

Bromegrass in Alaska. VI. Effects of a Broad Array of Harvest Schedules and Frequencies on Forage Yield and Quality and on Subsequent Winter Survival of Cultivars Manchar and Polar

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SUMMARY

Objectives of this study were to compare several schedules and frequencies of forage harvest of smooth brome grass (*Bromus inermis* Leyss.): (a) for distribution of forage yields and total productivity in the year of differential harvests, (b) for percent crude protein in herbage in the various cuttings and for yields of crude protein, (c) for determining rates of growth (production of herbage dry matter) during the growing season, and (d) for effects of those different harvest schedules and frequencies on subsequent winter survival and on stand health and vigor the following year as measured by a uniform evaluation harvest in late June or early July.

Two brome grass cultivars, mid-temperate-adapted Manchar and subarctic-adapted Polar, were utilized in four experiments (Manchar in two, Polar in two) conducted at the University of Alaska's Matanuska Research Farm (61.6°N) near Palmer in the Matanuska Valley in southcentral Alaska.

- All of the more frequent harvests (3, 4, or 5 per year) resulted in lower total forage yields than the highest-yielding two-harvest treatments (All Exps.).

- During the entire month of June and into early July, smooth brome grass supplied with adequate fertilizer nutrients and soil moisture put forth remarkably rapid growth, producing high forage yields (Exps. III, IV).

- Rate of forage dry-matter accumulation during most of the month of June ranged from 70 to 197 pounds per acre per day, and much of the difference among rates appeared related to differences in moisture supply (Exps. II, III, IV).

- The highest rate of herbage dry-matter production during a measurable short period in these experiments was 273 pounds per acre per day from 3 to 10 June with Polar brome grass when it benefited from abundant soil moisture following markedly above-normal precipitation during May (2.54 inches received versus normal = 0.74 inches) (Exp. IIIb).

- With two cuttings per year, the first about 20 June and second about 1 September, approximately one half of the total-year yield was obtained in each cutting; with the first cutting about 1 July (and the second about 1 Sep.), averages of 57% and 43% were obtained in first and second cuttings, respectively. However, relative abundance or scarcity of precipitation in either half of the growing season had a strong influence on yield distribution (Exps. II, III, IV).

- In general, little or no increase in herbage yields accrued from deferring the second of two cuttings to

later than late August or very early September. With three cuttings, some increases were obtained with progressively later third cuttings throughout September; however, those late cuttings interrupted the final, pre-winter regrowth period and sometimes predisposed stands to severe winter injury (Exps. II, III, IV).

- Percent crude protein in first-cutting herbage declined from 19.3% on 2 June to 13.1% on 2 July, the latest of four first-cutting dates (Exp. II).

- With two harvests per year, percent crude protein in the second cuttings was highest when the first cutting was taken latest (2 July), lowest when the first cutting was taken earliest (10 June), and intermediate with the intermediate first-cutting date of 22 June (Exp. II).

- Similarly, within each of three groups of treatments (first cuttings harvested on three different dates), as second cuttings were progressively later by about 10-day increments (from 20 July to 22 Sep.) percent crude protein in harvested herbage declined with each later harvest. Thus, as with first cuttings, percent crude protein in the regrowths declined as that grass became more mature with longer periods of growth before harvest (Exp. II).

- With frequent harvests (4 or 5 per year), percent crude protein in herbage remained high in all regrowth harvests, ranging mostly from 25% to 34% (Exp. II).

- Total yields of crude protein ranged from 443 to 1398 lbs/A; however, the lowest yields were from 2-cut treatments with early second cuttings that did not recover crude protein in unharvested regrowth that developed after those early second cuttings (Exp. II).

- Highest yields of crude protein (1398 and 1337 lb/A) were obtained from 5-cut and 4-cut treatments, respectively. However, those treatments were lower in total dry-matter yields than many of the 2-cut treatments, and most of those 4- and 5-cut treatments predisposed the brome grass to severe winter injury (Exp. II).

- Among all 2-cut treatments, highest total yields of crude protein (1026 to 1114 lb/A) generally were obtained from treatments with the second cutting harvested at the end of August; earlier or later second cuttings tended to result in lower total-year yields of crude protein (Exp. II).

- The combination of a stressful winter following 34 different harvest treatments with Manchar brome grass revealed in considerable detail the markedly different effects of the various harvest schedules, frequencies, and lengths of regrowth periods on subsequent winter

survival and stand vigor as measured by first-cut yields the following year (Exp. II).

- Most of the 13 treatments involving three, four, or five harvests per year were more damaging to Manchac winter survival and stand vigor than any of the 21 treatments with two harvests per year (Exp. II).

- With three or four cuttings, Manchac stands were predisposed to maximum subsequent winter injury (almost total winterkill) when the final harvest was taken on 10 September; slightly less, but still very severe, injury occurred where the final cutting had been taken on 31 August or 22 September. Greatest injury with five cuttings occurred where the final harvest had been on 22 September (Exp. II).

- Polar was most injured by two 3-cut treatments with first cutting on 12 June, the second on 20 July, and the third on either 1 or 12 September. Strangely, those treatments were more injurious to Polar stands than 4-cut or 5-cut treatments, all of which had shorter regrowth periods between cuttings, and regardless of final cutting dates from 21 August to 22 September (Exp. IV).

- Dates of occurrence of first killing frost in autumn (about 24°F) can differ greatly from year to year—during the years of these experiments the range was 16 September to 18 October.

- The amount of precipitation received in this area (mean = about 15 inches annually) is marginal for realizing the full forage-production potential of bromegrass. Above-normal amounts promote high forage yields, but below-normal precipitation can severely limit productivity. Moreover, the timing of precipitation during the growing season can markedly influence forage productivity of bromegrass.

- Because rainfall during April, May, and June at the Matanuska Research Farm typically is very limited (normal = 0.63, 0.74, and 1.59 inches, respectively), any deficiencies in those precipitation amounts severely curtailed the very considerable potential for rapid herbage production by bromegrass during June and early July; moreover, that suppressing effect on productivity was magnified if precipitation was much below normal during the latter portion of the previous growing season (Exps. II, III, IV).

- With two cuttings per year, moisture supply had a marked effect on amount of regrowth produced after the first cutting; for example, in Exp. II with first cutting on 22 June, and with June+July+August precipitation 1.41 inches above normal, second-cutting yield on 22 September was 2.80 T/A; in

Exps. III and IV, with the same first-cut date and when precipitation for the same months averaged 1.44 inches below normal, yield on 21 September (mean date) averaged only 1.63 T/A.

- Northern-adapted bromegrass harvested on an appropriate frequency and schedule, one that is in harmony with grass growth requirements and seasonal physiological processes (first cut late June or very early July, second cut late August or very early September), sustained little or no reductions in stand vigor or winter survival. Conversely, inappropriate harvest frequencies or scheduling (usually 3 to 5 cuts per year) tended to weaken stands and predispose them to moderate-to-severe winter injury (Exps. I, II, IV).

- A winterhardy, northern-adapted bromegrass cultivar, well supplied with soil moisture and recommended rates of fertilizer nutrients and harvested only twice, will produce high yields of good quality forage and will not be weakened in stand vigor as generally occurs with more frequent harvests (All Exps.).

- Although these experiments simulated farm-equipment harvest of forage as done for storage or green-chop feeding, the more frequent harvests, their scheduling, productivity, regrowth rates, and herbage quality can relate broadly to bromegrass utilization by rotational grazing also.

INTRODUCTION

Smooth bromegrass (*Bromus inermis* Leyss.), a tall-growing, leafy, sod-forming species, is the most widely used perennial forage on rotational croplands in Alaska. On well-drained, deep loamy soils, and with adequate supplies of moisture and nutrients, properly managed stands of winterhardy cultivars will remain highly productive for several years (Klebesadel 1994c).

Moreover, the sod-forming growth habit, extensive fibrous root system, and good persistence of subarctic-adapted strains make smooth bromegrass a highly valued and versatile species for many off-farm uses including soil stabilization and erosion control in Alaska.

Northern and Southern Types

Smooth bromegrass was introduced into North America from various European and Asian sources during the late 1800s (Carlson and Newell 1985; Smith *et al.* 1986). Two major types of the grass, “northern” and “southern,” are recognized in North America. Several improved cultivars have been

developed and released in the U.S. and Canada within each type; most are of the southern type and a few are classed as intermediate between the two (Carlson and Newell 1985; Hanson 1972; Smith *et al.* 1986).

Hanson (1972) states that the northern type is adapted to western Canada and the northern Great Plains, and the southern type to Corn Belt states and the central Great Plains area. Trials at various geographic locations within the culture area of smooth brome grass in North America have demonstrated distinct differences in forage and seed production between the two types (Fortmann 1953; Knowles and White 1949; Thomas *et al.* 1958).

The northern and southern types are called “meadow” and “steppe” types, respectively, in Russia (Carlson and Newell 1985; Fortmann 1953; Knowles and White 1949; Smith *et al.* 1986). The morphological, behavioral, and ecological/ geographic characteristics of the two groups and their differences are discussed in detail by Knowles and White (1949).

Numerous experimental tests at this station have shown cultivars and strains of southern-type smooth brome grass to be inadequately winterhardy for dependable use in Alaska (Anonymous 1953(?); Klebesadel 1970, 1971, 1985, 1993a, 1994a, 1994c; Klebesadel and Helm 1992).

The Problem

Northernmost-adapted strains of northern-type smooth brome grass generally are adequately winterhardy in this geographical area, except during winters of abnormally severe stresses. During those unusually severe winters, the hybrid cultivar Polar, developed in Alaska, survives markedly better than all introduced strains of smooth brome grass (Klebesadel 1994a; Wilton *et al.* 1966).

In addition to winter stresses, however, inappropriate scheduling or frequency of harvests can weaken brome grass stands and predispose them to severe winter injury in this area of Alaska (Klebesadel 1993b, 1994a, 1994b). An earlier study at this location (Klebesadel 1994a) demonstrated with several cultivars and strains of established brome grass that certain schedules and frequencies of harvest are tolerated well while others have the potential to weaken stands to the extent that they can be severely injured or killed by the subsequent winter if it is more than moderately stressful.

Matanuska Valley Winter Stresses

The Matanuska Research Farm is located centrally in the Matanuska Valley, an area routinely subjected during winter to winds and temperature fluctuations that together impose considerable, and frequently injurious, stresses on overwintering forages.

Snowfall usually is modest in amounts, but the protective insulation from low air temperatures that it could provide to plants often is lost when randomly occurring strong winter winds from the northeast remove that snow cover (Dale 1956; Klebesadel 1974; Watson 1959). A suspected further harmful effect of those winds is dehydration of overwintering plant tissues exposed at or near the soil surface.

Another stress imposed on overwintering forages locally is the random occurrence during winter of thaw periods (+40° to +45°F) occasioned by southeasterly winds from the Gulf of Alaska that typically continue for one to four or five days. These melt snow that often refreezes as ice layers where drainage is poor. If rain occurs during winter, it can freeze on the soil surface and build up to an ice layer. Not only is ice a poorer insulator than snow that protects plants from low air temperatures, ice remaining in place for extended periods can cause plants to die from smothering (Klebesadel 1974; Smith *et al.* 1986).

If no snow is present when warm winter winds blow, the upper layer of soil may thaw with deleterious effects on plants (Dexter 1941; Smith 1964a, 1964b). Alternate thawing and refreezing can cause “heaving” of taprooted legume seedlings, pushing them up out of the soil and causing death; however, the fibrous roots and interlaced rhizomes of brome grass render it immune to that harmful action.

A peculiarity of this northern latitude, and a disadvantage to winter survival of introduced forages that are adapted at more southern latitudes, is the brief period of critical-length short days/long nights important to promoting development of freeze tolerance prior to onset of freezing temperatures (Klebesadel 1993c). Those introductions are not induced to prepare adequately for winter’s cold and therefore may exhibit poor winter survival (Klebesadel 1971, 1985). In 1975 that effect was exaggerated with temperatures that were abnormally warm in early to mid-October; warm temperatures during the pre-winter period tend to retard cold-hardiness development (Smith 1964a). The unseasonably warm October temperatures of

1975 were followed abruptly by a precipitous plunge to near -10°F in late October and early November; that anomalous temperature pattern caused widespread winterkilling locally of even many ordinarily hardy herbaceous and woody perennials (Klebesadel 1977).

Adapted Perennial Forages Are Resilient, But May Fail If Over-Utilized

Perennial forages such as bromegrass are unique in being the most “punished” of crops. With fruit-producing vines, bushes, and trees, the total plants are left mostly intact with only the fruit removed near ripeness. Annual and winter-annual crops such as the cereals, potatoes, and other vegetables are left intact until crop harvest, with no further growth contribution or production expected from the plants.

Perennial forages, in contrast, have virtually their entire photosynthetic (food-manufacture) apparatus removed one to several times per year and many times over the life of the plants. Yet growers expect those plants to recover rapidly from each defoliation, vigorously putting forth new growth and maintaining good stand health through succeeding harvests as well as surviving a series of intervening winters.

To require that much output and continual recovery by forage plants requires that growers in areas of cold winters understand (a) the importance of an adequate genetic level of winterhardiness in cultivars chosen for the area in which they are to be grown, (b) the extent of growth and production possible within the limits imposed by the growing season and other factors (moisture supply, temperature, available nutrients, etc.), and (c) the practical limitations on utilization of the aerial growth of plants so that plants are permitted to maintain adequate internal energy levels for fulfillment of vital physiologic functions throughout the year.

Factor (c) then requires a basic understanding of the interrelationships of a plant’s food manufacture (photosynthesis), translocation of those carbohydrate foods within the plant, apportioned use of those carbohydrates for growth and/or storage, and how food-reserve levels within the plant vary during the growing season. The changes in levels of food reserves within forage plants are affected by (a) basic development patterns of the plant and (b) removal of the plant’s aerial growth by forage harvest or grazing.

Harvest Management Affects Food-Reserve Levels in Plants

All of the aforementioned winter stresses emphasize that perennial forages should enter the dormant winter period with high levels of food reserves. Those food reserves permit development of high levels of freeze tolerance, enable plants to survive the winter with good health and vigor and, in addition, provide the needed energy to put forth vigorous growth in spring (Smith 1964a, 1964b; Smith and Nelson 1985). Therefore, forage harvest schedules and frequencies should permit plants to achieve those desired functions.

Several reviews of earlier literature have been published concerning the storage and use of carbohydrate food reserves in herbage plants as influenced by management (Graber 1931; May 1960; Weinmann 1948). At this location, one investigation with bromegrass showed the effects of seeding-year management on pre-winter levels of food reserves and on subsequent winter survival (Klebesadel 1993b). Other studies with several forage species have compared the relationship of food-reserve levels in subarctic-adapted versus more southern-adapted forages and related those levels to subsequent winter survival (Klebesadel 1993a, 1993c, 1993d).

