardy, productive perennial species can circumvent many of the disadvantages of annual forages that include annual costs of seed and establishment, dangers of soil losses to erosion, annual problems and costs of weed control, and the possibilities of seeding failures from moisture deficit, poor weed control, or insect damage.

Moreover, properly managed stands of adapted perennials can remain productive for many years. Toward this end, it is of paramount importance that growers select the most winterhardy and productive perennial forage species and strains to fulfill their forage needs.

In other utilization avenues, grasses and legumes are used for various permanent revegetation purposes including soil stabilization, turf, roadside protection and beautification, and other non-forage purposes in Alaska; they too should be adapted, winterhardy, and persistent (Klebesadel 1973; Mitchell 1979b, 1982b, 1987b). Failure to select strains ideally adapted for the purposes intended can result in substandard performance or costly, repeated seedbed preparation and reseeding.

Only Certain Cool-Season Perennial Grasses and Legumes Are Dependably Winterhardy In Alaska

The forage crops of greatest concern to most growers in Alaska, and the subject of this study and report, are the cool-season, perennial forage grasses and legumes. Unfortunately, however, many forage strains and cultivars adapted for good performance in other cool-season areas do not achieve adequate levels of winterhardiness for dependable use at the high latitudes of Alaska.

Within this large group, some species are totally unsuited for use as perennials at our northern latitudes. Within other species, however, a great range of adaptation and, therefore, suitability exists. Although some cultivars and regional strains within such a species are inadequately winterhardy for use in Alaska, other more northern-adapted cultivars or strains *within the same species* may be dependably winterhardy, productive, and well-suited for culture in this northernmost state.

Crop Transfers: Successes and Difficulties

Many ecotypes, regional strains, and cultivars within numerous perennial grass and legume species have been transferred successfully over great east-west (longitudinal) distances from European and Asiatic origins to become important elements in North American agriculture. In fact, most of the major forage grasses and legumes in North American agriculture have been introduced from Old World sources. These include smooth bromegrass, timothy, orchardgrass, tall fescue, crested wheatgrass, alfalfa, red clover, the lespedezas, and many others.

In contrast, attempts to transfer temperate-adapted perennial forages northward a much lesser distance from the conterminous 48 states and southern Canada to subarctic Alaska often have led to disappointing performance, with many of those crops failing to survive Alaskan winters.

This is because crops moved longitudinally for great distances around the world, and grown at near-similar latitudes and altitudes, are subjected in their new locations to a near-similar annual pattern of photoperiod/nyctoperiod (daily duration of light/dark cycles) and the critical interrelationship of that seasonal light/dark pattern with the termination of the growing season.

In contrast, plants taken northward a few hundred miles, as from temperate-zone areas (e.g., the 48 conterminous states) to Alaska, are exposed abruptly in their new growth environment to unaccustomed late-summer and autumn conditions that deter adequate physiologic preparation for winter stresses (Hodgson 1964, Klebesadel 1971a, 1985c, 1992b, 1992c, 1993a, 1993e). Consequently, those crops are not induced to undergo full preparation for winter and can be badly injured or killed by winter stresses in Alaska that often are no more severe, and sometimes less so, than in their area of origin.

Other Evaluations in Alaska

Irwin (1945) summarized nearly a half-century of agronomic crop trials conducted prior to 1945 at seven widely dispersed early experiment stations in Alaska (Sitka, Kodiak, Kenai, Copper Center, Rampart, Fairbanks, and Matanuska; only the latter two continue in operation). Those evaluations of mostly introduced grasses and legumes provide some general insights on the performance of numerous species under the different sets of climatic conditions prevalent at those seven widely separated Alaska locations. However, those early tests often were rudimentary observation-type trials, of short term, with strains from unstated or unknown origins, and certainly without benefit of newer crop cultivars or more recently determined optimum rates of fertilizer use.

Some more recent reports have documented performance in Alaska (including winterhardiness, forage yield, etc.) of numerous strains within certain species with emphasis on relating latitudinal adaptation to field results here; these have included Kentucky bluegrass and red fescue (Klebesadel 1984a, 1993c; Klebesadel *et al.* 1964), bromegrass (Klebesadel 1970, 1993a,1994a; Klebesadel and Helm 1992a), timothy (Klebesadel 1970; Klebesadel and Helm 1986; Mitchell 1989), wheatgrasses (Klebesadel 1991; Klebesadel and Helm 1992b), reed canarygrass (Klebesadel and Dofing 1991), wildryes (Klebesadel 1993d), alfalfa (Klebesadel 1971b, 1992a), sweetclover (Klebesadel 1992b, 1992c, 1994c), and other legumes (Klebesadel 1971b, 1980, 1993e).

Recently Mitchell (1982a, 1986, 1987a) has reported informative experimental comparisons of forage yields and quality of numerous strains of perennial grasses in southcentral Alaska with emphasis on native Alaska species.

Objectives and Scope of This Study

No published reports exist comparing forage production, winterhardiness, and persistence over several years of a broad array of perennial grass and legume species, cultivars, and strains from various world sources and evaluated in several replicated experiments under uniform experimental conditions in subarctic Alaska. The purpose of the present study was to fill that informational void, comparing introduced grass and legume cultivars and strains from elsewhere in North America and from northern Europe with cultivars developed in Alaska and also with several native Alaskan species.

Criteria for comparisons included winterhardiness, forage yields, and duration of stand persistence. Results reported here are from four separate, 6-year field experiments, representing 24 harvest-years, and conducted over a period of nine years at the University of Alaska's Matanuska Research Farm (61.6°N) near Palmer in the Matanuska Valley of southcentral Alaska.

Experimental Procedures

Experimental sites were selected for good surface drainage and were fully exposed to maximum winter stresses that occur locally (Klebesadel 1974). Soil pH in the field areas used ranged from 5.8 to 6.2. In each experiment, commercial fertilizer disked into plowed Knik silt loam (Typic Cryochrept) seedbeds before planting supplied nitrogen (N), phosphorus (as P_2O_5), and potassium (as K_2O) at 32, 128, and 64 lb/A, respectively.

Field sites used were fully exposed to winter winds that removed insulating snow cover, thereby exposing plants to dehydration stress and to prevailing air temperatures, including the full effects of freeze-thaw stresses common during typical winters locally (Dale 1956; Klebesadel 1974; Watson 1959).

One or more cultivars, regional strains or native collections were planted within each of the species evaluated; entries included in Exps. I through IV appear in Tables 1 through 4, respectively. Scientific names of species and origins of strains are listed in Table 5. Grasses and legumes were broadcast-seeded without companion crops in plots 5 feet wide and from 15 to 20 feet long in the various experiments. Appropriate bacterial (*Rhizobium*) inoculants were mixed with legume seed immediately prior to planting. Randomized complete block experimental designs were utilized with three replications. Experiment I was planted 15 June 1967, Exp. II on 18 June 1968, Exp. III on 6 June 1969, and Exp. IV on 25 June 1970.

A pre-emergence application of dinoseb was sprayed in water solution uniformly onto each seedbed one to four days after planting to control broadleaf weeds. In Exps. II, III, and IV, however, plots of bluejoint and polargrass were covered with plastic sheets during spraying because seedlings of those species showed evidence of spray injury in Exp. I and stands were thinned somewhat; in Exps. II, III, and IV, those plots were hand-weeded.

Each experiment was harvested once near the end of the seeding-year growing season and twice during each of the subsequent five years on dates that appear in the tables. All forage harvests were conducted as described earlier (Klebesadel 1969b). All forage yields are reported on the oven-dry basis (140°F).

Each spring following establishment, commercial fertilizer topdressed in late March or early April and before initiation of spring growth supplied N, P_2O_5, and K_2O at 126, 96, and 48 lb/A, respectively. Ammonium nitrate supplying N at 80 lb/A was topdressed one to three days after first-cutting forage harvest each year.

Results and Discussion

Several years of below-normal precipitation occurred during the terms of the four experiments reported here (Table 6). Five of the nine years concerned were below normal, resulting in curtailed forage yields below what would have been produced with a more adequate, normal supply of moisture.

To offset those moisture deficits to a minor extent, some modest amounts of supplemental sprinkler irrigation were supplied in certain of those years. However, those applications generally served as emergency measures after moisture stress became conspicuous, so forage yields were below what would have been produced with more abundant and timely precipitation.

Harvest dates usually were somewhat later than the times considered ideal for best-quality forage here. First-cuttings were delayed to permit maximum recovery of winter-injured strains prior to harvest; second-cutting dates were delayed to near the end of the growing season to avoid possibly critical dates of late summer and autumn harvest that could differentially disadvantage certain grasses. No quality characteristics of forages are reported.

The four field experiments were not identical as to species and strains of grasses and legumes evaluated. Species are discussed in generally the same order as they appear in the tables. To a considerable extent, common names of species are used in this report.

Prior to discussion of experimental results with each species, brief background remarks describe characteristics, origin, uses elsewhere, and previous performance in Alaska if earlier evaluations have been reported.

Certain portions of data have been extracted from this study and combined with other experimental results on crop performance to present detailed earlier reports on certain grass species. However, for unity of the total study, those data are retained in this report to summarize completely all strains compared, thus permitting the full range of comparisons among all strains evaluated.

Grasses

SMOOTH BROMEGRASS is native to Europe and Asia. It was first introduced into North America about 1884, is widely used in mid-to-northern U.S. and in Canada (Carlson and Newell 1985; Smith *et al*. 1986), and has become the most dependable and most widely used forage grass in Alaska. It is a tall-growing, long-lived, sod-forming species with good leafiness, and it responds well to fertilizers (Branton *et al*. 1966; Laughlin 1953, 1962, 1963). Bromegrass seeds are fairly large, seedling vigor is good, and stands are relatively easily established and eradicated when desired. This grass serves well as harvested forage for hay or silage, and provides excellent pasture as well (Brundage and Sweetman 1958, 1964).

Irwin (1945) reported generally good performance of smooth bromegrass in early trials at several experiment stations in Alaska, and Alberts (1933) rated it second to slender wheatgrass for use in the Matanuska Valley; origin of seed and adaptation of bromegrass strains or types evaluated were not reported.

"Northern" and "southern" types of bromegrass are used in the U.S. and Canada, and many cultivars have been developed within each type (Carlson and Newell 1985; A.A. Hanson 1972; Smith *et al*. 1986). The northern and southern types apparently correspond to groupings in Russia termed "meadow" and "steppe" types, respectively (Knowles and White 1949; Wilsie 1962). The two types differ in "ecological preferences" and in several morphological characteristics.

In addition to the Alaska cultivar Polar, six other cultivars were included in the four experiments: two of the northern type (Carlton from Saskatchewan, Frigga from Sweden), two intermediate between the two types (Magna from Saskatchewan, Manchar from the U.S. Pacific Northwest), and two of the southern type (Redpatch from Ontario and Achenbach from Kansas).

The genetic composition of Polar is predominantly derived from hybridization between smooth bromegrass and native North American pumpelly bromegrass (Hodgson *et al*. 1971a; Wilton *et al*. 1966). Eleven of the 16 clones that comprise this cultivar are hybrid; the other five derived from smooth bromegrass. Polar's genetic background results in somewhat less uniformity of plants than in other cultivars, but also confers excellent winterhardiness, due to the northern adaptation of the pumpelly germplasm.

Polar was consistently the highest yielding bromegrass in all four experiments (Tables 1, 2, 3, 4). However, other cultivars that produced 6-year total yields not significantly lower than Polar included Carlton, Magna, Manchar, and Frigga. Only one of the winters during these tests (1970-71) presented the extreme stresses that Polar and native Alaskan pumpelly brome survive much better than the introduced brome cultivars (Wilton *et al*. 1966).

In contrast to the good performance of the above-mentioned cultivars, the southern-type cultivars Redpatch and Achenbach (Tables 2, 3, 4) were very deficient in winterhardiness and are poor choices for use in Alaska. No southern-type cultivars or strains of smooth bromegrass evaluated in these or in other tests in this area (Klebesadel 1970, 1994a; Klebesadel and Helm 1992a) have been adequately winterhardy for use in Alaska.

PUMPELLY BROMEGRASS is a sod-forming, long-lived perennial native in North America (Hitchcock 1951; Hulten 1968); it hybridizes in nature with the closely related, introduced smooth bromegrass when they come into contact (Elliott 1949). Various agronomic characteristics of pumpelly bromegrass have been reported earlier (Klebesadel 1984b). An Alaska strain was included in all four experiments (Tables 1 through 4).

Native Alaskan pumpelly brome is extremely winterhardy (Fig. 1), more so than Polar or the hardiest introduced smooth brome cultivars (Klebesadel 1993a, 1994a). This was most apparent in these experiments in the generally higher first-cut forage yields of pumpelly brome in 1971 after the stressful winter of 1970-71 (Tables 1 through 4). In years following moderate winters, yields of pumpelly approximated those of the hardiest smooth bromes. However, second-cut yields of pumpelly brome often were significantly lower than those of the smooth bromegrasses. Persistence of stands of this native brome was excellent, with continued high yields in the sixth (final) year of all experiments.

MEADOW BROMEGRASS is native in Asia Minor; it is classed as a bunchgrass but with some vegetative spreading (Foster *et al*. 1966). The introduction from which the cultivar Regar was selected was collected in northeastern Turkey (ca. 41°N) in 1949. Regar has been winterhardy and a good forage producer in tests in the Pacific Northwest states (Foster *et al*. 1966) and at about 50°N in southwestern Saskatchewan (Lawrence and Ratzlaff 1985).

Regar was included in Exps. I, II, and IV; it winterkilled the first winter in Exps. I (Figs. 2, 3) and IV, and during the third winter in Exp. II after sustaining severe injury during the first two winters in that experiment. The relatively southern origin of this species and the poor performance of Regar in these tests indicate that it is a poor choice for use in this area.

TIMOTHY is highly valued as a forage grass and is one of the dominant forage species in cool humid areas of the world (Childers and Hanson 1985; Smith *et al*. 1986). It was introduced into the American colonies from Europe no later than the early 1700's. Timothy is somewhat more tolerant of acidic soils than bromegrass; therefore it is favored over bromegrass on areas of the Kenai Peninsula where soils tend to be more acidic than at this location. The relatively shallow root system of timothy, however, renders it more susceptible to drouth stress than bromegrass.

Irwin (1945) summarized at least 27 evaluation plantings of timothy between 1902 and 1942 at seven widely separated Alaska Territorial experiment stations with the statement "Trials in most sections of Alaska show that it is not well-adapted to our soil and climatic conditions." Disadvantages listed for timothy included winterkill, shortness of growth, low yields, poor competitiveness, late spring growth, poor recovery after cutting, sensitivity to low-moisture conditions, and poor

Table 1. Seeding-year and subsequent forage dry-matter yields of grasses and legumes from various world origins during a 6-year test at the Matanuska Research Farm. Experiment I, planted 15 June 1967.

Species and strains	1967	1968		1969		1970		1971		1972		Six-year total
	2 Oct	25 June	18 Sep	25 June	15 Oct	2 July	14 Sep	7 July	23 Sep	6 July	25 Sep	
	Harvest dates — Tons oven-dry forage per acre											
Smooth bromegrass (*Bromus inermis*):												
*Polar[1]	1.62 b-h[2]	2.12 cd	1.40 c-f	0.54 c	0.56 bc	1.42 abc	1.34 bc	0.92 b	1.88 bcd	2.95 abc	0.96 d	15.71 ab
Carlton	1.60 d-h	1.40 ef	1.55 bcd	0.52 c	0.72 ab	1.56 ab	1.41 b	0.42 c	2.01 bc	2.59 cd	1.31 c	15.09 abc
Manchar	1.67 b-g	1.17 fg	1.44 b-e	0.61 bc	0.68 ab	1.23 a-d	1.32 bcd	0.40 c	1.70 cde	2.37 de	1.54 b	14.13 bc
Pumpelly bromegrass (*Bromus pumpellianus*):												
*Native	0.37 klm	2.30 c	1.37 c-f	0.88 a	0.31 de	1.32 a-d	1.09 b-e	1.42 a	1.45 c-f	3.05 abc	0.41 f	13.97 bc
Meadow bromegrass (*Bromus biebersteinii*):												
Regar	1.43 f-j(WK)[3]	–	–	–	–	–	–	–	–	–	–	1.43 j
Timothy (*Phleum pratense*):												
Engmo	1.62 c-h	0.33 ij	1.86 b	Tr[4]	Tr	0.19 ij	0.44fg(WK)	–	–	–	–	4.44 hi
Orchardgrass (*Dactylis glomerata*):												
Chinook	1.88 bcd(WK)	–	–	–	–	–	–	–	–	–	–	1.88 j
Creeping foxtail (*Alopecurus arundinaceus*):												
Garrison	1.76 b-f	1.96 cd	1.01 efg	0.30 def	0.42 cd	1.01 cde	1.11 b-e	1.10 ab	2.38 ab	2.88 bcd	1.00 d	14.93 abc
P-111	1.23 hij	0.34 ij	0.51 hi	0.19 fg	0.09 fg	0.48 ghi	1.00 b-e(WK)	–	–	–	–	3.84 i
Meadow foxtail (*Alopecurus pratensis*):												
Oregon comm.	1.32 g-j	0.84 gh	0.84 gh	0.17 fg	0.31 de	0.31 hij	0.81 ef(WK)	–	–	–	–	4.60 hi
Reed canarygrass (*Phalaris arundinacea*):												
Frontier	2.66 a	Tr	1.33 def(WK)	–	–	–	–	–	–	–	–	3.99 i
Superior	1.85 b-e(WK)	–	–	–	–	–	–	–	–	–	–	1.85 j
Red fescue (*Festuca rubra*):												
*Arctared	1.10 ij	1.77 de	1.81 bc	0.49 cd	0.80 a	0.97 de	1.31 bcd	1.27 a	1.57 c-f	1.98 ef	1.70 b	14.77 abc
Kentucky bluegrass (*Poa pratensis*):												
*Nugget	1.04 j	1.97 cd	2.32 a	Tr	0.55 bc	0.90 def	2.07 a	0.84 b	2.70 a	1.79 f	2.10 a	16.28 a
Big bluegrass (*Poa ampla*):												
Sherman	1.39 f-j(WK)	–	–	–	–	–	–	–	–	–	–	1.39 j
Siberian wildrye (*Elymus sibiricus*):												

Table 1. Continued

Species and strain	1967	1968		1969		1970		1971		1972		Six-year total
	2 Oct	25 June	18 Sep	25 June	15 Oct	2 July	14 Sep	7 July	23 Sep	6 July	25 Sep	
	Tons oven-dry forage per acre											
*Native	0.64 k	3.53 a	1.41 c-f	0.79 ab	0.16 efg	1.21 bcd	0.89 c-f	0.05 d	0.45 h	2.89 a-d	Tr	12.02 de
Russian wildrye (*Elymus junceus*):												
Sawki	0.49 kl	0.15 ij	0.28 ij	0.47 cde	0.20 efg	1.56 ab	1.05 b-e	0.92 b	1.13 efg(WK)	–	–	6.25 g
Slender wheatgrass (*Agropyron trachycaulum*):												
Primar	2.04 b(WK)	–	–	–	–	–	–	–	–	–	–	2.04 j
Arctic wheatgrass (*Agropyron sericeum*):												
*Native	0.59 kl	2.79 b	1.49 bcd	0.32 def	0.29 def	1.02 cde	0.85 def	1.31 a	1.38 def	3.05 abc	0.32 f	13.41 cd
Polargrass (*Arctagrostis arundinacea*):												
*Native	Tr	1.52 ef	1.19 d-g	0.53 c	Tr	0.70 e-h	1.12 b-e	1.13 ab	1.06 fg	3.47 a	0.63 e	11.35 e
Bluejoint (*Calamagrostis canadensis*):												
*Native	Tr	0.37 ij	0.50 hi	0.30 def	Tr	0.55 f-i	0.98 b-e	1.27 a	Tr	3.42 ab	0.80 de	8.19 f
Siberian alfalfa (*Medicago falcata*):												
*Alaska strain	0.38 klm	0.61 hi	0.97 fg	0.64 bc	0.17 efg	1.63 a	1.39 b (K)[5]	–	–	–	–	5.79 gh
Alfalfa (*Medicago sativa*):												
*A-Syn.B	1.58 d-h(WK)	–	–	–	–	–	–	–	–	–	–	1.58 j
White sweetclover (*Melilotus alba*):												
*AK-Syn.1	2.02 bc(WK)	–	–	–	–	–	–	–	–	–	–	2.02 j
Sainfoin (*Onobrychis viciaefolia*):												
Europe comm.	1.45 e-i(WK)	–	–	–	–	–	–	–	–	–	–	1.45 j
Cicer milkvetch (*Astragalus cicer*):												
P-498	0.22 lm(WK)	–	–	–	–	–	–	–	–	–	–	0.22 j
Williams milkvetch (*Astragalus williamsii*):												
*Native	Tr	Tr	Tr	Tr	Tr	1.17 bcd	Tr (K)	–	–	–	–	1.17 j

*Of Alaskan origin (either a cultivar or breeder's strain selected in Alaska, or a species native to the state). All unmarked strains are introduced; origins discussed in text.
[1]Predominantly of hybrid origin (*B. inermis x B. pumpellianus*).
[2]Within each column, values followed by a common letter are not significantly different (5% level) using Duncan's Multiple Range Test.
[3]No further yields; stands winterkilled completely.
[4]Trace amount of herbage insufficient for harvestable yield.
[5]Stands of this legume killed with broadleaf herbicide sprayed on all plots in June 1971 to combat weed invasion in some thinned grass stands.

