Fescue Grasses Differ Greatly in Adaptation, Winter Hardiness, and Therefore Usefulness in Southcentral Alaska

Leslie J. Klebesadel
Emeritus Professor of Agronomy
Agricultural and Forestry Experiment Station
Palmer, Alaska

UNIVERSITY OF ALASKA FAIRBANKS
Agricultural and Forestry Experiment Station
School of Agriculture and Land Resources Management

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Summary

This report summarizes agronomic research with several species of fescue (*Festuca* spp.) conducted over recent decades at the Matanuska Research Farm (61.6°N) near Palmer in southcentral Alaska. Cultivars and strains within five species of fescue from Alaska, Canada, the conterminous states, and Europe were evaluated for winter hardiness and for forage production in comparison with two standard, non-fescue forage cultivars. Certain aspects of physiological behavior associated with winter hardiness were compared in red fescue cultivars of diverse latitudinal adaptation.

- Tall fescue (*F. arundinacea*) and meadow fescue (*F. elatior*), broad-leaved species used for forage and pasture in Europe, Canada, and the conterminous states, usually winter-killed during the first winter or sustained severe winter injury; only low forage yields were produced by those badly injured strains, and none survived beyond the second winter. Neither of these species is suited for dependable use in this area.

- The two strains evaluated of the fine-leaved chewings fescue (*F. rubra* var. *commutata*) were slightly more winter hardy than the broad-leaved species. However, both always sustained severe winter injury, produced low yields of forage, and no stands survived beyond the fourth winter.

- One cultivar of the fine-leaved hard fescue (*F. ovina* var. *duriuscula*) survived for the full term of a two–year experiment but frequently sustained severe winter injury and produced only modest yields of forage from badly thinned stands.

- Seven cultivars of the fine-leaved red fescue (*F. rubra* var. *rubra*) were compared; these represented a wide range of latitudinal adaptation and they showed a very wide range of winter hardiness in experiments.

- Red fescue cultivars from the northernmost origins, and from where winter stresses are greatest, were the most winter hardy and produced most forage. Conversely, cultivars from southernmost origins, and from areas where winter stresses are least severe, were least winter hardy; they either winter-killed early or produced low forage yields from injured stands. Cultivars from intermediate latitudes were intermediate in both winter hardiness and forage production.

- General rank of winter hardiness of the red fescue cultivars was: Arctared > Duraturf > Boreal ≥ Olds > Ranier = Pennlawn > Illahee.

- Of three Canadian cultivars, Duraturf, derived from an introduction from relatively northern latitudes (Scandinavia), was more winter hardy and productive than Olds and Boreal, cultivars developed from germplasm that originated from more southern origins (Czechoslovakia).

- Three red fescue cultivars from a wide range of latitudinal origins were compared for certain characteristics associated with winter hardiness. The northernmost-adapted cultivar, Arctared from Alaska, had highest percent dry matter and highest level of stored food reserves in crown tissues at onset of winter, showed best winter survival and produced highest forage yields. Illahee, the southernmost-adapted cultivar, was lowest in percent dry matter and level of stored food reserves in autumn, poorest in winter survival, and therefore lowest in forage yields. Duraturf, of intermediate latitudinal origin, was intermediate for all characteristics.

- Arctared red fescue gave evidence of being somewhat more winter hardy than the very winter-hardy Polar bromegrass, and tended to be slightly more productive of forage over long-term (six–year) experiments. However, conventional farm-type forage-harvest equipment would recover virtually all forage produced by the taller-growing bromegrass, but would not recover as much of the forage produced by the shorter-growing red fescue as was accomplished by small-plot equipment in these experiments.

- Of the two standard forage grass cultivars used to compare with fescues, Polar bromegrass was considerably more winter hardy and productive of forage than was Engmo timothy.

- These results show that, of five fescue species compared, the most winter-hardy and productive cultivars were found within red fescue.

- These results also reveal that a great range of winter hardiness, and therefore suitability for use in southcentral Alaska, exists among the several cultivars compared within red fescue. Alaska growers should be aware of these differences and choose the best adapted, most winter-hardy cultivars for use here.

Introduction

Grasses called fescues belong to the taxonomic genus called *Festuca*, an old Latin name for a weedy grass (Hitchcock 1951). Some of the annual fescues can be weedy, but weedy annual fescues are problems elsewhere and not in Alaska. Most of the fescue species are long-lived perennials and several of those are valuable for pasture, harvested forage, turf, and stabilization of soils to prevent erosion (Buckner 1985).

Fescue Types and Species

Globally, there are about 80 species of fescue and they are found mostly in temperate and cool zones of the world (Buckner 1985). Within the perennial species, there are two main types; these are differentiated principally by leaf width and are referred to as "broad-leaved" and "fine-leaved" (Table 1).

There is not complete agreement on the taxonomic classification of fescues of interest in Alaska (Hulten 1968; Welsh 1974). A compromise listing, however, that includes the principal species and taxonomic varieties (sometimes called subspecies) with their Latin names appears in Table 1. That listing also indicates the existence or absence of named cultivars (commercial varieties) for each species.

Broad-Leaved Species

The two broad-leaved, perennial species of fescue used in Europe and North America are tall fescue and meadow fescue. Both are bunch-type and are adapted to cool humid areas of the temperate region. Neither is native in North America; both have been introduced to this continent from Europe. Though generally similar in appearance, tall fescue is the taller and more robust of the two. They differ in chromosome number; tall fescue is a hexaploid species (2n = 42) and meadow fescue is a diploid (2n = 14) (Buckner 1985).

Tall fescue popularity and acreage have grown rapidly in the United States during recent decades (Buckner and Bush 1979). Several improved cultivars have been developed (Hanson 1972; Smith et al. 1986) and the species has become the dominant cool-season perennial forage grass in the United States. Buckner (1985) relates that cold winter temperatures restrict the occurrence and use of tall fescue at high latitudes as in Canada and Scandinavia.

Meadow fescue has never been used extensively in the United States owing to its high susceptibility to diseases. Where adapted it is used in pasture mixtures on wetlands. It is recognized as an excellent pasture grass in western Europe (Buckner 1985).

Fine-Leaved Species

Buckner (1985) states that sheep fescue and red fescue are the most important of the fine-leaved group and both are used primarily for lawns and turf; other species important as range pasture species in the western United States are Idaho fescue (*F. idahoensis* Elmer), Arizona fescue (*F. arizonica* Vasey), and greenleaf fescue (*F. viridula* Vasey). None of the last three isnative in Alaska.

Red fescue is said by Hanson (1972) to be introduced into North America from Europe; that claim may be true for the conterminous states but is at variance with the fact that the species is native in Alaska (Hulten 1968).

Red fescue is the only sod-forming fescue species in this report; it spreads slowly by underground stems called rhizomes. Due to this activity of vegetative spread, it is sometimes referred to as creeping red fescue. Hanson (1972) reports that this species occurs in pastures in northern and Pacific northwest states in relatively moist, cool areas.

Farther north in Canada, red fescue is used for turf and also is included in pasture mixtures to increase carrying capacity and to extend the grazing season into the fall and winter months in most agricultural areas of the country. A substantial red fescue seed-production industry has developed in Canada both for local and export markets (Elliott and Baenziger 1973).

