Bromegrass in Alaska. VII.
Heading, Seed Yield, and Components of Yield as Influenced by Seeding–Year Management and by Time and Rate of Nitrogen Application in Subsequent Years

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Crop–management practices developed for more southern latitudes can be totally inappropriate in Alaska. However, **Research in Alaska** can reveal desired management practices for our high–latitude agriculture.

Management of left plot followed recommendations for bromegrass seed production appropriate for the northern tier of the "South 48" states (42° – 49°N Lat.).

Right plot shows markedly increased heading for seed production (approximately a 900% increase over the left plot) using research–identified strategies found to be necessary at this high latitude (61.6°N).

See discussion of these plots of Polar bromegrass in Experiment II of this bulletin.

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SUMMARY

Several management variables in the seeding year and on established bromegrass were evaluated for their effects on heading, on other components of yield, and on seed production in five field experiments at the University of Alaska's Matanuska Research Farm (61.6°N) near Palmer (one at the Palmer Research Center) in the Matanuska Valley of southcentral Alaska.

All experiments used the cultivar Polar, representing hybridization between Eurasian smooth bromegrass (*Bromus inermis* Leyss.) and native North American pumpelly bromegrass (*B. pumpellianus* Scribn.).

- Nitrogen (N) fertilizer applied at various rates in spring had virtually no effect toward increasing the number of panicles in the same year's seed crop (Exps. I, II, III).
- Nitrogen applied in August of the year before a seed crop was to be produced resulted in markedly increased panicle numbers and much higher seed yields the following year (Exps. I, II, III, IV).
- Nitrogen applied in spring resulted in more seed weight per panicle in that year's seed crop than N applied during the previous growing season, a factor that increased seed yields only slightly (Exps. I, II, III).
- Nitrogen (at 100 lb/A) applied on 19 April 1986 resulted in more seed weight per panicle in the 1986 seed crop than nine other times of application, two later in 1986 and seven during 1985 (Exp. III).
- Despite higher seed weight per panicle with N application in early spring of the year of seed production, the effect of markedly more panicles, fostered by N application in August of the prior year, was the more dominant factor in increasing seed production (Exp. III).
- Nitrogen (at 100 lb/A) applied on 10 different dates showed that application on 15 or 27 August 1985 resulted in markedly more panicles and seed in 1986 than any of the other application dates compared; as topdressing dates were progressively earlier or later than those dates, panicle numbers and seed yields in 1986 gradually decreased (Exp. III).
- A split application of N (90 lb/A on 28 Aug. 1984 and 45 lb/A on 24 Apr. 1985) totalling 135 lb/A, produced virtually as much seed (575 lb/A) in 1985 as a single application of N at 180 lb/A applied 28 August 1984 (583 lb seed/A) (Exp. II).
- Phosphorus at two different rates, applied alone or with N, had no significant beneficial effect on seed yield or on components of yield. Addition of P_2O_5 at 180 lb/A (with N at 180 lb/A) reduced seed yields; P_2O_5 had no effect with both N and P_2O_5 at 90 lb/A (Exp. I).
- Bromegrass seeded in rows on 17 May produced a seeding-year forage yield on 15 August of 1.4 T/A oven-dry herbage. Compared with 10 other treatments, N at 50 or 100 lb/A applied immediately after forage harvest:
  - (a) produced many more leafy, unelongated tillers prior to freeze-up,
  - (b) resulted in many more panicles in the following year's seed crop, and
  - (c) resulted in high seed yields of 539 and 638 lb/A, respectively (Exp. IV).
- In contrast, seeding bromegrass in mid-May, adding no N during the growing season, and harvesting forage from the rows near killing frost (previously standard practice) resulted in:
  - (a) seeding-year forage yield of 1.8 T/A,
  - (b) the fewest panicles produced the following year of 12 treatments, and
  - (c) seed yield of only 293 lb/A the following year (Exp. IV).
- The greater effectiveness of N applied near mid-August in promoting panicle production the following year suggests that stimulated late-season tiller growth and/or enhanced N supply within plants during the occurrence of critical-length photoperiods/nyctoperiods during September/October contributed significantly to induction of floral primordia that emerged as seed heads the following year.
- Spring application of N satisfactorily promotes good heading and seed production of smooth bromegrass during the same growing season at more southern latitudes, apparently because critical-length photoperiods/nyctoperiods occur during the early spring growth of tillers there. These factors cause many growing points to shift from vegetative primordia (which produce culms with leaves only) to floral primordia that later produce seed heads. The failure of spring N application to increase panicle numbers in Alaska (contrasted with N application the previous August that markedly increased heading the following year) indicates that induction of floral primordia occurs only during late summer/autumn at this latitude. Critical-length photoperiods/nyctoperiods necessary for floral induction occur at this latitude while grass foliage is receptive during late summer/autumn, but those critical-length photoperiods/nyctoperiods have already occurred in spring before bromegrass tillers begin growth. Thus, the grass is precluded from being exposed to, and responding to, that stimulus in spring in this far-northern area.
- Occurrence of "white-top" (insect-damaged panicles that produce no seed) was as high as 37% of total panicles produced (Exp. III).
- Incidence of white-top differed markedly with different times, rates, and elements of fertilizers applied (Exps. I, II).
- White-top incidence was higher with N applied in August of the year before seed production than with the same N rates applied in spring of the year of seed production (Exps. I, II).
- White-top incidence was higher with the lowest rate of N applied (90 lb/A) than with higher rates (200 and 300 lb/A) (Exp. I).
- Unfortunately, the percentage of total panicles afflicted with white-top generally was highest with treatments that resulted in the most panicles (Exps. I, III); thus, fertilization practices that resulted in high seed yields in those experiments were ineffectual in controlling white-top. Insecticide use may be the most effective control for this malady that can severely lower seed yields.
- Highest seed yields in the first year of production were obtained from rows 24 inches apart (596 lb/A); progressively lower yields were obtained from other row spacings in the following order: 30 in.> 36 in.> 18 in.> 12 in.; broadcast seeding resulted in the lowest yield (399 lb/A)(Exp. V).