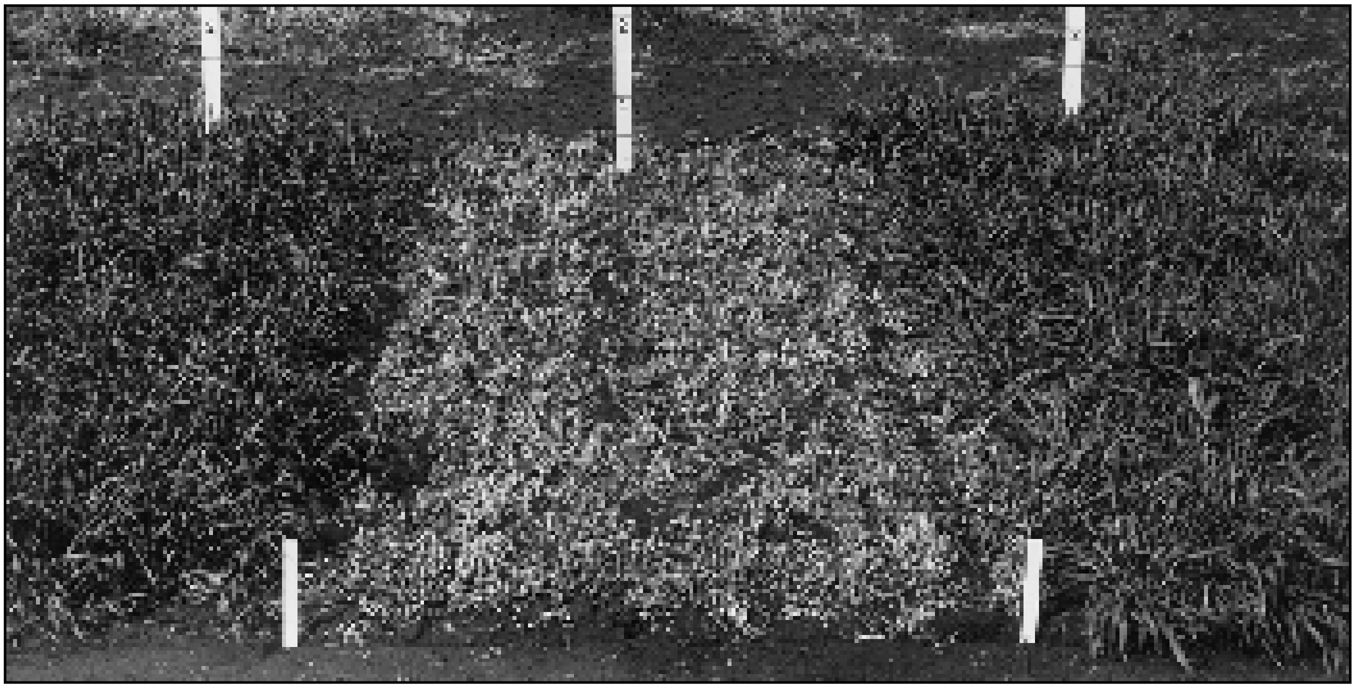


Figure 1. Comparative winter survival in Exp. I of (left) *native Alaskan pumpelly bromegrass,* (center) *Chinook orchardgrass = dead, and* (right) *native Alaskan Siberian wildrye. Photo 31 May, plots seeded 15 June of the previous year. Numbers on tall stake in center of each plot indicate height in feet.*

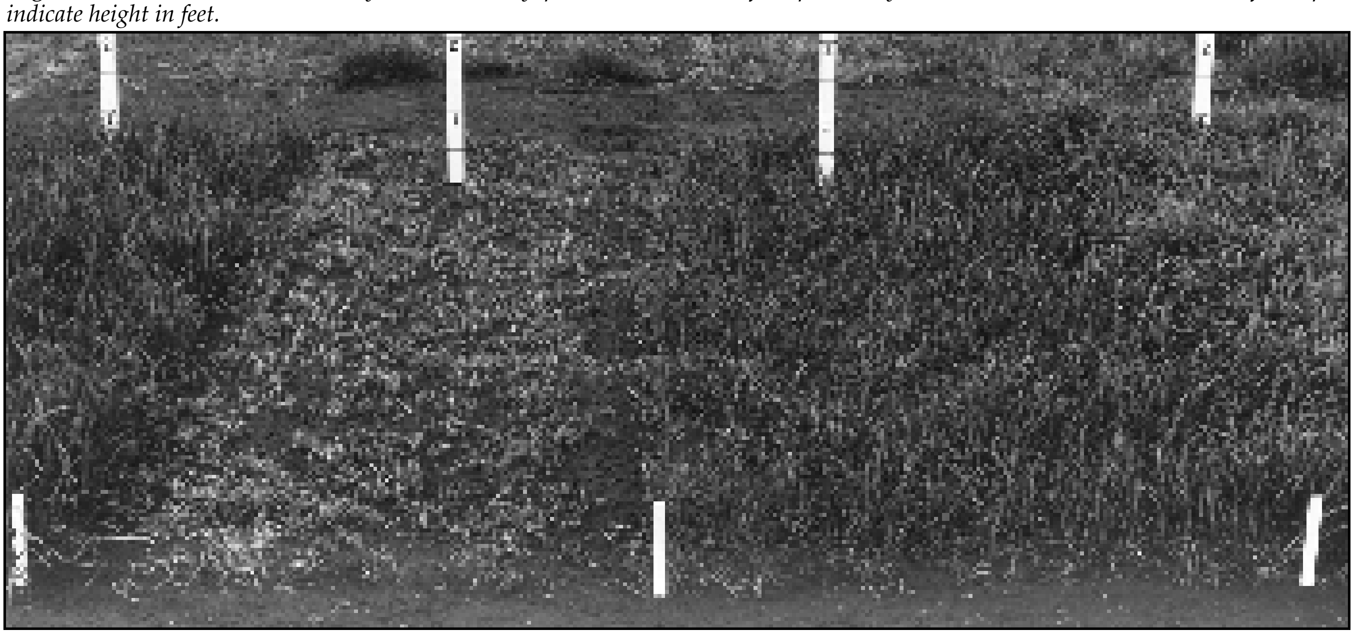


Figure 2. Comparative winter survival in Exp. I of (far left) *Polar bromegrass,* (center left) *Regar meadow bromegrass = dead,* (center right) *Carlton smooth bromegrass, and* (far right) *native Alaskan arctic wheatgrass. Photo 31 May, plots seeded 15 June of previous year. Numbers on tall stake in center of each plot indicate height in feet.*

persistence. Origin or adaptation of the strain(s) evaluated were not recorded, but best results were obtained at Kenai where winter stresses are less severe than at most of the other stations; there it was judged to be "... one of the best of the cultivated varieties for this district."

There exists a greater diversity of timothy types and latitudinal dispersal of the species in Europe, the area of its origin, than in North America. Moreover, the many commercial cultivars developed in North America (Childers and Hanson 1985; A.A. Hanson 1972) have been selected for latitudes and climates quite different from Alaska's. Consequently, the best strains for use in Alaska derive from far-northern areas of Europe, particularly Norway and Iceland (Klebesadel 1970, 1992b, 1993e; Klebesadel and Helm 1986; Klebesadel and Dofing 1991; Mitchell 1989).

In all, nine cultivars and numbered strains from the conterminous U.S., Canada, Sweden, Finland, Iceland, and Norway were compared in these tests (Tables 1, 2, 3, 4). Stresses during the winter of 1970-71 clearly were devastating to all timothy strains in all four tests, as noted by total winterkill of many cultivars and greatly reduced first-cutting yields in 1971 of injured but surviving strains.

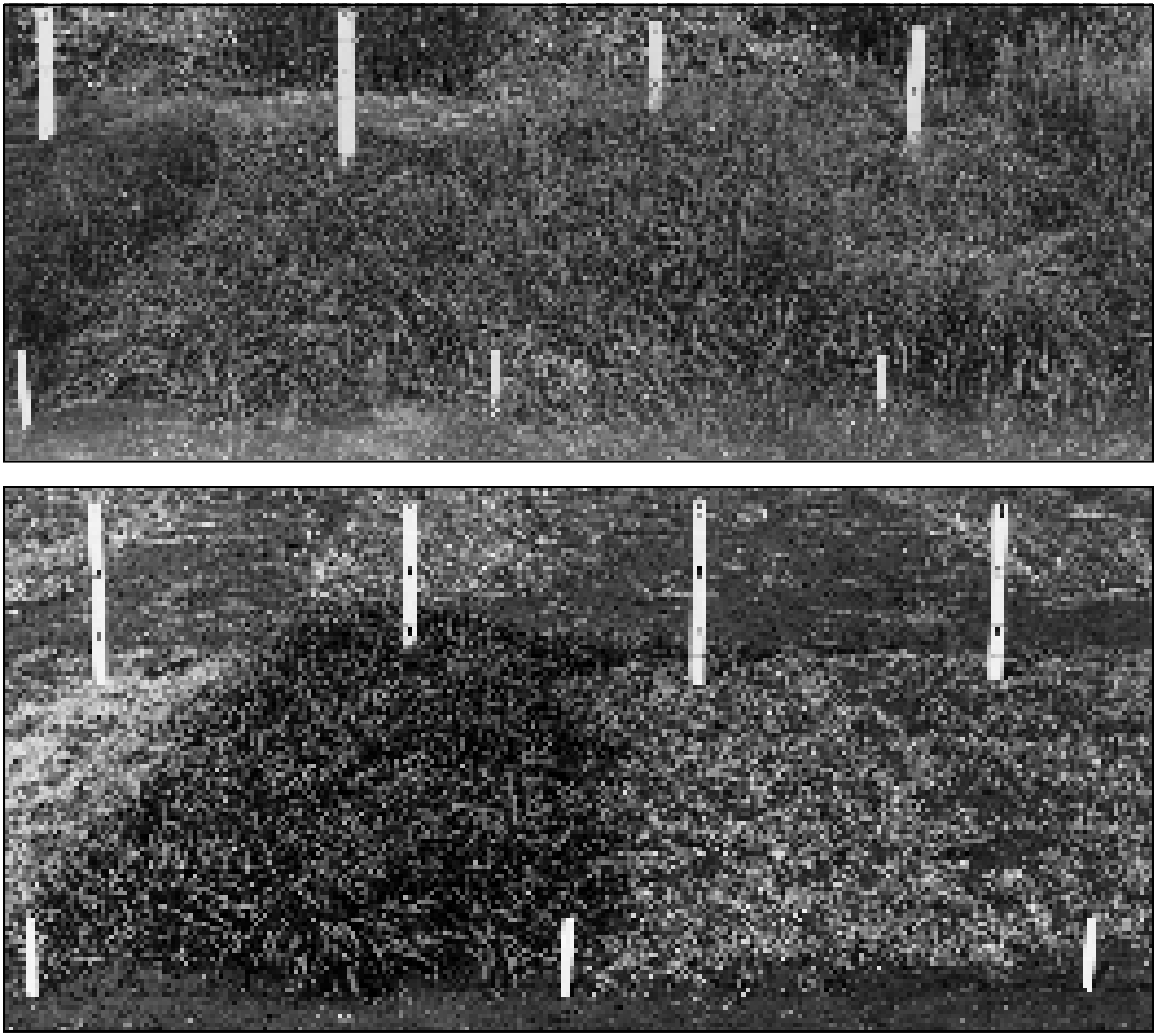


Figure 3. (Upper photo)*: Comparative seeding-year growth on 2 October of one native Alaskan grass and three introduced cultivars in Exp. I seeded 15 June.* (Lower photo)*: Comparative winter survival of the same grasses photographed 31 May of the following year. (*Far left*) Sherman big bluegrass = dead,* (center left) *native Alaskan Siberian wildrye,* (center right) *Engmo timothy = severely injured, (*far right*) Regar meadow bromegrass = dead. Numbers on tall stake in center of each plot indicate height in feet.*

Of all strains evaluated, Engmo from northern Norway and Korpa from Iceland were clearly the most winterhardy (Tables 3, 4). Those cultivars should be preferred for use in Alaska when timothy is to be grown, even though their total forage yields were surpassed by several other, more winterhardy grasses. Despite the superior winterhardiness of Engmo, it was severely injured during the first winter of Exp. I (Fig. 3) and Exp. II (Tables 1, 2); stands succumbed totally during the fourth winter in Exp. I and during the third winter in Exp. II. Following mild winters, and with adequate soil moisture, full stands of the hardiest timothies can produce forage equal to yields obtained from most adapted bromes and other highest-yielding grasses (Table 3, 1970 yields).

As noted with bromegrass, there was a tendency for the most winterhardy cultivars to be lower in seeding-year forage yield; this was apparent in Exps. III and IV (Tables 3, 4) where more timothy strains were compared than in Exps. I and II.

ORCHARDGRASS, native to Europe and called "cocksfoot" in Britain, is a cool-season, bunch-type grass highly valued for forage and pasture in regions where it is adapted (Jung and Baker 1985; Smith *et al*. 1986). Orchardgrass has been grown in the U.S. for over 200 years and its area of principal use is in the midwest states, the mid-Atlantic region, and the northeastern states. Numerous improved cultivars have been developed in the U.S. and Canada (A.A. Hanson 1972; Jung and Baker 1985).

Orchardgrass was seeded in Alaska as early as 1902 at the Sitka, Kenai, and Copper Center experiment stations, and later at the Rampart, Fairbanks, and Matanuska stations (Irwin 1945). It died during the first winters at the Fairbanks and Matanuska stations. Orchardgrass

Table 2. Seeding-year and subsequent forage dry-matter yields of grasses and legumes from various world origins during a 6-year test at the Matanuska Research Farm. Experiment II, planted 18 June 1968.

Species and strains	Harvest dates: 1968	1969		1970		1971		1972		1973		Six-year total
	26 Sep	7 July	14 Oct	6 July	15 Sep	7 July	24 Sep	10 July	2 Oct	9 July	7 Sep	
	Tons oven-dry forage per acre											
Smooth bromegrass (*Bromus inermis*):												
*Polar[1]	0.79 f-m[2]	0.69 c-i	0.71 de	1.65 b-e	1.41 d-i	0.60 ghi	2.14 bc	2.52 cd	0.51 cd	3.06 a	0.90 bcd	14.98 abc
Carlton	0.97 d-j	0.79 b-g	0.70 de	1.58 b-e	1.52 c-i	0.67 gh	1.98 b-f	1.93 de	0.65 c	2.93 ab	1.17 ab	14.89 abc
Manchar	1.08 a-h	0.69 c-i	0.72 de	1.26 c-h	1.36 e-i	0.52 hij	1.58 c-i	1.24 ef	0.65 c	2.50 abc	1.21 ab	12.81 cde
Redpatch	1.19 a-g	0.52 g-j	0.65 de	0.79 h-m	1.90 a-f	0.02 l	1.00 i-l(WK)[3]	–	–	–	–	6.07 jkl
Pumpelly bromegrass (*Bromus pumpellianus*):												
*Native	0.22 n-r	0.90 a-e	0.26 h-k	1.70 a-d	1.18 g-j	1.15 de	0.91 jkl	3.55 ab	0.14 e	2.89 ab	0.53 ef	13.43 a-e
Meadow bromegrass (*Bromus biebersteinii*):												
Regar	0.77 f-m	0.50 g-j	0.67 de	0.49 k-p	1.42 d-i(WK)	–	–	–	–	–	–	3.85 l-r
Timothy (*Phleum pratense*):												
Engmo	1.52 abc	0.37 hij	0.14 jkl	0.43 l-p	1.67 b-g(WK)	–	–	–	–	–	–	4.13 k-q
Orchardgrass (*Dactylis glomerata*):												
Chinook	1.17 a-g(WK)	–	–	–	–	–	–	–	–	–	–	1.17 qrs
Creeping foxtail (*Alopecurus arundinaceus*):												
Garrison	0.76 f-m	0.50 g-j	0.53 efg	1.65 b-e	1.71 b-g	1.43 cd	2.05 b-e	3.02 abc	0.57 cd	3.00 ab	0.84 cd	16.06 ab
P-111	0.71 g-p	0.28 jk	0.39 f-i	0.31 nop	0.63 jkl	0.15 kl	0.52 lm	0.75 fg	Tr[4]	0.46 hi	0.24 fg	4.44 k-o
Meadow foxtail (*Alopecurus pratensis*):												
Sweden comm.	0.48 j-r	0.28 jk	0.39 f-i	0.37 m-p	1.13 g-j	0.27 i-l	0.56 lm	0.68 fg	0.11 e	0.61 ghi	0.28 fg	5.16 k-n
Oregon comm.	0.73 f-o	0.28 jk	0.57 ef	0.16 op	0.96 ijk(WK)	–	–	–	–	–	–	2.70 m-s
Reed canarygrass (*Phalaris arundinacea*):												
Frontier	1.43 a-e(WK)	–	–	–	–	–	–	–	–	–	–	1.43 p-s
Ioreed	1.57 ab(WK)	–	–	–	–	–	–	–	–	–	–	1.57 o-s
Superior	1.00 c-j(WK)	–	–	–	–	–	–	–	–	–	–	1.00 rs
Red fescue (*Festuca rubra*):												
*Arctared	0.84 f-l	1.23 a	0.95 bc	1.92 ab	1.55 c-i	1.88 a	1.74 b-h	2.63 cd	0.12 e	2.41 a-d	0.98 bc	16.25 a
Duraturf	0.64 g-p	0.97 a-d	1.23 a	1.08 f-j	1.91 a-f	0.65 gh	2.19 bc	Tr	0.59 cd	1.48 ef	0.61 de	11.35 d-g
Boreal	1.61 a	0.89 a-e	1.19 a	0.93 g-k	2.00 a-f	0.23 jkl	2.08 bcd(WK)	–	–	–	–	8.93 ghi
Olds	1.28 a-f	1.07 ab	1.31 a	0.67 j-n	2.09 a-d	0.02 l	1.68 b-h(WK)	–	–	–	–	8.12 hij
Ranier	0.96 d-j	0.71 c-h	1.12 ab	0.70 i-n	2.17 abc	0.02 l	1.11 h-l(WK)	–	–	–	–	6.79 ijk
Illahee	0.07 qr	0.93 a-d	1.29 a	0.61 j-o	2.17 abc	0.01 l	0.01 m(WK)	–	–	–	–	5.09 k-n
Chewings fescue (*Festuca rubra var. commutata*):												
Commercial (USA)	0.53 i-r	0.56 f-j	0.83 cd	Tr	0.54 jkl	Tr	0.02 m(WK)	–	–	–	–	2.48 n-s
Meadow fescue (*Festuca elatior*):												
Bottnia II	1.50 a-d(WK)	–	–	–	–	–	–	–	–	–	–	1.50 o-s
Canada comm.	1.49 a-d(WK)	–	–	–	–	–	–	–	–	–	–	1.49 o-s
Tall fescue (*Festuca arundinacea*):												
Alta	0.09 qr(WK)	–	–	–	–	–	–	–	–	–	–	0.09 s

Table 2. Continued

Species and strains	1968 26 Sep	1969 7 July	1969 14 Oct	1970 6 July	1970 15 Sep	1971 7 July	1971 24 Sep	1972 10 July	1972 2 Oct	1973 9 July	1973 7 Sep	Six-year total
	Tons oven-dry forage per acre											
Kentucky bluegrass (*Poa pratensis*):												
*Nugget	0.80 f-m	0.35 ijk	0.69 de	1.68 a-d	2.04 a-e	1.03 ef	2.93 a	1.99 d	1.61 a	1.29 fg	1.47 a	15.88 ab
Park	1.10 a-h	0.44 g-j	0.43 fgh	1.37 c-g	2.05 a-e	0.72 fgh	2.30 b	0.97 f	1.12 b	2.54 abc	1.08 bc	14.12 a-d
Delta	0.81 f-m	0.58 e-j	0.44 fgh	1.22 d-h	2.00 a-f	0.52 hij	1.88 b-g	0.52 fg	0.15 e	1.10 fgh	0.23 fg	9.45 f-i
Merion	0.86 f-l	0.30 jk	0.55 ef	1.28 c-g	2.42 a	0.01 l	1.40 e-j(WK)	–	–	–	–	6.82 ijk
Newport	0.93 e-k	0.30 jk	0.44 fgh	0.88 g-l	2.35 ab	0.01 l	0.66 klm(WK)	–	–	–	–	5.57 j-m
Big bluegrass (*Poa ampla*):												
Sherman	0.64 g-p	0.48 g-j	0.52 efg	0.90 g-l	1.32 f-i(WK)	–	–	–	–	–	–	3.86 l-r
Siberian wildrye (*Elymus sibiricus*):												
*Native	0.53 i-r	0.97 a-d	0.18 i-l	2.12 a	1.18 g-j	0.90 efg	1.36 f-j	2.96 bc	Tr	2.19 b-e	0.10 g	12.49 cde
Russian wildrye (*Elymus junceus*):												
Sawki	0.27 m-r	0.44 g-j	0.30 h-k	1.43 c-f	1.08 g-k	1.47 bcd	1.93 b-g	0.92 f	0.57 cd	1.62 def	0.64 de	10.67 e-h
Slender wheatgrass (*Agropyron trachycaulum*):												
*Native	0.21 o-r	0.36 ij	0.17 jkl	1.37 c-g	0.39 kl	1.98 a	1.01 i-l	3.11 abc	Tr	2.16 b-e	Tr	10.76 e-h
*Alaska-44S	0.03 r	1.02 abc	0.13 jkl	1.61 b-e	0.57 jkl	0.45 h-k	0.97 i-l	2.98 bc	Tr	1.83 c-f	Tr	9.59 fgh
Primar	0.35 l-r	0.92 a-d	0.29 h-k	0.78 h-n	0.64 jkl(WK)	–	–	–	–	–	–	2.98 m-s
Arctic wheatgrass (*Agropyron sericeum*):												
*Native	0.46 j-r	0.62 d-j	0.33 g-i	1.73 abc	0.97 h-k	1.76 ab	1.45 d-j	3.80 a	0.12 e	2.89 ab	0.13 g	14.26 a-d
Redtop (*Agrostis alba*):												
Comm. (USA)	0.19 pqr(WK)	–	–	–	–	–	–	–	–	–	–	0.19 s
Polargrass (*Arctagrostis arundinacea*):												
*Native	0.39 k-r	0.41 hij	0.10 kl	0.56 k-o	0.40 kl	1.77 ab	1.63 b-i	3.32 abc	0.17 e	2.75 ab	0.30 fg	11.80 def
Bluejoint (*Calamagrostis canadensis*):												
*Native	0.31 l-r	0.64 d-j	0.21 i-l	1.22 d-h	1.04 g-k	1.53 bc	1.27 g-k	3.16 abc	0.40 d	3.17 a	0.36 efg	13.31 b-e
Siberian alfalfa (*Medicago falcata*):												
*Alaska strain	0.60 h-q	0.88 b-f	0.15 jkl	1.15 e-i	1.60 c-i (K)[5]	–	–	–	–	–	–	4.38 k-p
Alfalfa (*Medicago sativa*):												
*A-Syn.B	0.97 d-j	Seed[6]	Seed	Tr	1.66 b-h (K)[5]	–	–	–	–	–	–	2.63 m-s
White sweetclover (*Melilotus alba*):												
*AK-Syn.1	1.07 b-i	Seed	Seed (D)[7]	–	–	–	–	–	–	–	–	1.07 rs
Sainfoin (*Onobrychis viciaefolia*):												
Europe comm.	0.81 f-m(WK)	–	–	–	–	–	–	–	–	–	–	0.81 s

*Of Alaskan origin (either a cultivar or breeder's strain selected in Alaska, or a species native to the state). All unmarked strains are introduced; origins discussed in text.
[1]Predominantly of hybrid origin (*B. inermis x B. pumpellianus*).
[2]Within each column, values followed by a common letter are not significantly different (5% level) using Duncan's Multiple Range Test.
[3]No further yields; stands winterkilled completely.
[4]Trace amount of herbage insufficient for harvestable yield.
[5]These legume stands killed with broadleaf herbicide sprayed on all plots in June 1971 to combat weed invasion in thinned grass stands.
[6]Thinned stands not harvested for forage (left for seed production).
[7]The only non-perennial in test; stands of this biennial routinely die completely during second winter.

Table 3. Seeding-year and subsequent forage dry-matter yields of grasses and legumes from various world origins during a 6-year test at the Matanuska Research Farm. Experiment III, planted 6 June 1969.