Early Evaluations in Alaska

Piper (1905), in an early survey of grass species and uses in southern Alaska, noted the frequent occurrence of red fescue in coastal areas, and "Siberian" fescue (*F. altaica*—now commonly called Altai fescue, Table 1) in gravelly areas and open timber up to 1,000 feet above sea level.

Irwin (1945) summarized early evaluations of numerous grasses and legumes at seven widely-dispersed experiment stations in Alaska during most of the first half of the present century. Seven species of fescue are mentioned in those trials. Sources of seed were not identified and no named cultivars were available at that time.

Tall fescue was first seeded in 1902 at the Sitka, Kenai, and Copper Center stations, in 1906 at Rampart, and in 1909 at Fairbanks. Sixteen separate plantings of tall fescue were reported at the seven experiment stations between 1902 and 1940. At all locations, the stands were thinned rapidly by winter injury. Two seedings were made at the Matanuska station and both winter-killed totally the first winter.

Meadow fescue was seeded in 1906 at the Rampart station, in 1938 and 1939 at Fairbanks, and in 1919 and 1940 at the Matanuska station. It was non-hardy at Rampart, but was recommended for inclusion in hay and pasture mixtures for the Matanuska Valley – Cook Inlet area as well as for the Tanana Valley – Yukon area.

Red fescue, sheep fescue, and chewings fescue were seeded several times between 1930 and 1942; on the basis of performance, all were recommended for utilization in southcentral Alaska (Irwin 1945).

Table 1. The principal fescue species of interest in Alaska.

Latin name	Common name	Native in Alaska	Cultivars
Fine-leaved species:			
Festuca altaica	Altai fescue	yes	no
" *brachyphylla*	Alpine fescue	yes	no
" *ovina* var. *ovina*	Sheep fescue	yes	no
" " var. *duriuscula*	Hard fescue	no	Durar
" *rubra* var. *rubra*	Red fescue	yes	many
" " var. *commutata*	Chewings fescue	no	many
" *subulata*	Bearded fescue	yes	no
Broad-leaved species:			
Festuca arundinacea	Tall fescue	no	many
" *eliator* [1]	Meadow fescue	no	many

[1] Meadow fescue is classified as *F. pratensis* in Europe.

Aamodt and Savage (1949), in a survey of native and introduced forage and range plant species in Alaska, summarized the relatively superficial knowledge of fescue species occurrence and uses as of that time. They stated that the three most valuable species were red, meadow, and "Siberian" fescues.

Alaska Plant Exploration, Seed Collections, and Evaluations

Beginning in the late 1950s, a series of grants from The Rockefeller Foundation made possible extensive travel by Alaska Experiment Station agronomists into remote regions of Alaska by aircraft and riverboat to collect seed and vegetative transplants of native grasses and legumes. Those were grown as individual plants in rows in large field nurseries and compared for various evaluative criteria such as vigor, winter hardiness, disease susceptibility, etc., as well as potential usefulness for turf, forage, pasture, soil stabilization, or other purposes.

Seed was then increased from promising Alaska red fescue collections in the spaced-plant nurseries. That seed was used in turn to establish these Alaska lines in a solid-seeded row experiment to compare them with red fescue cultivars from the conterminous states, Canada, and Sweden (Figure 1). The second winter after planting revealed marked differences in winter survival, with Alaska collections surpassing significantly the introduced cultivars from other sources (Klebesadel et al. 1964).

On the basis of those early results, an expanded turfgrass research program was established, leading to, among other advances, the selection and release of one of the Alaska collections as the cultivar Arctared (Hodgson et al. 1978; Klebesadel and Taylor 1972; Taylor 1970). Arctared is a good seed producer in Alaska and certain management options that ensure high seed yields have been defined (Klebesadel 1976; 1992a).

Recent Evaluations in Alaska

Mitchell (1972, 1981) reported high yields of forage from northern-adapted red fescues, both with two cuttings per year and with more frequent harvests. Mitchell (1985) evaluated nine cultivars of fine-leaved fescue for turf; the best red fescues surpassed two cultivars of chewings fescue and three of hard fescue in desirability for turf. Fine-leaved fescues have been found useful for revegetation purposes, often providing better ground cover for dry and low-fertility soil conditions than many other grasses (Mitchell 1982, 1987).

In a separate study conducted at this station but reported elsewhere (Klebesadel and Dofing 1990), two cultivars of meadow fescue from Norway, Salten and Salten II, were evaluated as forage crops; both sustained severe winter injury during both winters of the test (1984-85 and 1985-86, both moderate in winter stress). In the same experiment, standard northern-adapted forage grasses in several other species survived both winters without apparent injury.

This report summarizes several experiments that have evaluated a number of species, strains, and cultivars of fescue to determine their usefulness in Alaska. An abbreviated technical report of a portion of these data was published earlier (Klebesadel 1985a). All experiments reported here were conducted at the Univer-

Table 2. *Seeding-year and subsequent oven-dry forage yields of fescue species and strains, and two standard, non-fescue forage cultivars at the Matanuska Research Farm. Experiment I; planted 18 June 1968.*

	1968	1969		1970		1971		1972		1973		
Species and strain	26 Sep	7 July	14 Oct	6 July	15 Sep	7 July	24 Sep	10 July	2 Oct	9 July	7 Sep	Total
	Tons dry matter per acre											
Red fescue (*Festuca rubra* var. *rubra*):												
Arctared	0.84 cd[1]	1.23 a	0.95 bc	1.92 a	1.55 ab	1.88 a	1.74 ab	2.63 a	0.12 b	2.41 a	0.98 a	16.25 a
Duraturf	0.64 d	0.97 ab	1.23 a	1.08 b	1.91 ab	0.65 b	2.19 a	Tr[2]	0.59 a	1.48 b	0.61 b	11.35 b
Boreal	1.61 a	0.89 ab	1.19 a	0.93 b	2.00 ab	0.23 c	2.08 a (WK)[3]	—	—	—	—	8.93 c
Olds	1.28 abc	1.07 a	1.31 a	0.67 bc	2.09 a	0.02 c	1.68 ab (WK)	—	—	—	—	8.12 c
Ranier	0.96 bcd	0.71 bc	1.12 ab	0.70 bc	2.17 a	0.02 c	1.11 b (WK)	—	—	—	—	6.79 cd
Illahee	0.07 e	0.93 ab	1.29 a	0.61 bc	2.17 a	0.01 c	0.01 c (WK)	—	—	—	—	5.09 de
Chewings fescue (*F. rubra* var. *commutata*):												
Commercial (USA)	0.53 de	0.56 c	0.83 cd	Tr	0.54 c	Tr	0.02 c (WK)	—	—	—	—	2.48 efg
Meadow fescue (*F. elatior*):												
Bottnia II	1.50 ab (WK)	—	—	—	—	—	—	—	—	—	—	1.50 fg
Commercial (Can.)	1.49 ab (WK)	—	—	—	—	—	—	—	—	—	—	1.49 fg
Tall fescue (*F. arundinacea*):												
Alta	0.09 e (WK)	—	—	—	—	—	—	—	—	—	—	0.09 g
Checks:												
Polar bromegrass	0.79 cd	0.69 bc	0.71 d	1.65 a	1.41 b	0.60 b	2.14 a	2.52 a	0.51 a	3.06 a	0.90 a	14.98 a
Engmo timothy	1.52 a	0.37 c	0.14 e	0.43 c	1.67 ab (WK)	—	—	—	—	—	—	4.13 def

1 Means followed by a common letter within a column do not differ significantly at the 5% probability level using Duncan's Multiple Range Test.
2 Trace amount of herbage, insufficient for harvestable yield.
3 Stands winter-killed completely.