Investigators in Wisconsin have monitored during the growing season the changing levels of carbohydrate reserves in smooth bromegrass as influenced by different times and frequencies of harvest (Paulsen and Smith 1968, 1969; Reynolds and Smith 1962).

Initiation of growth in spring (Point A, Fig. 1) draws upon food reserves that were stored in the plant during the previous growing season. That growth lowers the level of reserves within the plant (from points A to B) until the time that photosynthetic activity by the new leaves gradually surpasses the rate of use of food reserves; that reverses the lowering trend of reserves and a generally upward trend of accumulation begins (from point B to first cutting date = C1).

After each cutting, stored food reserves again are drawn upon to initiate new regrowth, resulting once more in a lowering of total available carbohydrates (TAC) levels as shown in Figure 1 between C1 and D1, C2 and D2, C3 and D3. Again, as occurred with the initial growth of the year, a low point of food-reserve levels is reached (D1, D2, D3) before photosynthetic activity and TAC restoration once more surpasses utilization, raising the level of TAC in storage tissues (note increasing

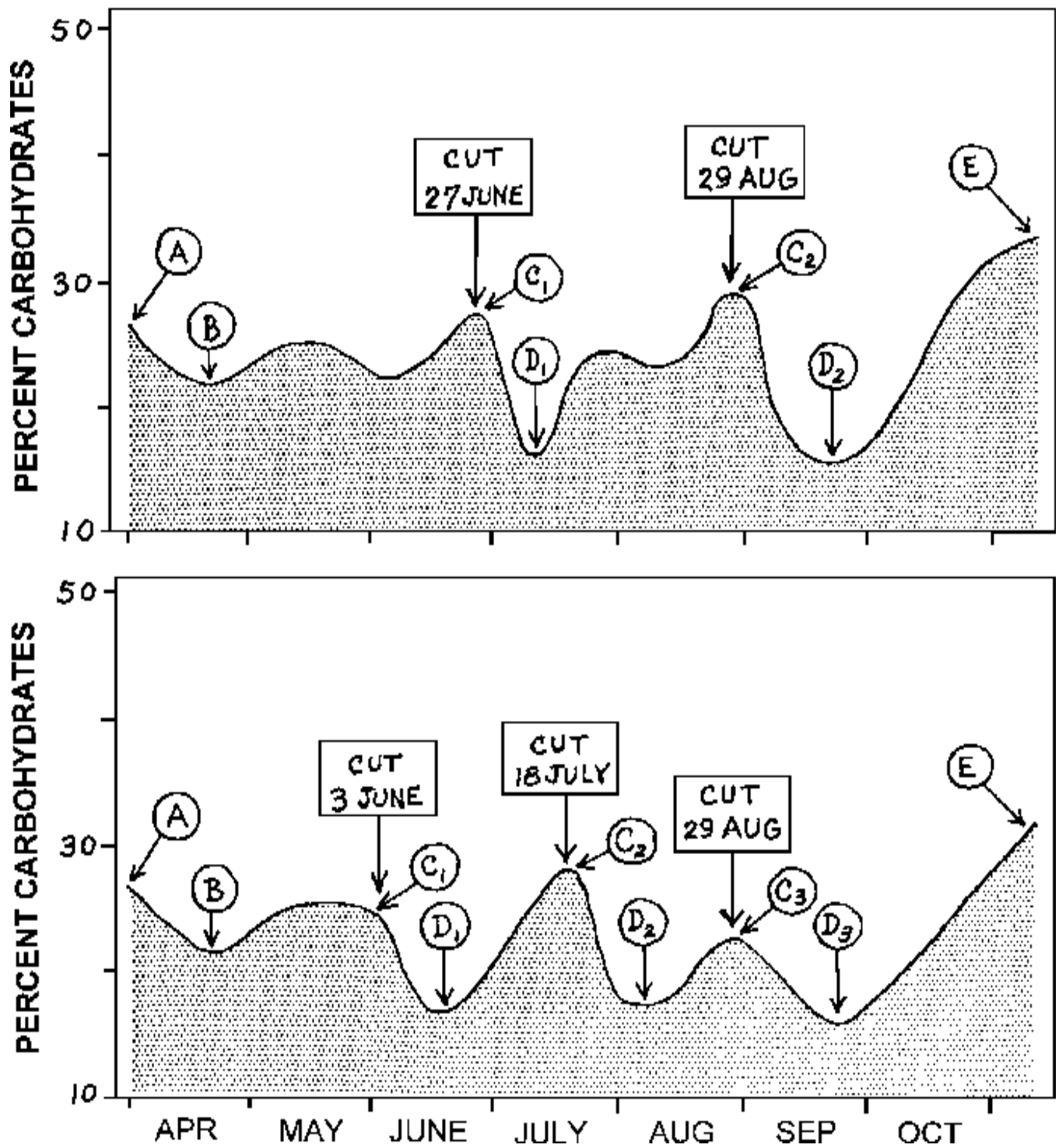


Figure 1. Percent total available carbohydrates (TAC) in storage tissues of smooth brome grass as influenced by (upper) two cuttings and (lower) three cuttings for forage. This work, at a much more southern latitude (43.1°N in Wisconsin) shows that from the final cutting date (29 Aug. with both cutting frequencies) until the final sampling date for TAC (11 Nov.), a period of 74 days was adequate for plants to restore TAC to high levels prior to onset of winter conditions. (Adapted from Reynolds and Smith 1962).

trend of TAC level after D1, D2, D3).

The Wisconsin results shown in Figure 1 had the final cutting on 29 August with both the 2-cut and the 3-cut frequencies. From that date to the final TAC sampling date (11 Nov.), the 74-day regrowth period was adequate for restoring TAC to high levels (points E, Fig. 1) before onset of winter conditions. Note that the pre-winter TAC levels at points E are higher than the early spring TAC levels were at points A; this is due to the minor utilization of stored food reserves during the winter period (Smith 1964a, 1964b; Smith and Nelson 1985).

Alaska's Matanuska Valley has a shorter growing season than the southern Wisconsin locale where the results in Figure 1 were derived; thus, brome grass in Alaska initiates growth later in spring and growth activities are terminated sooner in autumn by earlier killing frost than in Wisconsin. This difference and its implications for brome grass management in Alaska is discussed later in this report.

Brome grass Harvest Studies Elsewhere

Brome grass management studies have been reported from many locations in the U.S. and Canada. However, most have dealt with such concerns as productivity, forage quality, palatability, establishment, competitive ability, seed production, etc. Very few have reported that winter survival was influenced by management; this attests to the generally good winterhardiness of the species throughout its cultural range in North America.

Even a report on an 8-year series of trials by Opsahl (1962) near 60°N in Norway reported only on forage productivity and foliar diseases, with no reference to winterhardiness or winter survival problems. Moreover, in a summary of tests at nine stations located between 49° and 55°N in western Canada, Knowles and White (1949) stated: "Southern strains in these tests were fully as hardy as the northern strains."

Jung and Kocher (1974) observed that four harvests per year had little harmful effect on six cultivars of smooth brome grass in central Pennsylvania. However, their latest cutting in early October was about six weeks prior to first killing frost in mid-November; thus the authors postulate that the long autumn regrowth period probably permitted adequate restoration of plant reserves lowered with frequent harvesting.

A review of numerous reports concerning responses of smooth brome grass to various harvest schedules and frequencies was published earlier (Klebesadel 1994a) in this bulletin series on brome grass in Alaska.

General consensus confirms that this species is more productive of forage with only two to three harvests per year than with more frequent cuttings (Bird 1943; Fairey 1991; Jung *et al.* 1974; Marten and Hovin 1980; Paulsen and Smith 1968).

Reports of work in Alaska (Klebesadel 1994a, 1994b) generally agree with those findings; however, the shorter growing seasons in Alaska and the aforementioned results from this station indicate that brome grass stand health and vigor can be disadvantaged by as many as three harvests per year (especially if a poorly timed third cutting is followed by a rigorous winter), and that two cuttings per year should be the maximum harvest frequency in this area.

Contradicting that general guideline, however, are results (Exp. II in Klebesadel 1994a) showing that brome grasses can tolerate as many as four or even five harvests per year if those harvests are sufficiently early in the growing season that a lengthy regrowth period between the final harvest and freeze-up is of adequate duration for the grasses to recover a healthy status prior to winter.

Moreover, the specific reasons that some of the harvest schedules predisposed brome grasses to winter injury in that earlier-reported study (Klebesadel 1994a) were somewhat tentative, for only a very few schedules were compared. Comparisons of a broader array of different harvest schedules and frequencies should assist in showing more definite patterns of grass responses. Then the tolerances and intolerances of brome grass to specific harvest-management treatments could be better seen, permitting management recommendations to be based on a more comprehensive understanding of the interrelationships between grass physiology and times of defoliation.

Cultivars Used In This Study

The cultivar Manchar was selected in the Pacific Northwest area from an introduction of smooth brome grass from Manchuria in 1935 (Stark and Klages 1949). Its desirable characteristics listed in that report included high forage and seed yields, resistance to most common diseases, rapid recovery after cutting, and good compatibility with legumes due to modest rate of spread by rhizomes. Stark and Klages (1949) categorized it as a northern-type cultivar; however, other reports (Carlson and Newell 1985; Hanson 1972) consider it intermediate between northern and southern types.

Evaluations of bromegrass strains and cultivars during the late 1940s and early 1950s at this station led to recommending Manchar for use in this area {Anonymous 1953(?)}. Accordingly, Manchar was used in Experiments I and II in this report.

The cultivar Polar, developed at this station (Hodgson *et al.* 1971; Wilton *et al.* 1966), includes northern-adapted North American pumpelly bromegrass (*B. pumpellianus* Scribn.) in its genetic makeup. This confers a higher level of freeze tolerance on Polar than is possessed by Manchar (Klebesadel 1993a), and Polar has exhibited better winter survival than Manchar in several field tests at this location (Klebesadel 1970, 1993a, 1993c, 1994a, 1994c; Wilton *et al.* 1966). Polar was used in Experiments III and IV.

This Investigation

To better understand the responses of bromegrass to various schedules and frequencies of harvest in this area of Alaska, the few treatments compared earlier (Klebesadel 1994a) were expanded upon in the present study to determine more precisely the various desirable harvest-management options available to growers, and inappropriate management avenues to be avoided.

This report summarizes four experiments, each of three years duration (Exp. III = 4 years), and each involving a broad array of harvest schedules and frequencies. All were conducted at the University of

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

EXPERIMENTAL PROCEDURES

All experiments were planted in Knik silt loam (Typic Cryochrept) with good surface drainage and in field areas fully exposed to winter winds that occasionally blew snow cover away. Preplant commercial fertilizer disked into plowed seedbeds supplied N, P₂O₅, and K₂O, respectively, at 24, 96, and 48 lb/A in Experiments I and II, and at 28, 112, and 56 lb/A in Experiments III and IV.

Plots were broadcast-seeded without companion crops at 20 pounds of germinable seed per acre using a corrugated-roller seeder. Individual plots measured 5 by 16 feet in Exp. I, 5 x 20 in Exps. II and III, and 5 x 18 in Exp. IV. Plots were left unharvested during the seeding year in all experiments. In the year after establishment, old growth present on plots from the previous growing season was clipped and removed shortly after snow melt and before bromegrass spring growth had started. Experiments were topdressed uniformly with a complete commercial fertilizer (see following table) shortly after snow melt. A second topdressing of ammonium nitrate, supplying approximately 40% of total N for the year, was made near mid-season in the year of differential harvests.

Twelve treatments (different harvest schedules and frequencies) were compared in Exp. I, 34 in Exps. II

Planting dates, fertilizer topdressing dates and rates, and date of final uniform harvest of all plots in each experiment were as follows:

Experiment	Brome cultivar	Date planted	Spring topdressing second year ¹	Mid-season topdressing second year ²	Spring topdressing third year ³	Uniform harvest of all plots third year
I	Manchar	10 June 1962	3 May 1963	21 June 1963	13 April 1964	23 June 1964
II	Manchar	18 May 1964	9 Apr 1965	7 July 1965	8 April 1966	14 June 1966
IIIa	Polar	27 May 1966	4 April 1967	7 July 1967		
IIIb ⁴	Polar	27 May 1966	3 April 1968 ⁵	2 July 1968 ⁵	3 April 1969 ⁶	2 July 1969 ⁶
IV	Polar	18 June 1971	15 May 1972	12 July 1972	16 April 1973	3 July 1973

¹ N-P₂O₅-K₂O applied in lb/A, respectively: Exp. I = 105-80-40; all other Exps. = 126-96-48.

² N at 84 lb/A.

³ N-P₂O₅-K₂O applied in lb/A, respectively: Exp. I = 105-80-40; all other Exps. = 126-96-48.

⁴ The identical differential harvests conducted in 1967 were repeated on the same plots in 1968 in Exp. IIIb.

⁵ Third year in Exp. IIIb.

⁶ Fourth year in Exp IIIb.

and III, and 40 in Exp. IV during the second–last year of each experiment. Experiment III differed from the other three in that differential harvest treatments were repeated for a second year (1968) because no treatment effects were apparent in early spring growth of 1968 from harvest treatments conducted in 1967.

Randomized complete block experimental designs were used with four replications. Harvest dates for the different schedules and frequencies of harvest during the second year (also third year in Exp. III) in Exps. I through IV (mean dates for two harvest years in Exp. III) appear in Figures 2, 3, 7 and 8, respectively. To remove border effects, a strip 1.25 feet wide was clipped and removed immediately before each harvest from both ends of plots to be harvested. Harvests were accomplished by then clipping and weighing a swath 2.5 feet wide from the centerline of each plot, leaving about a 2–inch stubble. The remaining grass growth on each plot, bordering the harvested swath, was also clipped and removed immediately.

A small, bagged sample of harvested herbage was taken from each treatment and replicate on each date, weighed immediately, then dried to constant weight at 140°F (60°C); percents dry matter in samples were used to calculate oven–dry yields reported. In Experiment II, those samples were then ground finely and analyzed for crude protein (N x 6.25) by the Kjeldahl method.

After killing frost at the end of the second year of growth (also at end of the third year in Exp. III), the entire area of each experiment was clipped to about a 2–inch stubble and raked clean to provide uniform exposure of all plots to winter stresses and to prevent differential retention of snow on plots over winter.

RESULTS AND DISCUSSION

Experiment I: Comparisons Among 12 Harvest Treatments With Manchar Bromegrass

Forage Yields in Year of Differential Harvests

The first cutting for all 12 treatments in this experiment was taken on 20 June; mean yield was 1.51 T/A (range = 1.37 to 1.66, Fig. 2). The first four treatments were harvested three times with the second cutting for each taken on 8 August, 49 days after the first cutting; mean yield for that date was 0.87 T/A (range = 0.84 to 0.91 T/A). Third cuttings for treatments 1 through 4

were progressively later and about 10 days apart from 11 September to 15 October. Yield in the third harvest increased slightly for treatments 1 through 3, but no yield increase occurred by delaying the third cutting from 3 to 15 October (trtmts. 3 versus 4).