Species and strains	Harvest dates 1969	1970		1971		1972		1973		1974		Six-year total
	7 Oct	9 July	16 Sep	7 July	27 Sep	5 July	2 Oct	10 July	10 Sep	21 June	17 Sep	
	Tons oven-dry forage per acre											
Smooth bromegrass (*Bromus inermis*):												
*Polar[1]	0.22 k-p[2]	2.98 a-f	1.57 b-e	0.83 f	2.20 bc	3.12 abc	0.80 bcd	3.53 ab	1.01 cde	2.25 abc	0.54 de	19.05 abc
Manchar	0.83 b-e	2.59 b-f	1.47 b-f	0.19 h	1.84 b-e	2.16 def	1.25 b	3.46 abc	1.38 b	2.00 bcd	0.86 bcd	18.03 bc
Carlton	0.28 j-p	2.78 a-f	1.71 a-d	0.31 gh	1.71 b-f	2.08 def	1.07 b	3.19 bcd	1.20 bcd	2.05 bcd	0.61 cde	16.99 bcd
Frigga	0.70 b-h	2.30 e-h	1.37 c-g	0.57 g	1.91 b-e	2.02 def	1.19 b	3.05 b-e	1.17 bcd	1.84 bcd	0.51 de	16.63 b-e
Redpatch	0.92 bc	2.16 f-i	1.42 c-f	0.01 h	0.46 gh(WK)[3]	–	–	–	–	–	–	4.97 l-o
Pumpelly bromegrass (*Bromus pumpellianus*):												
*Native	Tr[4]	2.28 e-h	0.98 e-k	1.02 ef	1.53 c-f	3.19 abc	0.21 de	3.26 bcd	0.58 g	2.59 ab	0.49 de	16.13 cde
Timothy (*Phleum pratense*):												
Korpa	Tr	3.55 a	1.20 d-i	0.01 h	2.29 b	Tr	0.72 bcd	1.10 hi	0.67 fg	0.72 efg	Tr	10.26 g-j
Engmo	0.07 op	3.23 a-d	1.34 c-h	0.01 h	1.42 def	Tr	Tr	0.85 ij	Tr	1.27 def	Tr	8.19 i-l
Bottnia II	0.58 d-j	2.45 c-g	1.70 a-d(WK)	–	–	–	–	–	–	–	–	4.73 m-p
Omnia	0.54 d-k	0.83 jkl	1.66 a-d(WK)	–	–	–	–	–	–	–	–	3.03 n-q
Wisconsin T-10	0.87 bcd	0.46 kl	0.77 g-m(WK)	–	–	–	–	–	–	–	–	2.10 opq
W:S T-48	1.28 a(WK)	–	–	–	–	–	–	–	–	–	–	1.28 pq
W:S T-59	0.71 b-h	0.10 l	Tr(WK)	–	–	–	–	–	–	–	–	0.81 q
Orchardgrass (*Dactylis glomerata*):												
Brage	0.96 b(WK)	–	–	–	–	–	–	–	–	–	–	0.96 q
Frode	0.97 b(WK)	–	–	–	–	–	–	–	–	–	–	0.97 q
Creeping foxtail (*Alopecurus arundinaceus*):												
Garrison	0.45 g-m	2.40 d-g	1.19 d-i	0.94 ef	1.95 b-e	3.15 abc	1.35 b	3.30 bcd	1.01 cde	2.59 ab	0.72 cde	19.05 abc
Meadow foxtail (*Alopecurus pratensis*):												
Oregon comm.	0.79 b-g	1.65 g-j	1.04 e-k	0.11 h	1.45 def	1.48 fg	1.07 b	1.79 fgh	0.73 efg	1.55 cd	0.56 de	12.22 fgh
Reed canarygrass (*Phalaris arundinacea*):												
Superior	0.76 b-g(WK)	–	–	–	–	–	–	–	–	–	–	0.76 q
Red fescue (*Festuca rubra*):												
*Arctared	Tr	3.00 ab	1.48 b-f	1.90 a	2.13 bcd	2.63 bcd	2.41 a	3.01 b-e	1.28 bc	2.58 ab	0.97 bc	21.39 a
Boreal	0.50 e-l	3.19 a-d	1.92 abc	0.53 g	2.95 a	0.80 gh	1.24 b	0.58 ij	0.82 efg	1.42 de	0.63 cde	14.58 def
Olds	0.26 j-p	3.22 a-d	2.20 a	0.01 h	1.00 fg (WK)	–	–	–	–	–	–	6.69 klm
Meadow fescue (*Festuca elatior*):												
Bottnia II	0.17 l-p	0.22 kl	1.05 e-k(WK)	–	–	–	–	–	–	–	–	1.44 pq
Canada comm.	0.26 j-p	Tr	0.56 j-p(WK)	–	–	–	–	–	–	–	–	0.82 q
Tall fescue (*Festuca arundinacea*):												
Alta	0.85 bcd (WK)	–	–	–	–	–	–	–	–	–	–	0.85 q
Kentucky bluegrass (*Poa pratensis*):												
*Nugget	Tr	3.21 a-d	1.84 abc	1.02 ef	3.07 a	1.81 ef	2.77 a	1.74 gh	1.71 a	1.29 def	1.46 a	19.92 ab
Merion	Tr	2.56 b-f	2.03 ab	0.01 h	1.40 def	Tr	Tr	1.08 hi	Tr	1.37 de	1.13 ab	9.58 h-k
Siberian wildrye (*Elymus sibiricus*):												
*Native	Tr	3.37 ab	0.67 i-o	1.42 c	1.43 def	2.93 abc	Tr	2.29 efg	Tr	0.58 fg	Tr	12.69 fgh

Table 3. Continued

Species and strains	1969	1970		1971		1972		1973		1974		Six-year total
	7 Oct	9 July	16 Sep	7 July	27 Sep	5 July	2 Oct	10 July	10 Sep	21 June	17 Sep	
	Tons oven-dry forage per acre											
Russian wildrye (*Elymus junceus*):												
Sawki	Tr	1.40 ij	0.89 f-l	1.12 de	1.40 def	0.91 g	Tr (WK)	–	–	–	–	5.72 lmn
Slender wheatgrass (*Agropyron trachycaulum*):												
*Native	Tr	2.72 a-f	0.45 l-p	1.77 ab	1.07 fg	3.23 ab	Tr	2.60 c-f	Tr	1.54 cd	Tr	13.38 efg
*Alaska-44S	0.26 j-p	3.30 abc	1.13 d-j	1.36 cd	2.04 b-e	2.41 cde	Tr (WK)	–	–	–	–	10.50 ghi
Revenue	0.78 b-g	3.12 a-e	1.37 c-g	0.26 h	1.58 b-f (WK)	–	–	–	–	–	–	7.11 j-m
Primar	0.11 nop	0.38 kl	0.25 l-p (WK)	–	–	–	–	–	–	–	–	0.74 q
Arctic wheatgrass (*Agropyron sericeum*):												
*Native	Tr	2.57 b-f	0.74 h-n	1.83 ab	1.44 def	3.23 ab	0.43 cde	3.27 bcd	0.08 h	2.24 abc	0.54 de	16.37 cde
Violet wheatgrass (*Agropyron violaceum*):												
*Native	Tr	3.00 a-f	0.33 l-p	1.86 ab	1.32 ef	2.47 b-e	Tr	3.20 bcd	Tr	2.49 ab	Tr	14.67 def
Polargrass (*Arctagrostis arundinacea*):												
*Native	Tr	0.82 jkl	0.14 nop	0.91 ef	0.45 gh	2.96 abc	0.34 cde	2.58 def	Tr	2.95 a	0.45 e	11.60 fgh
Bluejoint (*Calamagrostis canadensis*):												
*Native	Tr	2.47 c-f	1.12 d-j	1.59 bc	1.30 ef	3.44 a	0.87 bc	4.19 a	0.91 def	2.52 ab	0.56 de	18.97 abc
Siberian alfalfa (*Medicago falcata*):												
*Alaska strain	Tr	1.57 hij	0.62 i-p(K)[5]	–	–	–	–	–	–	–	–	2.19 opq
Alfalfa (*Medicago sativa*):												
*A-Syn.B	0.56 d-k	0.32 kl	0.49 k-p(K)[5]	–	–	–	–	–	–	–	–	1.37 pq
White sweetclover (*Melilotus alba*):												
*Matanuska white	Tr	0.81 jkl	0.10 op(D)[6]	–	–	–	–	–	–	–	–	0.91 q
*AK-Syn.1	0.40 h-o	1.41 ij	0.01 p(D)[6]	–	–	–	–	–	–	–	–	1.82 opq
Arctic	0.62 c-i	0.96 jk	0.09 op(D)[6]	–	–	–	–	–	–	–	–	1.67 opq
Yellow sweetclover (*Melilotus officinalis*):												
*Arctic Circle strain	0.34 i-p	1.53 hij	0.79 g-m(D)[6]	–	–	–	–	–	–	–	–	2.66 n-q
Sainfoin (*Onobrychis viciaefolia*):												
P-15596	0.50 e-l(WK)	–	–	–	–	–	–	–	–	–	–	0.50 q
Harrington milkvetch (*Astragalus harringtonii*):												
*Native	Tr	1.63 g-j	Tr (K)[5]	–	–	–	–	–	–	–	–	1.63 opq
Alpine sweetvetch (*Hedysarum alpinum*):												
*Native	Tr	0.82 jkl	Tr (K)[5]	–	–	–	–	–	–	–	–	0.82 q

*Of Alaskan origin (either a cultivar or breeder's strain selected in Alaska, or a species native to the state). All unmarked strains are introduced; origins discussed in text.
[1]Predominantly of hybrid origin (*B. inermis x B. pumpellianus*).
[2]Within each column, values followed by a common letter are not significantly different (5% level) using Duncan's Multiple Range Test.
[3]No further yields; stands winterkilled completely.
[4]Trace amount of herbage insufficient for harvestable yield.
[5]These legume stands killed with broadleaf herbicide sprayed on all plots in June 1971 to combat weed invasion in some thinned grass stands.
[6]The only non-perennials in this test; stands of these biennials routinely die completely during second winter.

Table 4. Seeding-year and subsequent forage dry-matter yields of grasses and legumes from various world origins during a 6-year test at the Matanuska Research Farm. Experiment IV, planted 25 June 1970.

Species and strains	Harvest dates 1970 22 Sep	1971 8 July	1971 7 Oct	1972 5 July	1972 18 Oct	1973 11 July	1973 12 Sep	1974 27 June	1974 10 Sep	1975 26 June	1975 19 Sep	Six-year total
	Tons oven-dry forage per acre											
Smooth bromegrass (*Bromus inermis*):												
*Polar[1]	0.11 s-v[2]	0.12 ij	1.13 h-m	2.22 c-f	0.62 e-i	2.94 ab	0.62 def	2.96 ab	0.17 e-h	2.10 ab	1.95 bcd	14.94 b-f
Magna	0.62 f-q	0.01 j	0.57 l-p	1.26 ghi	0.72 e-h	2.67 bcd	0.45 f-i	1.92 c-f	0.07 gh	1.70 bcd	2.15 abc	12.14 e-j
Frigga	0.32 m-v	0.02 j	0.62 k-p	1.51 fgh	0.52 f-j	1.78 d-i	0.49 e-h	1.72 def	0.11 fgh	1.11 c-j	1.87 bcd	10.07 g-k
Redpatch	0.76 d-n	0.01 j	0.23 nop	0.04 j	0.27 i-l	1.42 g-j	0.62 def	0.85 ghi	0.23 d-h	0.88 f-m	1.22 d-g	6.53 l-o
Achenbach	0.60 g-r(WK)[3]	—	—	—	—	—	—	—	—	—	—	0.60 rst
Pumpelly bromegrass (*Bromus pumpellianus*):												
*Native	Tr[4]	0.48 fgh	1.00 i-m	3.08 ab	0.32 h-l	2.76 bc	0.39 f-k	2.87 ab	0.34 c-g	1.51 b-f	0.67 fgh	13.42 c-g
Meadow bromegrass (*Bromus biebersteinii*):												
Regar	0.43 l-v(WK)	—	—	—	—	—	—	—	—	—	—	0.43 rst
Timothy (*Phleum pratense*):												
Korpa	0.26 o-v	0.22 hij	1.80 c-g	0.85 hij	0.49 g-k	0.92 ijk	0.55 d-g	2.17 b-e	0.08 gh	1.45 b-f	0.68 fgh	9.47 h-l
Engmo	0.21 o-v	0.10 ij	1.65 d-i	1.07 ghi	0.47 g-k	0.95 h-k	0.49 e-h	2.20 b-e	0.19 e-h	0.31 lmn	1.42 c-f	9.06 jkl
Bottnia II	0.96 c-i	Tr	0.63 k-o	Tr	0.02 l	Tr	0.16 j-m	0.81 ghi	Tr	Tr	0.65 fgh	3.23 o-t
Tammisto	0.93 c-j	Tr	0.51 m-p	Tr	Tr	Tr	Tr(WK)	—	—	—	—	1.44 p-t
Wis. T-10	1.06 b-g(WK)	—	—	—	—	—	—	—	—	—	—	1.06 q-t
Climax	1.02 b-g(WK)	—	—	—	—	—	—	—	—	—	—	1.02 q-t
Omnia	0.85 c-l(WK)	—	—	—	—	—	—	—	—	—	—	0.85 q-t
W:S T-48	0.73 d-n(WK)	—	—	—	—	—	—	—	—	—	—	0.73 q-t
W:S T-59	0.42 l-v(WK)	—	—	—	—	—	—	—	—	—	—	0.42 rst
Orchardgrass (*Dactylis glomerata*):												
Brage	1.44 ab(WK)	—	—	—	—	—	—	—	—	—	—	1.44 p-t
Frode	1.08 b-f(WK)	—	—	—	—	—	—	—	—	—	—	1.08 q-t
Creeping foxtail (*Alopecurus arundinaceus*):												
Garrison	0.98 c-h	0.07 ij	1.66 d-h	3.17 ab	0.75 efg	2.85 abc	0.77 cd	2.89 ab	0.35 c-f	2.68 a	1.36 c-g	17.53 ab
Meadow foxtail (*Alopecurus pratensis*):												
Oregon comm.	1.05 b-g	Tr	0.62 k-o	0.80 hij	0.30 i-l	0.56 jk	0.25 h-m	0.98 gh	0.18 e-h	0.47 i-n	0.87 e-h	6.08 l-o
Reed canarygrass (*Phalaris arundinacea*):												
Frontier	0.96 c-i(WK)	—	—	—	—	—	—	—	—	—	—	0.96 q-t
Grove	0.79 d-n(WK)	—	—	—	—	—	—	—	—	—	—	0.79 q-t
Superior	0.16 q-v(WK)	—	—	—	—	—	—	—	—	—	—	0.16 st
Red fescue (*Festuca rubra*):												
*Arctared	0.54 h-s	1.85 cd	1.58 e-i	2.04 def	1.26 bc	2.51 b-f	1.05 b	2.68 abc	0.56 bc	1.71 bcd	1.66 b-e	17.44 ab
Duraturf	Tr	0.61 fg	2.05 b-e	1.14 ghi	1.37 ab	1.62 f-i	1.04 b	1.47 efg	0.45 cd	1.19 c-i	1.94 bcd	12.88 d-h
Olds	0.51 i-t	0.27 hij	2.24 a-d	Tr	0.89 def	2.17 b-g	0.95 bc	Tr	0.06 h	0.39 j-n	1.43 c-f	8.91 i-l
Boreal	1.11 b-e	0.19 hij	1.74 d-h	0.63 ij	0.91 cde	1.61 f-i	0.54 d-g	Tr	0.17 e-h	Tr	0.78 fgh	7.68 k-n
Ranier	0.17 p-v	0.11 ij	2.26 a-d	0.15 j	0.34 h-l	0.16 k	0.29 g-m	Tr	Tr	0.35 k-n	0.61 fgh	4.44 n-q
Pennlawn	1.02 b-g	Tr	1.25 g-k	0.28 j	0.28 i-l	Tr	0.19 i-m	Tr	Tr	0.49 h-n	0.64 fgh	4.15 n-r
Illahee	Tr(WK)	—	—	—	—	—	—	—	—	—	—	Tr
Chewings fescue (*Festuca rubra* var. *commutata*):												
Comm. (USA)	0.35 m-v	Tr	2.47 ab	Tr	Tr	Tr	0.11 klm(WK)	—	—	—	—	2.93 o-t
Highlight	0.76 d-n	Tr	1.25 g-k(WK)	—	—	—	—	—	—	—	—	2.01 p-t
Hard fescue (*Festuca ovina* var. *duriuscula*):												
Durar	Tr	1.06 e	1.92 b-f	Tr	Tr	Tr	0.73 cde	Tr	Tr	0.53 h-n	0.71 fgh	4.95 m-p
Meadow fescue (*Festuca elatior*):												
Comm. (Canada)	1.54 a(WK)	—	—	—	—	—	—	—	—	—	—	1.54 p-t
An-2356	1.02 b-g(WK)	—	—	—	—	—	—	—	—	—	—	1.02 q-t
Bottnia II	0.88 c-l(WK)	—	—	—	—	—	—	—	—	—	—	0.88 q-t
Tammisto	0.84 c-l(WK)	—	—	—	—	—	—	—	—	—	—	0.84 q-t

Table 4. continued

Species and strains	1970 22 Sep	1971 8 July	1971 7 Oct	1972 5 July	1972 18 Oct	1973 11 July	1973 12 Sep	1974 27 June	1974 10 Sep	1975 26 June	1975 19 Sep	Six-year total
	Tons oven-dry forage per acre											
Tall fescue (*Festuca arundinacea*):												
Alta	0.97 c-i(WK)	—	—	—	—	—	—	—	—	—	—	0.97 q-t
Kentucky bluegrass (*Poa pratensis*):												
*Nugget	0.16 r-v	1.90 bc	2.45 abc	2.05 def	1.73 a	1.91 d-h	1.37 a	1.94 c-f	0.95 a	1.33 c-g	2.90 a	18.69 a
Park	0.67 e-o	1.05 e	1.82 b-g	1.76 efg	1.38 ab	2.06 b-g	1.06 b	2.46 a-d	0.78 ab	0.93 e-l	1.87 bcd	15.84 a-d
Delta	0.81 d-m	0.70 f	2.13 a-e	1.86 efg	1.30 b	1.65 e-i	1.13 b	2.65 abc	0.38 cde	1.05 d-k	1.98 bcd	15.64 a-e
Merion	0.22 o-v	1.06 e	2.75 a	1.15 ghi	1.50 ab	1.26 g-j	1.09 b	2.15 b-e	0.96 a	0.70 g-n	2.50 ab	15.34 a-f
Newport	0.50 i-t	0.04 ij	2.15 a-e	0.01 j	0.17 jkl	Tr	0.16 j-m	Tr	Tr	Tr	0.74 fgh	3.77 o-t
Salt bluegrass (*Poa eminens*):												
*Native	0.04 uv	0.34 g-j	1.27 f-k	2.50 a-e	1.24 bcd	2.81 abc	0.75 cde	2.65 abc	0.84 a	1.82 bc	1.28 c-g	15.54 a-f
Siberian wildrye (*Elymus sibiricus*):												
*Native	0.47 j-u	2.20 ab	1.33 f-j	3.27 a	0.33 h-l	1.70 d-i	0.36 f-k	2.81 ab	0.04 h	0.16 mn	Tr	12.67 d-i
Russian wildrye (*Elymus junceus*):												
Sawki	0.07 tuv	Tr	0.19 op	0.02 j	0.03 l	Tr	0.06 lm(WK)	—	—	—	—	0.37 st
Slender wheatgrass (*Agropyron trachycaulum*):												
*Alaska-44S	0.48 j-u	0.63 fg	2.40 abc	2.78 a-d	0.13 jkl	1.60 f-i	0.02 m	1.36 fg	Tr	0.37 k-n	0.48 gh	10.25 g-k
*Native	0.47 k-v	1.07 e	1.51 e-i	3.02 ab	0.30 i-l	1.75 d-i	Tr	Tr	Tr	Tr	Tr	8.12 klm
Revenue	0.76 d-n(WK)	—	—	—	—	—	—	—	—	—	—	0.76 q-t
Primar	0.72 d-n(WK)	—	—	—	—	—	—	—	—	—	—	0.72 q-t
Crested wheatgrass (*Agropyron desertorum*):												
Summit-62	0.44 k-v	0.38 ghi	2.11 a-e	0.02 j	Tr	0.03 k	Tr(WK)	—	—	—	—	2.98 o-t
Arctic wheatgrass (*Agropyron sericeum*):												
*Native	0.36 m-v	2.41 a	1.19 g-l	3.08 ab	0.39 g-l	2.62 b-e	0.41 f-j	2.88 ab	0.49 c	1.45 b-f	1.27 c-g	16.55 abc
Violet wheatgrass (*Agropyron violaceum*):												
*Native	Tr	2.05 bc	1.12 h-m	2.89 abc	0.02 l	1.88 c-i	0.07 lm	2.64 abc	0.08 gh	1.63 b-e	0.91 e-h	13.29 c-g
Polargrass (*Arctagrostis arundinacea*):												
*Native	Tr	1.27 e	0.80 j-o	2.40 b-e	0.48 g-k	2.56 b-f	0.24 h-m	2.46 a-d	0.22 d-h	1.20 c-h	0.31 h	11.94 f-j
Bluejoint (*Calamagrostis canadensis*):												
*Native	Tr	1.25 e	0.85 j-n	3.06 ab	0.48 g-k	3.68 a	0.60 def	3.03 a	0.17 e-h	0.59 h-n	0.28 h	13.99 b-f
Alfalfa (*Medicago sativa*):												
Vernal	0.93 c-j (WK)	—	—	—	—	—	—	—	—	—	—	0.93 q-t
White sweetclover (*Melilotus alba*):												
Arctic	0.79 d-m (WK)	—	—	—	—	—	—	—	—	—	—	0.79 q-t
Yellow sweetclover (*Melilotus officinalis*):												
Erector	0.90 c-k (WK)	—	—	—	—	—	—	—	—	—	—	0.90 q-t
Red clover (*Trifolium pratense*):												
*Alaskland	0.12 s-v (WK)	—	—	—	—	—	—	—	—	—	—	0.12 st
Alsike clover (*Trifolium hybridum*):												
Aurora	0.63 f-p (WK)	—	—	—	—	—	—	—	—	—	—	0.63 rst
Kurir	0.48 j-u (WK)	—	—	—	—	—	—	—	—	—	—	0.48 rst

*Of Alaskan origin (either a cultivar or breeder's strain selected in Alaska, or a species native to the state). All unmarked strains are introduced; origins discussed in text.

1 Predominantly of hybrid origin (*B. inermis x B. pumpellianus*).

2 Within each column, values followed by a common letter are not significantly different (5% level) using Duncan's Multiple Range Test.

3 No further yields; stands winterkilled completely.

4 Trace amount of herbage insufficient for harvestable yield.

was considered short-lived at Kenai but was recommended for pasture mixtures there. It was rated as poorly adapted at the other stations.

In the present experiments, all three cultivars, Chinook from Canada (Tables 1, 2), and Brage and Frode from Sweden (Tables 3, 4), produced good seeding-year forage yields, but none survived the first winter (Fig. 1). In another study at this location (Klebesadel and Dofing 1991), the Norway cultivars Hattny and Hattfjeldal also were nonhardy. In still another study (Klebesadel 1993d) at this location, the Norway orchardgrass strains Va-BL-67 and Hattfjeldal established well in broadcast-seeded plots during 1972 but both winterkilled 100% during the first winter.

All of these orchardgrass strains are from northern sources and are among the most winterhardy available; therefore, there is little likelihood that orchardgrass strains exist that would be adequately winterhardy for dependable use as a perennial in southcentral Alaska. Orchardgrass cultivars ranked among the least winterhardy of the major forage grasses at numerous locations in Canada (Ouellet 1976). Previous reports from this location have described potential use of orchardgrass for annual forage production in Alaska (Brundage and Branton 1967; Brundage *et al*. 1963).

CREEPING FOXTAIL is a long-lived, cool-season perennial grass native in a broad zone across much of Europe and Asia, from the Mediterranean to above the Arctic Circle (Stroh *et al*. 1978). Creeping foxtail, and the closely related meadow foxtail (discussed below), are valuable species and should not be confused with foxtail barley, a troublesome, unpalatable, weedy species common in Alaska in many permanent pastures and in disturbed sites, as along roadways, airstrips, etc.

Creeping foxtail's seed head is a compact spike, resembling that of timothy, but broader. The first seed heads of creeping foxtail appear relatively early, compared to most grasses; however, heading is not dense in this area and is somewhat indeterminate, with seed ripening over a period of time. The light, hairy seed also shatters when ripe. These factors make seed production and handling more difficult than with many other grasses.

Irwin (1945), reporting on a seeding of creeping foxtail in 1940 at the Matanuska Experiment Station, observed that the strain evaluated was hardy, a good soil binder, and yielded forage "about equal to timothy." He rated creeping foxtail less valuable than meadow foxtail for hay or pasture.

Garrison, a cultivar originating from a naturalized population in North Dakota (A.A. Hanson 1972; Stroh *et al*. 1978), was included in all four tests (Tables 1, 2, 3, 4). Strain P-111, selected from stock originating from 43°N in Russia (A.A. Hanson 1972), was included in Exps. I and II (Tables 1, 2). Garrison was much more winterhardy than P-111 (Fig. 4), persisted well in all four tests, and produced forage yields equal to Alaska-developed cultivars. P-111 persisted for the full term of Exp. II but produced low forage yields; in Exp. I it winterkilled totally during the fourth winter.

The very favorable winter survival and forage production of Garrison in these experiments and in others in this area (Klebesadel 1992d, 1993d; Mitchell 1982a) is somewhat surprising, considering the generally poorer performance of several other species from similar latitudes. The naturalized population near Max (47.8°N) in North Dakota, from which Garrison was selected, is believed to have originated in Ukraine which spans 45° to 52°N (Stroh *et al*. 1978).