Table 3. *Seeding-year and subsequent oven-dry forage yields of fescue species and strains, and two standard, non-fescue forage cultivars at the Matanuska Research Farm. Experiment II; planted 6 June 1969.*

	1969	1970		1971		1972		1973		1974		
Species and strain	7 Oct	9 July	16 Sep	7 July	27 Sep	5 July	2 Oct	10 July	10 Sep	21 June	17 Sep	Total
	Tons dry matter per acre											
Red fescue (*Festuca rubra* var. *rubra*):												
Arctared	Tr[1]	3.00 a[2]	1.48 bc	1.90 a	2.13 bc	2.63 a	2.41 a	3.01 a	1.28 a	2.58 a	0.97 a	21.39 a
Boreal	0.50 b	3.19 a	1.92 ab	0.53 c	2.95 a	0.80 b	1.24 b	0.58 b	0.82 b	1.42 b	0.63 ab	14.58 b
Olds	0.26 bc	3.22 a	2.20 a	0.01 d	1.00 d (WK)[3]	—	—	—	—	—	—	6.69 c
Meadow fescue (*F. elatior*):												
Bottnia II	0.17 bc	0.22 b	1.05 cd (WK)	—	—	—	—	—	—	—	—	1.44 d
Commercial (Can.)	0.26 bc	Tr	0.56 d (WK)	—	—	—	—	—	—	—	—	0.82 d
Tall fescue (*F. arundinacea*):												
Alta	0.85 a (WK)	—	—	—	—	—	—	—	—	—	—	0.85 d
Checks:												
Polar bromegrass	0.22 bc	2.98 a	1.57 bc	0.83 b	2.20 b	3.12 a	0.80 b	3.53 a	1.01 ab	2.25 a	0.54 b	19.05 a
Engmo timothy	0.07 c	3.23 a	1.34 bc	0.01 d	1.42 cd	Tr	Tr	0.85 b	Tr	1.27 b	Tr	8.19 c

1 Trace amount of herbage, insufficient for harvestable yield.
2 Means followed by a common letter within a column do not differ significantly at the 5% probability level using Duncan's Multiple Range Test.
3 Stands winter-killed completely.

Table 4. *Seeding-year and subsequent oven-dry forage yields of fescue species and strains, and two standard, non-fescue forage cultivars at the Matanuska Research Farm. Experiment III; planted 25 June 1970.*

Species and strain	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	Total
	Tons dry matter per acre											
Red fescue (*Festuca rubra* var. *rubra*):												
Arctared	0.54 cde[1]	1.85 a	1.58 cd	2.04 a	1.26 ab	2.51 ab	1.05 a	2.68 a	0.56 a	1.71 ab	1.66 a	17.44 a
Duraturf	Tr[2]	0.61 c	2.05 abc	1.14 b	1.37 a	1.62 bc	1.04 a	1.47 b	0.45 a	1.19 bc	1.94 a	12.88 b
Olds	0.51 bcd	0.27 d	2.24 ab	Tr	0.89 c	2.17 ab	0.95 ab	Tr	0.06 b	0.39 d	1.43 ab	8.91 c
Boreal	1.11 b	0.19 d	1.74 bcd	0.63 bc	0.91 bc	1.61 bc	0.54 cd	Tr	0.17 b	Tr	0.78 b	7.68 cd
Ranier	0.17 e	0.11 d	2.26 ab	0.15 c	0.34 d	0.16 d	0.29 de	Tr	Tr	0.35 d	0.61 b	4.44 efg
Pennlawn	1.02 b	Tr	1.25 d	0.28 c	0.28 d	Tr	0.19 e	Tr	Tr	0.49 cd	0.64 b	4.15 fg
Illahee	Tr (WK)[3]	—	—	—	—	—	—	—	—	—	—	Tr
Chewings fescue (*F. rubra* var. *commutata*):												
Commercial (USA)	0.35 de	Tr	2.47 a	Tr	Tr	Tr	0.11 e (WK)	—	—	—	—	2.93 g
Highlight	0.76 bcd	Tr	1.25 d (WK)	—	—	—	—	—	—	—	—	2.01 g
Hard fescue (*F. ovina* var. *duriuscula*):												
Durar	Tr	1.06 b	1.92 abc	Tr	Tr	Tr	0.73 bc	Tr	Tr	0.53 cd	0.71 b	4.95 def
Meadow fescue (*F. elatior*):												
Commercial (Can.)	1.54 a (WK)	—	—	—	—	—	—	—	—	—	—	1.54 g
An-2356	1.02 b (WK)	—	—	—	—	—	—	—	—	—	—	1.02 g
Bottnia II	0.88 bc (WK)	—	—	—	—	—	—	—	—	—	—	0.88 g
Tammisto	0.84 bc (WK)	—	—	—	—	—	—	—	—	—	—	0.84 g
Tall fescue (*F. arundinacea*):												
Alta	0.97 bc (WK)	—	—	—	—	—	—	—	—	—	—	0.97 g
Checks:												
Polar bromegrass	0.11 e	0.12 d	1.13 d	2.22 a	0.62 cd	2.94 a	0.62 c	2.96 a	0.17 b	2.10 a	1.95 a	14.94 ab
Engmo timothy	0.21 e	0.10 d	1.65 bcd	1.07 b	0.47 d	0.95 cd	0.49 cd	2.20 ab	0.19 b	0.31 d	1.42 ab	9.06 c

1 Means followed by a common letter within a column do not differ significantly at the 5% probability level using Duncan's Multiple Range Test.

2 Trace amount of herbage, insufficient for harvestable yield.

3 Stands winter-killed completely.

Figure 1. *Two views of row experiment comparing red fescue strains from numerous world sources planted 3 Aug. 1960 and photographed 23 May 1962 after a winter (1961–62) of severe stress on perennial plants. (Upper): Overview of the experiment; rows showing good winter survival and vigorous spring growth are from seed collections in various areas of Alaska, while dead rows are introduced cultivars from other states and countries. Rows with no grass evident were very non-hardy, introduced cultivars that winter-killed during the first winter. (Lower photo shows close-up of part of above experiment): Center row is the cultivar Viking from Sweden rated as 95% winter killed; the little-injured row to left of center is Alaska collection No. 339 from the Matanuska Valley that later was released as the cultivar Arctared; row to right of center is collection No. 340 from Holy Cross in western Alaska.*