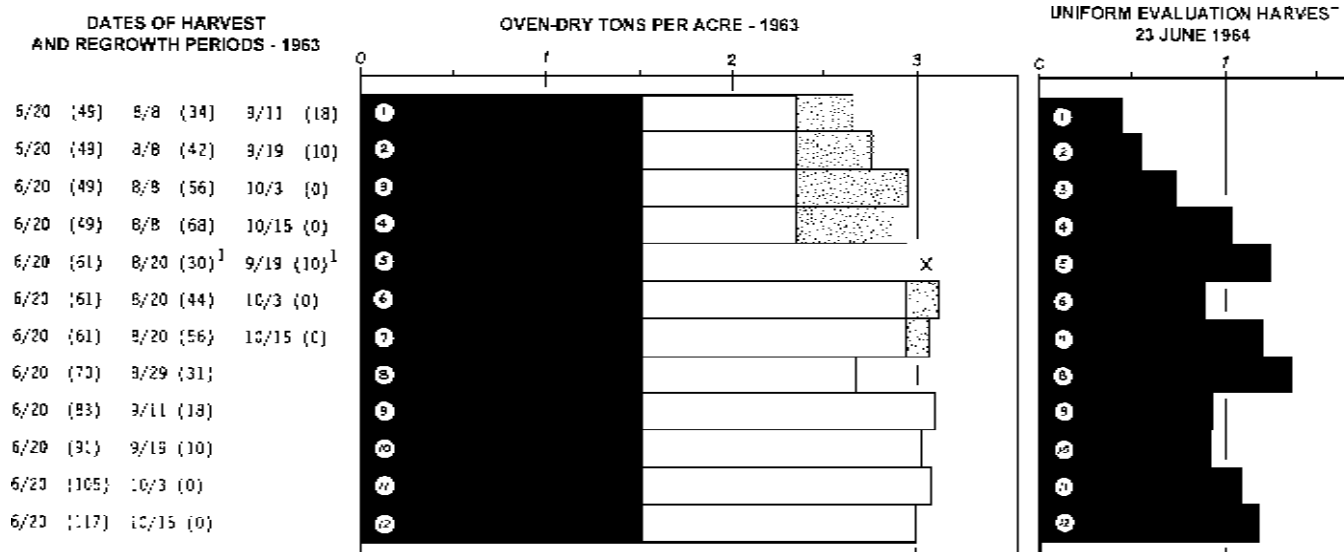
Three cuttings were planned for treatments 5 through 7 also but, with the later second cutting on 20 August, 61 days after the first, regrowth was insufficient for a recoverable third harvest when treatment 5 was clipped 30 days later on 19 September. Treatments 6 and 7, with third cuttings on 3 and 15 October (44 and 56 days after 2nd cutting) produced only 0.17 and 0.13 T/A, respectively, in that third harvest. Earlier reports (Klebesadel 1992, 1994b) from this location also showed very little increase in bromegrass herbage production during September and October.

Treatments 8 through 12 had two harvests with the second cuttings progressively later from 29 August to 15 October, 70 to 117 days after the 20 June first cutting. A modest increase in second–cutting yield of 0.44 T/A occurred between treatments 8 (1.15 T/A) and 9 (1.59 T/A). Thereafter, however, later second cuttings from 11 September to 15 October (trtmts. 9 through 12) resulted in no further yield increases, demonstrating again little late–season herbage increase during the time that the grass diverts more photosynthetic product toward food–reserve storage (Smith and Nelson 1985). As a result, the total two–harvest yields of treatments 9 through 12 were very similar (mean = 3.09 T/A).

Uniform Evaluation Harvest in Year After Differential Harvests

Three cuttings with the final harvest on 11 September in 1963 (trtmt. 1) resulted in the lowest yield in the 23 June 1964 uniform evaluation harvest (Fig. 2). Progressively higher yields were obtained from treatments 2 through 4 which had the first two harvests identical to treatment 1 but with successively later third cuttings (19 Sep., 3 and 15 Oct.), thus affording the grass progressively longer regrowth periods before the final harvest.

The regrowth periods between the second and third cuttings for treatments 1 through 4 were 34, 42, 56, and 68 days, respectively. It is obvious that the more time allotted to the grass to grow without interruption in that late–season period (important for food–reserve manufacture and storage), the better was the vigor of the grass stand in spring of the following year. These results are consistent with an earlier report from this location wherein a third harvest on 17 September



¹ Regrowth at intended third cutting was too short for harvestable yield; thus final regrowth period from 20 August to killing frost was 30 + 10 = 40 days.

Figure 2. (Left) Forage yields of Manchar bromegrass in Exp. I in 1963 as influenced by 12 different harvest schedules involving two and three harvests. Numbers in parentheses between harvest dates = number of days between cuttings; numbers in parentheses after final cutting = number of days between final cutting and killing frost on 29 September 1963. Mean yields are shown where several first or second cuttings were harvested on same date. Black portion of yield bars = first cutting, open portion = second cutting, stippled portion = third cutting. The symbol (X) at end of the treatment 5 bar indicates intended third harvest on 19 September, but height of regrowth was inadequate for a harvestable yield. (Right) Effects of those treatments on subsequent vigor of stands as measured by a uniform evaluation harvest of all treatments the following year on 23 June 1964. Treatment number appears in circle in left end of each graph bar.

predisposed several smooth bromegrass cultivars to greater winter injury than a third harvest on 4 October (Exp. I in Klebesadel 1994a).

Treatment 5, intended for three cuttings but harvested only on 20 June and 20 August (inadequate regrowth precluded recoverable yield on 19 Sep.), was the second-highest yielder in the uniform evaluation harvest (Fig. 2).

Treatments 6 and 7, as with treatment 5, had first and second cuttings on 20 June and 20 August, but the later final cut (15 Oct.) of treatment 7, that allotted 56 days between second and third cuttings, resulted in 1.20 T/A in the evaluation harvest. In contrast, treatment 6, with a 12-day earlier final harvest the previous year (and only 44 days between second and third harvests), resulted in only 0.89 T/A in the evaluation harvest.

Both 2-cut treatments with final harvest near mid-September (trtmt. 9 on 11 Sep., trtmt. 10 on 19 Sep.) produced less in the uniform evaluation harvest (mean = 0.93 T/A) than treatment 8 with an earlier second cutting (29 Aug.), or treatments 11 and 12 harvested later on 3 and 15 October, respectively. Thus, interrupting the regrowth period with a harvest near mid-September disadvantaged the grass more than earlier or later second cuttings.

Another factor that could have contributed a harmful

effect on grass vigor and winter survival is inappropriate timing of the final harvest that leaves a regrowth period (a) sufficient for the grass to draw upon stored reserves to put forth a modest basal-leaf regrowth, but (b) too short prior to killing frost for that regrowth to effectively manufacture and contribute to the plant's level of stored reserves.

That situation, with regrowth periods of only 18 and 10 days prior to killing frost, could have adversely affected stand health of treatments 1, 2, 9, and 10. In contrast, treatment 8, with a shorter regrowth period (70 days) between first and second cuttings than treatments 9 and 10 (83 and 91 days, respectively), but with a 31-day regrowth period prior to killing frost, surpassed treatments 9 and 10 in the uniform evaluation harvest (Fig. 2). Additional support for the critical effect of (a) timing of the late cutting date, (b) duration of regrowth period before killing frost, and (c) effect of these factors on bromegrass stand vigor and winter survival is found in an earlier report (Klebesadel 1993b).

It should be noted that the tendency for the grass to put forth new growth after final cutting diminished considerably as final cuttings were taken on successively later dates (as will be shown also in later experiments in this report). Elongated culms devel-

oped after final harvests prior to about 10 August. Predominantly low leafy regrowth without elongated culms developed after final cuttings taken from about 10 to 30 August. Little regrowth developed after final cuttings in early September or later.

Amounts of late-season regrowth can be influenced by soil moisture, temperatures, and availability of N. Below-normal precipitation resulting in dry soil can severely curtail regrowth. Also, normally lowering temperatures (and shortening photoperiods) during the latter part of the growing season also increasingly suppress regrowth in September and October. Nitrogen fertilizer applied later than the midyear topdressings in late June/early July, as done in these experiments, can stimulate considerably more late-season regrowth than occurs otherwise. However, late-season N application (e.g., 15 to 20 Aug.) is desirable only for bromegrass seed production (Klebesadel 1996) but not for forage.

Experiment II: Comparisons Among 34 Harvest Treatments With Manchar Bromegrass

Forage Yields in Year of Differential Harvests

Grass development on the various dates of first cutting were as follows: on 2 June, grass height was 10 to 12 inches, on 10 June it was 14 to 16 inches, and on 22 June and 2 July, topmost leaves were 22 to 24 inches above the soil surface and seed heads 28 to 32 inches tall.

There was a regular progression of increasing yield with each later first-cut harvest date. However, yields on all four first-cutting dates (2, 10, 22 June, 2 July) were modest; mean oven-dry yields on those dates were 0.39, 0.66, 1.24, and 1.44 T/A, respectively (Fig. 3). First-cut dry-matter yields of Manchar in other experiments better supplied with precipitation and therefore soil moisture have surpassed 3 T/A on 23

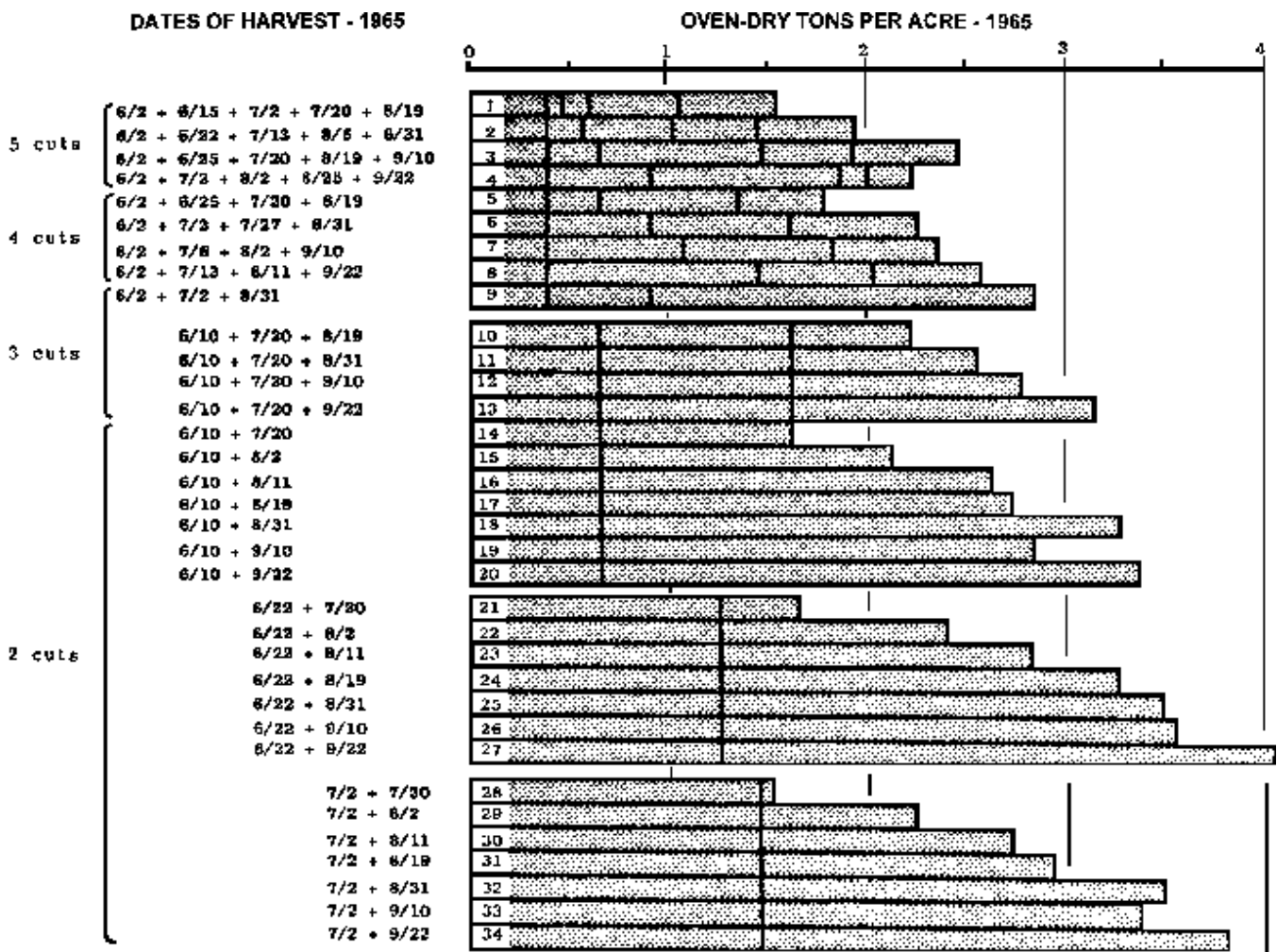


Figure 3. Forage yields of Manchar bromegrass in Exp. II as influenced by 34 harvest treatments (different schedules and frequencies of harvest). Mean yields are shown where a group of several first or second cuttings were harvested on the same date. Number in left end of each graph bar is treatment number, as referred to in text.

June and 30 June (Exp. VI, Klebesadel 1994a).

Those curtailed first-cutting yields in the present experiment were due to a prolonged period of subnormal precipitation (Table 1) both during the previous year (July + Aug. + Sep., 1964 = 3.21 inches below normal) and in April and May of the year of differential harvests (1965). The relatively shallow silt mantle (18– to 22–inch depth) over coarse sand and gravel at the experimental site represents a very modest moisture-storage layer; therefore, timely replenishment of soil moisture by precipitation or irrigation is important for vigorous crop growth.

Precipitation during the latter portion of the previous-year growing season is important to spring growth of bromegrass because of the typically low amounts of precipitation received during April, May, and June in this area (Table 1); precipitation during both periods is critical to realizing the full potential of bromegrass productivity when it puts forth its greatest surge of growth during June (Klebesadel 1994a).

The earliest final cuttings were on 20 July and on 2, 11, and 19 August (trtmts. 1, 5, 10, 14, 15, 16, 17, 21, 22, 23, 24, 28, 29, 30, and 31); those early final cuttings would be considered impractical in farm practice because they did not fully utilize all of the herbage produced during the total growing season. With each of those treatments, considerable amounts of unharvested regrowth were produced after the early final cuttings and prior to freeze-up. Those harvest schedules were included to gain insights into the effects on subsequent winter survival of long, uninterrupted regrowth periods after an early final harvest. It was noted in an earlier report from this location that a long regrowth period after five early cuttings resulted in good subsequent winter

survival (Exp. III in Klebesadel 1994a).