Winter conditions for the specific location of origin in Ukraine are not known; however, minimum temperatures recorded at five locations near Max in McLean County, ND, average -50.4°F, while the minimum recorded for the Matanuska Research Farm is -36°F (U.S. Dep. Agric. 1941). Mean January temperature for the five McLean County locations is 8.1°F; at the Matanuska Research Farm it is 12.6°F. During the 48 years from introduction of the original creeping foxtail in 1902 until collection in 1950 of the stock that became Garrison (Stroh *et al*. 1978), natural selection for survival under conditions of severe winter stress may have occurred. Such natural selection for enhanced winterhardiness has been noted in Alaska in numerous other grass and legume species (Klebesadel 1971b, 1985a, 1991, 1992b, 1992c, 1993b).

The strongly rhizomatous habit and tolerance to high-moisture soils and flooding make Garrison a useful grass for soil stabilization in a number of erosion-prone situations (Stroh *et al*. 1978); however, its long-term persistence was generally poor as a revegetation grass on coal-mine overburden locally (Mitchell 1987b). The northern limits of the range of creeping foxtail in Europe reach to far above the latitudes of southcentral Alaska, affording the opportunity to secure additional subarctic-adapted ecotypes for evaluation as well. The full potential of Garrison and other northern ecotypes of creeping foxtail for forage and soil stabilization in Alaska remains to be determined.

MEADOW FOXTAIL is not widely used as a forage grass, but it is valued in special situations. Among these are relatively wet meadowlands, especially in the Pacific Northwest states (Hafenrichter *et al*. 1968; A.A. Hanson 1972; Lewis 1958; Schoth 1947). Meadow foxtail is a long-lived, slightly spreading, perennial bunchgrass useful for hay, pasture, and silage. It was introduced into North America from Eurasia and is sometimes called "Scotch timothy." The seed heads of this grass resemble those of timothy, though they are generally more slender and more tapered at both ends.

A disadvantage of this grass is found in the very fluffy nature of its seeds, leading to difficulty in uniform flow and delivery through planting equipment. Moreover, meadow foxtail tends to lodge more than most tall-growing grasses at moderate to high rates of nitrogen fertilization (Unpublished information, Alaska Agric. and Forestry Exp. Sta.)

Meadow foxtail was seeded for evaluation early in this century at several experiment stations in Alaska—1902 at Sitka, 1902 and 1903 at Kenai, 1906 at Rampart, 1902 through 1908 at Copper Center, 1919 at Fairbanks, and 1938 and 1940 at the Matanuska Station (Irwin 1945). Those trials led to recommending its use in hay and pasture mixtures in coastal and southcentral Alaska.

An Oregon common strain included in all four of the present experiments winterkilled completely during the

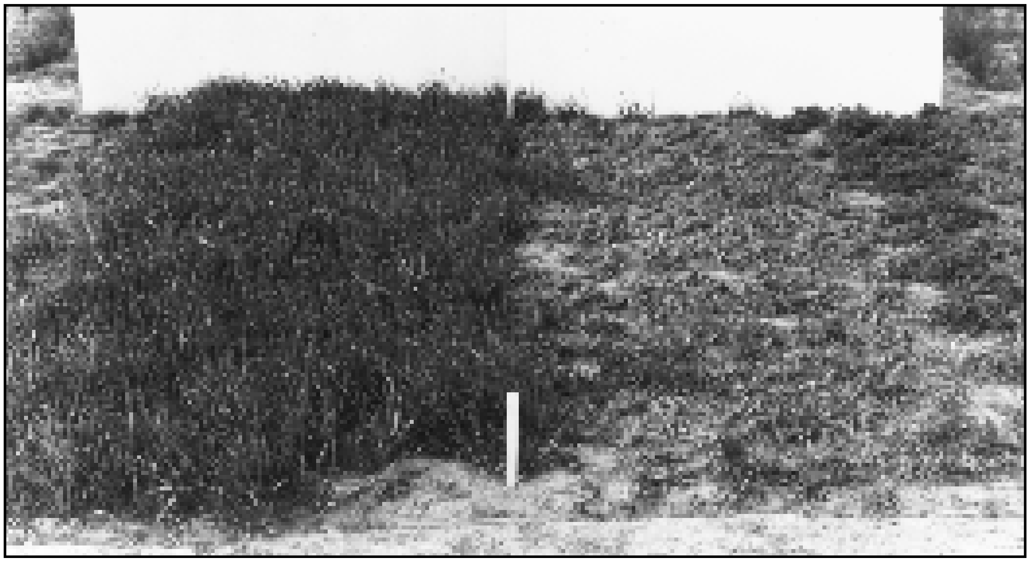


Figure 4. Comparative winter survival of two strains of creeping foxtail following the second winter after planting in Exp. II: (left) *Garrison, and* (right) *P-111. Visual estimates of percent winterkill in these plots: Garrison 0%, P-111 90%; means of three replications, Garrison 0%, P-111 77%.*

1970-71 winter in the first two experiments; that occurred during the fourth winter in Exp. I (Table 1), and during the third winter in Exp. II (Table 2). In Exps. III and IV, the same strain survived all five winters. A more northern-adapted strain from Sweden, included in Exp. II, survived all five winters. Despite harvestable yields in all six years, however, the Swedish strain produced only a modest total forage yield.

Meadow foxtail is more tolerant of moderate soil acidity than is bromegrass. Farmers on Alaska's Kenai Peninsula grow meadow foxtail successfully where soils are more acidic and winters usually are somewhat less severe than in the Matanuska Valley. Although cultivars are not available (A.A. Hanson 1972), more regional strains or ecotypes from the northernmost areas of adaptation and culture for this species should be sought for evaluation in Alaska. Such strains should be more winterhardy and hence more productive than the evaluated strains which derived from areas of modest winter stresses.

REED CANARYGRASS is a tall-growing, sod-forming species native to both Eurasia and North America. The first known cultivated use of this grass was in Sweden about 1750. Where adapted, it produces high yields of forage and is utilized for pasture, hay, and silage and for revegetation purposes. It is more tolerant than most forage grasses of wet growing sites and even tolerates some flooding. However, it also grows well on upland, better-drained soils as well (Marten 1985; Smith *et al*. 1986).

Irwin (1945) summarized several early evaluations of reed canarygrass during the first half of the century at various experiment stations in Alaska. Winter survival of strains evaluated was poor and the grass was not recommended for use.

The cultivar Superior from Oregon, included in all four experiments (Tables 1, 2, 3, 4), established well but never survived the first winters. Frontier, a cultivar derived from native collections (latitude not known) in Canada (A.A. Hanson 1972), also produced good seeding-year forage yields but, despite its somewhat more northern origin than Superior, showed only slightly better winter survival. Frontier winterkilled during the second winter in Exp. I and during the first winter in Exp. II (Tables 1 and 2). The cultivar Ioreed from Iowa was included in Exp. II, and Grove from Ontario in Exp. IV; both succumbed during the first winter also.

A few random patches of introduced reed canarygrass persist locally along roadsides where they are not cropped and where insulating winter snows accumulate. This results in a much more protected microenvironment than in farm fields that typically are swept bare of insulating snow cover in this area by strong winter winds. The species can survive mild winters in this area (Mitchell 1989) and has been grown successfully in certain areas with somewhat more modest winter stresses on Alaska's Kenai Peninsula, 90 to 200 miles south of this test site. Reed canarygrass is valued there for its relatively better tolerance (than most other forage grass species) of the moderately acidic soils common in that area.

Subsequent to the experiments summarized here, strains of reed canarygrass from northern Norway (69° to 70°N) evaluated in several tests at the Matanuska Research Farm were found to be markedly more winterhardy than all other strains that derived from, and are adapted at, more southern latitudes in both Europe and North America; some strains from 55° to 60°N in Russia were intermediate in winterhardiness (Klebesadel and Dofing, 1991).

Those results reveal that reed canarygrass, like many other forage species, is comprised of ecotypes, regional strains, and cultivars with a great range of winterhardiness under Alaska conditions, and that the considerable diversity of performance is related to latitude-of-origin or climatic adaptation. Additional investigations can now define more clearly the potential contributions and avenues of utilization for those better adapted strains of reed canarygrass in Alaska.

Porsild and Cody (1980) identified several occurrences of this species at above 60°N in northwestern Canada. If those are not recent introductions, but are indigenous and therefore well adapted there, collections from that northern area should show good performance in Alaska. One collection of seed from 61°52' N near Fort Simpson in Northwest Territories, Canada, showed better winter survival and subsequent spring vigor in one test than other North American strains from more southern latitudes (Klebesadel and Dofing 1991). This indicates that more collections from that area should be obtained and evaluated here.

RED FESCUE is sometimes referred to as creeping red fescue, due to its moderately spreading habit from growth of short rhizomes (underground stems). This species is native in Alaska and occurs widely throughout the state (Hulten 1968), despite the contention of A.A. Hanson (1972) that it was introduced into North America from Europe.

Red fescue is valued in the conterminous states and Canada primarily for lawns, general purpose turf, erosion control, and pastures (Buckner 1985; Elliott and Baenziger 1973; Hafenrichter *et al*. 1968; A.A. Hanson 1972; Hanson and Juska 1969). Irwin (1945) reported generally indifferent to disappointing results from seedings of red fescue at Copper Center in 1908 and on Kodiak Island in 1913. However, on the basis of four seedings at the Matanuska Experiment Station between 1930 and 1942 with seed of unstated origin, its good growth, winterhardiness, and persistence led to recommending red fescue for use in pasture mixtures for this area (Irwin 1945).

The Alaska cultivar Arctared (Hodgson *et al*. 1978) was included in all four of the present experiments (Tables 1 through 4), the Canadian cultivars Duraturf, Boreal, and Olds were included in Exps. II, III, and IV (Duraturf not in Exp. III), the Oregon cultivars Ranier and Illahee were included in Exps. II and IV, and Pennlawn from Pennsylvania was included only in Exp. IV.

Stands of Arctared and Duraturf persisted for the full term of all experiments in which they were included. Boreal winterkilled during the fourth winter of Exp. II but remained alive for the full terms of Exps. III and IV. Stands of Olds persisted for the full term of Exp. IV, but winterkilled during the fourth winter in Exp. II and during the fifth winter in Exp. III.

In Exps. II and IV, which included the most cultivar comparisons, total forage yields of Arctared were significantly higher than those of Duraturf, and yields of Duraturf in turn were significantly higher than those of all other cultivars compared.

Duraturf was clearly intermediate in winterhardiness, and therefore forage production, between the extremely hardy Arctared and the less hardy Canadian cultivars Boreal and Olds (Tables 2, 4). Duraturf and Olds are reported as similar in hardiness in Canada (Ouellet 1976). Duraturf was selected in Ontario but possesses inherent northern adaptation as it was derived from "Scandinavian material" (A.A. Hanson 1972).

Olds was selected in Canada at about 52°N from genetic stock from Czechoslovakia (ca. 48° to 51°N). In turn, Boreal was selected at a more northern latitude in Canada (ca. 55°N) from within Olds, and winterhardiness was one of the selection criteria (A.A. Hanson 1972). In view of this background, it is understandable that Boreal should be somewhat more winterhardy than Olds in Alaska; this difference was more apparent in Exp. III than in Exps. II and IV where the two were generally similar.

The cultivars Ranier and Illahee were included in Exps. II and IV, and only Ranier in Exp. IV persisted for the full term of the experiment. Illahee winterkilled during the fourth winter in Exp. II, and during the first winter in Exp. IV. Pennlawn was included in Exp. IV; although its stands survived marginally for the full term of the experiment, winter injury was reflected in very low first-cut forage yields each year and in low 6-year total yields, very similar to Ranier.

These results reveal that within red fescue, as in several other species, the various cultivars represent a considerable range of winterhardiness under Alaska conditions. As noted in other reports (Klebesadel 1992a, 1992d, 1993c, 1993e; Klebesadel *et al*. 1964), the range in winterhardiness within this species paralleled the latitudinal origins of cultivars, with best survival related to northernmost origins or adaptation. With reference to data in Tables 1 through 4, and winter-injury ratings recorded each spring in each experiment, winterhardiness of cultivars ranked: Arctared > Duraturf > Boreal ≥ Olds > Ranier = Pennlawn > Illahee. As noted with the bromegrasses and timothy strains, there was a tendency for the most winterhardy cultivars of red fescue to produce lower seeding-year forage yields than the less hardy cultivars, and vice versa (see esp. Tables 3, 4).

More detailed discussions of winter-hardening behavior and general performance of subarctic-adapted and introduced strains of red fescue at this location appear elsewhere (Klebesadel 1985b, 1993c, 1993e; Mitchell 1987b). Arctared, although selected primarily for winterhardiness and turf characteristics (Hodgson *et al*. 1978), was one of the highest-yielding grasses in all four experiments. It should be recognized, however, that farm-scale forage-harvest equipment would not recover all of the forage that the short clipping height of plot mowers and hand-raking accomplished in these experiments. Arctared has performed well in revegetation trials also (Mitchell 1987b).

CHEWINGS FESCUE is a fine-leaved bunchgrass introduced from Europe and used for lawns and general-purpose turf in humid areas of the northern U.S. (A.A. Hanson 1972). Irwin (1945), reporting on five seedings of chewings fescue of unstated origin between 1930 and 1942 at the Matanuska station, classed it as hardy and "one of the best pasture grasses" evaluated.

A commercial lot of chewings fescue from the U.S. was included in Exps. II and IV, and the cultivar Highlight from Holland was included in Exp. IV. The commercial strain winterkilled during the fourth winter in both experiments after producing very low forage yields, and Highlight winterkilled during the second winter. Highlight also sustained severe winter injury in another study at this location (Klebesadel 1992d).

These generally disappointing results contrast with the earlier, more favorable findings reported by Irwin (1945). Unless more winterhardy (northern-adapted) strains can be obtained than those evaluated in Exps. II and IV, chewings fescue should be considered a poor choice for use in this area.

HARD FESCUE, a fine-leaved bunchgrass introduced into the U.S. from Europe, is used for erosion control and soil improvement in areas of the Pacific Northwest states (Hafenrichter *et al*. 1968; A.A. Hanson 1972). In unharvested revegetation trials in this area, some strains of hard fescue have provided persistent ground cover (Mitchell 1987b).

The cultivar Durar, selected at Pullman, Washington, from an old planting established with seed of unknown origin (Hafenrichter *et al*. 1968), was included in Exp. IV. Although stands of this grass persisted for the full term of the experiment, winter injury usually resulted in low first-cut forage yields and it was among the lowest yielders of the grasses that survived throughout the test. Durar was significantly inferior in winter survival and forage production to the hardiest red fescue strains in a separate study at this location (Klebesadel 1992d).

MEADOW FESCUE is a broad-leaved bunchgrass native to Europe. It is considered to be an excellent pasture grass, widely grown in western Europe, but has never been utilized extensively in the U.S. due to a high susceptibility to diseases (Buckner 1985).

Meadow fescue was seeded for experimental evaluation in Alaska at the Rampart station in 1906, Fairbanks in 1938 and 1939, and at the Matanuska station in 1919 and 1940 (Irwin 1945). Origin of the seed was not stated, but this species was "not hardy" at Rampart, "winterkilled badly" at Fairbanks, and survived some winters well at the Matanuska station, but winterkilled when snow cover was light. Despite this marginal performance, meadow fescue was recommended for hay and pasture mixtures for the Matanuska and Tanana Valley areas (Irwin 1945).

In the present experiments, the Swedish cultivar Bottnia II and Canadian "commercial" meadow fescue were included in Exps. II, III, and IV. They established well but both winterkilled during the first winter in Exps. II and IV; in Exp. III they sustained severe injury during the first winter, produced meager yields during the second year, and were eliminated during the second winter (Table 3). Two strains from Finland, Tammisto and An-2356, were included only in test IV; they too sustained total winterkill during the first winter (Fig. 5).

In a more recent study at this location (Klebesadel and Dofing 1991), two Norway cultivars, Salten and Salten II, produced modest forage yields in both the seeding year and the following year, but were so severely winter-injured during the second winter that no yields were obtained thereafter. In another experiment at this location, the Norwegian cultivars Loken and Vagones winterkilled the first winter (Klebesadel 1993d).

The above strains evaluated here are from near the northernmost limits of meadow fescue culture and hence should possess inherent northern adaptation and near maximum winterhardiness for the species. Therefore, the consistently poor winter survival of all six strains suggests there is little likelihood that strains of meadow fescue exist that are sufficiently winterhardy for dependable use as a perennial forage in this area. Meadow fescue cultivars were ranked as relatively poor in winterhardiness in Canada also (Ouellet 1976).

TALL FESCUE is a bunchgrass introduced into North America from Europe prior to 1880 (Buckner 1985). It is adapted to a wide range of soil conditions, and is utilized for pasture, hay, silage, soil stabilization, and turf, primarily in the eastern half of the U.S. (Buckner 1985; Smith *et al*. 1986).

Smith *et al*. (1986) noted that winterhardiness of tall fescue is similar to that of orchardgrass, and Buckner (1985) states that "cold winter temperatures" restrict its distribution into more northern latitudes (Scandinavia and Canada) than the humid-temperate areas where it is ideally adapted.

Irwin (1945) reported on approximately 15 different experimental plantings of tall fescue in Alaska. Some were as early as 1902 at the experiment stations at Sitka, Kenai, Rampart, and Copper Center, in 1909 at Fairbanks, and in 1940 at the Matanuska station. Performance was generally poor and at the Matanuska station the only two seedings winterkilled the first winter.

The cultivar Alta, selected from a 4-year-old stand of tall fescue in Oregon in 1923 and named in 1940 (A.A. Hanson 1972), was seeded in Exps. II, III, and IV. Seeding-year yields ranged from 0.09 to 0.97 T/A and all three seedings winterkilled the first year. On the basis of these and earlier results here, and because this species is neither adapted nor used at other high-latitude areas of the world (Buckner 1985; A.A. Hanson 1972; Hitchcock 1951), there appears to be little potential for dependable use of tall fescue in this area.

KENTUCKY BLUEGRASS is a relatively fine-leaved, sod-forming, long-lived perennial believed introduced into North America from Europe (Duell 1985; Hulten 1968). It is widely used as a pasture grass and for lawns in midwestern and northeastern U.S. In some areas, dried and pelletized clippings from sod farms are utilized

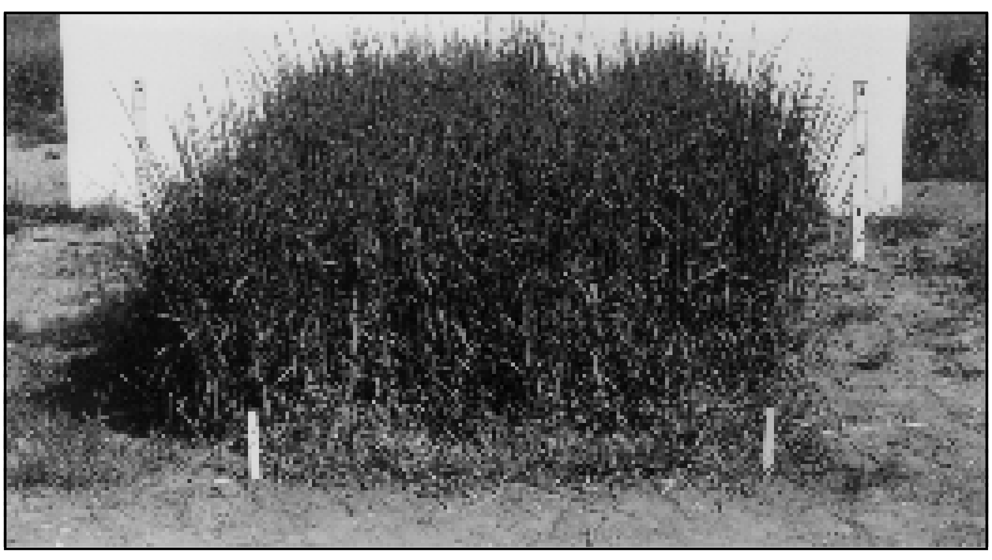


Figure 5. Center plot of native Alaskan violet wheatgrass on 5 July of third year of growth in Exp. IV shows tall, dense growth produced by date of first cutting. Plots to left and right, respectively, were An-2356 meadow fescue from Finland and W:S T-59 timothy from Sweden; both succumbed during the first winter after planting. Numbers on tall stake in center of each plot indicate height in feet.

in feeding poultry. Numerous improved cultivars have been developed (A.A. Hanson 1972).

Kentucky bluegrass was seeded in 1902 at Alaska's Sitka and Kenai experiment stations and later at the Rampart, Fairbanks, Kodiak, and Matanuska stations (Irwin 1945). Neither adaptation of the strains used nor sources of seed were reported. Although winter survival was poor at Rampart, the northernmost station, generally good performance at other stations led to recommending Kentucky bluegrass for pasture mixtures in south-coastal, southcentral, and Tanana Valley areas.

In the present study, the Alaska cultivar Nugget (Hodgson *et al*. 1971b) was included in all four experiments; Merion, a cultivar selected in Maryland, was included in Exps. II, III, and IV; and cultivars Delta from Canada, Park from Minnesota, and Newport from Oregon were included in Exps. II and IV. Stands of all cultivars persisted for the full terms of all experiments, except Merion and Newport winterkilled during the fourth winter in Exp. II (Table 2).

On the basis of first-cut forage yields (especially after the severe winter of 1970-71), and total forage produced (Tables 2, 3, 4), Nugget was clearly the most winterhardy, and Newport the least winterhardy, of the five cultivars compared. Moreover, Merion was less winterhardy than Park and Delta in Exp. II; in that experiment, the rank for both total forage yield and winterhardiness of cultivars was Nugget > Park > Delta > Merion > Newport. In Exp. IV the differences were less clearly defined, except for the poor performance of Newport from Oregon, an area of very modest winter stresses.

These results agree with other reports (Klebesadel 1984a, 1992a, 1992d, 1993e; Klebesadel *et al*. 1964; Klebesadel and Dofing 1991) of winterhardiness of Kentucky bluegrass cultivars and strains at this location. All results are in agreement that Kentucky bluegrass strains are most winterhardy here that derived from (a) far-northern areas and (b) areas of severe winter stresses. The combination of those contributory factors is more effective than either alone (Klebesadel 1984a).

Nugget, selected locally for superior turfgrass characteristics and winterhardiness (Hodgson *et al*. 1971b), ranked first in forage production over all four tests of all grass strains compared. This suggests that intentional selection for forage productivity within subarctic-adapted Kentucky bluegrass germplasm (not an objective in the selection of Nugget) could identify even more productive forage lines. However, as with red fescue, which also produces mostly low, basal leaves, these results must be viewed with the recognition that farm-scale forage-harvest equipment would not recover as much bluegrass herbage as the close mowing and raking accomplished in these small-plot experiments.

Kentucky bluegrass is not valued highly as a full-season forage species in more southern, mid-temperate latitudes, due to its summer dormancy and cessation of growth with onset of high mid-summer temperatures (Duell 1985; Smith *et al*. 1986). The relatively cooler growing seasons characteristic of southcentral Alaska circumvent this problem with Kentucky bluegrass, permitting the species to be productive for the entire growing season as shown in these and other experiments (Klebesadel 1992d).

BIG BLUEGRASS is a bunch-type, cool-season species reputed to begin growth very early in spring (Hafenrichter *et al*. 1968). Irwin (1945) reported seedings of big bluegrass at the Matanuska Station in 1940 and 1942; origin of the seed used was not reported. Summary comments included: "Begins growth early in spring, produces heavy foliage and recovers rapidly from grazing or clipping. An excellent pasture grass and quite hardy."

The cultivar Sherman, included in Exps. I and II, was selected at Pullman, Washington from native stock collected in Sherman County (ca. 45° to 46°N), Oregon. It established well in both tests; seeding-year forage yields were 1.39 T/A in Exp. I (Table 1), when precipitation was above average, but only 0.64 T/A in Exp. II (Table 2) when moisture stress was greater. It winterkilled during the first winter in Exp. I (Fig. 3), and during the third winter in Exp. II after producing only modest yields of forage.

The native range occupied by big bluegrass is curiously disjunct. The dominant area, from which Sherman derived, is located in the Pacific Northwest states and southern British Columbia. A smaller area of occurrence, however, has been identified much farther north in southwest Yukon Territory (Hulten 1968).