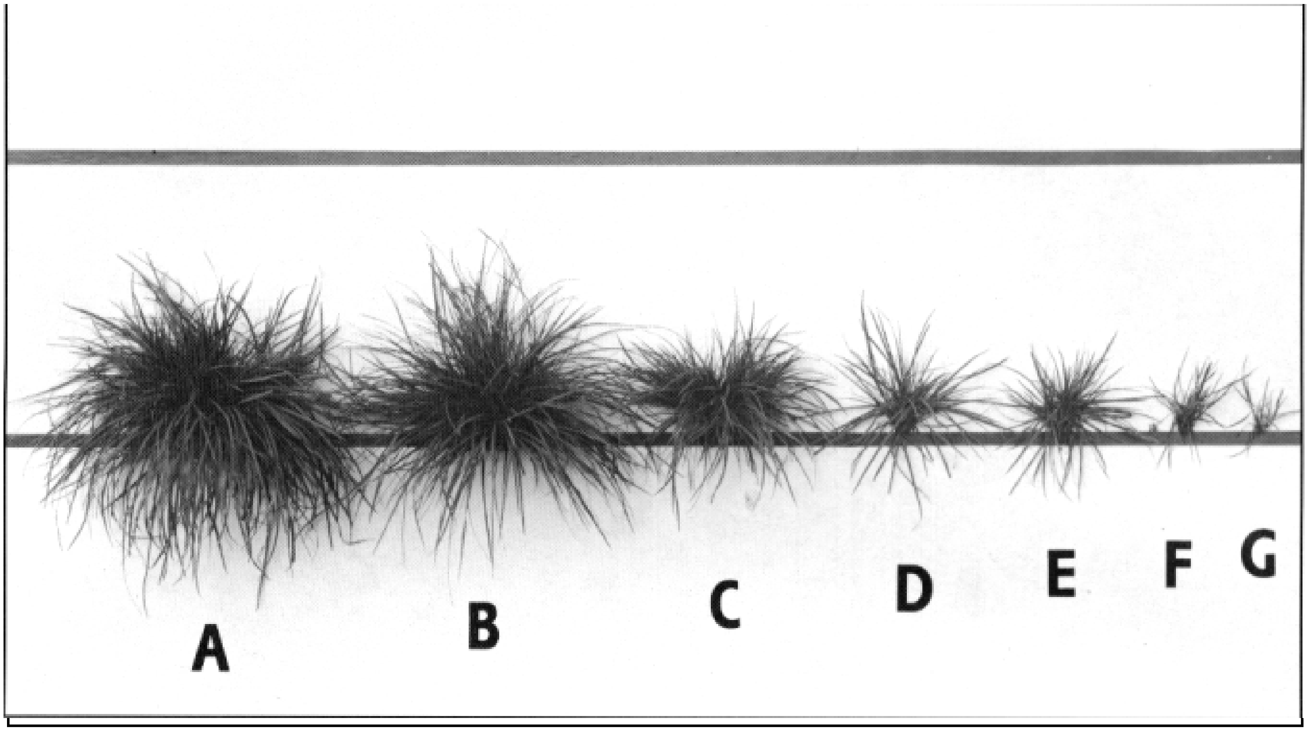

Figure 2. *Seeding-year development of Arctared red fescue plants as influenced by seven dates of planting, showing that only basal leaves and no elongated culms or seed heads are produced during the first year of growth. Plants were seeded: A = 21 May, B = 31 May, C = 11 June, D = 21 June, E = 2 July, F = 12 July, and G = 23 July. Photo taken 3 October near end of growing season; black lines are 12 inches apart.*

sity of Alaska's Matanuska Research Farm (61.6°N) near Palmer in southcentral Alaska.

Experimental Procedures

All experiments were conducted on Knik silt loam soil (Typic Cryochrept) with good surface drainage. Commercial fertilizer disked into plowed seedbeds before planting supplied nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) at 32, 128, and 64 lb/A, respectively. No cereal companion crops were used.

Experiments I, II, and III: Three separate six-year broadcast-seeded plot experiments were planted to compare several fescue species and strains from different latitudinal origins for winter hardiness and forage yields. Planting dates, grasses compared, harvest dates, and forage yields for Experiments I, II and III appear in Tables 2, 3, and 4, respectively.

Two standard forage cultivars in southcentral Alaska, Polar bromegrass (predominantly *Bromus inermis* Leyss. x. *B. pumpellianus* Scribn.) and Engmo timothy (*Phleum pratense* L.), were included as checks for comparison. Seeding rates were adjusted on the basis of germination trials to provide the following rates in pounds of pure live seed per acre: all fescues 18, bromegrass 22, and timothy 8. Plots measured 5 by 20 feet. All three experiments utilized randomized complete block experimental designs with three replications.

Forage harvests were made with a sickle-equipped plot mower leaving approximately a two–inch stubble. Small, bagged samples from each plot were dried to constant weight at 140°F. All forage yields are reported on the oven-dry basis. Each spring following establishment, commercial fertilizer top-dressed in late March or early April, before initiation of spring growth of grasses, supplied N, P_2O_5, and K_2O at 126, 96, and 48 lb/A, respectively. After the establishment year, all tests were top-dressed one to three days after the first-cutting forage harvest to supply N at 80 lb/A.

Experiment IV: Red fescue cultivars Arctared, Duraturf, and Illahee were seeded in two separate, similar experiments in rows 1 foot apart and 50 feet long on 22 June 1966 and 20 June 1967. Randomized complete block experimental designs were used with four replications. When seedlings were 2 to 3 inches tall, rows were thinned by hand-pulling to leave individual seedlings 4 to 6 inches apart.

During late summer and autumn of each year of planting, seedlings were dug from the field to determine levels of stored food reserves in overwintering crown tissues. In both years, 10 to 15 seedlings were dug in each row on each of three sampling dates (10 Aug., 30 Aug., and 10 Oct., 1966; 22 Aug., 19 Sep., and 10 Oct., 1967). Aerial growth beyond two inches above the soil surface was severed and discarded just before

Figure 3. *Comparative winter survival of fescues in broadcast-seeded plots. Left to right: Boreal red fescue from Canada, Arctared red fescue from Alaska, commercial chewings fescue from the United States. Plots seeded 18 June 1968; photo taken 21 May 1970.*

plants were dug. Immediately after digging, seedlings were wrapped in saturated paper toweling and kept wrapped except during washing and trimming until weighed for potting. All roots were severed and discarded and the main culm and tillers were severed one inch above the seminal node. Final traces of soil and loose plant debris were removed by washing, and surface moisture was blotted from plants with cloth toweling. Prepared crowns were weighed individually and embedded slightly in water-saturated vermiculite in pots so that tissues that had been below the soil surface were also below the vermiculite surface. Five plants of each entry were potted from each replication on each sampling date.

Five to eight plants from each row, prepared in the same manner as those potted, were weighed fresh, dried to constant weight at 140°F, and reweighed. Percent dry matter in each lot was used to derive extrapolated oven-dry weight of crowns potted.

All pots were placed into a dark chamber maintained at 65°±2.5°F with the base of each pot immersed in one-quarter to one-half inch of water. A fungicide in water spray was applied as needed, usually three times weekly, to prevent mold development. All etiolated regrowth was harvested (severed at the point where it emerged from the tiller stubble) at successive two–week intervals after potting until exhaustion of food reserves and death of plants. Harvested etiolated growth was dried at 140°F. Stored food reserves were calculated as milligrams (mg) oven-dry regrowth per oven-dry gram (g) of plant tissue potted.

On 25 Oct. 1966 and 20 Oct. 1967, after killing frosts, aerial growth of plants remaining in the field was clipped and removed, leaving a two–inch stubble to prevent differential snow retention on rows during winter. In mid-May of 1967 and 1968, after spring growth had started, living and dead plants were counted in all rows planted the previous year and winter survival percentages were calculated. Averaged over both years and all cultivars, number of plants per row on which winter survival data were determined was 89.

Results and Discussion

Experiment I: Winter Hardiness and Forage Yields

All entries except Illahee red fescue became well established in 1968 as indicated by seeding-year forage yields (Table 2); Illahee was rated at 60% of full stand on 19 Aug. 1968. Seeding-year forage yields of the fine-leaved fescues, especially the more northern-adapted red fescues such as Arctared and Duraturf, were generally quite low. Seeding-year growth of red fescues consists only of basal leaves with no elongation of culms (stems) until the second year of growth (Figure 1).