The above-listed treatments resulted generally in lower total-year forage yields than other treatments with later final harvest dates (Fig. 3). The effects of the treatments with early final harvest dates on subsequent winter survival is discussed in the following section.

There was a general trend toward progressively lower total-year yields as harvest frequencies increased. Within each group of treatments with the same frequency of harvests (5, 4, 3, or 2 cuts), total-year forage yields generally increased as final harvests were later (Fig. 3).

Among the treatments that recovered maximum amounts of herbage produced (i.e., schedules with final harvests near 31 Aug. or later), highest yields generally were obtained from treatments harvested twice with the first cutting on either 22 June or 2 July (Fig. 3). Those yields generally ranged between 3.5 and 4.0 T/A. Other reports also have shown higher total-year yields when the initial growth of the year is not harvested until fully headed to anthesis (flowering) stages (Klebesadel 1994a; Knievel *et al.* 1971; Kunelius 1979; Paulsen and Smith 1969; Raese and Decker 1966; Wright *et al.* 1967).

Uniform Evaluation Harvest in Year After Differential Harvests

Five cuttings: All of the 5-cut treatments of the previous year (trtmts. 1 through 4) were less productive in the uniform evaluation harvest than all of the treatments that had been cut twice (Fig. 4). With the four different schedulings of five cuttings, all had been harvested on the same initial date (2 June), but the intervals between later cuttings increased from treatment 1 through treatment 4 such that the final

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

Year	Apr.	May	June	July	Aug.	Sep.	Net departure
1962	-0.11	+1.30	+2.43	-1.49	+0.52	-1.31	+1.34
1963	+0.18	-0.27	+0.97	+0.08	+0.89	-1.61	+0.24
1964	+0.69	+0.08	+1.16	-0.67	-1.05	-1.49	-1.28
1965	-0.27	-0.46	+1.23	+0.05	+0.13	+2.92	+3.60
1966	+0.43	+0.21	0.00	+0.35	-0.52	-1.06	-0.59
1967	+0.46	+0.19	+0.06	+0.46	-0.04	+0.78	+1.90
1968	+0.08	+1.80	+0.36	-0.50	-2.23	-1.57	-2.06
1969	-0.37	+0.2	-0.90	+1.04	-2.08	-1.93	-3.95
1971	+0.59	-0.47	+0.49	-0.14	+2.00	+0.09	+2.56
1972	+0.18	+0.49	+0.05	-0.64	-1.85	+2.54	+0.77
1973	+0.69	-0.36	+0.32	-2.04	+1.66	-1.50	-1.23
Normal	0.63	0.74	1.59	2.50	2.38	2.33	

four cuttings were about 10 days apart. Accordingly, the final harvest for treatments 1, 2, 3, and 4 were 19 and 31 August and 10 and 22 September, respectively.

Despite the growth intervals between cuttings increasing from treatment 1 to treatment 4, yields the following year were progressively lower as final harvest was later. This indicates that the final harvest date was a more dominant factor in determining subsequent stand health (and therefore following-year yield) than growth intervals between cuttings. The final harvest dates determine how much regrowth time is available to the grass from the final cutting until grass growth is terminated by killing frost, unless the final harvest date is so late that no regrowth occurs.

With a fifth cutting on 19 August (trtmt. 1), the grass was afforded a growth period of about seven weeks before killing frost temperatures of 24° and 18°F occurred on 8 and 9 October (Table 2); that treatment resulted in the highest yield (1.02 T/A) the following year of all 5-cut treatments (Fig. 4).

In contrast, a fifth cutting on 22 September (trtmt. 4) left a much shorter period (about 17 days) prior to freeze-up, and that treatment resulted in a very low yield (0.31 T/A) the following spring, indicating considerably increased winter injury and reduced stand vigor. Final harvest on 22 September left inadequate time for putting forth regrowth that could develop sufficiently to accomplish any replenishment

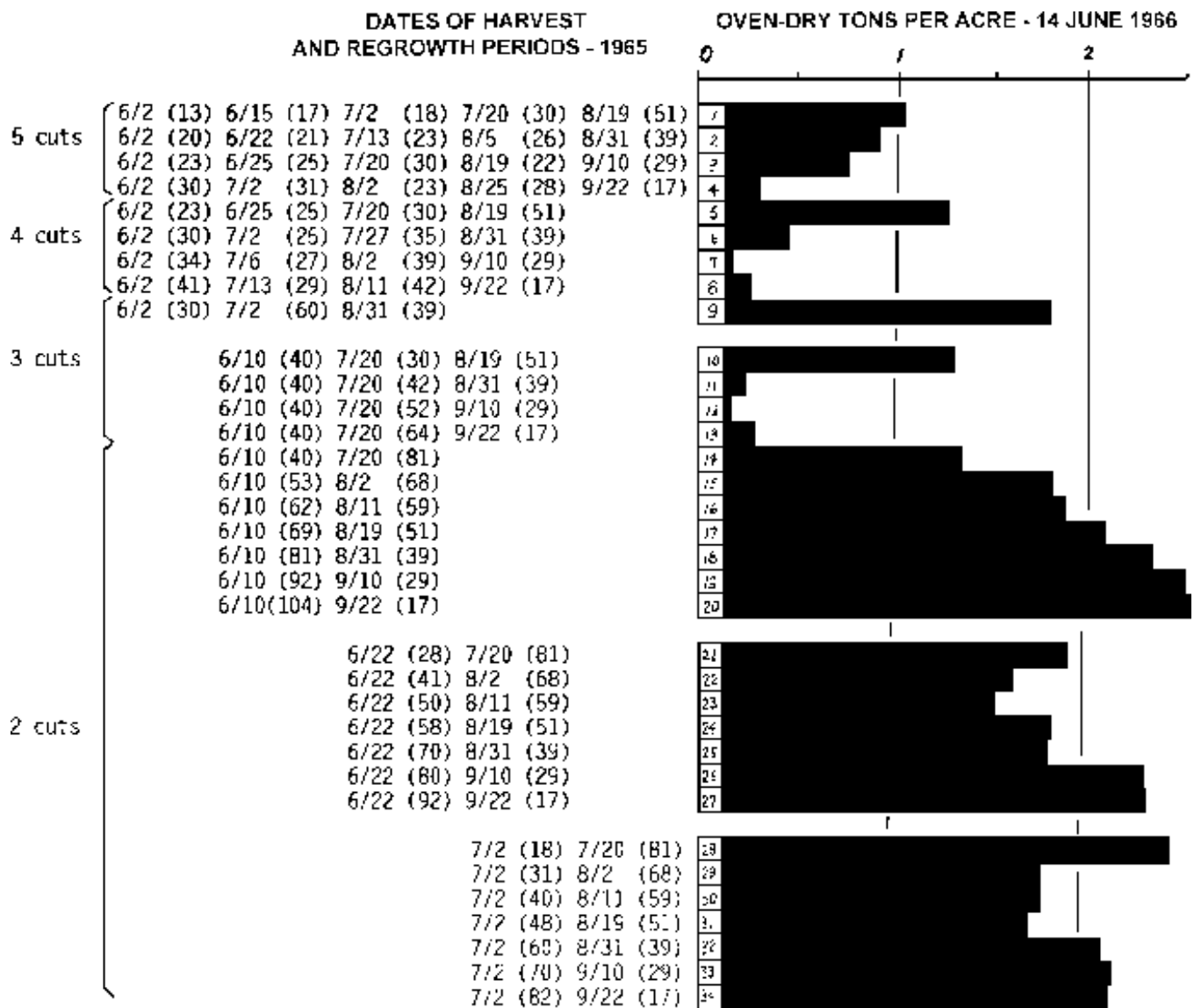


Figure 4. Forage yields of Manchar bromegrass in Exp. II in the uniform evaluation harvest on 14 June 1966 as influenced by 34 different schedules and frequencies of harvest during 1965 as shown in Figure 3. Numbers in parentheses = number of days between cuttings; numbers in parentheses after final cuttings = number of days between final cut and killing frost on 9 October 1965. Number in left end of each graph bar is treatment number as referred to in text.

of food reserves; additionally, it also removed foliage that served for photosynthetic activity during that critical pre-winter period. The other two 5-cut treatments (trtmts. 2 and 3) with intermediate dates of final harvest resulted in intermediate forage yields between treatments 1 and 4 the following year (Fig. 4).

Beyond considerations of food reserves, harvest of leaf growth on 22 September removed the receptor tissue (Loehwing 1938) for the pre-winter short photoperiod/long nyctoperiod stimulation effect toward development of freeze tolerance (Klebesadel 1993c) that promotes improved winter survival in grasses (Klebesadel 1971, 1985).

Four cuttings and three cuttings: The pattern of forage yields in the uniform evaluation harvest was virtually identical for the four 4-cut treatments (first cutting on 2 June) and for the four 3-cut treatments that had first cutting on 10 June (Fig. 4), and that pattern differed considerably from the aforementioned pattern of yields for the 5-cut treatments. The 4-cut and 3-cut treatments with the final harvest on 19 August (trtmts. 5 and 10) afforded the grass the longest regrowth period prior to killing frost and also resulted in highest yields the following spring. The 51-day regrowth period from final cutting to killing frost (trtmts. 5, 10, also trtmt. 1 of 5-cut series)

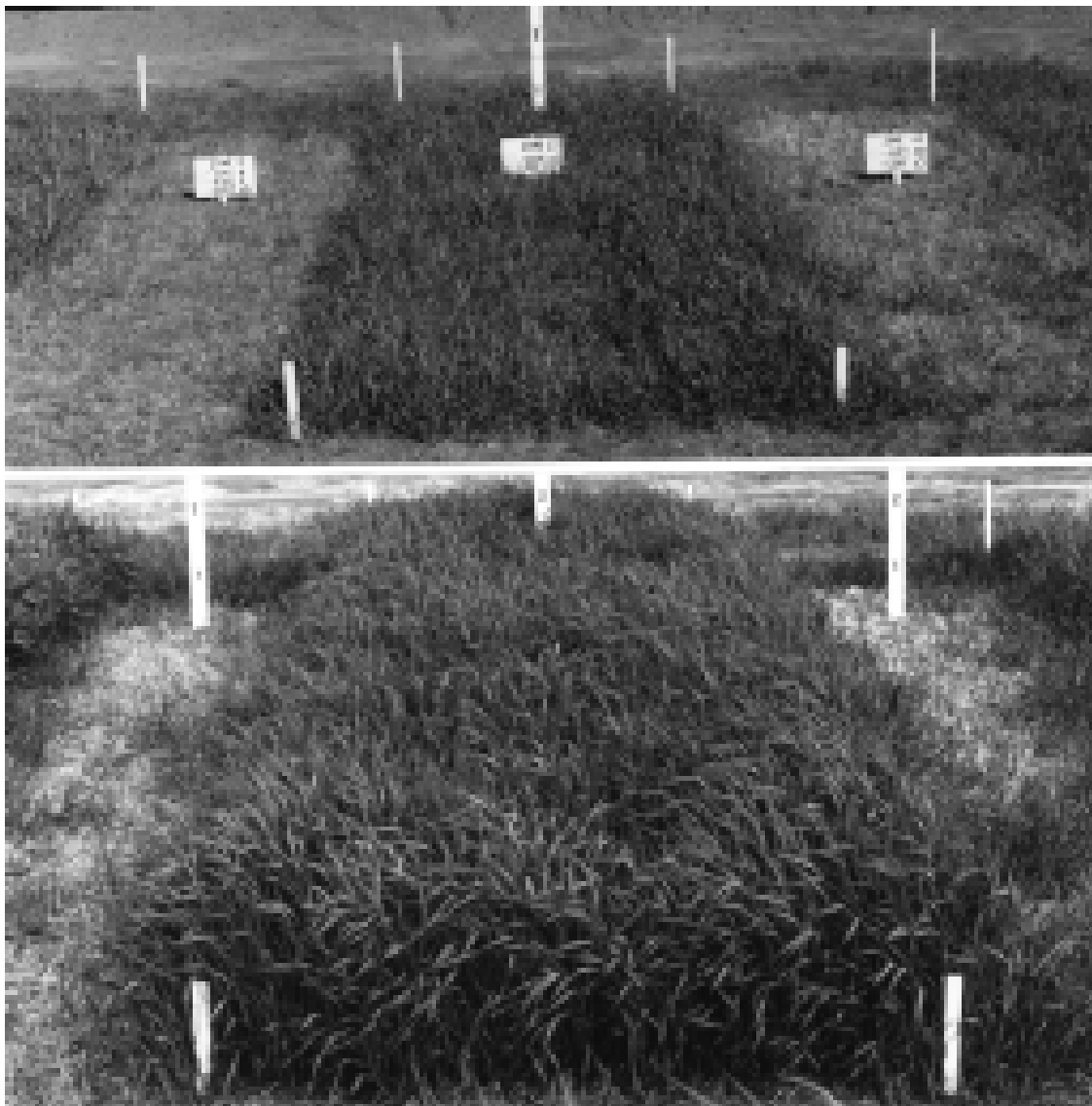


Figure 5. (Upper) Influence of harvest frequency during the previous year (1965) on winter survival and vigor of Manchar brome grass plots in Exp. II photographed on 20 May 1966. Left plot (trtmt. 7) was harvested four times in 1965 (2 June + 6 July + 2 Aug. + 10 Sep.), right plot (trtmt. 12) was harvested three times (10 June + 20 July + 10 Sep.), center plot (trtmt. 26) was harvested only twice (22 June + 10 Sep.). (Lower) The same plots photographed two weeks later (3 June) showing that the badly injured plots made very little recovery. Numbers on white stake in center of each plot indicate height in feet.

benefited the grass considerably more than shorter regrowth periods prior to killing frost (trtmts. 2, 3, 4, 6, 7, 8, 11, 12, 13) (Fig. 4).

Lowest yields the following spring occurred with the 3- and 4-cut treatments that had the final harvest on 10 September (trtmts. 7 and 12, see Fig. 5). In another study at this location (Klebesadel 1994a), several strains of brome grass were predisposed to severe winter injury when the third of three cuttings was taken on 10 September. Moreover, a 10 September seeding-year harvest date was the most harmful to seedling stands of Manchar when compared with other earlier and later seeding-year harvests (Klebesadel 1993b).

Treatment 9 differed from the other four 3-cut treatments in that its first two harvests (2 June and 2 July) were earlier than the 10 June and 20 July harvests of treatments 10, 11, 12, and 13. That difference in cutting dates in 1965 had a profoundly beneficial effect on evaluation-harvest yields in 1966 (Fig. 4).