A collection from "east of Whitehorse" (60.7°N) recently has been compared with Sherman at several locations in Alaska by Alaska Plant Materials Center personnel (State of Alaska 1989). Paralleling performance patterns of latitudinal ecotypes within other species when grown in Alaska, the more northern-adapted Yukon strain, named Service, "has consistently surpassed Sherman in vigor and hardiness" (State of Alaska 1989). More extensive collections and evaluations of big bluegrass from its northern range in Canada should be of value in determining more fully the potential usefulness of this species in Alaska.

SALT BLUEGRASS is an unusually coarse, tall-growing bluegrass (Fig. 6). The natural range of this rhizomatous species is limited to coastal habitats in northeastern Asia, Alaska, and eastern Canada (Hulten 1968). Seed used in Experiments III and IV was collected on local tidal flats.

Performance of this grass differed greatly in the two tests. In Exp. III, establishment was very poor (visual estimate in autumn of seeding year = 15% stand). Very limited precipitation was received during that seeding year; moreover, the moisture stress was exacerbated by much lower-than-normal rainfall during the latter half of the previous year (Table 6). No measurable forage yields were obtained until the fourth year of that experiment, so only the results from Exp. IV are reported (Table 4).

In Exp. IV, seeding-year moisture supply again was low; an estimated 60% stand of salt bluegrass was established, and a very low seeding-year yield was obtained. The severe winter of 1970-71 killed many ecotypes in Exp. IV as well as in the other experiments; both the stress of that winter and lingering effects of moisture deficiency suppressed first-cut yields of survivors, including salt bluegrass. Over the final four years of Exp.

IV, however, salt bluegrass was among the highest forage yielders, averaging about 3 ½ T/A annually.

Under the conditions of relatively high N fertilization used in these tests, salt bluegrass tended to lodge worst of all grasses compared (Fig. 6). Herbage of this grass at the mid-season harvest was usually highest in moisture content of all grasses. Salt bluegrass should be evaluated more extensively; it may be suited for use as both a forage grass and for soil stabilization, especially in coastal habitats (and perhaps saline conditions?) that may be unsuited for growth of other species.

SIBERIAN WILDRYE is native to Russia, and perhaps also to northwestern Canada and to central and southcentral Alaska (Hulten 1968; Klebesadel 1969b); Porsild and Cody (1980), however, incline toward believing it was introduced into North America. It is a tall-growing bunchgrass with conspicuously pendulous seed heads; agronomic characteristics of this grass have been reported earlier (Klebesadel 1969b, 1993d). Denisov and Netrebov (1976) report this species is the "champion of winter hardiness" in Siberia. Lawrence and Troelsen (1964) reported that a severe drought in Saskatchewan killed Siberian wildrye and five other species of wildrye in experimental trials there.

The only known recorded seeding of Siberian wildrye for evaluation in Alaska, prior to the experiments reported here, was at the Matanuska Experiment Station in 1941 (Irwin 1945). Origin of the seed was not stated; however, the grass was judged very hardy, a good seed producer and soil binder, and it produced early pasture. The seed heads of Siberian wildrye bear sizable, scabrous awns that likely would present feeding problems, especially if dried for hay. It was probably for this reason Irwin (1945) judged it "of little forage value after seed stalks form."

A native Alaskan ecotype of this species, from local seed collections, was included in all four experiments. Seeding-year forage yields were modest, averaging only 0.40 T/A. Also, low first-cutting yields were obtained in 1969 (Tables 1, 2) when yields of all species were suppressed by moisture deficit, and in 1971 (Tables 1, 2, 3), following the severe winter of 1970-71 that eliminated a number of strains in other species. This indicated some winter injury to Siberian wildrye. In other years, winter survival was excellent (Figs. 1, 3). First-cut yields generally were quite high but second-cut yields tended to be low.

Although Siberian wildrye persisted for the full term of all four tests, a conspicuous trend toward lower yields was apparent with aging of stands. Over the four experiments, percents of total 5-year forage yields produced each year after establishment were 28, 22, 20, 18, and 12, respectively, paralleling visual observations of gradual stand deterioration. This suggests that about four years may represent the maximum practical productive life for stands of this grass. Other reports (Hafenrichter *et al*. 1968; Lawrence and Ratzlaff 1985; Weintraub 1953) have noted that Siberian wildrye was "short-lived." The present results indicate a similar characteristic for this Alaska ecotype, although in another study at this location Siberian wildrye continued to produce high forage yields in the sixth year (Klebesadel 1994b).

Figure 6. Plot of native Alaskan salt bluegrass showing susceptibility of this tall, succulent grass to lodging with relatively high rate of fertilizers applied. Photograph taken 5 July in third year of growth in Exp. IV. Numbers on stake indicate height in feet.

RUSSIAN WILDRYE is a long-lived, bunch-type grass native to the steppe region of Siberia. It was introduced into Canada in 1926 and has become useful as a pasture grass in the prairie provinces (Heinrichs and Lawrence 1956; Lawrence 1978).

The cultivar Sawki, selected in Saskatchewan, is ranked as one of the most winterhardy grass strains at several locations in Canada (Ouellet 1976). It was included in all four experiments, and was the only strain evaluated within this species. Only in Exp. II did stands of this cultivar persist for the full term of the experiment; Sawki winterkilled during the fifth winter in Exp. I and during the fourth winters in Exps. III and IV. Total forage yields of Sawki in Exps. I and II were more than double those in the second two experiments (Tables 1, 2, 3, 4). Sawki has also displayed mediocre to poor performance in other experiments at this location (Klebesadel 1993d). This cultivar clearly is marginally winterhardy in this area and should be considered a relatively poor choice for use here.

Irwin (1945) reported that trials at this location in the early 1940s showed Russian wildrye to be "very hardy," the "best perennial grass yet tried," and "(forage) yields of this grass have been higher than those of any other grass tried." The origin and latitudinal adaptation of the Russian wildrye used in those early tests is not known. Those earlier results suggest that within the total species there is better adapted material for use here than is represented in Sawki.

Sawki was selected from commercial seed of uncertain origin, but believed from Omsk (ca. 55°N) in Russia (Lawrence 1967); Sawki's selection for good performance at more southern latitudes (49° to 52°N) in Saskatchewan would not be expected to confer good adaptation or performance at Alaska's more northern latitudes. If more northern-adapted germplasm of Russian wildrye is available from Asia, its performance in Alaska likely would surpass that of Sawki.

ARCTIC WHEATGRASS is an indigenous Alaskan bunch-type species with a native range restricted to northern latitudes in northwest Canada, Alaska, and northeast Siberia (Hulten 1968); a bulk lot of seed from several collections in Alaska was included in all four experiments. Of the grasses included in all four tests, arctic wheatgrass ranked fifth overall in forage production and it was the highest-yielding native grass in Exps. II and IV. As with other native Alaska grasses, the dominant portion of each year's yield usually was obtained in the first cutting. Regrowth of this and other native grasses after the first cutting was relatively meager, but probably would have been better with somewhat earlier first-cutting dates.

Unlike the shorter-lived, native slender wheatgrass, *A. sericeum* remained fully productive for the full 6-year term of each test. Mitchell (1982a), in a shorter-term study with the same species (but identified in that report as *A. macrourum*) at the Palmer station, noted stand deterioration and weed ingress after two harvest years. Those results contrast with the continued good yields over six years in all of the four tests reported here. In fact, averaged over all four experiments, forage production of arctic wheatgrass was virtually as high in the final (sixth) year as in the first year after establishment.

The disparity in results between the two studies may be due to response of the grass to different harvest dates. Mean harvest dates employed by Mitchell (1982a) during the first two years were 23 June and 4 September, while mean harvest dates in the present study were 4 July and 24 September, permitting the grass longer periods of growth before each harvest. Mitchell's harvest dates, at earlier stages of grass growth, would result in higher quality forage, but may have been inappropriate for energy status within the plants, thereby tending to weaken the stands. Future investigations that compare various harvest schedules and responses of this species (that historically has not been subjected to harvest stresses) may resolve this question.

The good forage yields of the relatively unselected bulk lot of this extremely winterhardy wheatgrass (Fig. 2) suggest that further collections and evaluations may identify more productive selections. Owing to its excellent winterhardiness, high forage productivity, and good persistence, arctic wheatgrass may prove useful for both forage and soil stabilization purposes at northern latitudes (Klebesadel 1973). More extensive agronomic evaluations of this species have been reported elsewhere (Klebesadel 1994b; Klebesadel and Helm 1992b)

SLENDER WHEATGRASS is native in Alaska and throughout much of western North America (Hitchcock 1951; Hulten 1968). The cultivar Primar, derived from native stands of this species at 46.1°N in Montana, was included in all four tests (Tables 1, 2, 3, 4). A naturally occurring Matanuska Valley strain, Alaska-44S (discussed in detail elsewhere—Klebesadel 1991), and a composite of several native Alaskan collections were included in Exps. II, III, and IV. The cultivar Revenue, originating from near 52°N in Saskatchewan, was included in Exps. III and IV.

Primar, the southernmost-adapted strain, winterkilled completely during the first, third, second, and first winters in Exps. I through IV, respectively, (Tables 1,2,3,4; Fig. 7), showing clearly that this mid-temperate-adapted cultivar is not suited to Alaskan conditions. Revenue was only slightly more winterhardy than Primar; Revenue winterkilled during the third winter in Exp. III and during the first winter in Exp. IV.

Alaska-44S is believed to be a naturalized Alaskan ecotype originally introduced from more southern origins but which, through natural selection over many generations, has acquired a considerable measure of adaptation to subarctic climatic conditions (Klebesadel 1991). That strain was more winterhardy than Primar and Revenue. Alaska-44S winterkilled during the fourth winter in Exp. III but survived for the full term of Exp. IV. Total forage yields of Alaska-44S were not significantly different from the mean total yields produced by the composite strain of native Alaskan slender wheatgrass (Tables 2, 3, 4).

Earlier reports (Asay and Knowles 1985; Hafenrichter *et al.* 1968) have noted that slender wheatgrass is relatively short-lived. Over the full terms of three experiments, percents of total forage yield of native Alaskan slender wheatgrass produced during each year following establishment were 27, 29, 24, 12, and 7. These results agree with the above observations and suggest that for maximum forage production, slender wheatgrass stands should be tilled and replanted no later than after three full years of production. Alternatively, slender wheatgrass should be grown with other species more capable of extending the productive life of a mixed stand.

VIOLET WHEATGRASS was included in Exps. III and IV using seed increased from a single collection at Old Rampart (67°10′N) north of the Arctic Circle in northeastern Alaska. The total native range occupied by this grass is not well known, but it occurs also in eastern Canada and in Greenland (Hulten 1968).

Seeding-year growth of violet wheatgrass in these and other experiments at this location (Klebesadel and Helm 1992b) has consisted of basal leaves only (no elongated culms). This growth form during the seeding year, and limited in amount by relatively late seeding dates and moisture deficits in the establishment year in both experiments, resulted in no recoverable forage yields in the seeding year of either test (Tables 3, 4).

In subsequent years in both experiments, violet wheatgrass averaged 2.8 T/A per year with most produced in first cuttings. This species has been extremely winterhardy in these and in other tests here (Klebesadel and Helm 1992b), and it remained fully productive for the full 6-year terms of Exps. III and IV (Tables 3, 4). Those results contrast with findings of Mitchell (1982a) who noted stand deterioration and lowered yields of another Alaska strain of violet wheatgrass after two years of harvests. That poorer performance may be due to differences in genetic stock, or it could derive from differential grass response to dissimilar harvest dates in the two studies, as discussed in the section on arctic wheatgrass.

The relatively high forage production (Tables 3, 4) and otherwise good performance of the single accession in the present two tests (Fig. 5), suggest that additional collections and evaluations should be pursued to establish more fully the practical potentials inherent in this little-studied wheatgrass.

CRESTED WHEATGRASS, native in central Asia and first introduced into the U.S. in 1898, has been widely used in the U.S. northern Great Plains region for pasture, hay, and erosion control (Asay and Knowles 1985; A.A. Hanson 1972). It is an extremely long-lived perennial where adapted. Denisov *et al*. (1976) recognized this species as possessing extreme winterhardiness in Siberia.

The cultivar Summit-62, selected at Saskatoon (52°N), Saskatchewan, from material originating at Omsk (55°N) in Russia, was included in Exp. IV (Table 4). Summit-62 sustained severe winter injury during each of the first three winters after establishment, producing only very modest forage yields before winterkilling totally during the fourth winter. These results indicate that Summit-62 is poorly adapted for use in this area, despite its high ranking for winterhardiness at several more southern locations in Canada (Ouellet 1976).

Other, more northern-adapted ecotypes of crested wheatgrass should be obtained from Asia for evaluation in Alaska; such germplasm would be better adapted at this latitude and should perform better in this area than Summit-62.

Furthermore, the selection of Summit-62 at 52°N

Figure 7. Center plot shows native Alaskan bluejoint on 5 July of third year of growth in Exp. IV. Plot to left was Primar slender wheatgrass that winterkilled during the first winter after planting, right plot is Korpa timothy. Numbers on tall stake in center of each plot indicate height in feet.

(from a broader gene base originating at 55°N) for ideal adaptation at that more southern latitude logically would select against or eliminate genetic elements that confer good physiologic adaptation at these higher latitudes. Selection within introduced plant materials for good performance in Alaska should be accomplished by direct transfer from origins to Alaska for assessment of potentials and adaptation at this latitude, rather than pursuant to screening and narrowing of the gene base at lower latitudes (Klebesadel 1975, 1993d).

Additional results on the performance of Summit-62 and another cultivar of crested wheatgrass appear elsewhere (Klebesadel and Helm 1992b) in a report of more extensive evaluations of wheatgrasses at this location.

REDTOP was introduced into North America from Europe during Colonial times. It is used for forage, especially on poorly drained, acidic soils in northeastern and midwest U.S. (A.A. Hanson 1972). No cultivars are available; a single commercial lot was seeded in Exp. II.

Seeding-year forage yield was low and it winterkilled totally during the first winter. Irwin (1945), summarizing numerous early trials with redtop at several stations in Alaska, also noted frequent occurrences of winterkill in the Matanuska Valley and at other interior stations. Redtop survival and general performance were best at the Kenai and Kodiak stations where winter stresses are less severe than at this location.

On the basis of very limited results in this study, but reinforced by the above earlier findings, redtop should be considered for use only in southern Alaska areas with mildest winters. Although redtop is recognized as tolerant of acidic soils (Duell 1985; A.A. Hanson 1972), and soils in some areas of southern Alaska are moderately to strongly acidic, other acid-tolerant but more winterhardy grasses such as bluejoint or extreme northern strains of meadow foxtail or reed canarygrass (Klebesadel and Dofing 1991) probably would serve better than redtop.

POLARGRASS is a tall-growing, leafy native species widely dispersed in Alaska and elsewhere around the world at high latitudes (Hulten 1968). It occurs most commonly in sites well supplied with moisture. Polargrass is considered "a valuable food for reindeer" in Siberia (Denisov *et al*. 1976). The common name 'tall arcticgrass,' suggested for this species in an earlier report (Klebesadel 1969a), was found to be inappropriate as the name polargrass had been proposed earlier.

Seeds of polargrass are extremely small, numbering over three million per pound (Klebesadel 1969a). This contributes to poor seedling vigor; hence, seeding-year forage yields were very low to negligible (Tables 1, 2, 3, 4).

Stands of polargrass remained productive for the full 6-year terms of all four experiments, indicating good winterhardiness and persistence. However, this species was significantly lower in total 6-year yields than Polar bromegrass in all four tests. This was undoubtedly due to some extent to the lower-than-normal precipitation recorded during five of the nine years of these experiments (Table 6).

This grass is most productive with abundant soil moisture; conversely, it is very sensitive to moisture deficit and is more curtailed in herbage production than most grasses under slight to moderate moisture stress. Polargrass very likely would have ranked relatively better in forage production with normal to above-normal precipitation. Denisov *et al*. (1976) report that polargrass is very responsive to irrigation in Siberia.

Owing to its affinity in nature for habitats well supplied with moisture, and its behavioral responses to moisture abundance and deficit in these and other experimental trials, polargrass would be considered, like salt bluegrass and more than most grasses compared, a hydrophilic, or "moisture-loving" species. During years of ample moisture, polargrass forage yields equal or exceed those of other highest-yielding grasses (Klebesadel 1994b). In those years, the herbage of polargrass is often significantly more succulent (lower in percent dry matter) than other grasses, similar to salt bluegrass.

During the above-normal rainfall years in these experiments (1971, 1972), polargrass yields often equalled or exceeded those of Polar bromegrass. Polargrass ranked ninth in total forage production in comparison with the other species that were included in all four experiments. Mitchell (1982a, 1986, 1987a) reported good forage yields for selected strains of polargrass in several trials in this area.

Drawing upon the excellent winterhardiness and good adaptation of polargrass to Alaskan conditions, a cultivar named Alyeska was selected and released by the Alaska Agricultural and Forestry Experiment Station (Mitchell 1979b). The polargrass strain evaluated in the four tests reported here was a composite of native collections different from the Alyeska cultivar and subjected to less selection for superior productivity. Polargrass can be a highly productive forage grass or a valuable component in mixtures seeded for revegetation of disturbed sites in areas of Alaska (Mitchell 1987b), especially where adequate precipitation, relatively high soil-moisture content, or supplemental irrigation can be assured.

BLUEJOINT is the most widespread and abundant of Alaska's native grasses; it also occupies a considerable range elsewhere in North America (Hitchcock 1951; Hulten 1968). It is a tall-growing (Fig. 7), extremely winterhardy, fine-stemmed, long-lived perennial with a considerably greater tolerance for strong soil acidity than most grasses and legumes. Unlike most other grass species, bluejoint stems are sometimes branched, with a secondary stem arising from a juncture along the mainstem. This grass, in association with other native species, occupies vast areas of Alaska and is a conspicuous and dominant element of the native flora in many areas (Mitchell and Evans 1966).

Early visitors to Alaska, assessing soils, vegetation, and agricultural potentials and problems in the Territory (Aamodt and Savage 1949; Bennett 1918; Piper 1905) were impressed by the extensive acreages and tall, vigorous growth of bluejoint, especially in the south-coastal region. Those and other references to this species have used several common names in referring to this grass, including "redtop," "bluetop," and "marsh reedgrass," as well as the currently accepted "bluejoint" and "bluejoint reedgrass" (Mitchell 1979b).

A composited seed lot of collections from local, native stands was used to include bluejoint in all four experiments. Seeds of this species are extremely small

(Klebesadel *et al*. 1962); as a result, seedling vigor is poor and seeding-year forage yields were poor to nil in all four experiments (Tables 1, 2, 3, 4). However, once satisfactorily established, and when soil moisture was adequate, forage yields were good.

In Exps. I and II, forage yields of bluejoint, as with other species, were suppressed in the initial years by moisture deficits (Table 6). However, in the latter years of those experiments, and for most of the terms of Exps. III and IV, when moisture supply was better, bluejoint yielded well (Fig. 7). Among the grass strains that were included in all four experiments, bluejoint ranked seventh.

Early reports (Aamodt and Savage 1949; Irwin 1945; Klebesadel and Laughlin 1964) of Alaska grower experience in utilizing unmodified, unfertilized native stands of bluejoint indicated that stands became less productive with continued annual harvests or heavy grazing pressure. Where bluejoint has been subjected to long-term grazing, as on Kodiak Island, this tall-growing species has largely been supplanted by shorter-growing grasses that produce an abundance of basal leaves and are therefore more tolerant of grazing pressure (Klebesadel and Laughlin 1964).

However, the results of this study, as well as other investigations with modified and fertilized native stands (Klebesadel 1965; Laughlin 1969; Laughlin *et al*. 1984; Mitchell 1979a), and experimental seedings on cropland (Klebesadel 1994b; Mitchell 1982a), have shown that this species responds well to fertilizers and remains productive of forage with appropriate harvest schedules.

Winterhardiness of bluejoint was excellent, as evidenced by its good persistence for the full term of all four tests (except final year of Exp. IV) and good first-cut forage yields in 1971. Following the severe winter of 1970-71, first-cut yields of virtually all introduced grasses (that were not totally eliminated by that winter) were substantially diminished by winter injury (Tables 1, 2, 3, 4). In contrast, bluejoint and other extremely winterhardy native grasses sustained negligible winter injury and produced good first-cut yields in 1971.

Legumes

The search for dependably winterhardy, productive, biennial and perennial forage legumes for use in Alaska has been long and only marginally successful (Aamodt and Savage 1949; Bula *et al*. 1956; Hodgson 1964; Hodgson and Bula 1956; Hodgson *et al*. 1953; Irwin 1945; Klebesadel 1971b, 1971c, 1980, 1985a, 1992b, 1992c, 1993e; Klebesadel and Taylor 1973).

Legume forages are valued for their generally good palatability, high nutritional values, ability to capture or "fix" atmospheric nitrogen (through the action of symbiotic bacteria in root nodules), and to incorporate that element into legume plant tissues (Allen *et al*. 1964; Burton 1972; Heichel 1985; Klebesadel 1978; Sparrow *et al*. 1990). Nitrogen thus assimilated contributes to the high protein values characteristic of legume herbage and seeds, which in turn provide nourishment to consuming domestic stock or wildlife (Graham 1941). Decomposition of legume roots and plowed-under aerial growth add both N enrichment and humus to soils.

Legumes grown in mixture with grasses circumvent the need for applying high rates of expensive N-containing commercial fertilizers. The generally high crude protein concentration of the legume herbage elevates the protein level of the forage mixture; moreover, nitrogen released to the soil through root-nodule senescence and decomposition (and perhaps some via N excretion?) becomes available for uptake by associated grasses that cannot fix N.

Introduced Legumes

SIBERIAN ALFALFA is a yellow-flowered, long-lived perennial with smaller leaflets and seeds than blue-flowered or variegated alfalfa. It has long been recognized as more winterhardy, and endures grazing better, than blue-flowered alfalfa (Hansen 1909; Irwin 1945). The Alaska strain used in these experiments derived originally from Russia but has been perpetuated in Alaska, primarily for experimental purposes, following its introduction at the Rampart station in 1909. That strain is the most winterhardy of all introduced legumes that have been evaluated in numerous trials in Alaska (Bula *et al*. 1956; Hodgson 1964; Irwin 1945; Klebesadel 1971b, 1980, 1985a, 1993e; Klebesadel and Brinsmade 1966; Klebesadel and Taylor 1973).

Seeding-year yields of this alfalfa were quite low (Tables 1, 2, 3), due to its characteristically poor seedling vigor. Siberian alfalfa survived the first three winters in Exp. I (Table 1), two winters in Exp. II (Table 2), and one winter in Exp. III (Table 3); it was not included in Exp. IV. Forage yields were generally disappointing although yields for 1970 averaged 2.65 T / A over the three experiments. Stands of Siberian alfalfa were sacrificed in spring 1971 in all three experiments when an overall spray of a broadleaf herbicide was applied to eliminate invasion of several weed species in some thinned grass stands.

The superior winterhardiness of Siberian alfalfa is offset by several agronomic deficiencies that have precluded its recommendation by this Experiment Station or its adoption by the few growers that have tried it on a small scale. Those deficiencies include small seed size and slow seedling growth, slow spring growth and poor competitive abilities when grown in mixture with vigorous grasses, and low seed yields that discourage growers from producing seed; hence, only occasionally do small amounts of relatively expensive seed become available for purchase.

ALFALFA (purple or variegated flowered) is a taprooted, long-lived perennial, native to Eurasia, that has been grown as a forage for over 2000 years. It is called "lucerne" in Europe and Australia and is one of the dominant legume forages of the world (Barnes and Sheaffer 1985; C.H. Hanson 1972; Smith *et al*. 1986).