The winter of 1968-1969 was medium in severity, as judged by general plant winter survival at the Matanuska Research Farm, and all red fescues, chewings

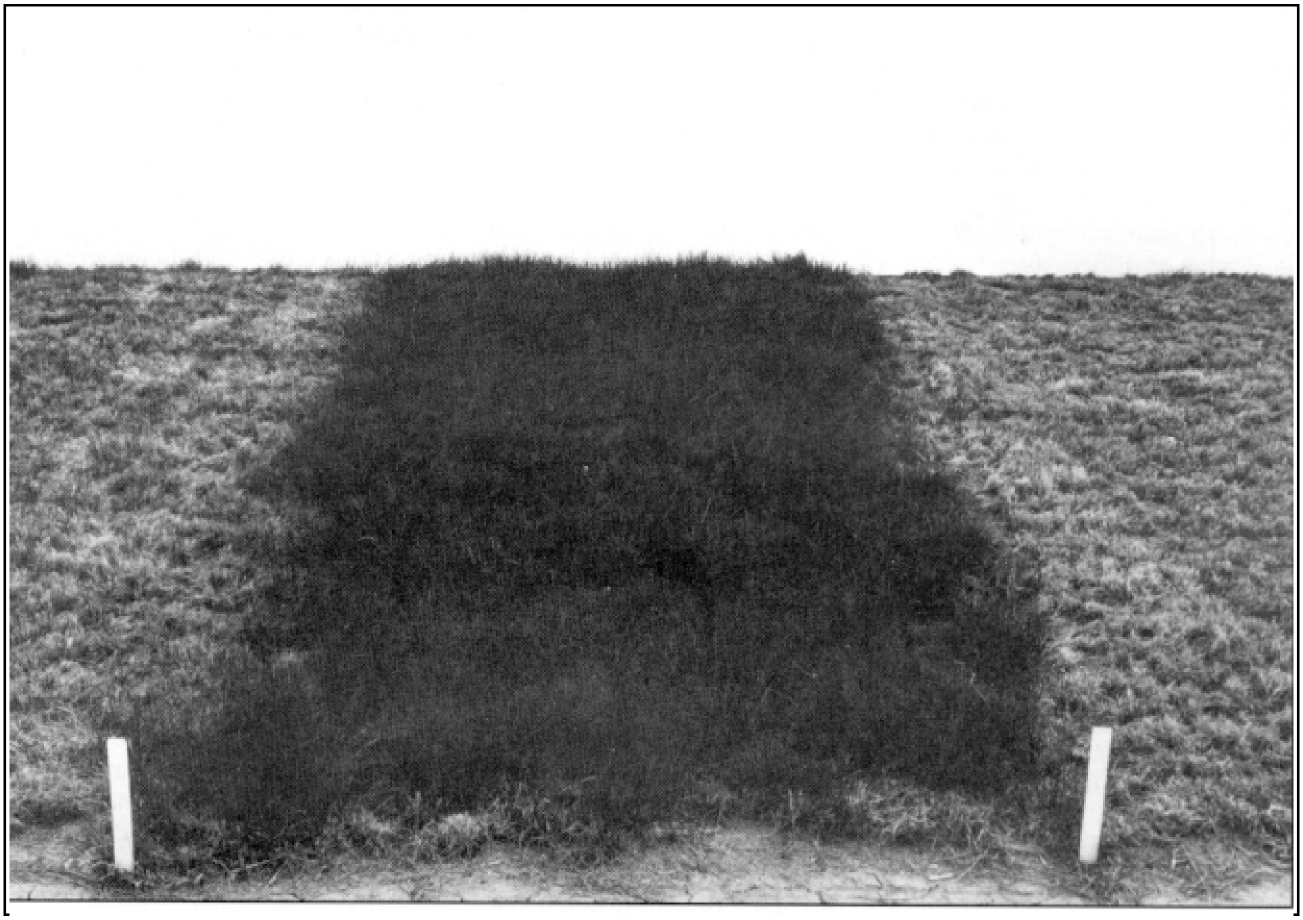

Figure 4. *Comparative winter survival of three red fescue cultivars in broadcast-seeded plots. Severely injured plots on left and right are the cultivars Boreal and Olds, respectively, from Canada; vigorous plot in center is the Alaska cultivar Arctared. Plots seeded 6 June 1969; photo taken 28 May 1971.*

fescue, and Polar bromegrass survived with negligible damage. Engmo timothy from northern Norway was rated one-third winter killed, and all three strains of meadow and tall fescue winter-killed completely (Table 2).

The 1969–1970 winter was somewhat more damaging to plants than 1968–1969; this was apparent in general observations and as seen in reduced forage yield of winter-injured Boreal, Olds, Ranier, and Illahee red fescues, and especially chewings fescue (Figure 3). Visual estimates of no apparent winter injury in the more winter-hardy Arctared red fescue and Polar bromegrass were supported by high forage yields.

The winters of 1970–1971 and 1971–1972 imposed comparatively more stress than the previous two; during 1970–1971 Engmo timothy was eliminated completely and Duraturf, Boreal, Olds, Ranier, and Illahee red fescues sustained severe injury; Duraturf, however, was injured considerably less than the other four. All but Illahee, however, recovered during the growing season to produce fair to good second-cutting yields. The winter of 1971–1972 virtually eliminated the remaining thinned stands of Boreal, Olds, Ranier, and Illahee red fescue and commercial chewings fescue. Arctared red fescue and Polar bromegrass sustained only minor injury during the 1970–1971 winter and none was apparent after the two subsequent winters. Arctared was clearly the most winter hardy of the 10 fescues compared.

Experiment II: Winter Hardiness and Forage Yields

Below-normal precipitation, especially during the latter half of the 1969 growing season, resulted in lower seeding-year forage yields (Table 3) than in Experiment I in the previous year (Table 2). As in the previous experiment, Alta tall fescue did not survive the first winter. The two meadow fescues were severely injured during the first winter; mean visual estimates of winter kill were 80% for Bottnia II from Sweden and 90% for the commercial strain from Canada. These estimates were corroborated by low first-cutting forage yields in 1970. Both recovered to produce fair second-cutting yields in mid-September, but both winter-killed completely during the second winter of the experiment.