- In the second year of production in Exp. V, average seed yield was only 32% of first–year yield, and highest yield (212 lb/A) in that year of moisture stress was from rows seeded 36 inches apart.
- Results in these experiments and reports from studies elsewhere indicate that adequacy of soil moisture can markedly affect bromegrass seed yields. Limited precipitation during the first half of the growing season in this area suggests that supplemental irrigation could contribute to assured high seed yields.
- In an unreported experiment with native Alaska pumpelly bromegrass, (26 trtmts., very similar to Exp. I with Polar, but including applications of potassium) K_2O applied in summer versus in spring at two rates (90 and 180 lb/A), alone as well as with N, with P_2O_5, and with both of the latter nutrients, had no effect on panicle density, seed weight per panicle, or seed yield. Heading and seed production of pumpelly bromegrass, in response to N rates and times of application, was very similar to that of Polar.

INTRODUCTION

Smooth bromegrass (*Bromus inermis* Leyss.) is one of the most widely used forage and pasture species in the northern U.S. and Canada. The most winterhardy strains and cultivars from those areas generally are dependable for use in Alaska but succumb to severe injury or total winterkill during occasional winters of extreme stress (Klebesadel 1994; Wilton *et al.* 1966).

The Alaska cultivar Polar (Hodgson *et al.* 1971; Wilton *et al.* 1966), representing hybridization (11 of 16 clones) between Eurasian smooth bromegrass and northern–adapted North American pumpelly bromegrass (*B. pumpellianus* Scribn.) (Elliott 1949; Klebesadel 1984b), is more tolerant of freeze stress than introduced cultivars and offers a greater measure of winterhardiness for dependable use in Alaska (Klebesadel 1993a, 1994).