The purple-flowered species of major agricultural usage is classified as *Medicago sativa*. Hybridization with the yellow-flowered "Siberian" alfalfa (*M. falcata*) has resulted in "variegated" alfalfa strains with multi-colored flowers; many of those strains are more winterhardy than the pure purple-flowered species. That hybrid type sometimes has been referred to taxonomically as *M. media* (Hansen 1909), but more often as *M. sativa*, the parental species which variegated alfalfa most resembles.

Irwin (1945) summarized early alfalfa trials at several widely separated experiment stations in Alaska, beginning as early as 1904 at Kenai. Most evaluations were conducted at the Rampart, Fairbanks, and Matanuska stations; the hardiest of the variegated alfalfas evaluated seldom survived the second or third winter.

Owing to the popularity of alfalfa in many agricultural regions of the world, a great number of regional strains have evolved and numerous named cultivars have been developed and released by plant breeders (Barnes and Sheaffer 1985). The Alaska strain A-Syn.B evolved through many generations of artificially guided natural selection in this state; it has proved to be more winterhardy than all introduced variegated alfalfas in Alaska (Klebesadel 1971b, 1985c, 1992a, 1993e; Klebesadel and Taylor 1973). Since these experiments were conducted, the Alaska alfalfa cultivar Denali was released, based principally on A-Syn.B germplasm.

Seeding-year forage yields of A-Syn.B ranged from 0.56 to 1.58 T/A (Tables 1, 2, 3). Despite its superior winterhardiness to other variegated alfalfa cultivars and strains, A-Syn.B was neither as winterhardy nor as productive of forage as many of the grasses in these experiments.

A-Syn.B winterkilled during the first winter in Exp. I (Table 1). In Exp. II it was severely injured during the first winter (spring stand counts showed 13% winter survival). The reduced stands were not harvested for forage and were left to produce seed that year. Winter injury during the second winter resulted in no harvestable yield for the first cutting; with gradual recovery from injury during the year, a yield of 1.66 T/A was obtained in the second cutting. In spring of the following year, the stand remaining was killed with an herbicide applied to the entire experiment to control broadleaf weeds.

In Exp. III, stand counts showed that A-Syn.B survived the first winter at only 9%. Only modest forage yields were obtained that year and the thin surviving stand with considerable weed invasion was eliminated the following spring with a broadleaf herbicidal spray.

The cultivar Vernal was the only alfalfa included in Exp. IV; it produced 0.93 T/A in the late-September seeding-year harvest and winterkilled totally during the first winter.

Alfalfa may be more useful in areas of Alaska not as subject to removal of insulating snow cover by strong winter winds as commonly occurs in the Matanuska Valley (Dale 1956; Klebesadel 1974). Alfalfa grown on Tanana silt loam soil (Histic Pergelic Cryaquept) in interior Alaska performed poorly without liberal annual fertilizer topdressings of potassium (Klebesadel and Brinsmade 1966). Better-adapted strains than the cultivar Vernal used in that test have produced well at Fairbanks with adequate applied potassium, both alone and in mixture with bromegrass (unpublished information, Alaska Agric. and Forestry Exp. Sta.). Work is continuing to increase the winterhardiness levels and nitrogen-fixing capabilities of alfalfa strains for use in Alaska (Sparrow *et al*. 1990).

Some potential exists for use of alfalfa as an annual forage (Brundage and Branton 1967; Brundage *et al*. 1963). Non-hardy southern strains should be preferred for this use because of their more vigorous and productive growth during the seedling year.

SWEETCLOVER species used in agriculture include annual types as well as two species of biennials, differentiated by their white and yellow flower color (Table 5). Sweetclovers are native to Eurasia and were introduced into North America during the Colonial period; they are valued as a pasture, green manure, and honey sources in Canada, the Great Plains, Corn Belt, and southern states (Smith *et al*. 1986). The most winterhardy biennial sweetclovers are among the most winterhardy of all forage legumes (Ouellet 1976).

Irwin (1945) reported general results of early trials with biennial sweetclovers at several Alaska experiment stations, beginning in 1913 at the Rampart station. Winterkill was common and discouraged its use.

During recent decades, selection for improved winterhardiness in Alaska has resulted in sweetclover strains more winterhardy than cultivars from elsewhere. Three of those strains were included in these experiments.

"Matanuska white" is a local ecotype of biennial white sweetclover that, since its introduction into Alaska, has undergone genetic/physiologic modification toward subarctic adaptation during several decades of generational cycling and natural selection along a Matanuska Valley roadside. That adaptive modification has increased its winterhardiness to levels superior to temperate-latitude cultivars (Klebesadel 1985a, 1992c, 1993b, 1994c).

The "Arctic Circle" strain of biennial yellow sweetclover has undergone acclimatization in an unguided manner similar to Matanuska white, but during a shorter period and at a considerably more northern location near the Arctic Circle (Klebesadel 1985a, 1992b, 1994c).

"AK-Syn.1" is an experimental Alaska selection derived primarily from the biennial white Canadian cultivar Arctic; AK-Syn.1 represents three generations of managed selection for improved winterhardiness locally and generally surpasses Arctic in winter survival (Klebesadel 1992c, 1994c).

Seeding-year forage yields of sweetclover ranged from nil (Matanuska white in Exp. III) to 2.02 T/A (AK-Syn.1 in Exp. I). The relatively late planting dates in these experiments, ranging from 6 to 25 June, sacrificed significant portions of the growing seasons, portions with very long photoperiods that would have contributed to higher seeding-year yields of all grasses and legumes. Perhaps no other crops of those compared are curtailed as greatly in seeding-year dry-matter production as sweetclovers when planting is delayed; sweetclovers seeded four to six weeks earlier (10 to 15 May) than the dates of these experiments typically produce considerably higher seeding-year yields in this area (Klebesadel 1992c, 1994c).

Despite the superior winterhardiness of these strains over other sweetclover cultivars in numerous other tests (Klebesadel 1992b, 1992c, 1993b, 1994c), their survival in the extremely exposed winter environment of the experiments in this study was generally poor except in Exp. III (Table 3). In Exp. I, AK-Syn.1, the only sweetclover included, winterkilled 100%. In Exp. II, winter survival of the same strain was 25%. No forage yields appear for the second year (Table 2) as those surviving plants were left uncut to produce seed.

Four sweetclover strains were included in Exp. III; stand counts in spring of the second year revealed that winter survival of three strains of biennial white were: AK-Syn.1 51%, Matanuska white 72%, and the Canadian cultivar Arctic 29%. The yellow Arctic Circle strain survived at 66%. Better winter survival of these sweetclovers likely would have been realized with better winter protection afforded by a tall (10- to 12-inch) stubble left after harvest of the sweetclovers or of a cereal companion crop during the year of establishment as described in the discussion of red clover and elsewhere (Klebesadel 1992a).

First-cut forage yields for the four sweetclovers in the year after establishment in Exp. III did not differ significantly and averaged 1.24 T/A (Table 3). Second cuttings of the white strains were very low, averaging only 0.08 T/A. Second-cut yield of the yellow-flowered Arctic Circle strain was significantly higher at 0.79 T/A. All of these sweetclovers are biennials that die naturally after the second year of growth, so no further yields were produced.

SAINFOIN, native to temperate areas of Europe and southern Asia, has been cultivated in France for over 400 years; there it acquired the name sainfoin, which reportedly means "wholesome hay." It is valued as one of the few forage legumes, along with birdsfoot trefoil and cicer milkvetch, that does not cause bloat in cattle.

Interest has grown in sainfoin culture during recent years in the northern Rocky Mountain Region of the U.S. and adjacent areas of Canada (Hoveland and Townsend 1985). The cultivars Melrose and Nova have been developed and released in Canada, Eski and Remont in Montana, and Renumex in New Mexico. A "commercial" seed lot of European origin was included in Exps. I and II, and strain P-15596 from Montana was included in Exp. III.

Seeding-year forage yields ranged from 0.50 to 1.45 T/A (Tables 1, 2, 3); however, those were the only yields obtained as neither of the strains evaluated survived the first winter. These results are consistent with other instances of disappointing winter survival with several different cultivars and strains of sainfoin in Alaska (Klebesadel 1971b, 1980); these indications of poor adaptation in Alaska probably are due to the generally more southern latitudinal origin and adaptation of the species. On the basis of these negative findings, there can be little optimism for successful use of sainfoin as a perennial forage in this area of Alaska.

CICER MILKVETCH is a long-lived perennial legume (where adapted) that spreads by rhizomes; it is native from Spain across southern Europe to the Caucasus Mountains of southern Eurasia (Hoveland and Townsend 1985). It was introduced into the U.S. in the 1920's and has been utilized increasingly as pasture, hay, and for conservation purposes in the Great Plains, western U.S.,

Table 5. Common and scientific names of grass and legume species, the cultivars and strains evaluated, and their origins. The area where the variety or strain was selected is the first origin given; when a different original source of the genetic stock is known, that source follows in parentheses.

GRASSES:

Smooth bromegrass (*Bromus inermis* Leyss.):
- Polar - Alaska
- Frigga - Sweden
- Carlton - Saskatchewan (Europe)
- Redpatch - Ontario (Europe)
- Manchar - Washington (Manchuria)
- Achenbach - Kansas (Europe)

Pumpelly bromegrass (*B. pumpellianus* Scribn.):
- Native strain - Alaska

Meadow bromegrass (*B. biebersteinii* Roem. & Schult.):
- Regar - Idaho (Turkey)

Timothy (*Phleum pratense* L.):
- Engmo - Norway
- Korpa - Iceland
- Tammisto - Finland
- Bottnia II - Sweden
- Omnia - Sweden
- W:S T-48 - Sweden
- W:S T-59 - Sweden
- Climax - Ontario (Europe)
- Wis. T-10 - Wisconsin (Europe)

Orchardgrass (*Dactylis glomerata* L.):
- Chinook - Canada (Europe)
- Brage - Sweden (Germany)
- Frode - Sweden

Creeping foxtail (*Alopecurus arundinaceus* Poir.):
- Garrison - North Dakota (USSR)
- P-111 - Washington (USSR)

Meadow foxtail (*A. pratensis* L.):
- Sweden commercial - Sweden
- Oregon commercial - Oregon (Eurasia)

Reed canarygrass (*Phalaris arundinacea* L.):
- Frontier - Ontario
- Grove - Ontario
- Ioreed - Iowa
- Superior - Oregon

Red fescue (*Festuca rubra* L.):
- Arctared - Alaska
- Duraturf - Ontario (Scandinavia)
- Boreal - Alberta (Czechoslovakia)
- Olds - Alberta (Czechoslovakia)
- Pennlawn - Pennsylvania (Europe)
- Ranier - Oregon (Europe)
- Illahee - Oregon (England)

Chewings fescue (*F. rubra* var. *commutata* Gaud.):
- Highlight - Holland
- Commercial - USA (Europe)

Hard fescue (*F. ovina var. duriuscula* (L.) Koch):
- Durar - Washington (Oregon)

Meadow fescue (*F. elatior* L.):
- Bottnia II - Sweden
- Tammisto - Finland
- An-2356 - Finland

Tall fescue (*F. arundinacea* Schreb.):
- Alta - Oregon (Europe)

Kentucky bluegrass (*Poa pratensis* L.):
- Nugget - Alaska
- Delta - Ontario
- Park - Minnesota
- Merion - Maryland (Pennsylvania)
- Newport - Washington (Oregon)

Big bluegrass (*P. ampla* Merr.):
- Sherman - Washington (Oregon)

Salt bluegrass (*P. eminens* Presl.):
- Native strain - Alaska

Siberian wildrye (*Elymus sibiricus* L.):
- Native strain - Alaska

Russian wildrye (*E. junceus* Fisch.):
- Sawki - Saskatchewan (USSR)

Slender wheatgrass (*Agropyron trachycaulum* (Link) Malte):
- Native strain - Alaska
- Alaska-44S - Alaska (USA?)
- Revenue - Saskatchewan
- Primar - Washington (Montana)

Crested wheatgrass (*A. desertorum* (Fisch.) Schult.):
- Summit-62 - Saskatchewan (USSR)

Arctic wheatgrass (*A. sericeum* Hitchc.) = (*A. marourum* (Turcz.) Drobov)?
- Native strain - Alaska

Violet wheatgrass (*A. violaceum* (Hornem.) Lange):
- Native strain - Alaska

Redtop (*Agrostis alba* L.):
- Commercial - USA (Europe)

Polargrass (*Arctagrostis arundinacea* (Trin.) Beal):
- Native strain - Alaska

Bluejoint (*Calamagrostis canadensis* (Michx.) Beauv.):
- Native strain - Alaska

LEGUMES:

Siberian alfalfa (*Medicago falcata* L.):
- Alaska strain - Alaska (USSR)

Alfalfa (*M. sativa* L.):
- A-Syn.B - Alaska (USA/Eurasia)

White sweetclover (*Melilotus alba* Desr.):
- Matanuska white - Alaska (USA?/Eurasia)
- AK-Syn.1 - Alaska (Saskatchewan/USSR)
- Arctic - Saskatchewan (USSR)

Yellow sweetclover (*M. officinalis* (L.) Lam.):
- Arctic Circle strain - Alaska (USA?/Eurasia)

Red clover (*Trifolium pratense* L.):
- Alaskland - Alaska (USSR)

Alsike clover (*T. hybridum* L.):
- Kurir - Sweden
- Aurora - Alberta (Europe)

Sainfoin (*Onobrychis viciaefolia* Scop.):
- Europe commercial - Europe
- P-15596 - Montana (Europe)

Cicer milkvetch (*Astragalus cicer* L.):
- P-498 - Washington (Sweden)

Williams milkvetch (*A. williamsii* Rydb.):
- Native strain - Alaska

Harrington milkvetch (*A. harringtonii* Cov. & Standl.):
- Native strain - Alaska

Alpine sweetvetch (*Hedysarum alpinum* L. var. *americanum* Michx.):
- Native strain - Alaska

and adjacent areas of Canada, where it is considered very winterhardy (Hafenrichter *et al*. 1968; Hoveland and Townsend 1985). Irwin (1945) reported that a strain of cicer milkvetch of unstated origin, seeded at the Matanuska station in 1940, succumbed during the first winter.

A strain of cicer milkvetch identified as P-498, included only in Exp. I, winterkilled during the first winter. That strain derived from an import from the Stockholm Botanic Gardens brought to the U.S. about 1935. In other experimental plantings here, P-498 usually has winterkilled 100% during the first winter; in one trial it survived the first winter at 28% (Klebesadel 1971b, 1980).

New cultivars have been selected and released in western states and Canada in recent years (Hoveland and Townsend 1985). These and any other strains from the northern limits of the range of adaptation for the species should be evaluated in Alaska; however, the principally temperate-latitude original range indicated for this species suggests a generally discouraging outlook for its successful use as a winterhardy perennial in Alaska.

RED CLOVER is a relatively short-lived perennial and is the most widely grown species of the so-called "true" clovers. It is believed to have originated in southwestern Asia. The first recorded use of red clover as a forage crop was in the 1200's, and it was introduced into North America by the colonists (Smith *et al*. 1986). It is widely grown in the U.S. Midwest and northeast states, usually in mixture with timothy; however, red clover acreage has declined somewhat during recent decades (Taylor 1985; Smith *et al*. 1986).

Two major forms of red clover are grown: medium or double-cut, and mammoth or single-cut. Irwin (1945) summarized numerous evaluation trials with red clover during the first half of this century at seven experiment stations in Alaska. Winterkill was common during the first or second winter. In those trials, the mammoth type was noted to be somewhat more winterhardy than the medium type, a generally accepted ranking elsewhere as well.

The Alaska cultivar Alaskland was formulated from old stands of generally winterhardy and persistent plants of mammoth-type red clover at the Fairbanks station (Hodgson *et al*. 1953). That cultivar was included in Exp. IV. Mammoth red clovers tend to produce rosettes of principally basal leaves with little or no elongation of stems during the seeding year. That growth behavior, and the relatively late seeding date (25 June), resulted in a very modest seeding-year forage yield (0.12 T/A).

Alaskland winterkilled 100% during the first winter. The procedure of seeding-year harvest that left only a short stubble in this study departed from acknowledged and preferred red clover establishment in this area; to ensure snow cover for insulation of plants from low winter air temperatures, red clover should be seeded with a small-grain companion crop. The companion crop is then harvested, preferably for forage at an immature stage of growth (a) to shorten the period of strong competitive shading by the companion crop, (b) to lessen the chance of lodging of the companion crop (which tends to smother the shorter, weaker clover seedlings), and (c) to permit a longer period of unimpeded growth between companion-crop harvest and termination of the growing season, resulting in larger clover seedlings prior to winter.

Importantly, the companion crop should be harvested to leave a tall (10- to 12-inch) stubble which holds a protective layer of snow in place against the strong force of winter winds common in this area (Dale 1956; Klebesadel 1974); the protection provided to the legume seedlings by the snow layer can markedly enhance winter survival of clover (Klebesadel 1992a). The same condition of insulating snow cover that routinely remains in place along roadways permits better winter survival of red and alsike clovers when seeded as N-fixing species in revegetation mixtures for highway verges in Alaska.

Winter air temperatures in the Tanana Valley of interior Alaska, where Alaskland was selected, commonly are much colder than in the Matanuska Valley, but, except near the Alaska Range, snow remains in place to provide insulation. Hence, red and alsike clovers commonly survive winters better there than in the more exposed, wind-blown fields in the Matanuska Valley. In areas where snow cover remains in place, however, overwintering grasses and legumes may be more subject to injury from snow mold and other pathogens (Andersen 1960; Kallio 1966).

ALSIKE CLOVER, believed to have originated in Sweden, was introduced into the U.S. about 1840 but is grown in eastern Canada and Europe more than in the U.S. It somewhat resembles red clover in growth form but has smaller, lighter-colored pink-white flowers and is somewhat more tolerant of soil acidity than red clover.

Irwin (1945) reported generally poor winter survival in early Alaska evaluations of alsike clover at all stations except at Kenai where winter stresses tend to be comparatively modest.

The cultivars Kurir from Sweden and Aurora from Canada were included in Exp. IV. Seeding-year yields were about ½ T/A and both cultivars winterkilled 100% the first winter. Preferred seeding-year management of alsike clover for this area was not used in these experiments. The practice of leaving a tall cereal companion-crop stubble to retain insulating snow cover to enhance winter survival of legume seedlings during the first winter (Klebesadel 1992a) is similar to that discussed for red clover.

Alsike clover is commonly included in roadside revegetation seedings in this area. In that habitat, where protective snow cover insulates plants from low and sometimes strongly fluctuating air temperatures during winter, northernmost-adapted strains of alsike clover persist quite well.

The overwintering crown tissues of alsike and red clover, as with many of the introduced grasses that survived winters poorly in these experiments, are positioned above the soil surface and thus are more exposed to winter stresses than the better protected crowns of sweetclover and alfalfa. Alaska-adapted strains of sweetclover and alfalfa generally survive winters in this area much better than the hardiest alsike and red clovers. Although such comparisons were not made in these experiments, those survival differences have been clearly demonstrated in other trials at this location (Klebesadel 1971b, 1980).

Native Alaskan Legumes

The goal of identifying dependably winterhardy, vigorous, and productive introduced legumes from other world areas for use in Alaska has been largely unrealized, principally because introduced ecotypes are poorly adapted to certain unusual characteristics of subarctic Alaska's seasonal/climatic patterns. Specifically, those introduced, temperate-adapted legumes are subjected to an inadequate term of short daily photoperiods (and simultaneously long nyctoperiods) prior to freeze-up to stimulate proper physiological preparation to survive low winter temperatures when grown in the Subarctic (Hodgson 1964; Klebesadel 1985c, 1992b, 1992c, 1993b; Moschkov 1935, Pohjakallio 1961).

This problem of poor adaptation of introduced legumes then focuses attention on Alaska's numerous species of native legumes that, having evolved under subarctic climatic conditions, possess ideal adaptation to northern latitudes. Hulten (1968) lists approximately 50 species of native legumes in Alaska; these vary greatly in size and growth form, geographic distribution, habitat affinities, etc. (Hulten 1968; Klebesadel 1971c).

Native legumes serve valuable roles in nature through N fixation (Allen *et al*. 1964) that benefits associated vegetation (Klebesadel 1978), and in supplying protein-rich herbage and seeds for wildlife consumption (Graham 1941). Some species appear superficially to offer potential as forage crops (Fig. 8). Earlier reports of experimental plantings here (Klebesadel 1971b, 1971c, 1978, 1980, 1993e) have documented excellent winterhardiness and certain other desirable agronomic characteristics, as well as significant limitations to practical use, in some of the native Alaska legumes.

Milkvetches belong to the genus *Astragalus*; species and subspecies native to Alaska number about 15 (Hulten 1968). Two species were included in these experiments: Williams milkvetch occurs predominantly in east-central Alaska. Seed collected at about 64°N in the Delta Junction area was used to include that species in Exp. I; Harrington milkvetch occurs across parts of southern Alaska, and seed collected locally was used to include that species in Exp. III.

WILLIAMS MILKVETCH is a relatively tall-growing legume usually occurring with associated grasses where observed in the Delta Junction area in interior Alaska (Fig 8). I have observed that bison ranging throughout that area occasionally grazed off the seed pods that extend above most of the foliage, but surprisingly did not consume the entire plant, although it was leafy and succulent.

Seeding-year growth of this species was extremely slow; in early October when plots were harvested, seedlings of Williams milkvetch were only about one to two inches tall, too short to provide a harvestable yield (Table 1). Observation the following spring showed no evidence of winterkill. However, when first-cut harvest was taken on 25 June, milkvetch plants were only three to four inches tall; no yield was obtained but all plots were trimmed to a 2-inch stubble. At the second harvest on 18 September, tallest plants of Williams milkvetch were only about eight inches tall and again no measurable yield was obtained.

Observation the second spring after planting again showed excellent winter survival. On 14 May plants were one to three inches tall with floral buds showing, and on 21 May plants were in early flowering stage. Growth was again inadequate for harvestable forage yields in either cutting of that year.

In the fourth year of growth, winter survival again was good and plants were two to six inches tall on 14 May. At first harvest on 2 July, plants were 14 to 16 inches tall with small green seeds forming in the pods. Forage yield was 1.17 T/A (Table 1). Regrowth was so slow and uncompetitive, however, that invasive weeds in the milkvetch stands led to mowing plots to a 2-inch stubble on 20 August to prevent weed-seed production; a "trace" amount of forage is shown in Table 1 for the 14 September harvest to indicate some growth present.

In spring of 1971, the milkvetch plants were in early to mid-bloom on 23 June. However, plots of this and all other legumes were sacrificed when an overall spray of a selective herbicide was applied 25 June to eliminate several broadleaf weed species in some thinned grass plots; therefore, no further forage yields were obtained.

Winterhardiness of Williams milkvetch was good; however, the extremely poor seedling vigor and slow growth in subsequent years that led to a first harvestable forage yield in the fourth year of growth preclude consideration of this species for competitive forage use. It may be useful for other purposes such as revegetation of disturbed sites (Klebesadel 1973) where a very winterhardy, native, N-fixing legume is desired and where rapid early growth is less important.

HARRINGTON MILKVETCH seedling growth also was very slow; therefore, no seeding-year yield was obtained (Table 3). Stand counts in spring of the year after establishment showed 100% winter survival. Flowering was very early with some flowers in bloom on 10 June. First-cut forage yield of 1.63 T/A was the only yield obtained as regrowth after cutting was very meager. At the first-harvest date of 9 July, plants of this legume were only 8 to 10 inches tall and seed was already mature and shattering.

Winter survival the following winter was estimated at 85%. No further forage yields were obtained as this and other broadleaf species were eliminated when an herbicidal spray was applied.

This species obviously is extremely winterhardy and performs a useful role in nature, often serving as a pioneer species in colonizing gravels and other soil materials left during glacial retreat or other disturbances (Fig. 8). However, its very early flowering and seed production, modest forage yield from relatively short plants, and very poor regrowth after first harvest argue against its utilization as a useful agricultural forage species.

ALPINE SWEETVETCH (Fig. 8) is sometimes referred to as Eskimo or Indian potato because the somewhat fleshy root of this widely distributed native legume has sometimes been consumed as a survival food by Alaska Natives. Seed collected from local stands of this species was used to include it in Exp. III (Table 3).