Boreal and Olds red fescue and Engmo timothy

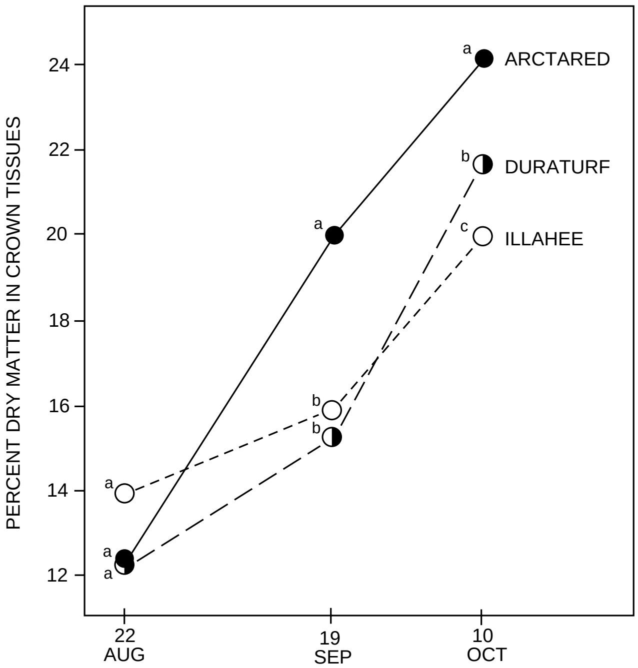

Figure 5. *Changes in percent dry matter during winter-hardening period in overwintering crown tissues of three red fescue cultivars of diverse latitudinal adaptation. On each sampling date, values not accompanied by the same letter differ significantly (5% level).*

sustained serious injury during the winter 1970–1971 (Figure 4); mean visual estimates of winter kill were Boreal 72%, Olds 96%, and Engmo 94%. Engmo never recovered to full productivity during the ensuing four years of the experiment, and Olds succumbed completely during the subsequent winter of 1971–1972 (Table 3).

Although Boreal red fescue slightly surpassed Arctared in herbage yields in 1970, first-cutting yields from Boreal for the next four years were markedly lower than from Arctared; those lower first-cutting yields were due to continuing winter injury observed each year in the more southern-adapted Boreal. Polar bromegrass sustained more winter injury during the winter 1970–1971 than Arctared, as seen in comparing first-cutting yields in 1971. For the remaining four years of the experiment, however, neither of these extremely winter-hardy Alaska cultivars showed apparent winter injury, and forage yields of both continued high.

Experiment III: Winter Hardiness and Forage Yields

As in the previous two experiments, Alta tall fescue winter-killed the first winter. Similarly, all four meadow fescues (Bottnia II from Sweden, Tammisto and An-2356 from Finland, and commercial from Canada), though well established as shown by seeding-year forage yields, also winter-killed completely the first winter (Table 4).

Durar hard fescue, a cultivar selected at Pullman, Wash. (Hanson 1972), was severely injured during the winter of 1971–1972. Though the Durar stands never winter-killed completely thereafter, neither did Durar recover sufficiently to produce more than occasional modest yields of herbage.

The two chewings fescues, Highlight from Holland and an U.S. commercial lot, also fared poorly. Highlight succumbed completely during the second winter and the commercial lot was so severely winter-injured that it produced no appreciable yields before total kill during the winter 1973–1974.

Of the red fescue cultivars from the conterminous United States, Illahee winter-killed completely the first winter, and Ranier and Pennlawn were damaged severely the first two winters, never recovering sufficiently thereafter to produce meaningful forage yields. The somewhat more northern-adapted Boreal and Olds from Canada sustained appreciable injury during the winters of 1970–1971, 1971–1972, and 1973–1974, but they were little-injured during the winters of 1972–1973 and 1974-1975 as confirmed by visual assessments in spring and subsequent first-cutting forage yields (Table 4).

During the six years of harvests, Boreal and Olds were about equal in forage yield, producing about twice as much as Ranier and Pennlawn, but only about half the total for Arctared. Duraturf, the most winter hardy of the three Canadian cultivars, produced total forage yields over the full term of the experiment that were intermediate between the less-winter-hardy Boreal and Olds and the more-hardy Arctared. Second-cutting yields of Duraturf often equalled or surpassed those of Arctared, but first-cutting yields (when effects of winter injury are most apparent) were always considerably less than those of the more northern-adapted Arctared.

The two non-fescue cultivars, Polar bromegrass and Engmo timothy, were both severely injured during the first winter; thereafter, the more winter-hardy Polar showed little evidence of winter injury while Engmo sustained moderate injury during several winters. Six-year forage yields of Engmo totaled only about 60% of Polar.

Normal dates of first occurrence of freezing temperatures near the end of the growing season at the Matanuska Research Farm are: 32°F = 9 September; 28°F = 19 September; 24°F = 4 October; 20°F = 12 October (Watson et al. 1971). Termination of the growing season and onset of winter conditions generally occur earlier in southcentral Alaska than in mid-temperate areas of the United States and Canada, whence many forage and turf cultivars routinely were obtained in the past for use in this area, prior to development here of more winter-hardy, subarctic-adapted cultivars.

In mid-to-late September of each year in all three of the previous experiments, it was noted that only

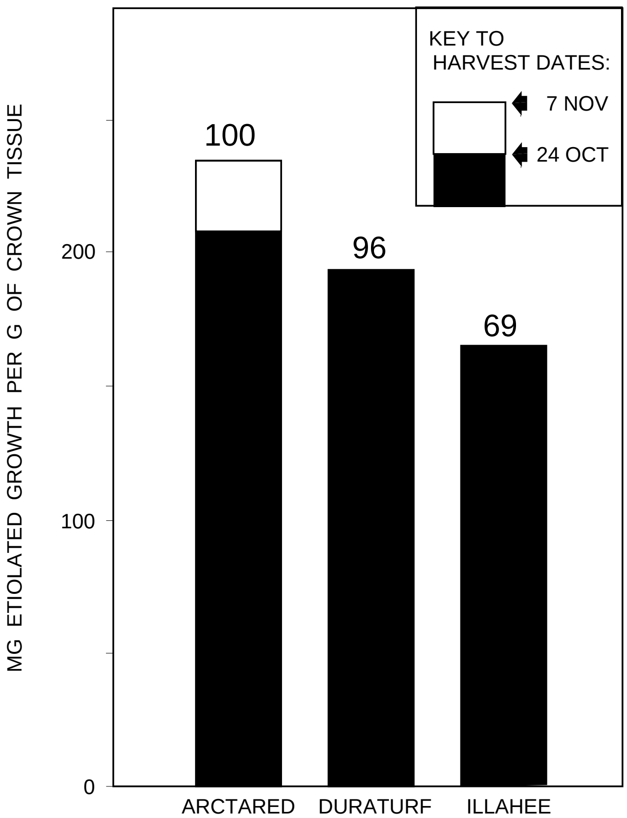

Figure 6. *Two-year means of stored food reserves as measured by etiolated growth harvested at two-week intervals (24 October and 7 November) from crowns of three red fescue cultivars of diverse latitudinal adaptation. Plants removed from field on 10 October both years, 111 days after planting; all weights on oven-dry basis. Numbers above bars are two-year means of percent winter survival of plants of each cultivar remaining in the field over winter. Each mean of survival differed significantly from the other two (5% level).*

Arctared of all the red fescues showed a gradual and progressive onset of yellow-brown coloration in its foliage while leaves of all other red fescues which were less winter hardy remained green; this parallels earlier differences observed here between subarctic-adapted and introduced red fescues (Klebesadel et al. 1964) and far-northern versus mid-temperate-adapted reed canarygrass strains (Klebesadel and Dofing 1990). This foliar senescence is interpreted as indicating growth cessation and early onset of dormancy in response to changing autumn environmental stimuli, probably involving the seasonal shortening of daylight hours (photoperiods) and lowering temperatures. If so, it probably represents an acquired sensitivity, through long residence and natural selection at high latitudes, for initiating preparation for winter under longer photoperiods/shorter daily dark periods (nyctoperiods) than is necessary at lower latitudes. In more southern regions (except at high altitudes), a longer term of short photoperiods prevails prior to frost-killing of foliage in autumn to condition perennials for winter stresses.