Treatments 9 and 11 had the same third cutting date, thus the same period for regrowth between final harvest and killing frost (39 days); however, the 1966 evaluation harvest yield of treatment 9 was 1.81 T/A, while the severely winter-injured treatment 11 yielded only 0.25 T/A. That marked difference in harvest effects on the grass apparently lies in the considerably longer regrowth period of 60 days between second and third cuttings in treatment 9, versus only 42 days in treatment 11.

Two cuttings—first cut on 10 June: With all of the seven, 2-cut treatments where first cut was taken 10

June (trtmts. 14 through 20), uniform evaluation yields in 1966 were increasingly higher (ranging from 1.36 to 2.55 T/A) with progressively later dates of second cuttings from 20 July to 22 September in 1965 (Fig. 4).

This pattern of yields suggests that the first cutting on 10 June was taken when the stands were in a low-food-reserve condition (see Fig. 1, but in Alaska, with later start of spring growth than in Wisconsin, food-reserve level was more like point B than C1). Thus, the longer the regrowth recovery period between the first and second cuttings (thereby permitting increased restoration of food reserves), the more the grass stand benefited (Fig. 6). Treatment 14, with only 40 days between the first and second cuttings was therefore too brief to permit full replenishment of food reserves to a high level.

At the other extreme of treatments with first cutting on 10 June, treatments 18, 19, and 20 allowed 81, 92, and 104 days of growth between first and second cuttings, respectively, and those recovery periods obviously were adequate for satisfactory replenishment of food reserves. Date of the final cutting apparently was of relatively minor importance with those treatments, for their yields in the uniform-evaluation harvest were among the highest of all 34 treatments.

Two cuttings—first cuts on 22 June or 2 July: The seven treatments with first cutting on 22 June, and the seven with first cutting on 2 July, showed similar patterns of yields in the evaluation harvest the following year (Fig. 4).

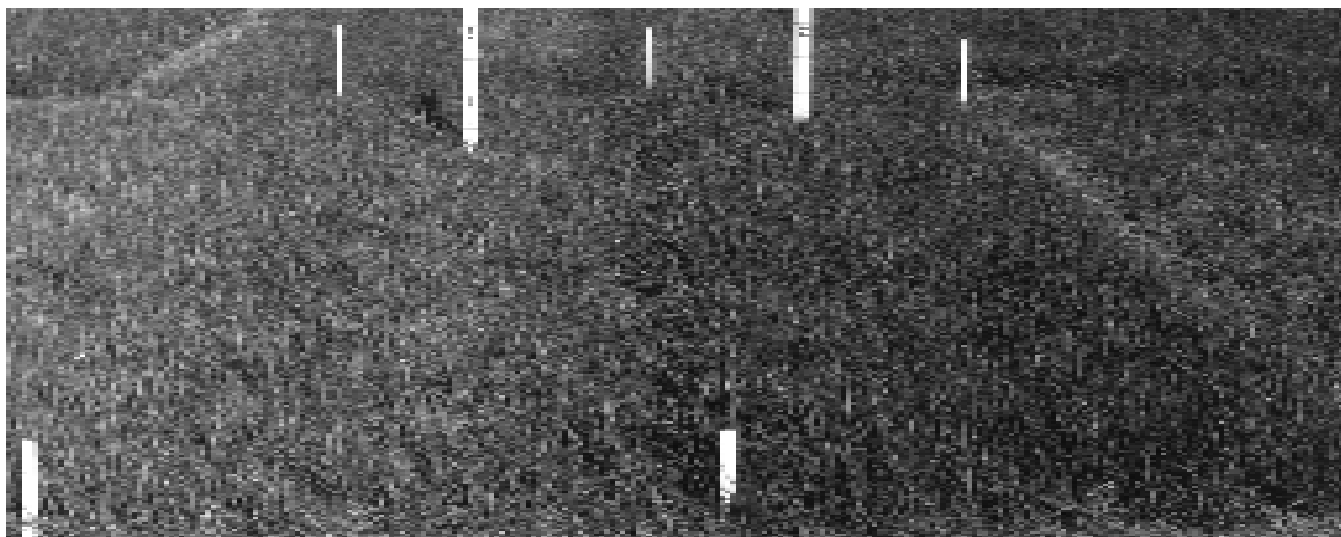


Figure 6. Influence of different harvest schedules during the previous year (1965) on vigor of Manchar brome grass plots in Exp. II photographed 20 May 1966. Left plot (trtmt. 15) was harvested 10 June and 2 August, right plot (trtmt. 19) showing more vigorous growth was harvested 10 June and 10 September. Regrowth interval between first and second cuttings for left plot was 53 days, for right plot 92 days. Numbers on white stake in center of each plot indicate height in feet.

Unlike the previously discussed seven treatments with first cutting on 10 June, the pattern of yield differences in the evaluation harvest for 2-cut treatments with later first cuttings on 22 June and 2 July was more influenced by the different dates of second cuttings. The date of the second cutting determines the duration of the regrowth periods both (a) between first and second cuttings and (b) between second cutting and termination of growth at freeze-up, although some second cuttings can be too late for any regrowth to develop. As discussed earlier, the length of those regrowth periods are important for replenishment of food reserves which must be at a high level when low temperatures terminate growth in autumn.

Treatments 21 and 28, with second cutting on 20 July in 1965, produced relatively good yields in 1966 (trtmt. 28 somewhat higher than 21), indicating good energy status at the end of the 1965 growing season. Although both treatments were allotted very brief regrowth periods between first and second cuttings (28 days for trtmt. 21, 18 days for trtmt. 28), that disadvantage was offset by long periods of interrupted regrowth between the 20 July harvest and killing frost (about 80 days). Although a final harvest on 20 July would be impractical for grower interests (see low second-cut yields in Fig. 3), it serves in this experiment, in comparison with other treatments, to illustrate how that harvest schedule affected stand health.

Treatments 22 and 23, with second cuts on 2 and 11 August (first cut on 22 June), and treatments 29, 30, and 31, with second cuts on 2, 11, and 19 August (first cut on 2 July), all produced lower yields in the uniform-evaluation harvest than other treatments with earlier or later second-cut dates (Fig. 4). Those five

treatments had a mean regrowth period of 42 days (range = 31 to 50 days) between first and second cuttings, and a mean final regrowth period between second cut and killing frost of about 60 days (range = 51 to 68 days).

Treatments 26, 27, 32, 33, and 34 produced high yields (mean = 3.71 T/A) in the year of differential harvests (Fig. 3), and also produced good yields in the mid-June uniform-evaluation harvest (mean = 2.24 T/A) the following year (Fig. 4). Those five treatments had only very short periods between second cutting and killing frost (mean = about 25 days, range 17 to 39 days). Although those periods were quite short, all five treatments had long regrowth periods to restore high levels of reserves between first and second cuttings (mean = 77 days, range = 60 to 92 days).

Treatments 24 and 25 were intermediate in duration of regrowth periods and also in forage yields in the uniform evaluation harvest between the 2-cut treatments that resulted in highest and lowest yields in that evaluation harvest.

Harvest Timing and Frequency, Duration of Regrowth Periods, and Winter Survival

No measurements of food-reserve levels were conducted with any of the experiments reported here. However, studies conducted with smooth brome grass in Wisconsin have documented the patterns of food-reserve storage and utilization during the growing season as influenced by different harvest schedules and frequencies (Paulsen and Smith 1968, 1969; Reynolds and Smith 1962).

The winter-survival and evaluation-harvest results in Exp. II conform rationally with the previously reported brome grass findings in Figure 1. However,

Table 2. Occurrence of sub-freezing temperatures at the Matanuska Research Farm from mid-September to mid-October showing the variation in onset of lethal temperatures for brome grass aerial growth for the years during which the reported experiments were conducted. Probable first killing frosts for brome grass foliage are circled; first occurrence of definite killing frosts (temperatures below 24°F) have underline; dates for the latter range from 16 September to 18 October.

September / October

Year	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18					
	Degrees Fahrenheit																																							
1962				28	27	31									31	23	30			30	22		25	23		26	28	23	18	30										
1963										30	28	29	29					29	25	28	26			29	24		24	25	22											
1964																				31								26	24	26	26	25	25	22	10					
1965															25									30	24	18	23	22	22	25	16	9	8	6	2					
1966									30	25																		30	25			28			25	18				
1967								31							29	25		24		30	20	25	24	23	25	25	29					25	24	19						
1968	27		29	28			25	26	22	23	21						28	29				26	31	26		27			25	28	25	30	30	20	15	21				
1971															31	28	25	27	28								29	22	24					28	28	22	24	24		
1972			23	21						23	25	23	28	30	30	26			25	26	21	16	29			19	17	20	26		31	26								

differences in length of growing seasons at the widely separated latitudes of the Wisconsin studies (43.1°N) and the present Alaska experiments (61.6°N) should be recognized when relating our Alaska bromegrass performance to the TAC patterns as influenced by harvests in Figure 1.

Growing seasons in this area of Alaska are shorter

than those occurring in southcentral Wisconsin, thus the time available for bromegrass herbage growth, harvests, and fulfillment of physiological requirements is more compressed at this far-northern latitude. For example, the earlier beginning of growing seasons in Wisconsin results in bromegrass flowering about 20 June (Table 1, Reynolds and Smith 1962),

Table 3. Harvest dates, percent crude protein in herbage (in parentheses), followed by crude protein yield in pounds per acre in each harvest, and total pounds-per-acre yield of crude protein for each treatment; Experiment II, Manchac bromegrass.

Treatment		Harvest dates, percents crude protein, and pounds-per-acre yields of crude protein								Total yield crude protein
Cuts	no.									
5 cuts	1	6/2 (19.3) 137	6/15 (25.0) 45	7/2 (30.0) 78	7/20 (29.0) 201	8/19 (29.2) 287				748
	2	6/2 (19.3) 133	6/22 (24.5) 91	7/13 (26.9) 243	8/5 (28.0) 237	8/31 (28.7) 282				986
	3	6/2 (19.3) 177	6/25 (25.7) 161	7/20 (25.3) 414	8/19 (30.6) 285	9/10 (34.2) 361				1398
	4	6/2 (19.3) 163	7/2 (25.9) 257	8/2 (24.1) 465	8/25 (33.0) 88	9/22 (30.1) 129				1102
4 cuts	5	6/2 (19.3) 149	6/25 (25.7) 110	7/20 (25.3) 347	8/19 (28.7) 259				865	
	6	6/2 (19.3) 168	7/2 (25.9) 286	7/27 (27.3) 395	8/31 (25.0) 314				1163	
	7	6/2 (19.3) 141	7/6 (22.3) 311	8/2 (25.8) 379	9/10 (25.3) 271				1102	
	8	6/2 (19.3) 124	7/13 (18.7) 401	8/11 (27.5) 311	9/22 (26.6) 297				1133	
3 cuts	9	6/2 (19.3) <u>168</u>	7/2 (25.9) 258	8/31 (16.2) 627				1053		
	mean	151								
2 cuts	10	6/10 (18.2) 203	7/20 (23.0) 371	8/19 (24.4) 325				899		
	11	6/10 (18.2) 196	7/20 (23.0) 398	8/31 (23.9) 444				1038		
	12	6/10 (18.2) 268	7/20 (23.0) 501	9/10 (19.7) 460				1229		
	13	6/10 (18.2) 259	7/20 (23.0) 469	9/22 (19.9) 609				1337		
	14	6/10 (18.2) 168	7/20 (23.0) 463				631			
	15	6/10 (18.2) 206	8/2 (18.3) 535				741			
	16	6/10 (18.2) 312	8/11 (16.5) 653				965			
	17	6/10 (18.2) 261	8/19 (15.4) 631				892			
	18	6/10 (18.2) 302	8/31 (13.9) 724				1026			
	19	6/10 (18.2) 240	9/10 (13.0) 564				804			
2 cuts	20	6/10 (18.2) <u>225</u>	9/22 (12.2) 663				888			
	mean	240								
	21	6/22 (14.4) 333	7/20 (29.8) 241				574			
	22	6/22 (14.4) 394	8/2 (22.1) 506				900			
	23	6/22 (14.4) 362	8/11 (18.8) 589				951			
	24	6/22 (14.4) 377	8/19 (17.2) 691				1068			
	25	6/22 (14.4) 341	8/31 (15.5) 694				1035			
	26	6/22 (14.4) 353	9/10 (13.3) 615				968			
27	6/22 (14.4) <u>369</u>	9/22 (13.3) 745				1114				
mean	361									
2 cuts	28	7/2 (13.1) 398	7/20 (30.6) 45				443			
	29	7/2 (13.1) 393	8/2 (26.9) 430				823			
	30	7/2 (13.1) 287	8/11 (21.6) 551				838			
	31	7/2 (13.1) 367	8/19 (19.0) 567				934			
	32	7/2 (13.1) 408	8/31 (17.2) 706				1114			
	33	7/2 (13.1) 375	9/10 (14.2) 552				927			
	34	7/2 (13.1) <u>401</u>	9/22 (13.6) 646				1047			
	mean	376								

while bromegrass flowers in this area usually during the second and third weeks of July (Table 6, Klebsadel 1994a).

Moreover, growing seasons terminate earlier in Alaska than in southern Wisconsin; for example the normal first occurrence of 24°F in the area of the Wisconsin studies is 30 October, while it is 7 October at the Matanuska Research Farm, over three weeks earlier. Thus, the critical period for pre-winter manufacture and storage of food reserves by bromegrass during September and October is much shortened in Alaska due to earlier termination of the growing season (Table 2).

The significance of this to bromegrass cutting schedules, food-reserve utilization and replenishment, and winter survival, is seen in Figure 1. Note that with low points (D2, D3) of food reserves in late September, after second or third harvests (C2, C3) on 29 August, the later-terminating growing season permitted adequate restoration of food-

reserve levels (G). In contrast, earlier termination of the growing season in this area of Alaska precludes a long pre-winter regrowth period; thus treatments 4, 6, 7, 8, 11, 12, and 13, harvested 5, 4, or 3 times with final harvests from 31 August to 22 September, understandably entered the winter in very low food-reserve status, sustained severe winter injury and produced very low yields in the uniform evaluation harvest the following year (Fig. 4).