This legume also grew very slowly during the establishment year and the very small seedlings ceased growth early; some leaves were drying and dropping from plants before the late (7 Oct.) harvest date. Consequently, no seeding-year forage yield was obtained.

Winter survival was excellent (97%); however, the first-cut forage yield was relatively low (0.82 T/A) and little regrowth occurred, so no measurable second-cut yield was obtained. Further yields of alpine sweetvetch were sacrificed due to the selective herbicidal spray applied to the entire experiment to combat invasion of broadleaf weeds in many thinned grass plots.

These and other trials (Klebesadel 1971b, 1980) with this native legume indicate that it is extremely winterhardy and fulfills a valuable role in natural habitats (Klebesadel 1971c, 1978). Alpine sweetvetch may be useful for revegetation purposes (Klebesadel 1973) but it is too slow to establish and is not sufficiently productive of herbage to serve as a worthwhile forage crop.

Conclusions

The earlier report by Irwin (1945), summarizing 47 years (1898-1945) of experimental work with grasses and legumes at seven widely dispersed experiment stations in Alaska provided some valuable insights concerning performance of many species. However, most of those evaluations were conducted in observation-type, non-replicated trials and under low soil-fertility conditions.

Ecotypic Differences Within Species

Perhaps the greatest deficiency in early grass and legume evaluations and observations in Alaska (Aamodt and Savage 1949; Alberts 1933; Irwin 1945), however, was the tendency to base judgment of the suitability of a total species on the performance of a single selection, ecotype, or strain within that species, usually with no reference to, or appreciation of the importance of, the latitude of origin or adaptation of the strain evaluated.

With that approach, evaluations of plant materials were judged primarily on the basis of a species as an unvarying, monolithic category, rather than concern for, and awareness of, the great range of variability and thus adaptational differences that can and often do exist within a single species.

That approach did not appreciate the sometimes great geographic ranges occupied by some species and therefore the implicit equally great range of climatic peculiarities to which widely dispersed ecotypes within such a species individually have adjusted, via natural selection. Such adaptational adjustments have resulted in each ecotype being in physiologic harmony with its specific environmental conditions (Mason and Stout 1954; Wilsie 1962).

Thus, two ecotypes from widely separated geographic origins, but belonging to the same species, would possess widely divergent adaptational affinities (having evolved under two greatly different sets of environmental conditions) and therefore could differ greatly in performance when evaluated in Alaska.

If one ecotype that had evolved under environmental conditions greatly different from those prevalent in Alaska understandably performed poorly here, then the entire species was previously judged poorly adapted here. Conversely, if a strain or ecotype evaluated here originated from an area where conditions were similar to this part of Alaska, the entire species would be pronounced well adapted here when, in fact, many other ecotypes from dissimilar environments within that broad-ranging species would actually be poorly adapted to this area's conditions and therefore would perform poorly here.

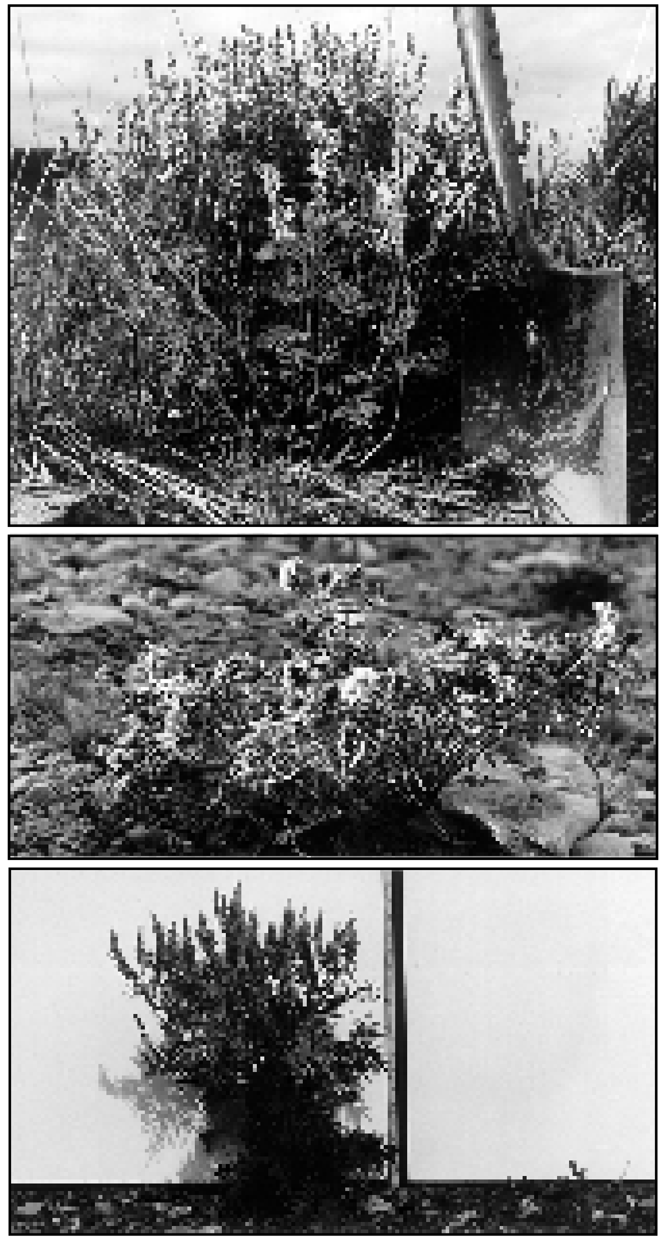


Figure 8. General appearance of native Alaskan legumes included in experiments: (top) *Williams milkvetch plant in full bloom (16 to 17 in. tall) photographed 2 June in abandoned field near Delta Junction,* (center) *Harrington milkvetch plant in early flower (8 to 10 in. tall) photographed 20 May, growing in gravelly substrate in the Matanuska Valley, and* (bottom) *alpine sweetvetch plant in full bloom (17 to 18 in. tall) photographed 12 June, growing in gravelly substrate in the Matanuska Valley.*

Thus, the results of the present study reinforce those of several other investigations at this location (Klebesadel 1970, 1971b, 1984a, 1985b, 1991, 1992a, 1992b, 1992c, 1992d, 1993a, 1993b, 1993c, 1993e, 1994c; Klebesadel *et al.*

1964; Klebesadel and Dofing 1991; Klebesadel and Helm 1986, 1992a, 1992b; Klebesadel and Taylor 1973) in confirming that a great adaptational and therefore winterhardiness diversity exists within many species of cool-season forage crops. Recognition of that diversity, and the influence of latitudinal adaptation on the considerable range in winterhardiness within many species, is crucial to enlightened selection of strains for optimum performance in Alaska.

Thus, for superior performance here, plants should possess adaptation to this north-latitude environment. That adaptation is inherent in native Alaska ecotypes. However, to benefit from similar ideal adaptation in introduced plant strains, they should be sought from (a) other northern origins and (b) regions with winter climates relatively analogous to Alaska areas where they are to be grown.

Latitude-of-Origin and Winter Survival

In several instances within the four experiments, a single species was represented by from three to nine cultivars or strains from a broad range of latitudinal (north-to-south) origins. The species and experiments affording such comparisons include smooth bromegrass (Exps. II, III, IV), timothy (Exps. III, IV), red fescue (Exps. II, III, IV), Kentucky bluegrass (Exps. II, IV), and slender wheatgrass (Exps. II, III, IV).

In each of those comparisons, the northernmost-adapted strains were the most winterhardy and persistent. With progressively more southern origins the winterhardiness, persistence, and forage yield became generally poorer (a single exception was the early demise of native Alaskan slender wheatgrass in Exp. IV, where that relatively short-lived species became unproductive after the fourth year).

Several studies at this location (Hodgson 1964; Klebesadel 1971a, 1985c, 1992b, 1993b) and elsewhere (Moschkov 1935; Pohjakallio 1961) have confirmed that temperate-adapted grasses and legumes, when grown at more northern latitudes, experience an inadequate term of critical-length short photoperiods (long nyctoperiods), prior to a relatively abrupt onset of winter conditions, to induce them to develop winterhardiness levels to their full inherent capacity.

Once the winterhardening process (development of freeze tolerance) is initiated by critical-length photoperiods/nyctoperiods (Hodgson 1964; Klebesadel 1993b), that process proceeds slowly, but is propelled by lowering temperatures and continues well beyond the time of killing-frost destruction of foliage (Klebesadel 1993b). Maximum levels of freeze tolerance are not achieved until near mid-winter (Bula *et al*. 1956). Early onset of lethal temperatures during October/November can be so abrupt on occasion that it kills even some generally well adapted perennials before adequate freeze-tolerance has developed (Klebesadel 1977).

As a result of being poorly attuned to preparation for winter stresses under the unusual interrelationship of photoperiod/nyctoperiod pattern and termination of the growing season at high latitudes (Klebesadel 1971a, 1985c, 1992b, 1993b), those more southern-adapted crops fail to survive winters in southcentral Alaska, even though some survive colder winters in their areas of origin.

When grown where they have evolved, and therefore where they are adapted, they respond adequately to the longer term of short photoperiods/long nyctoperiods prior to growing-season termination to undergo more adequate physiological preparation to tolerate winter stresses. Artificial provision of conditions in the Subarctic similar to those that occur in their more southern area of origin promotes much improved winter survival at northern latitudes (Klebesadel 1971a, 1985c; Moschkov 1935; Pohjakallio 1961).

A Canadian report (Kilcher and Looman 1983) illustrates well the important relationship of latitudinal ecotypes and adaptation to winter survival and forage productivity of grasses. Those authors identified grasses native to southwestern Saskatchewan (ca. 50°N), but then obtained seed of ecotypes of those species from a much more southern source in Kansas (37° to 40°N), and compared those more southern-adapted introductions with five Saskatchewan-adapted ecotypes of wheatgrass and wildrye. They demonstrated that the Kansas-adapted ecotypes were poor for forage production and winter survival in the more northern area where their physiologic behavior understandably was adversely affected by unaccustomed climatic, growing season, and photoperiodic influences.

Winter Climates

In addition to the influence of latitudinal origin on winterhardiness, different winter climates at near-similar latitudes in the conterminous 48 states influence strongly the relative performance of cultivars in Alaska. This is clearly evident in the disparate performance of two Kentucky bluegrass cultivars, Park and Newport, in Exps. II and IV (Tables 2, 4).

Park, selected at St. Paul, MN, from material collected "throughout Minnesota" (A.A. Hanson 1972), is adapted to the upper Midwest where very low winter temperatures occur. The January average for St. Paul is +13.1°F and the record minimum was -41°F (U.S. Dep. Agric. 1941). The winter survival and persistence of Park was much superior to that of Newport which is adapted at near the same latitude but from coastal Oregon (A.A. Hanson 1972). The much milder January average at Newport, OR, is +43.7°F and the recorded minimum there was +1°F.

The same two main types of winter climates exist at more northern latitudes as well, and they subject plants to considerably different patterns of winter stresses (Andersen 1960). The *continental* type prevails distant from moderating oceanic influences and within large land masses. Examples include the central land masses of Canada, Alaska, western Russia, and northcentral Asia. Northern continental-type winters are characterized by extreme low temperatures and a relative constancy of those lows.

The opposite extreme is the *maritime* type of winter where oceanic effects preclude the extremely low temperatures that occur in large continental masses. However, coastal or near-coastal locations with maritime climates are subjected to a more variable fare of winter temperatures, often with freeze-thaw oscillations occasioned by random movements of air masses across those

Table 6. Monthly departures (inches) from normal precipitation recorded at the Matanuska Research Farm during the course of experiments discussed in this report.[1]

Year	Apr	May	June	July	Aug	Sep	Net departure
1967	+ .46	+ .19	+ .06	+ .46	- .04	+ .78	+1.90
1968	+ .08	+1.80	+ .36	- .50	-2.23	-1.57	-2.06
1969	- .37	+ .28	- .90	+1.04	-2.08	-1.93	-3.95
1970	- .05	- .66	+ .06	- .36	- .75	-1.55	-3.31
1971	+ .59	- .47	+ .49	- .14	+2.00	+ .09	+2.56
1972	+ .18	+ .49	+ .05	- .64	-1.85	+2.54	+ .77
1973	+ .69	- .36	+ .32	-2.04	+1.66	-1.50	-1.23
1974	+ .12	+ .06	- .94	-1.28	-1.43	- .09	-3.56
1975	+1.34	- .49	+ .71	- .13	-1.33	+1.02	+1.12
Normal	.63	.74	1.59	2.50	2.38	2.33	

[1]Some supplemental irrigation was applied at times of critical moisture deficit, but generally was applied after moisture stress was conspicuous; thus yields in rainfall-deficient years were lower than would have occurred with more adequate and timely precipitation.

locations and deriving from oceanic (warm) or continental (cold) origins.

In Alaska, the early Rampart station (1900-1924) and the present experiment station near Fairbanks experience continental-type climates. In contrast, the Matanuska Research Farm, the site of these experiments, is predominantly under a maritime-type climate, with tidewater only about two miles distant at the head of Knik Arm. However, a wall of mountains and the Kenai Peninsula landmass to the south form a barrier against full-scale oceanic influences, thereby divorcing the Matanuska Valley from a truly coastal climate. This area is therefore somewhat transitional between maritime and continental climates, with major river valleys that funnel air movements across the Valley, and lend their names to either coastal ("Knik" winds) or interior air masses ("Matanuska" winds) (Dale 1956; Watson 1959).

The significance of the relationship between winter-climate type and plant winter survival is that, for best adaptation and survival, plant ecotypes for this area should be sought (a) from other north-latitude areas, but additionally (b) from north-latitude areas that are subjected to analogous winter climates that produce similar stresses on plants (Andersen 1960).

The results of the present study support this thesis in the superior performance here of Engmo timothy from northern, coastal Norway, Korpa timothy from the island of Iceland, and the good performance of Canadian Duraturf red fescue, originating from "Scandinavian material." Additional support derives from subsequent good performance here of Adda timothy from Iceland, Lavang Kentucky bluegrass from northern Norway, Canadian Dormie Kentucky bluegrass deriving from material from a coastal area in far northwestern Russia, and Rovik and Hansvoll reed canarygrass from north of the Arctic Circle in coastal Norway (Klebesadel and Dofing 1991).

Reciprocal transfers from North America to northern Europe have been successful also; examples include use of Alaska's Nugget Kentucky bluegrass in Norway and lodgepole pine (*Pinus contorta*) from the northern part of its range in Canada grown in Sweden.

Extensions of this logic involving circumpolar plant transfers suggest that (a) grasses for other purposes in this area, such as for golf greens (wherein inadequate winterhardiness is a problem) should be sought in *Agrostis* accessions that are native in far-northern Scandinavia and northwestern Russia (Hulten 1968), and (b) grasses and legumes selected for best adaptation to the continental climate of interior Alaska should derive, not from those maritime areas, but more appropriately from northern but continental origins where winter conditions and stresses are more similar to those of Alaska's Interior.

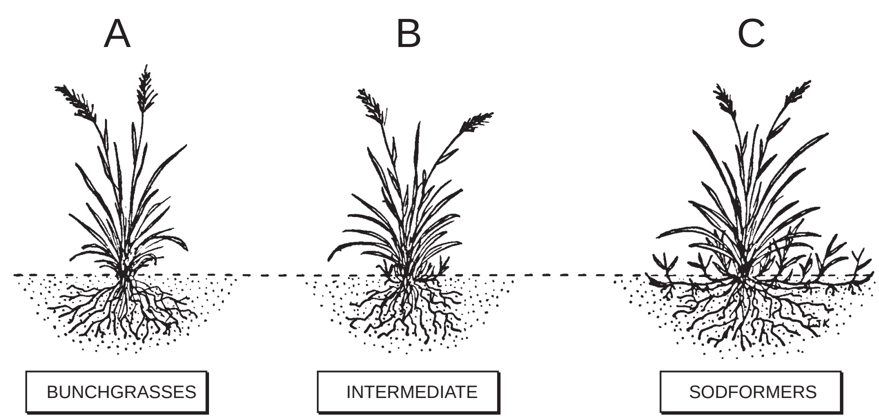
Position of Overwintering Plant Parts

Among the introduced grasses there appears a distinct association, in addition to the influence of latitudinal origins, between winter survival and positioning (above or below the soil surface) of the tissues and plant parts that must survive the winter and initiate new growth the following spring (Fig. 9).

Introduced bunchgrasses with principally aboveground overwintering tissues, and characterized by generally poor winterhardiness, include orchardgrass, tall fescue, meadow fescue, meadow bromegrass, meadow foxtail, and timothy.

Only the extremely northern-adapted timothy cultivars, Engmo and Korpa from Norway and Iceland, respectively, displayed fairly good winter survival in Exps. III and IV, yet they too were frequently winter injured and produced low first-cut yields. Moreover, Engmo winterkilled near mid-term in Exps. I and II. Both cultivars winterkilled 100% in another unrelated experiment where an unusually rapid plunge in temperatures during late October killed all timothy strains while, in the same test, smooth bromegrass, creeping foxtail, and Kentucky bluegrass, species with subterranean overwintering tissues, survived well (Klebesadel 1977).

In contrast to the bunchgrasses, sod-forming species (Fig. 9) which spread vegetatively by subterranean rhi-



Bunch-type or tufted grasses have most of their overwintering tissues at or above the soil surface.

Examples:

Introduced:
- Orchardgrass
- Tall fescue
- Meadow fescue
- Hard fescue
- Chewings fescue
- Meadow bromegrass
- Slender wheatgrass
- Timothy
- Big bluegrass
- Crested wheatgrass
- Russian wildrye

Native:
- Siberian wildrye
- Slender wheatgrass
- Violet wheatgrass
- Arctic wheatgrass

Intermediate growth type.

Examples:

Introduced:
- Red fescue
- Meadow foxtail

Native:
- Bluejoint
- Polargrass
- Red fescue

Sod-forming grasses (that spread by subterranean rhizomes) have much of their overwintering tissues protected below the soil surface.

Examples:

Introduced:
- Smooth bromegrass
- Creeping foxtail
- Kentucky bluegrass
- Reed canarygrass
- Redtop

Native:
- Pumpelly bromegrass
- Salt bluegrass

Figure 9. Sketches of growth types of grasses: (A) bunch or tufted, (B) intermediate, and (C) rhizomatous or sod-forming. These different types illustrate the exposed versus protected positioning of overwintering and regenerative tissues in relation to the soil surface; examples of each are listed. Although the influence of latitudinal origin within each growth type was a considerable factor in winterhardiness in this study, the introduced bunchgrasses were generally marginal to nonhardy.

zomes are better protected during winter from the damaging influences of (a) low air temperatures, (b) thaw-refreeze temperature oscillations, and (c) dehydration from winter winds (Smith 1964b). Those stresses are all common in occurrence in this area. Their influences are especially damaging when there is no protective snow cover (Andersen 1960; Smith 1964a, 1964b), and snow cover often is absent in this area due to frequent removal by strong winter winds (Dale 1956; Klebesadel 1974; Watson 1959).

Introduced sod-forming grass species within which northernmost-adapted cultivars showed relatively good winter survival included smooth bromegrass, creeping foxtail, Kentucky bluegrass, and red fescue. One exception was reed canarygrass, a rhizomatous species, the five cultivars of which were nonhardy. More recent investigations, however, have identified far-northern-adapted strains of reed canarygrass that are more winterhardy here (Klebesadel and Dofing 1991).

In contrast to the introduced bunchgrasses, several bunchgrass species native to Alaska were very winterhardy; those include Siberian wildrye, polargrass, bluejoint, and slender, arctic, and violet wheatgrasses. Polargrass and bluejoint are less strictly bunchgrasses than the others, as they spread to a limited extent via very short rhizomes.

Seasonal Distribution of Yields

With two forage harvests per year, the relative amounts of the total annual yield that is recovered in each cutting can be influenced primarily by (a) the date at which the first harvest is taken (thereby controlling the duration of the growth period contributing to each harvest), (b) whether or not winter injury occurred—slow recovery of injured forages reduces growth prior to the first harvest; moreover, the marginal use of spring-topdressed fertilizer by the meager growth of winter-injured stands can result in heavier-than-normal yields in the second harvest of healthy growth that has recovered from the winter injury, (c) the distribution of rainfall, and (d) the general inherent growth pattern of the forage species.

Differences in growth patterns can be noted among the grasses evaluated in this study. With the relatively late first-harvest dates utilized, and averaged over all experiments, approximately ¾ of the total annual dry-matter production of several of the native Alaskan grasses (pumpelly brome, bluejoint, polargrass, Siberian wildrye, arctic wheatgrass) was represented in the first cutting. With Polar brome, Garrison creeping foxtail, and Arctared red fescue, approximately ⅔ of total annual yield was taken in the first harvest. With Nugget Kentucky bluegrass, slightly less than ½ of total annual yield was removed in first harvests.

These results with Polar and Nugget contrast with intra-season yield distribution noted with smooth bromegrass and Kentucky bluegrass grown for forage at more southern latitudes. The much higher summer temperatures, and to some extent summer moisture deficit, greatly suppresses growth and forage yields of those species under those different growing conditions (Smith *et al*. 1986). In southcentral Alaska, the cool temperatures and usually abundant precipitation during summer promote active growth during the entire growing season (Klebesadel 1992d), resulting in higher proportions of annual yield of those grasses during the second half of the growing season.

Pathways of Introductions

Historically, many grasses and legumes introduced for experimental evaluation for use in Alaska have been regional strains or named cultivars developed for ideal adaptation at lower latitudes. Regardless of the Old World latitudinal origin, selection for various genetically controlled characteristics for harmony with climatic and photoperiodic conditions in temperate-latitude areas narrows the gene base and logically selects against or eliminates altogether the genetic constitution required for successful performance in this subarctic area.

Irwin (1945) described Russian wildrye as the "best perennial grass yet tried" at this location, yet the Canadian cultivar Sawki, selected for good adaptation in Saskatchewan, performed poorly in these experiments. This suggests that within this species, as well as others (e.g. crested wheatgrass), unselected germplasm from far-northern areas of their native ranges should be brought directly to Alaska for evaluation. With selection then made here for genotypes that display ideal agronomic performance within those species, genetic elements that confer adaptation to northern conditions can be preserved and elaborated within optimally adapted strains and cultivars.

The Legume Problem

No strains of introduced biennial or perennial legumes included in these experiments were as winterhardy, persistent, and productive of forage as many of the very winterhardy grass strains. The practice of seeding legumes with a cereal companion crop and leaving a tall cereal-crop stubble to retain protective snow cover in place over winter, a procedure not used in this study, can ensure better winter survival of legume forages during the first winter after establishment (Klebesadel 1992a).

Siberian alfalfa was the most consistently winterhardy and productive of the introduced legumes, but when grown in mixture with grasses (in other, unrelated experiments) its poor seedling vigor, slower initiation of growth in spring, and marginal competitiveness limit its usefulness. Moreover, general unavailability of commercial seed supplies further preclude its use. Termination of Siberian alfalfa stands with herbicidal spray in three experiments precluded learning how long those stands would have remained productive; however, Siberian alfalfa is known to be very long lived (Hansen 1909).

The native Alaskan legumes evaluated were markedly more winterhardy than introduced species. However, they possess various agronomic shortcomings that preclude their incorporation into agricultural practice as productive forages; those defects include poor seedling vigor, slowness to achieve productivity, poor regrowth after cutting, generally low forage yields, and (in some species) extreme earliness of flowering and seed maturation. A more logical avenue for utilizing their nitrogen-fixing capabilities is either alone or as components in mixture with grasses for revegetation purposes, an arena where herbage production is less important.

Taxonomic Note

Dewey (1983) has proposed a revision of scientific names in several grass genera that involves changes for Siberian wildrye and the wheatgrasses used in this study. However, the traditional nomenclature is followed in this report (see Tables) to better relate results with these species to earlier agronomic literature and floras referred to herein.