Evidence that grasses are conditioned by late-summer and autumn diurnal photoperiodic pattern to make adequate preparation for winter was found in earlier work at this location (Klebesadel 1971). In that study, mid-temperate-adapted bromegrass exposed to unaccustomed subarctic photoperiod/nyctoperiod pattern during late summer and autumn was predisposed to winter injury. In contrast, artificial provision of photoperiod/nyctoperiod pattern approximating that of its area of origin, for seven weeks prior to freeze-up, resulted in markedly less winter injury and enhanced winter survival. Photoperiod/nyctoperiod treatment effects on winter survival of mid-temperate-adapted Illahee red fescue exhibited the same general trend but were less pronounced than in Southland brome.

Experiment IV: Percent Dry Matter in Overwintering Tissues and Stored Food Reserves

To better understand the relationship of certain facets of hardening behavior to winter survival of red fescue in this subarctic area, three cultivars differing widely in inherent winter hardiness under Alaskan conditions (Tables 2 and 4) were compared in two separate, similar, two-year experiments for moisture changes in crown tissues during winter hardening, autumnal food-reserve storage, and subsequent winter survival of undisturbed individual plants that remained in the field. These changes in crown tissues of the plant during late summer and autumn are related to winter hardiness. Crown tissues are the dominant plant parts involved in preparation for, and tolerance to, winter stresses. Moreover, they are the site of origin of new aerial growth (stems and leaves) produced during the next growing season.

Arctared, one of the most winter-hardy grass cultivars here, traces to a single plant collected in Alaska's Matanuska Valley (at 61.6°N Lat); whether originally introduced or native is not known with certainty (Hodgson et al. 1978). Duraturf, intermediately winter hardy here, was selected at Ottawa, Ontario (45°N Lat) from "Scandinavian material" (Hanson 1972). Illahee, relatively nonhardy in this area, was chosen at Corvallis, Oregon (44.5°N Lat) from germplasm tracing to England. Neither Oregon nor England represents conditions requiring more than modest winter hardiness, compared to southcentral Alaska.

The sampling periods in the two years of the study overlapped termination of the growing seasons and onset of the dormant period. There had been four days with minimum temperatures below freezing (lowest 25°F) before the final sampling on 10 Oct. 1966, and 10 days below freezing (lowest = 19°F) by 10 Oct. 1967.

Percent Dry Matter in Overwintering Tissues

Except for the final sampling on 10 October of both years, dissimilar sampling dates during the two experiments precluded calculation of two-year means. Cultivar differences in percent dry matter in crown tissues followed generally the same pattern in both years and data for 1967 are presented in Figure 5. Percent dry matter in overwintering crown tissues of all three cultivars increased markedly during the winter-hardening period. The timing and the extent of change in percent dry matter differed between Arctared and the two less-hardy cultivars. The most rapid change in Arctared occurred before mid-September, between the first and second samplings, perhaps suggesting a more timely response to changing autumnal climatological stimuli. In contrast, the most rapid change in Duraturf and Illahee occurred between mid-September and the final sampling on 10 October. During the 49 days between first and final samplings, percent dry matter in Arctared increased 97%, in Duraturf 78%, and in Illahee 44%.

This change in percent dry matter in overwintering grass crowns is important to winter survival as it is involved with the complex physiological alterations in cell protoplasmic contents that occur during late summer and autumn in tissues that must endure winter stresses and provide for growth the following spring (Smith 1964). Metcalf et al. (1970) reported that percent moisture in winter wheat and barley plant crowns was closely associated with injury sustained at different freezing temperatures; least injury occurred with lowest crown moisture (highest dry-matter concentration) and vice versa. They noted also that a small difference in percent crown moisture at a certain level of freeze stress resulted in large differences in injury as measured by subsequent plant survival.

Ability of overwintering plants to withstand freezing with minimal injury is a major element in the complex problem of winter survival of forage species. The above information of Metcalf et al. (1970) agrees well with the interrelationships of red fescue crown moisture and winter survival reported here (Figure 5; Tables 2 and 4). After termination of the growing season and near the onset of winter (10 October sampling in both years), crown tissues of subarctic-adapted Arctared were significantly higher ($P = < 0.05$) in percent dry matter than Duraturf or Illahee. Duraturf crowns were significantly higher in percent dry matter than the more southern-adapted, less winter-hardy Illahee in October 1967 and in the two-year mean but not to a significant extent in 1966.

In these tests, differences in percent winter survival (of individual plants left in the field) between Arctared and Duraturf were not great; however, best winter survival in the field generally was associated with highest percent dry matter in crown tissues of the three cultivars, and poorest winter survival was associated with lowest percent dry matter in crowns (Tables 2 and 4; Figure 5). With the 1967-1968 winter, the difference in winter survival between Arctared and Duraturf was not statistically significant, but both significantly surpassed Illahee in survival. In the winter 1966-1967, and in the two-year means, differences in winter survival were significant ($P = < 0.05$) in the ranking: Arctared > Duraturf > Illahee (Figure 5).

Stored Food Reserves

No evidence of stored reserves, expressed as etiolated growth, was produced when plants of the three red fescue cultivars were taken from the field in early August (10 Aug. 1966) indicating that preparation for winter had not begun at that early date. When taken from the field just after mid-August (22 Aug. 1967), all three cultivars gave evidence of near-equal stored reserves as milligrams (mg) oven-dry etiolated growth per oven-dry gram (g) of crown tissue potted (Arctared = 102, Duraturf = 108, and Illahee = 106). Just after mid-September (20 Sep. 1967), all showed increased reserve storage over the 22 August sampling; Arctared and Duraturf were similar at 151 and 153 mg/g, respectively, while Illahee produced only 127 mg/g. No etiolated growth was produced by any plants after the single harvest of growth two weeks after plant crowns were placed in the dark chamber.

The early October sampling was on the same date both years; inasmuch as values and cultivar relationships were similar for both years, the two–year means are shown in Figure 6. When taken from the field on 10 October, Arctared, Duraturf, and Illahee produced etiolated growth (mg/g crown tissue) during the first two weeks in darkness as follows: Arctared 208, Duraturf 192, and Illahee 163. Thereafter, Duraturf and Illahee produced no further evidence of stored reserves as etiolated growth. Crowns of the extremely winter-hardy, subarctic-adapted Arctared, in contrast, produced another 27 mg of etiolated growth per gram of crown tissue during the second two-week growth period (Figures 6 and 7).

Arctared then averaged 235 mg/g in total stored reserves and 100% winter survival over the two years. The more southern-adapted, Canadian Duraturf averaged 192 mg/g and 96% winter survival. The southern-most-adapted cultivar, Illahee, expressed the lowest level of stored reserves at 163 mg/g and averaged only 69% winter survival. Although only three cultivars were compared, there was nonetheless a consistent relationship between latitude of origin, level of stored reserves expressed as etiolated growth, and winter survival in the field.

These relationships among latitudinal adaptation, levels of stored food reserves, and winter survival in red fescue parallel generally the results reported for the same parameters in timothy at this location (Klebesadel and Helm 1986).