At the other extreme, bromegrass can tolerate frequent cutting early in the growing season if provided a long uninterrupted regrowth period before winter. Paulsen and Smith (1968) in Wisconsin showed that bromegrass harvested five times with only 22- to 29-day regrowth periods between cuttings had a very low level of carbohydrate reserves after the final cutting on 29 August. Nonetheless, an 83-day period between that final harvest and

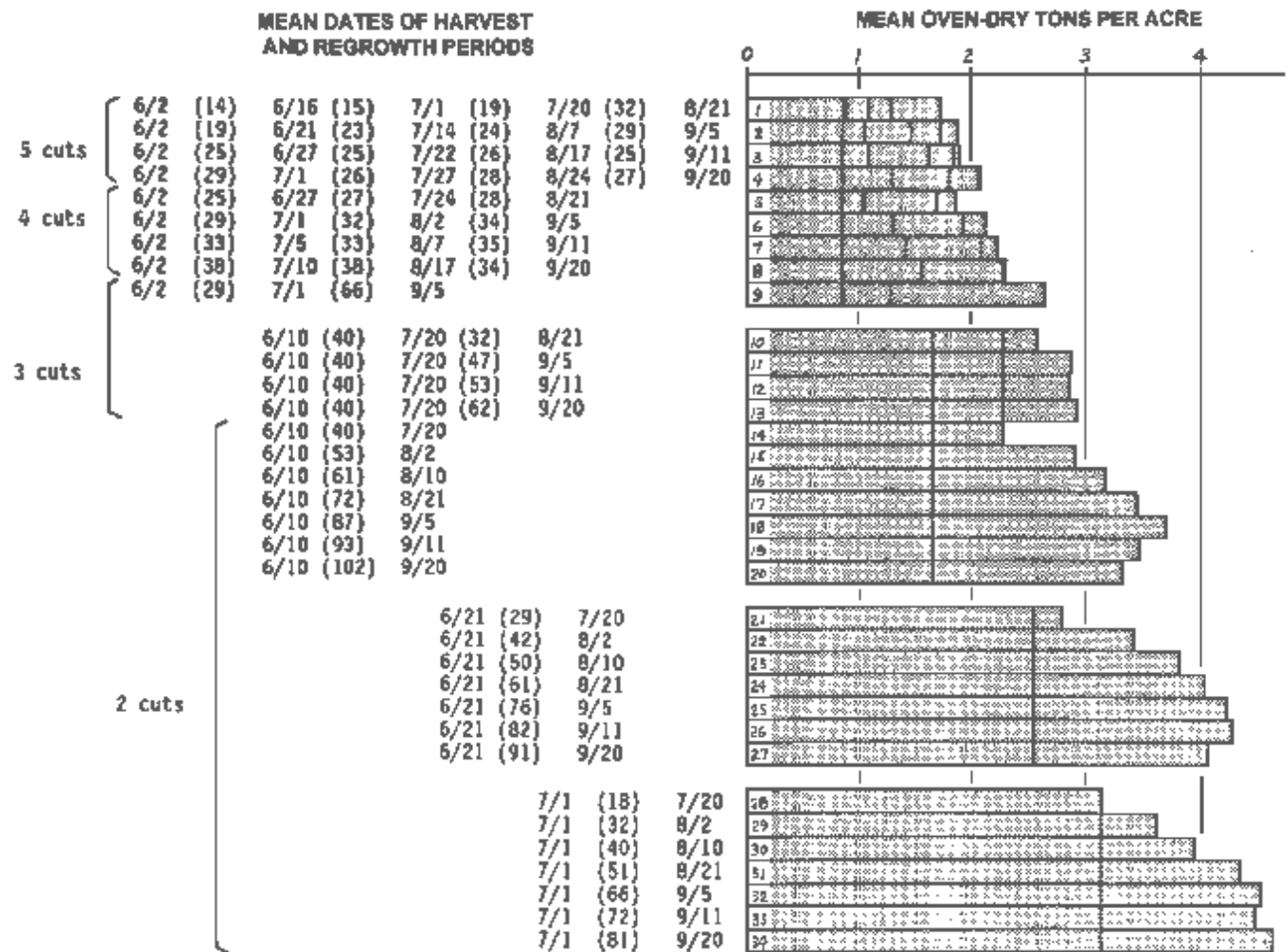


Figure 7. Mean forage yields of Polar bromegrass for two years in Exp. III, (Exp. IIIa = 1967, Exp. IIIb = 1968) as influenced by 34 harvest treatments (different schedules and frequencies of harvest). Mean yields are shown where a group of several first or second cuttings were harvested on the same date. Harvest dates are mean dates for the two years. Numbers in parentheses = number of days between cuttings. Number in left end of each graph bar is treatment number, as referred to in text.

final sampling for stored TAC on 20 November was adequate for restoration of a high pre-winter level of food reserves.

Similarly, five harvests of bromegrass at the Matanuska Research Farm (that logically reduced reserves to low levels), but with the fifth harvest on 7 August, left adequate time for late-season regrowth to prepare plants for winter to the extent that winter survival was equal to stands harvested only twice (Exp. III, Klebesadel 1994a).

Crude Protein Concentrations and Yields

Herbage of progressively later first cuttings contained decreasing concentrations of crude protein, from 19.3% on 2 June to 13.1% on 2 July (Table 3). However, those lowering percentages were offset by increasing dry-matter yields so that the yields of crude protein increased in those first cuttings from means of 151 lb/A on 2 June to 376 lb/A on 2 July.

With frequent harvests (4 or 5 per year), percent crude protein in herbage remained high in all regrowth harvests, ranging mostly from 25% to 34%; these results parallel similar findings reported earlier (Klebesadel 1994a).

With two cuttings per year (trtmts. 14 through 34, Table 3), percent crude protein in second cuttings declined with successively later dates of harvest; that is, as length of regrowth periods increased and grass growth became more mature. Even though very few seed heads are produced in the regrowth of bromegrass, elongation of the leafy culms results in a gradual increase in the stem to leaf ratio. Kilcher and Troelsen (1973) reported that bromegrass stems usually are 10 to 12 percentage points lower in crude protein than leaves.

Highest yields of crude protein (1398 and 1337 lb/A) were obtained from 5-cut and 4-cut treatments, respectively. However, those treatments were lower in total dry-matter yields than many of the 2-cut treatments, and those 4- and 5-cut treatments predisposed the bromegrass to severe winter injury. Among all 2-cut treatments, highest total yields of crude protein (1026 to 1114 lb/A) generally were obtained from treatments with the second cuttings harvested at the end of August; earlier or later second cuttings tended to result in lower total-year yields of crude protein.

Total yields of crude protein ranged from 443 lb/A (trtmt. 28 = 2 cuttings on 2 July and 20 July) to 1398 lb/A (trtmt. 4 = 5 cuttings from 2 June to 10 Sep.). The low yields of treatment 28, and other 2-cut treatments with early second cuttings, were due to considerable amounts of unrecovered crude protein in the unharvested herbage of the regrowths produced after those second cuttings.

Experiment III: Comparisons Among 34 Harvest Treatments with Polar Bromegrass

Forage Yields in Year of Differential Harvests

Experiment III differed from Exps. I, II, and IV in that the different harvest treatments were conducted for two years (referred to hereinafter as Exp. IIIa in 1967 and Exp. IIIb in 1968). Grass growth in spring of 1968 was uniform over the entire experiment and displayed essentially no effects from the different harvest schedules and frequencies of 1967; therefore, all treatments were repeated on the same plots in 1968 in the hope that a more rigorous winter of 1968-69 might result in differences in grass vigor and yields in 1969.

Grass development on the various first-cut harvest dates in the two years during Exp III was:

Harvest date	Exp. IIIa – 1967			Harvest date	Exp. IIIb – 1968		
	Height (inches)		Stage of development		Height (inches)		Stage of development
	Leaves	Seed heads			Leaves	Seed heads	
1 June	14 to 18	none visible	Leafy/ jointing	3 June	16 to 20	none visible	Leafy/ jointing
9 June	22 to 26	24 to 28	Late boot/ early heading	10 June	32 to 34	32 to 34	Late boot/ early heading
21 June	28 to 32	38 to 42	Fully headed/ pre-anthesis	21 June	40 to 42	48 to 50	Fully headed/ pre-anthesis
2 July	36 to 38	42 to 44	Fully headed/ pre-anthesis	1 July	44 to 46	54 to 58	Fully headed/ pre-anthesis



Figure 8. General view of a portion of Exp. IIIb on 21 June 1968 showing harvesting of the third date of first cuttings. Plots with tallest growth are those as yet unharvested in 1968 and to be harvested on this date or on 1 July. Plots harvested on earlier dates show different heights of regrowth.

Mean forage yields for the two years of differential harvests are shown in Fig. 7.

As in Exp. II, each later date of first-cutting resulted in markedly increased yields. However, mean yields for 2, 10, and 21 June and 1 July (mean harvest dates for 1967 and 1968) were 0.87, 1.66, 2.56, and 3.15 T/A, respectively, more than twice the yields on similar cutting dates in Exp. II (Fig. 3).

First-cutting yields in Exp. II, as noted earlier, were disadvantaged by below normal precipitation late in the previous growing season (July + Aug. + Sep. of 1964 = 3.21 inches below normal), followed by below-normal rainfall also in April and May of 1966. In contrast, the years 1967 and 1968 were better supplied with precipitation (Table 1), resulting in vigorous tall growth (Fig. 8) and thus higher yields.

Uniform Evaluation Harvest

Yields in the final uniform-evaluation harvest of Exp. III on 2 July 1969 are not shown. Precipitation during the latter half of the 1968 growing season and during spring of 1969 was so abnormally low (Table 1) that mean dry-matter yield for all treatments in the uniform evaluation harvest on 2 July was only 0.61 T/

A (range = 0.40 to 0.90 T/A), about 1/4 to 1/5 of yields that would be expected with normal precipitation.

On that harvest date, the topmost leaves were only 12 to 14 inches tall and seed heads (then in late-flower stage) only 20 to 24 inches tall. The stunted, moisture-starved herbage contained 61% dry matter when harvested. Thus, inasmuch as winter survival of grass stands in all treatments was uniformly good, the relatively small variations in the very low forage yields in the uniform evaluation harvest probably were more reflective of differences in previous-year soil-moisture use than due to harvest effects on grass vigor. Harrison and Romo (1994) also noted that timing and amounts of precipitation were critical in determining growth and regrowth of bromegrass in central Saskatchewan.

Experiment IV: Comparisons Among 40 Harvest Treatments with Polar Bromegrass

Forage Yields in Year of Differential Harvests

Grass height and stages of development on the successive first-cutting dates in 1972 were:

Harvest date	Height (inches)		Stage of development
	Leaves	Seed heads	
7 June	10 to 12	none visible	Leafy/jointing
12 June	16 to 18	18 to 20	Late boot/early heading
22 June	30 to 32	36 to 40	Fully headed/pre-anthesis
3 July	40 to 42	48 to 50	Fully headed/pre-anthesis
10 July	42 to 44	58 to 60	Fully headed/pre-anthesis

Yields of forage for the 40 different schedules and frequencies of harvest for Exp. IV (harvested in 1972) are shown in Figure 9.

Mean oven-dry forage yields on the five successively later first-cutting dates (7, 12, and 22 June, 3 and 10 July) were 0.43, 0.78, 1.87, 2.88, and 3.67 T/A (Fig. 9). The extremely rapid rate of growth near mid-June (with adequate nutrients and soil moisture—Table 1) is apparent between the 12 and 22 June cuttings where yields on 22 June were 2.4 times greater in only 10 days.

Compared with Exps. II and III, forage yields on the various first-cutting dates (Fig. 9) were intermediate between the low yields in Exp. II and much higher yields in Exp. III (Figs. 3, 7). Those differences in yields correlate generally with differences in precipitation received in the different years (Table 1).

Again, as with two-cut treatments in Exps. II and III, the increasing yields with later first-cuttings in June and July were offset by generally lower second-cut yields as less time was available for regrowth.

Also similar to Exps. II and III, the three, four, and five-cut treatments generally resulted in lower total yields than the highest yielding two-cut treatments. The only treatments in which planned harvests were not feasible were treatments 4 and 8. No harvestable regrowth developed for a fifth cutting after the fourth cutting on 24 August in treatment 4, nor for a fourth cutting after the third cutting on 16 August in treatment 8.

Uniform Evaluation Harvest

Yields in the uniform evaluation harvest on 3 July 1973 ranged from 0.97 to 3.26 T/A (Fig. 10); mean yield for the 40 treatments was 2.37 T/A. Differences in evaluation-harvest yields were considerably less

than with Manchar brome in Exp. II (Fig. 3). The lesser differences probably were due to Polar's higher level of winterhardiness (Klebesadel 1993a, 1994a), but also could have been due in part to milder winter stresses in 1972–73 (Exp. IV) than 1965–66 (Exp. II).

Highest yields occurred where first cutting the previous year had been taken on 12 June and second cuttings on 21 August or 1 or 12 September (trtmts. 17, 18, 19). However, those treatments had yielded somewhat less the previous year than other 2-cut treatments with the same second-cutting dates but which had later first cuttings on 22 June or 3 July (trtmts. 24, 25, 26 and 31, 32, 33).

None of the 2-cut treatments with second cuttings on 21 August or 1 or 12 September were afforded a useful final regrowth period (26, 15, and 4 days, respectively) between the second cutting and the abnormally early killing frost on 16 September. However, treatments 17, 18, and 19, with the earlier first cutting on 12 June had the benefit of longer regrowth periods between first and second cuttings (70, 81, and 92 days, respectively) that probably contributed to restoration of higher food-reserve levels than the above-noted treatments with first cutting on 22 June or 3 July.

The lowest-yielding treatments, indicating harvest schedules the previous year that most disadvantaged stand health and vigor, were 3-cut treatments 11 and 12 that had final harvests on 1 and 12 September (Fig. 10). Three-cut treatments with Manchar brome final harvests near those same dates also were predisposed to severe winter injury in Exp. II (Fig. 4). A somewhat similar harvest schedule (15 June + 30 July + 10 Sep.) in another study at this location also predisposed several strains of brome grass to severe winter injury (Klebesadel 1994a).

It is not clear why the 3-cut frequency in Exp. IV (with final cuts on 1 and 12 September) predisposed the grass to greater winter injury than 4- and 5-cut treatments that also had final cuttings on 1 and 12 September (trtmts. 2 and 3, 6 and 7, respectively). The repeated removals of new regrowth with four and five cuttings per year may have been so frequent that they exceeded the capacity of the plants to generate new tillers for regrowth. That in turn may have resulted in lesser reductions in stored food reserves than occurred with the 3-cut treatments; by that scenario, the more frequent cuttings (4 and 5 per year) could have resulted in relatively less weakening of stands than occurred with three cuttings per year. Future work, with monitoring of plant-reserve levels, may resolve this question on the basis of firm evidence.