Inasmuch as the extreme winterhardiness of Polar is not required at more southern latitudes, some classes of Polar seed must be produced at acceptable levels of efficiency in Alaska. The abundant heading and good seed production of Polar's 16 clones (Hodgson *et.al.* 1971) as individual spaced plants surprisingly were not continued beyond the first year after planting in row seedings spring–topdressed with nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) rates that have been adequate for high seed yields of other winterhardy grasses in Alaska (Klebesadel 1992).

Tiller Development

Seed production in bromegrass is dependent upon the production of seed heads or "panicles" (Fig. 1). Panicles are borne at the top of culms (stems) which originate from the parent plant as tillers (Fig. 2). Tillers that emerge from the soil surface during late summer and autumn usually do not elongate then. Some emerge early enough, however, to put forth several leaves prior to freeze–up (F,G,H in Fig. 3), while later–appearing tillers emerge through the soil surface as needle–like points that possess no opened leaf blades (A,B,C in Fig. 3). Leaves that appear on tillers prior to freeze–up die over winter. When the tillers that had appeared above the soil surface in autumn resume growth in spring, they are joined by other tillers that emerge through the soil surface in spring; all of those tillers become the primary growth of that year, elongating into tall culms.

As that tall first growth of the second and later growing seasons produces seed heads, a new crop of tillers begins growth at the base of the plants. If the first crop is removed for forage in late June or early July, those new tillers then elongate to become the regrowth for a second cutting of forage that is harvested ideally in late August or very early September (Klebesadel 1994, 1997).

If, however, the first growth of the season is left in place for a seed crop that usually is harvested about mid–August, the aerial growth (aftermath) left after seed harvest should be clipped short and removed from the field as soon as possible, and a topdressing of N fertilizer applied then (Klebesadel 1996). With shortening daylengths and seasonally lowering temperatures, the unshaded tillers that begin growth after seed harvest, field cleaning, and N application

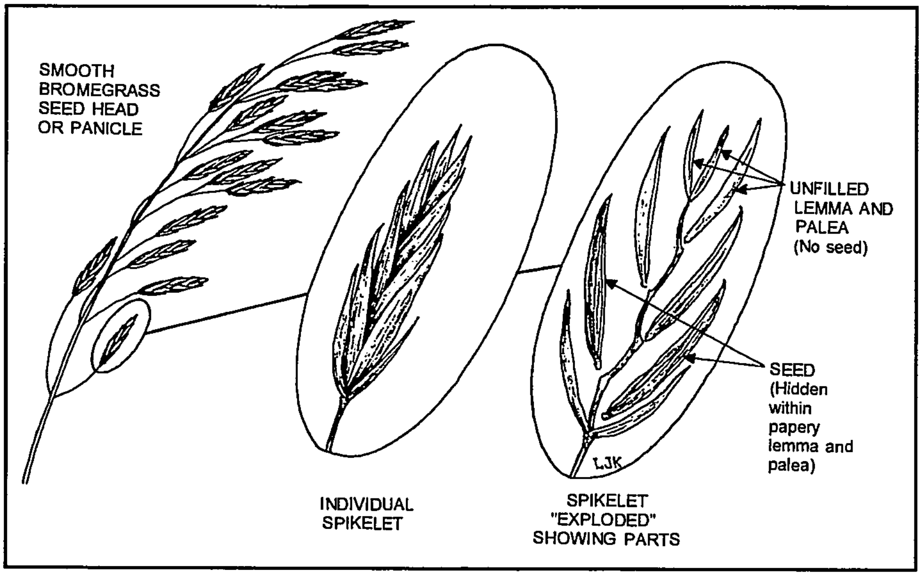

Figure 1. (Left): Fully developed smooth bromegrass panicle (branched seed head) showing 16 seed–containing spikelets, (center): Individual spikelet magnified to show detail, and (right): spikelet separated into individual parts (as occurs at combine–harvest or threshing). Basal two bracts are glumes that contain no seeds, next two to three elements are seeds hidden within papery coverings called lemma (outer) and palea (inner); above that are smaller lemma–palea combinations that do not contain seeds.