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Literature Cited

Aamodt, O.S., and D.A. Savage. 1949. Cereal, forage, and range problems and possibilities in Alaska. p. 87-125. (In) Report on exploratory investigations of agricultural problems in Alaska. U.S. Dep. Agric. Misc. Pub. 700. U.S. Government Printing Off., Washington, DC.

Alberts, H.W. 1933. Forage crops in the Matanuska Region, Alaska. Alaska Agric. Exp. Sta. Bull. 11.

Allen, E.K., O.N. Allen, and L.J. Klebesadel. 1964. An insight into symbiotic nitrogen-fixing plant associations in Alaska. p. 54-63. (In) Science in Alaska. Proceedings, 14th Alaskan Science Conf., Alaska Div., American Assoc. for the Advancement of Science.

Andersen, I.L. 1960. Investigation on the wintering of meadow plants in northern Norway. I. (Norwegian with English summary) Statens forsksgard Holt Report 27, Troms, Norway.

Asay, K.H., and R.P. Knowles. 1985. The wheatgrasses.

p. 166-176. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.). Forages—the science of grassland agriculture. (4th ed.) Iowa State University Press, Ames, IA.

Barnes, D.K., and C.C. Sheaffer. 1985. Alfalfa. p. 89-97. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.). Forages—the science of grassland agriculture. (4th ed.) Iowa State University Press, Ames, IA.

Bennett, H.H. 1918. Report on a reconnoisannce of the soils, agriculture, and other resources of the Kenai Peninsula Region of Alaska. U.S. Dep. Agric. Bur. of Soils. U.S. Government Printing Off., Washington, DC.

Branton, C.I., N.E. Michaelson, L.D. Allen, and W.M. Laughlin. 1966. Response of Manchar bromegrass and Engmo timothy to nitrogen in subarctic Alaska. p. 218-223. (In) Proceedings, 10th International Grassland Congress, Helsinki, Finland.

Brundage, A.L., and C.I. Branton. 1967. Ryegrass and orchardgrass-alfalfa for annual forage and pasture in southcentral Alaska. Jour. Dairy Science 50:856-862.

Brundage, A.L., and W.J. Sweetman. 1958. Comparative utilization of alfalfa-bromegrass pasture under rotational and daily strip grazing. Jour. Dairy Science 41:1777-1780.

Brundage, A.L., and W.J. Sweetman. 1964. Comparative utilization of irrigated bromegrass under rotational and strip grazing. Jour. Dairy Science 47:528-530.

Brundage, A.L., W.J. Sweetman, L.J. Klebesadel, N.E. Michaelson, and C.I. Branton. 1963. Grasses and alfalfa for annual forage and pasture in southcentral Alaska. Jour. Dairy Science 46:1260-1265.

Buckner, R.C. 1985. The fescues. p. 233-240. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.) Forages—the science of grassland agriculture. (4th ed.) Iowa State Univ. Press, Ames, IA.

Bula, R.J., Dale Smith, and H.J. Hodgson. 1956. Cold resistance in alfalfa at two diverse latitudes. Agronomy Jour. 48:153-156.

Burton, J.C. 1972. Nodulation and symbiotic nitrogen fixation. p. 229-246. (In) C.H. Hanson (ed.) Alfalfa science and technology. American Society of Agronomy Monograph 15. American Soc. Agronomy, Madison, WI.

Carlson, I.T., and L.C. Newell. 1985. Smooth bromegrass. p. 198-206. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.) Forages—the science of grassland agriculture. (4th ed.) Iowa State Univ. Press, Ames, IA.

Childers, W.R., and A.A. Hanson. 1985. Timothy. p. 217-223. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.). Forages—the science of grassland agriculture. (4th ed.) Iowa State Univ. Press, Ames, IA.

Dale, R.F. 1956. The climate of the Matanuska Valley. U.S. Dep. Commerce Tech. Paper 27. U.S. Government Printing Off., Washington, DC.

Denisov, G.V., and V.P. Netrebov. 1976. (1984 Translation.) Growth and development of fodder plants cultivated in the Kolyma Basin. p. 100-135. (In) L.G. Elovskaya (ed.). Biology of fodder plants in the Permafrost Zone. Acad. of Science of the USSR Siberian Div., Novosibirsk, USSR.

Denisov, G.A., V.S. Streltsova, N.E. Fomina, D.A. Samortseva, T.N. Rybinina, and I.L. Volpert. 1976. (1984 Translation.) Growth and development of fodder plants cultivated in the Lena and Vilni Basins. p. 1-99. (In) L.G. Elovskaya (ed.). Biology of fodder plants in the Permafrost Zone. Acad. of Science of the USSR Siberian Div., Novosibirsk, USSR.

Dewey, D.R. 1983. Historical and current taxonomic perspectives of *Agropyron, Elymus*, and related genera. Crop Science 23:637-642.

Duell, R.W. 1985. The bluegrasses. p. 188-197. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.). Forages—the science of grassland agriculture. (4th ed.) Iowa State University Press, Ames, IA.

Elliott, F.C. 1949. *Bromus inermis* and *B. pumpellianus* in North America. Evolution 3:142-149.

Elliott, C.R., and H. Baenziger. 1973. (rev.) Creeping red fescue. Agriculture Canada Pub. 1122.

Foster, R.B., H.C. McKay, and E.W. Owens. 1966. Regar bromegrass. Idaho Agric. Exp. Sta. Bull. 470.

Graham, E.H. 1941. Legumes for erosion control and wildlife. U.S. Dep. Agric. Misc. Pub. 412. U.S. Government Printing Off., Washington, DC.

Hafenrichter, A.L., J.L. Schwendiman, H.L. Harris, R.S. MacLauchlan, and H.W. Miller. 1968. Grasses and legumes for soil conservation in the Pacific Northwest and Great Basin states. U.S. Dep. Agric. Handbook 339. U.S. Government Printing Off., Washington, DC.

Hansen, N.E. 1909. The wild alfalfas and clovers of Siberia, with a perspective view of the alfalfas of the world. U.S. Dep. Agric. Bur. of Plant Industry Bull. 150. U.S. Government Printing Off., Washington, DC.

Hanson, C.H. (ed.) 1972. Alfalfa science and technology. American Society of Agronomy Monograph 15. American Soc. Agronomy, Madison, WI.

Hanson, A.A. 1972. Grass varieties in the United States. U.S. Dep. Agric. Handbook 170. U.S. Government

Printing Off., Washington, DC.

Hanson, A.A., and F.V. Juska. 1969. Turfgrass science. American Society of Agronomy Monograph 14, American Soc. Agronomy, Madison, WI.

Heichel, G.H. 1985. Symbiosis: Nodule bacteria and leguminous plants. p. 64-71. (In) C.H. Hanson (ed.) Alfalfa science and technology. American Society of Agronomy Monograph 15. American Soc. Agronomy, Madison, WI.

Heinrichs, D.H., and T. Lawrence. 1956. Russian wild rye grass. Canada Dep. Agric. Pub. 991.

Hitchcock, A.S. 1951. Manual of the grasses of the United States. (2nd. ed. rev. by A. Chase.) U.S. Dep. Agric. Misc. Pub. 200. U.S. Government Printing Off., Washington, DC.

Hodgson, H.J. 1964. Effect of photoperiod on development of cold resistance in alfalfa. Crop Science 4:302-305.

Hodgson, H.J., and R.J. Bula. 1956. Hardening behavior of sweetclover (*Melilotus* spp.) varieties in a subarctic environment. Agronomy Jour. 48:157-160.

Hodgson, H.J., A.C. Wilton, R.L. Taylor, and L.J. Klebesadel. 1971a. Registration of Polar bromegrass. Crop Science 11:939.

Hodgson, H.J., R.L. Taylor, A.C. Wilton, and L.J. Klebesadel. 1971b. Registration of Nugget Kentucky bluegrass. Crop Science 11:938.

Hodgson, H.J., R.L. Taylor, L.J. Klebesadel, and A.C. Wilton. 1978. Registration of Arctared red fescue. Crop Science 17:524.

Hodgson, H.J., W.B. Wilder, and J.E. Osguthorpe. 1953. Alaskland red clover. Alaska Agric. Exp. Sta. Circ. 20.

Hoveland, C.S., and C.E. Townsend. 1985. Other legumes. p. 146-153. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.). Forages—the science of grassland agriculture. (4th ed.) Iowa State University Press, Ames, IA.

Hulten, E. 1968. Flora of Alaska and neighboring territories. Stanford Univ. Press, Stanford, CA.

Irwin, D.L. 1945. Forty-seven years of experimental work with grasses and legumes in Alaska. Alaska Agric. Exp. Sta. Bull. 12.

Jung, J.G., and B.S. Baker. 1985. Orchardgrass. p. 224-232. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.). Forages—the science of grassland agriculture. (4th ed.) Iowa State University Press, Ames, IA.

Kallio, A. 1966. Chemical control of snow mold (*Sclerotinia borealis*) on four varieties of bluegrass (*Poa pratensis*) in Alaska. Plant Disease Reporter 50:69-72.

Kilcher, M.R., and J. Looman. 1983. Comparative performance of some native and introduced grasses in southern Saskatchewan, Canada. Jour. Range Management 36:654-657.

Klebesadel, L.J. 1965. Response of native bluejoint grass (*Calamagrostis canadensis*) in subarctic Alaska to harvest schedules and fertilizers. p. 1309-1314. (In) Proceedings, 9th International Grassland Congress, Sao Paulo, Brazil.

Klebesadel, L.J. 1969a. Agronomic characteristics of the little-known northern grass *Arctagrostis latifolia* var. *arundinacea* (Trin.) Griseb., and a proposed common name, tall arcticgrass. Agronomy Jour. 61:45-49.

Klebesadel, L.J. 1969b. Siberian wildrye (*Elymus sibiricus* L.): Agronomic characteristics of a potentially valuable forage and conservation grass for the North. Agronomy Jour. 61:855-859.

Klebesadel, L.J. 1970. Influence of planting date and latitudinal provenance on winter survival, heading, and seed production of bromegrass and timothy in the Subarctic. Crop Science 10:594-598.

Klebesadel, L.J. 1971a. Nyctoperiod modification during late summer and autumn affects winter survival and heading of grasses. Crop Science 11:507-511.

Klebesadel, L.J. 1971b. Selective modification of alfalfa toward acclimatization in a subarctic area of severe winter stress. Crop Science 11:609-614.

Klebesadel, L.J. 1971c. Native Alaskan legumes studied. Agroborealis 3(1):9-11.

Klebesadel, L.J. 1973. Grasses and legumes for revegetation in Alaska. p. 16-23. (In) 1973 Alaska Revegetation Workshop Notes. Alaska Coop. Extension Service Pub. RP-239.

Klebesadel, L.J. 1974. Winter stresses affecting overwintering crops in the Matanuska Valley. Agroborealis 6(1):17-20.

Klebesadel, L.J. 1975. A look at forage research in the Soviet Union: Alaska's interests. Agroborealis 7(1):4-10.

Klebesadel, L.J. 1977. Unusual autumn temperature pattern implicated in 1975-76 winterkill of plants. Agroborealis 9(1):21-23.

Klebesadel, L.J. 1978. Biological nitrogen fixation in natural and agricultural situations in Alaska. Agroborealis 10(1):9-11, 20.

Klebesadel, L.J. 1980. Birdvetch: Forage crop, ground cover, ornamental, or weed? Agroborealis 12(1):46-49.

Klebesadel, L.J. 1984a. Far-north-adapted bluegrasses from areas with rigorous winter climate perform best in southcentral Alaska. Agroborealis 16(1):37-42.

Klebesadel, L.J. 1984b. Native Alaskan pumpelly bromegrass: Characteristics and potential for use. Agroborealis 16(2):9-14.

Klebesadel, L.J. 1985a. Adaptational changes induced in temperate-adapted forage legumes by natural selection pressures in subarctic Alaska. p. 304-315. (In) A. Kaurin, O. Junttila, and J. Nilsen (eds.). Plant Production in the North. Proceedings of International Symposium on Physiological, Genetic, and Applied Aspects of Plant Adaptation to Northern Conditions. Sep., 1983. Norwegian University Press, Tromsø, Norway.

Klebesadel, L.J. 1985b. Hardening behavior, winter survival, and forage productivity of *Festuca* species and cultivars in subarctic Alaska. Crop Science 25:441-447.

Klebesadel, L.J. 1985c. The critical importance of north-latitude adaptation for dependable winter survival of perennial plants in Alaska. Agroborealis 17(1):21-30.

Klebesadel, L.J. 1991. Performance of indigenous and introduced slender wheatgrass in Alaska, and presumed evidence of ecotypic evolution. Alaska Agric. and Forestry Exp. Sta. Bull. 85.

Klebesadel, L.J. 1992a. Effects of planting date and latitude-of-adaptation on seeding-year development, winter survival, and subsequent seed and forage production potential of grasses and legumes in subarctic Alaska. Alaska Agric. and Forestry Exp. Sta. Bull. 86.

Klebesadel, L.J. 1992b. Extreme northern acclimatization in biennial yellow sweetclover (*Melilotus officinalis*) at the Arctic Circle. Alaska Agric. and Forestry Exp. Sta. Bull. 89.

Klebesadel, L.J. 1992c. Morphological, physiological, and winterhardiness comparisons among latitudinal ecotypes of biennial sweetclover (*Melilotus* species) in subarctic Alaska. Alaska Agric. and Forestry Exp. Sta. Bull. 91.

Klebesadel, L.J. 1992d. Seasonal distribution of forage yield and winter hardiness of grasses from diverse latitudinal origins harvested four times per year in southcentral Alaska. Alaska Agric. and Forestry Exp. Sta. Bull. 90.

Klebesadel, L.J. 1993a. Bromegrass in Alaska. II. Autumn food-reserve storage, freeze tolerance, and dry-matter concentration in overwintering tissues as related to winter survival of latitudinal ecotypes. Alaska Agric. and Forestry Exp. Sta. Bull. 93.

Klebesadel, L.J. 1993b. Effects of daily photoperiod/nyctoperiod and temperature on autumn development of crown buds and dormancy, freeze tolerance, and storage of food reserves in latitudinal ecotypes of biennial white sweetclover. Alaska Agric. and Forestry Exp. Sta. Bull. 95.

Klebesadel, L.J. 1993c. Fescue grasses differ greatly in adaptation, winter hardiness, and therefore usefulness in southcentral Alaska. Alaska Agric. and Forestry Exp. Sta. Bull. 92.

Klebesadel, L.J. 1993d. Winterhardiness and agronomic performance of wildryes (*Elymus* species) compared with other grasses in Alaska, and responses of Siberian wildrye to management practices. Alaska Agric. and Forestry Exp. Sta. Bull. 97.

Klebesadel, L.J. 1993e. Winter survival of grasses and legumes in subarctic Alaska as related to latitudinal adaptation, pre-winter storage of food reserves, and dry-matter concentration in overwintering tissues. Alaska Agric. and Forestry Exp. Sta. Bull. 94.

Klebesadel, L.J. 1994a. Bromegrass in Alaska. IV. Effects of various schedules and frequencies of harvest on forage yields and quality and on subsequent winter survival of several strains. Alaska Agric. and Forestry Exp. Sta. Bull. 102.

Klebesadel, L.J. 1994b. Comparative winterhardiness of cultivated and native Alaskan grasses, and forage yield and quality as influenced by harvest schedules and frequencies, and rates of applied nitrogen. Alaska Agric. and Forestry Exp. Sta. Bull. 99.

Klebesadel, L.J. 1994c. Responses of biennial sweetclovers of diverse latitudinal adaptation to various management procedures in Alaska. Alaska Agric. and Forestry Exp. Sta. Bull. 98.

Klebesadel, L.J., C.I. Branton, and J.J. Koranda. 1962. Seed characteristics of bluejoint and techniques for threshing. Jour. Range Management 15:227-229.

Klebesadel, L.J., and J.C. Brinsmade. 1966. Response of two alfalfas (*Medicago sativa* L. and *M. falcata* L.) to time and rate of potassium application in the Subarctic. Agronomy Jour. 58:545-549.

Klebesadel, L.J., and S.M. Dofing. 1991. Reed canarygrass in Alaska: Influence of latitude-of-adaptation on winter survival and forage productivity, and observations on seed production. Alaska Agric. and Forestry Exp. Sta. Bull. 84.

Klebesadel, L.J., and D.J. Helm. 1986. Food reserve storage, low-temperature injury, winter survival, and forage yields of timothy in subarctic Alaska as related to latitude-of-origin. Crop Science 26:325-334.

Klebesadel, L.J., and D.J. Helm. 1992a. Bromegrass in Alaska. I. Winter survival and forage productivity of *Bromus* species and cultivars as related to latitudinal adaptation. Alaska Agric. and Forestry Exp. Sta. Bull. 87.

Klebesadel, L.J., and D.J. Helm. 1992b. Relationship of latitude-of-origin to winter survival and forage and seed yields of wheatgrasses (*Agropyron* species) in subarctic Alaska. Alaska Agric. and Forestry Exp. Sta. Bull. 88.

Klebesadel, L.J., and W.M. Laughlin. 1964. Utilization of native bluejoint grass (*Calamagrostis canadensis*) in Alaska. Alaska Agric. Exp. Sta. Forage Research Report No. 2.

Klebesadel, L.J., and R.L. Taylor. 1973. Research progress with alfalfa in Alaska. Agroborealis 5(1):18-20.

Klebesadel, L.J., A.C. Wilton, R.L. Taylor, and J.J. Koranda. 1964. Fall growth behavior and winter survival of *Festuca rubra* and *Poa pratensis* in Alaska as influenced by latitude of adaptation. Crop Science 4:340-341.

Knowles, R.P., and W.J. White. 1949. The performance of southern strains of brome grass in western Canada. Scientific Agric. 29:437-450.

Laughlin, W.M. 1953. Influence of fertilizers on the crude protein yields of bromegrass pasture in the Matanuska Valley. Soil Science Soc. America Proceedings 17:372-374.

Laughlin, W.M. 1962. Fertilizer practices for bromegrass. Alaska Agric. Exp. Sta. Bull. 32.

Laughlin, W.M. 1963. Bromegrass response to rate and source of nitrogen applied in fall and spring in Alaska. Agronomy Jour. 55:60-62.

Laughlin, W.M. 1969. Nitrogen, phosphorus, and potassium influence yield and chemical composition of bluejoint forage. Agronomy Jour. 61:961-964.

Laughlin, W.M., G.R. Smith, and M.A. Peters. 1984. Influence of N, P, and K fertilization on yield and mineral composition of native bluejoint grass on the Lower Kenai Peninsula, Alaska. Agronomy Jour. 76:389-397.

Lawrence, T. 1967. Sawki, Russian wild ryegrass. Canadian Jour. Plant Science 47:612-613.

Lawrence, T. 1978. An evaluation of thirty grass populations as forage crops for southwestern Saskatchewan. Canadian Jour. Plant Science 58:107-115.

Lawrence, T., and D.C. Ratzlaff. 1985. Evaluation of fourteen grass populations as forage crops for southwestern Saskatchewan. Canadian Jour. Plant Science 65:951-957.

Lawrence, T., and J.E. Troelsen. 1964. An evaluation of 15 grass species as forage crops for southwestern Saskatchewan. Canadian Jour. Plant Science 44:301-310.

Lewis, R.D. 1958. Meadow foxtail. Wyoming Agric. Exp. Sta. Circ. 68.

Marten, G.C. 1985. Reed canarygrass. p. 207-216. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.). Forages—the science of grassland agriculture. (4th ed.) Iowa State University Press, Ames, IA.

Mason, H.L., and P.R. Stout. 1954. The role of plant physiology in plant geography. Annual Rev. Plant Physiology. 5:249-270.

Mitchell, W.W. 1979a. Managing native bluejoint reedgrass for forage production. Agroborealis 11(1):15-19.

Mitchell, W.W. 1979b. Three varieties of native Alaskan grasses for revegetation purposes. Alaska Agric. Exp. Sta. Circ. 32.

Mitchell, W.W. 1982a. Forage yield and quality of indigenous and introduced grasses at Palmer, Alaska. Agronomy Jour. 74:899-905.

Mitchell, W.W. 1982b. Grasses and their uses in Alaska. Agroborealis 14(1):34-237.

Mitchell, W.W. 1986. Perennial grass trials for forage purposes in three areas of southcentral Alaska. Alaska Agric. and Forestry Exp. Sta. Bull. 73.

Mitchell, W.W. 1987a. Grasses indigenous to Alaska and Iceland compared with introduced grasses for forage quality. Canadian Jour. Plant Science 67:193-201.

Mitchell, W.W. 1987b. Revegetation research on coal mine overburden materials in interior to southcentral Alaska. Alaska Agric. and Forestry Exp. Sta. Bull. 79.

Mitchell, W.W. 1989. Yield and quality of timothy in southcentral Alaska. Alaska Agric. and Forestry Exp. Sta. Bull. 82.

Mitchell, W.W., and J. Evans. 1966. Composition of two disclimax bluejoint stands in southcentral Alaska. Jour. Range Management 19:65-68.

Moschkov, B.S. 1935. Photoperiodism and frosthardiness of perennial plants. (In German.) Planta 23:774-803.

Ouellet, C.E. 1976. Winter hardiness and survival of forage crops in Canada. Canadian Jour. Plant Science 56:679-689.

Piper, C.V. 1905. Grass lands of the south Alaska coast. U.S. Dep. Agric. Bur. of Plant Industry Bull. 82. U.S. Government Printing Off., Washington, DC.

Pohjakallio, O. 1961. On the effect of daylength on the overwintering of clover. (In German) p. 390-394. (In) B.C. Christensen and B. Buchmann. (eds.) Progress in photobiology. Proceedings, Third International Congress on Photobiology. Elsevier Publishing Co., New York, NY.

Porsild, A.E., and W.J. Cody. 1980. Vascular plants of continental Northwest Territories, Canada. National Museums of Canada, Ottawa, Ontario.

Schoth, H.A. 1947. Meadow foxtail. Oregon Agric. Exp. Sta. Bull. 433.

Smith, Dale. 1964a. Freezing injury of forage plants. p. 32-56. (In) Forage plant physiology and soil-range relationships. American Society of Agronomy Special Pub. 5, American Soc. Agronomy, Madison, WI.

Smith, Dale. 1964b. Winter injury and the survival of forage plants. Herbage Abstracts 34:203-209.

Smith, Dale, R.J. Bula, and R.P. Walgenbach. 1986. Forage management. (5th ed.) Kendall/Hunt Pub. Co., Dubuque, IA.

Sparrow, S.D., V.L. Cochran, and E.B. Sparrow. 1990. Nitrogen-fixation by legumes in interior Alaska. Alaska Agric. and Forestry Exp. Sta. Research Progress Rep. 17.

State of Alaska. 1989. Notice of naming and release of 'Service' big bluegrass. Alaska Dep. Natural Resources, Div. of Agric. Plant Materials Center, Palmer, AK.

Stroh, J.R., J.L. McWilliams, and A.A. Thornburg. 1978. 'Garrison' creeping foxtail. U.S. Dep. Agric. Soil Conservation Service Pub. SCS-TP-156.

Taylor, N.L. 1985. Red clover. p. 109-117. (In) M.E. Heath, R.F. Barnes, and D.S. Metcalfe (eds.) Forages—the science of grassland agriculture. (4th ed.) Iowa State University Press, Ames, IA.

U.S. Department of Agriculture. 1941. Climate and man. U.S. Dep. Agric. Yearbook. U.S. Government Printing Off., Washington, DC.

Watson, C.E. 1959. Climates of the states—Alaska. U.S. Dep. Commerce Weather Bureau Pub. 60-49. U.S. Government Printing Off., Washington, DC.

Weintraub, F.C. 1953. Grasses introduced into the United States. U.S. Dep. Agric. Agricultural Handbook 58. U.S. Government Printing Off., Washington, DC.

Wilsie, C.P. 1962. Crop adaptation and distribution. W.H. Freeman and Co., San Francisco, CA.

Wilton, A.C., H.J. Hodgson, L.J. Klebesadel, and R.L. Taylor. 1966. Polar bromegrass, a new winterhardy forage for Alaska. Alaska Agric. Exp. Sta. Circ. 26.

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