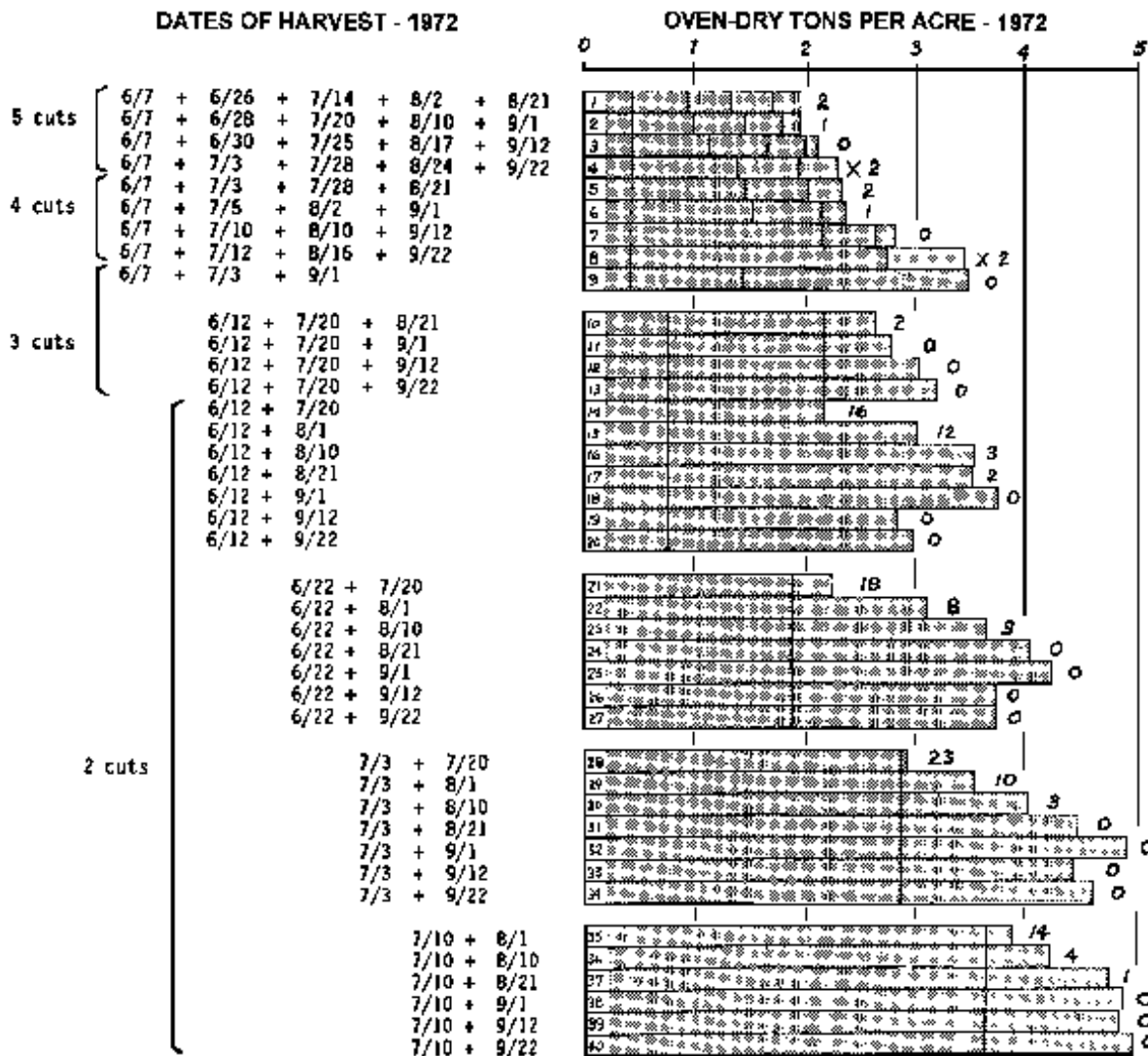


Figure 9. Forage yields of Polar bromegrass in Exp. IV as influenced by 40 harvest treatments (different schedules and frequencies of harvest). Mean yields are shown where a group of several first or second cuttings were harvested on the same date. The symbol (X) at end of bars for treatments 4 and 8 indicates intended fifth or fourth harvest on 22 September, but regrowths were inadequate for harvestable yield. Numbers at far right are average heights in inches (above the 2-inch stubble) of final regrowth measured on 6 October after killing frost and on date that regrowth was clipped and removed. Number in left end of each graph bar is treatment number, as referred to in text.

Rates of Herbage Dry-Matter Production

The numerous different harvest dates in Exps. II, III, and IV permitted calculating rate of herbage dry-matter production in both initial growth and in regrowth during different periods within the growing season (Figs. 11, 12). As noted earlier (Klebesadel 1994a), a very marked rate of herbage production occurs in unharvested initial growth of bromegrass during June and early July, a time of very long daily photoperiods (if supplies of soil moisture and nutrients are adequate).

In Exp. IV, herbage dry-matter increased more than twofold (0.78 to 1.87 T/A) in the 10 days from 12 to 22 June, and almost doubled again (1.87 to 3.67 T/A)

in the next 18 days from 22 June to 10 July (Fig. 9). Between the earliest (7 June) and the last (10 July) first-cutting harvest dates in Exp. IV, herbage dry-matter production was at the rate of 197 pounds per acre per day (Fig. 11). The rates of productivity in the initial growths of Exps. III and IV generally exceeded the 138 lb/A/day (155 kg/ha/day) reported by Rumburg *et al.* (1980) for spring-fertilized bromegrass in high-altitude northern Colorado.

The rates of herbage dry-matter production in regrowth periods (between first and second cuttings) cannot be compared with the aforementioned rates of productivity during June and early July because those

rates of initial growth of the season were measured between progressively later cuttings dates of the actively growing grass (Fig. 11). In contrast, rates of productivity during the various regrowth periods necessarily were calculated for growth periods that began with bare stubble from which new growth slowly appeared following a first-cutting date; thus rates of productivity during regrowth periods were understandably much lower (Fig. 12).

Moreover, as those regrowth periods occurred at successively later intervals, with shortening daily photoperiods and gradually lowering temperatures, the rate of dry-matter production generally became progressively lower.

Sample data that illustrate the general slowing of productivity of herbage with equal-duration regrowth intervals at progressively later periods during the growing

season are shown in Figure 12. Exp. II, in which growth was restricted during the first half of the growing season due to soil-moisture deficit, but was benefited by above-normal precipitation during the last half of the growing season (Table 1), did not show the above effect as clearly as Exps. III and IV. With the latter two experiments, especially Exp. IV, rate of herbage production decreased as each roughly 70-day regrowth period occurred progressively later during the growing season.

This same principle has been noted in other experiments with bromegrass at this location (Klebesadel 1992, 1994a, 1994b). One report (Klebesadel 1992) showed late-season productivity of bromegrass to be extremely low, averaging only 3 lb/A/day for regrowth between a third cutting on 14 August and a fourth cutting on 25 September. Brundage and Branton (1967) at this station noted similarly slowing rates of

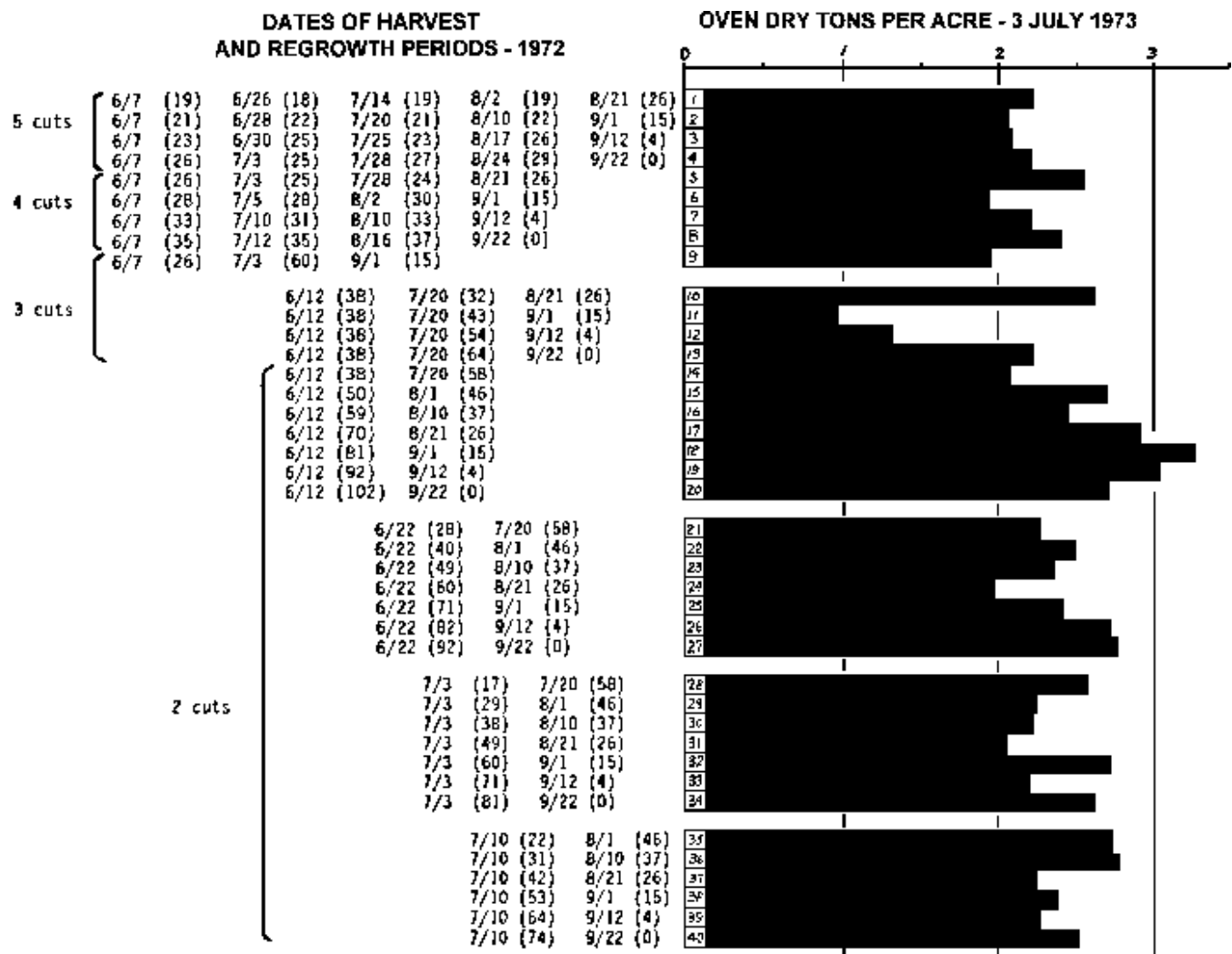


Figure 10. Forage yields of Polar bromegrass in Exp. IV in the uniform evaluation harvest on 3 July 1973 as influenced by 40 different schedules and frequencies of harvest during 1972 as shown in Figure 9. Numbers in parentheses = number of days between cuttings; numbers in parentheses after final cuttings = number of days between final cut and abnormally early killing frost on 16 September 1972. Number in left end of each graph bar is treatment number, as referred to in text.

dry-matter production in regrowth of other grass species during progressively later periods of the growing season. Their data showed this lowering productivity to be significantly correlated with shortening mean daily photoperiod, global shortwave radiation, and soil temperature at a 10-centimeter depth under the soil surface.

Unharvested Forage

Some of the treatments compared in these experiments were impractical from a grower's viewpoint because they did not fully utilize all herbage produced during the growing season. This was especially true of treatments with final cuttings in late July or early August that produced considerable

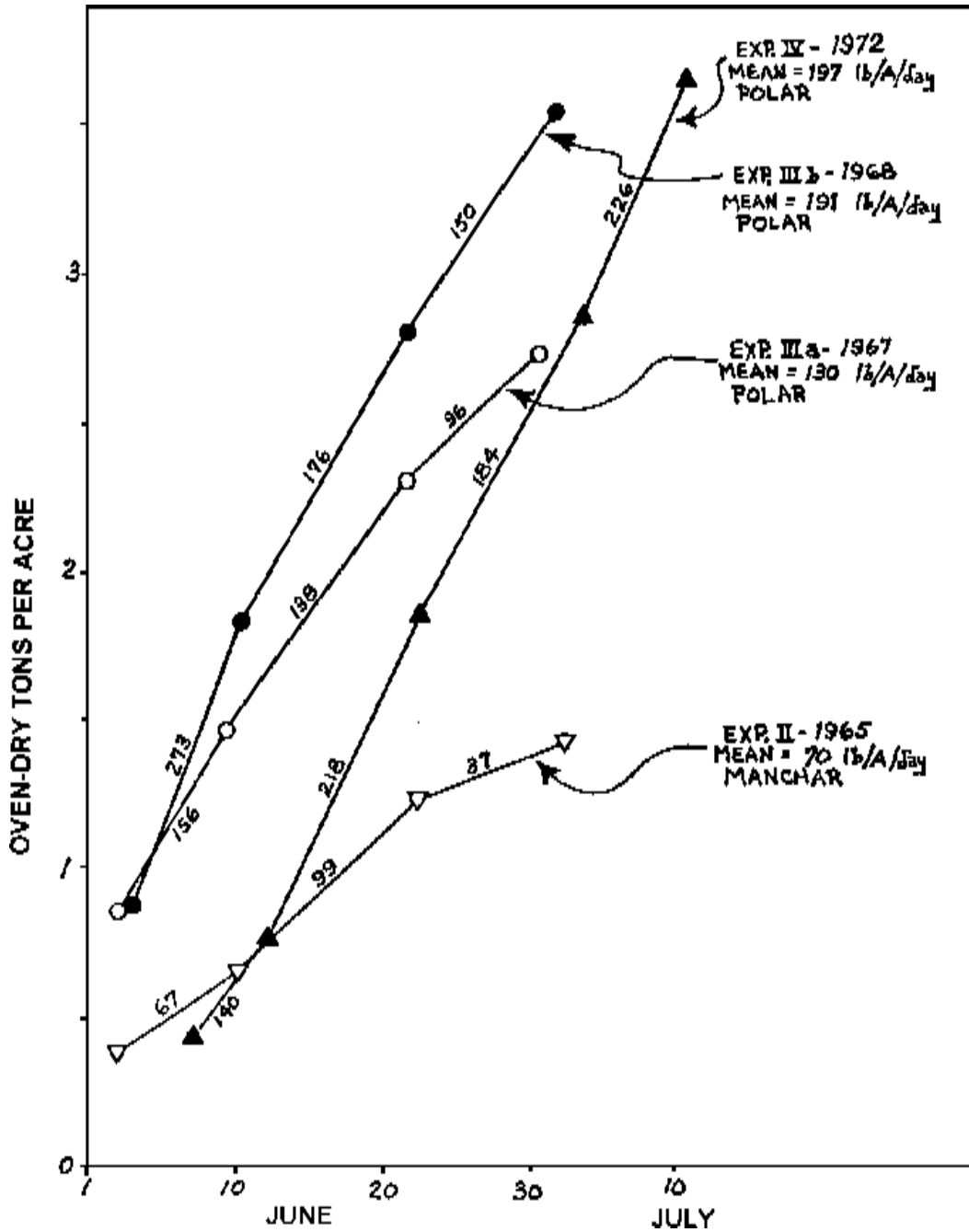


Figure 11. Forage yields on successive first cutting dates, and rates of herbage dry-matter production between those cutting dates, of Polar and Manchar bromegrass in Experiments II, IIIa and IIIb, and IV, and mean rates of dry-matter production from first to last cutting. Dates on base line (abscissa) for general reference; actual dates of first-cut harvests are found on previous graphs (Exp. II in Fig. 3, mean dates for Exps. IIIa and IIIb in Fig. 7, Exp. IV in Fig. 9). Experiment I does not appear because only one first-cutting date was used.