Palatability to Horses

An unplanned incident not related to the experi-

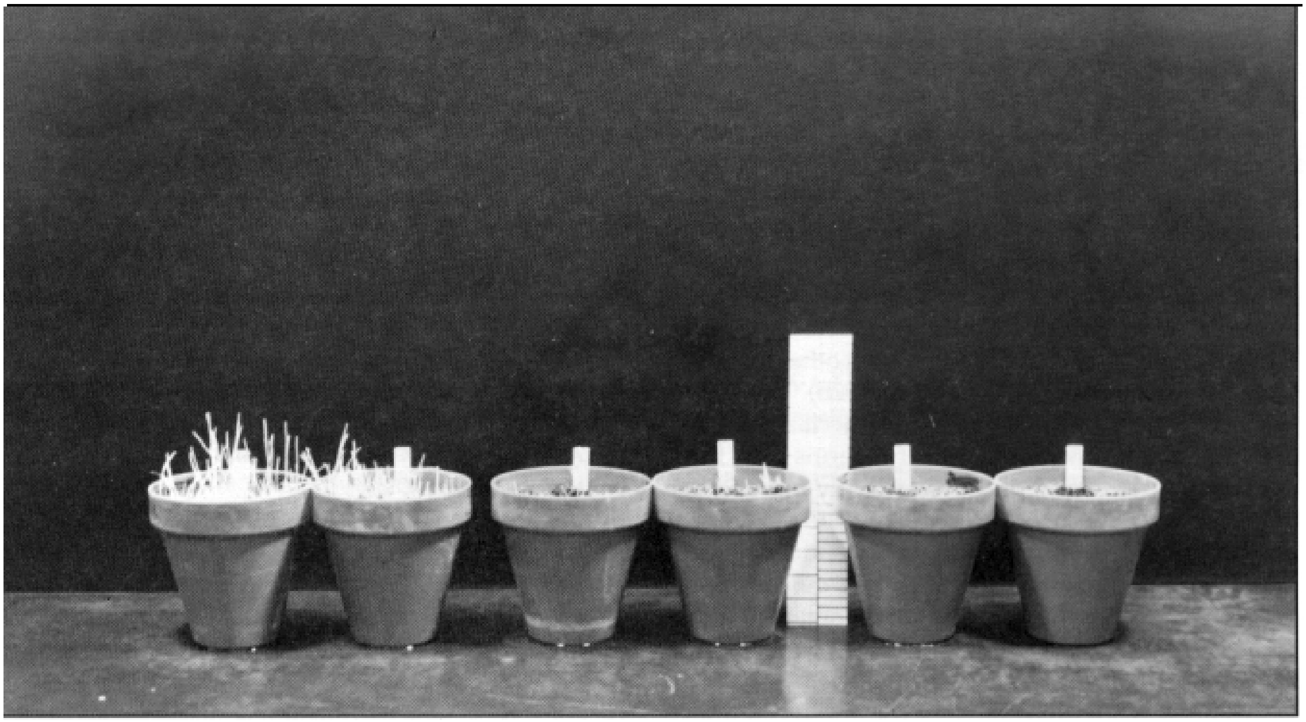

Figure 7. *Etiolated growth produced by three spring-planted red fescue cultivars by the end of the second, two-week growth period in darkness, after having been taken from field on 10 October after termination of the growing season. Paired pots contain crowns of (left) Arctared, (center) Duraturf, and (right) Illahee.*

ments reported here, but worthy of note and involving red fescue usefulness, occurred a few years ago at the Matanuska Research Farm. That incident provided an interesting insight into comparative palatability to horses of red fescue and Kentucky bluegrass and could serve as a basis for future research.

Long row plantings of eight different numbered experimental strains of red fescue alternated with seven different strains of Kentucky bluegrass. The various individual strains were represented by from 1 to 24 rows each. All rows were of the same age, and fertility was uniform over the area occupied by all rows. Horses confined on pasture in a neighbor's field adjacent to the experimental grass rows broke through the fence and had unhindered, free-choice opportunity to graze any or all of the grass rows for several hours.

It might be assumed from the traditional association of horses and Kentucky bluegrass that they would favor that species. Surprisingly, there was *no* evidence of grazing in any of the bluegrass rows, while five different strains of red fescue were grazed heavily. Moreover, the horses walked through and grazed very little from stands of annual ryegrass, bromegrass, and timothy before reaching the red fescue and bluegrass rows. This observation is at variance with Hanson's (1972) description of red fescue as "not highly palatable." Adapted red fescue therefore should be considered useful and evaluated further for horse pastures in Alaska.

Conclusions

All strains of both broad-leaved fescue species evaluated were inadequately winter hardy for dependable use under field conditions in southcentral Alaska. This was somewhat surprising, for some of the meadow fescue cultivars were from Sweden and Finland, origins roughly similar in latitude to southcentral Alaska. Comparisons of climatic data, however, reveal that low-temperature stresses during winter in those Scandinavian countries are less rigorous than occur generally in Alaska's Matanuska Valley. Further confirmation of this geographic/climatic comparison is seen in the good winter survival in northern Norway (Habjorg 1976) of Pennlawn red fescue, a mid-temperate-adapted cultivar that fared poorly in this area (Experiment III, Table 4).

Highlight chewings fescue, the commercial strain of the same species, and Durar hard fescue generally survived winters somewhat better than the broad-leaved fescues but markedly poorer than the hardiest red fescues. The generally poor performance of Durar hard fescue and both strains of chewings fescue parallel similar results with those fescues in another study at this location (Klebesadel 1992b).

Ranier, Pennlawn, and especially Illahee red fescue, from the conterminous United States, generally were less winter hardy than Canadian cultivars of red fescue.

Of the three Canadian red fescue cultivars, Duraturf, derived from Scandinavian material, was clearly more winter hardy than Boreal which was selected at Beaverlodge, Alberta (55.2°N Lat) from the cultivar Olds. Moreover, Boreal gave evidence (Table 3) of being more winter hardy than Olds, an older cultivar derived from germplasm originally introduced from Czechoslovakia (48° to 51°N Lat) (Hanson 1972). Subarctic-adapted Arctared was clearly the most winter hardy of all the fescues compared, and it surpassed all other fescues in forage yields in all three experiments. These comparisons are consistent with other results in this area (Klebesadel 1985b, 1992a, 1992b).

Comparing total forage yields of Arctared red fescue and Polar bromegrass for the full terms of all three experiments, Arctared produced slightly more forage than Polar. It should be recognized, however, that under normal farming practice, most standard types of harvest equipment would not recover as much herbage of the shorter-growing Arctared as was obtained under the very short clipping height (about two inches) and hand-raking used in these experiments.

General winter hardiness of the seven red fescue cultivars compared ranked thusly: Arctared > Duraturf > Boreal ≥ Olds > Ranier = Pennlawn > Illahee. Of the three red fescue cultivars compared most intensively in these tests, Arctared exemplified the most northern adaptation, highest percent dry matter and highest level of stored reserves in crown tissues at onset of winter, best winter survival, and highest forage yields. Illahee, the southernmost-adapted cultivar was lowest in stored reserves, percent dry matter in crowns, winter survival, and forage yields. Duraturf, of intermediate latitudinal origin, was intermediate for all characteristics between Arctared and Illahee.

These results provide a better understanding of winter hardiness patterns and specific factors associated with winter survival in various strains of grass within the genus *Festuca* in the far north. They also reveal facets of plant behavior associated with latitudinal adaptation as they are expressed in the Subarctic relative to winter survival. The high forage-yielding ability of Arctared red fescue, coupled with its extreme winter hardiness, suggests that this cultivar may become increasingly useful as a harvested forage or for pasture, in addition to current turf and revegetation uses.

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