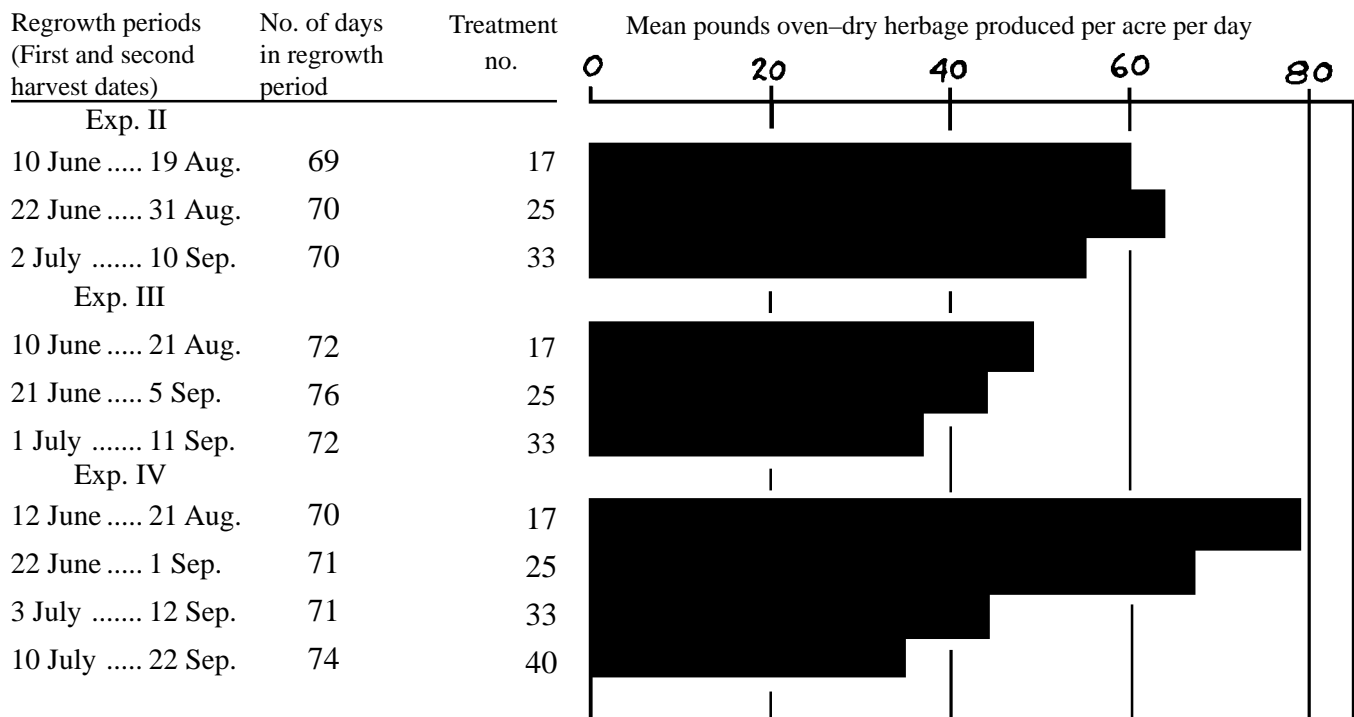


Figure 12. Mean pounds herbage dry matter produced per acre per day in progressively later regrowth periods (mean = 71.5 days) as both first and second cuttings were taken progressively later during the growing season.

regrowth between the last cutting and freeze-up. However, the primary concern of treatments compared was to discern grass responses, rather than maximum recovery of forage with all harvest treatments.

The considerable growth present on some plots at freeze-up was not harvested for yield, but was clipped to a uniform short stubble and removed prior to winter. Mean heights of regrowth above the 2-inch stubble as measured on 6 October in Exp. IV are shown in Figure 9; those heights are conservative measures of actual heights owing to some shriveling and curling of herbage due to several killing frosts after growth ceased (Table 2). An early snowfall on 2 October afforded sufficient contrast to show clearly the different amounts of regrowth remaining on plots in Exp. IV (Fig. 13) before regrowth was clipped and removed on 6 October.

CONCLUSIONS

These experiments confirm that successful culture of established bromegrass for forage in this area of Alaska involves the interplay of three important factors: (a) the genetic level of inherent winterhardiness of the strain grown, (b) the schedule and frequency of harvests, and (c) the severity of winter stresses that follow each growing season.

Also shown are the forage yields and crude protein

concentration in herbage that may be expected with various schedules and frequencies of harvest, and with similar amounts of precipitation and with equivalent rates of applied fertilizer nutrients, both critical to high yields of bromegrass.

Cultivar Hardiness and Winter Stresses

The two cultivars used, Manchar and Polar, were utilized in separate experiments and each experiment was subjected to stresses during different winters; thus, the two cultivars were never subjected to direct comparison in this study. However, it is known from other studies at this location (Klebesadel 1970, 1993a, 1994a, 1994c; Wilton *et al.* 1966) that subarctic-adapted Polar is more tolerant of freeze stress and is more winterhardy than mid-temperate-adapted Manchar.

The winters following differential harvests in Exps. I and II were sufficiently rigorous to reveal considerable differences in effects of the different harvest schedules and frequencies on Manchar, more so in Exp. II than in Exp. I.

The three winters that followed differential harvests of Polar (two winters in Exp. III, one in Exp. IV) were inadequately stressful to cause any but minor differences in the uniform evaluation harvests at the end of each of those experiments.

In Exp. II, the inherent level of winterhardiness of

Manchar brome grass, and the specific severity of stresses imposed by the 1965–66 winter, combined ideally to cause marked differences in stand injury among treatments and thus resulted in wide disparities in forage yields in the uniform–evaluation harvest in 1966. Those differences provide valuable insights into the relative effects of the different harvest schedules and frequencies on brome grass growth requirements and stand health.

Some of those effects were apparent also in Exp. I, but to a much lesser extent due to the more limited number of treatments for comparisons. Polar brome grass in Exps. III and IV did not exhibit the marked treatment differences in the final evaluation harvests that were seen with Manchar in Exps. I and II because the stresses of the winters involved were not sufficiently rigorous to disclose any but the slightest effects of the most harmful treatments on that more winterhardy cultivar. It is known from other experimental evidence at this location, however, that Polar brome grass can be severely winter–injured if inappropriate harvest frequency is followed by sufficiently severe winter stresses (Klebesadel 1994a).

Rates of Herbage Dry–Matter Production

Brome grass puts forth herbage at a remarkable rate during the month of June if adequately supplied with fertilizer nutrients and soil moisture, and if growth is not interrupted by harvest. Production of herbage dry matter during mid–June approximately

doubled within only 10 days.

In Exp. IV, average production of herbage dry matter by Polar brome from 7 June to 10 July was at the rate of almost 200 pounds (197) per acre per day. When soil moisture was limiting, however, production by Manchar brome from 2 June to 2 July in Exp. II was at the rate of only 70 pounds per acre per day.

Herbage production by regrowth during the last half of the growing season also is greatly influenced by availability of plant nutrients and soil moisture. When those growth factors are adequate, regrowth in Alaska’s cool growing–season temperatures is remarkably more productive of herbage than occurs in more southern areas where hot summer temperatures limit considerably the productivity of regrowth.

In general, the rate of herbage production by brome grass regrowth tends to slow late in the growing season as (a) daily photoperiods become shorter, (b) temperatures drop below optimum for growth, and (c) as photosynthetic product is increasingly diverted to storage within the plant and away from production of aerial growth (Smith and Nelson 1985).

Distribution of Yields

As discussed in an earlier report (Klebesadel 1994a), smooth brome grass tends to be relatively less productive during the latter half of the growing seasons in more southern areas of the U.S. where summer temperatures are higher (Fairbourn 1983; Fortmann 1953; Smith *et al.* 1986; Thomas *et al.*



Figure 13. Overall view of Exp. IV on 2 October 1972 after an early, light snowfall served to delineate differences in regrowth on plots, and showing that certain treatments did not utilize all growth produced. Tallest regrowth is on plots with last harvest in July or early August. Although impractical for growers, those treatments were included to study grass behavior with long, uninterrupted final regrowth periods.

1958). Fortmann (1953) in New York reported only about 15% of total annual forage yield in the second of two harvests. Thomas *et al.* (1958), summarizing numerous trials with northern and southern types of smooth brome grass in the northcentral states, reported that in 28 station-years results with three cultivars, an average of 28% of total annual yield was obtained in the second of two cuttings (no harvest dates reported).

Alaska's cooler growing seasons tend to promote more active growth and herbage production by brome grass during the latter half of the growing season. For example, using selected treatments with first harvests near 20 June or 1 July, with second cuttings near 1 September, Table 4 shows percentages of yield in first and second cuttings in the four experiments reported here.

With first cuttings near 20 June, the four-experiment average showed approximately half of total annual yield was obtained in each of the two harvests. Experiment II, with moisture deficit during the first half of the growing season, and greater abundance during the second half, had about 1/3 in the first cutting and 2/3 in the second.

With first cuttings near 1 July, a greater average percentage (56.7%) of total annual yield was obtained in the first cutting, but a considerable portion (43.2%) was represented in second cuttings as well.

Harvest Schedules and Frequencies: Play Safe? Or Gamble?

These experiments show that an extremely winterhardy cultivar (Polar) can withstand various schedules and frequencies of harvests if that growing season is followed by a winter of mild to modest stresses. However, even under those circumstances in

Exp. IV, certain 3-cut schedules (esp. trtmts. 11 and 12) were more injurious to stands than any of the 27 2-cut treatments.

In contrast, a moderately winterhardy cultivar (Manchar) harvested on schedules or frequencies not in harmony with the brome grass plant's growth and physiological requirements, and followed by a winter of severe stresses, can sustain moderate to severe winter injury.

Inasmuch as growers cannot predict the severity of forthcoming winters, and desire high productivity from ongoing brome grass stands, the best guarantees against severe injury or winterkill of stands are to plant the most winterhardy strain available and to harvest forage on schedules and frequencies that provide high yields of good quality forage but do not weaken stands and predispose them to winter injury in the event that a stressful winter should follow.

Two harvests, the first in late June or very early July and the second in late August or early September, provide high forage yields of good quality (as indicated by crude protein concentration) and allow adequate regrowth time between cuttings for restoration of food reserve levels.

Conversely, if a brome grass stand is to be terminated by tillage in the following year, the stand can be intentionally weakened by harvests inappropriate to stand health and vigor. Such a harvest schedule, that would also produce fairly high yields of high quality forage, would be three or four cuttings with the last near 10 September (see trtmts. 7 and 12 in Exp. II).

Precipitation and Forage Yields

As noted earlier (Klebesadel 1994a), the annual precipitation in this area (mean = 15.56 inches at the Matanuska Research Farm) is marginal for promoting

Table 4. Distribution of total annual yield in first versus second cutting with selected treatments from all experiments where first cuttings were taken about 20 June or 1 July and second cuttings near 1 September.

Exp.	Trtmt.	Harvest dates		Percent of total annual yield in:	
		First	Second	1st cut	2nd cut
First cut near 20 June:					
I	8	20 June	29 Aug.	57	43
II	25	22 June	31 Aug.	35	65
III	25	21 June	5 Sep.	58	42
IV	25	22 June	1 Sep.	<u>44</u>	<u>56</u>
				mean	48.5
First cut near 1 July:					
I	(no 1 st cut near 1 July)				
II	32	2 July	31 Aug.	43	57
III	32	1 July	5 Sep.	68	32
IV	32	3 July	1 Sep.	<u>59</u>	<u>41</u>
				mean	56.7

the full forage–production potential of bromegrass. Less than normal precipitation, or poor seasonal distribution can severely restrict herbage production. The present experiments supply additional evidence of that premise.

The year of differential harvests in Exp. I (1963), was in general adequately supplied with precipitation (Table 1) and highest yields for some of the 2–cut and 3–cut treatments surpassed 3 T/A (Fig. 2).

In contrast, a substantial precipitation deficit during July, August, and September of 1964 and during April and May of 1965 (Table 1), resulted in modest yields of Manchar in Exp. II during the first half of 1965 (Fig. 3). However, above–normal rainfall during June, July, August, and September of 1965 (Table 1) resulted in high yields in the second of two cuttings in that year when regrowth periods were long; yields in those second cuttings often exceeded by a considerable amount the yields in the first cuttings.

In Exp. III, precipitation during the first year of differential harvests (1967 = Exp. IIIa), and the first half of the second year of differential harvests (1968 = Exp. IIIb), was generally above normal (Table 1) and forage yields of Polar brome reflected that adequacy of moisture supply (Fig. 7). For example, first–cut yields harvested on 30 June 1967 averaged 2.74 T/A, while on 1 July 1968 yields averaged 3.56 T/A; precipitation in early 1968 was unusually ample with above–normal amounts in April, May, and June, the most received in May (1.80 inches above normal).

In contrast to that good supply of precipitation, from mid–season onward in 1968 rainfall was severely deficient (July + Aug. + Sep. = 4.3 inches below normal), followed by below–normal amounts in April and June of 1969 (Table 1). As a result, the severely moisture–starved and stunted spring growth in 1969 averaged only 0.61 T/A over all treatments in the uniform evaluation harvest on 2 July.

The generally marginal total annual precipitation in this area can restrict the full forage–production potential of bromegrass and thus curtail also the efficient utilization of costly applied fertilizers. This problem becomes especially pronounced when two to several consecutive months of precipitation are below normal.

Conversely, highest yields were achieved when precipitation was above normal. Recognition of the importance of adequate moisture supply has caused some growers to acquire supplemental irrigation systems to promote assured high forage production despite occasional precipitation deficiencies.

Relevance of Findings to Pasture Utilization

The grass productivity, regrowth rates, and quality of herbage on the more frequent schedulings of harvest in these experiments should be generally informative in planning utilization of bromegrass by rotational grazing.

However, the small, sickle–equipped plot mowers used for harvest accomplished more complete removal of herbage at a uniformly short height than typically occurs with grazing. Therefore, the effects of harvests on subsequent winter injury of stands probably were more severe than would occur with grazing on similar schedules and frequencies. The fact that grazing generally leaves more photosynthetic tissue in place would cause less abrupt interruption of growth and permit more continuous photosynthetic activity and less dependence on grass food reserves to be depleted to initiate new growth.

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