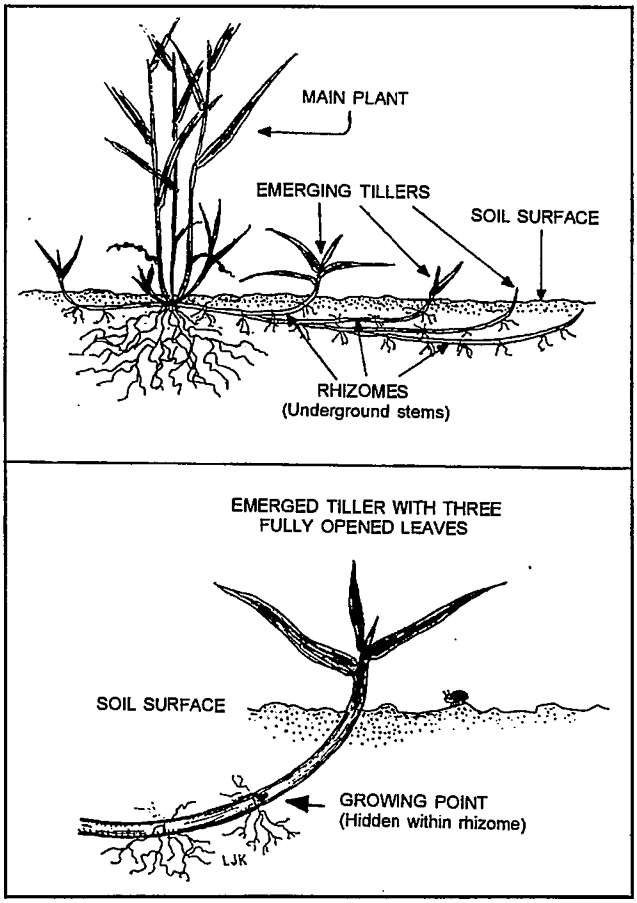

Figure 2. (Upper): Drawing of bromegrass plant showing horizontally spreading rhizomes that emerge to become tillers that later extend to become tall culms (stems). (Lower): An individual tiller showing location of the growing point (potential floral primordium) over winter That growing point (shoot apex) moves upward within the elongating culm in spring, producing either an abundance of leaves (=sterile culm) or five–to–six leaves and a panicle (=fertile culm); both types are shown in Figure 4.

develop more vigorously than if no N were applied, although they do not elongate into tall growth (Klebesadel 1996).

Culm Types

Smooth bromegrass produces two distinctly different kinds of culms as shown in Figure 4. The leafy, non–heading, vegetative culms are valuable in bromegrass herbage harvested for forage because their abundance of leaf blades contributes to forage quality (Kilcher and Troelsen 1973; Mowat *et al.* 1965).

A bromegrass stand intended for seed production, however, should possess as many panicle–bearing culms as possible because high seed yields are dependent upon a high density of panicles per unit of area (Churchill 1944). Management practices utilized by seed growers should be those that promote the generation of the maximum density of panicles possible.

Induction, Initiation, and Development of Panicles

Development of seed heads from the growing points hidden within the bases of tillers of cool–season grasses, such as bromegrass (Fig. 2), proceeds through a sequence of stages (Canode *et al.* 1972; Elliott 1967; Hodgson 1966; Lamp 1952; Sass and Skogman 1951). One generally accepted version of terminology concerning those stages is: (a) *induction*, a chemical change fostered by specific stimuli that disposes the growing point, meristem, or apex (enclosed within a tiller and near the soil surface) to eventually become a seed head, (b) *initiation*, the early, microscopic morphological transformation of that vegetative growing point (still at or near the soil surface) into a floral primordium, and (c) *development*, as the growing point continues differentiation of tissues and enlargement, is elevated upward through the culm, emerges as a fully formed panicle, and continues through anthesis (flowering) and seed formation to maturation.

Evans and Grover (1940) and Sharman (1947) relate in detail and illustrate the phenomenon of initiation of floral

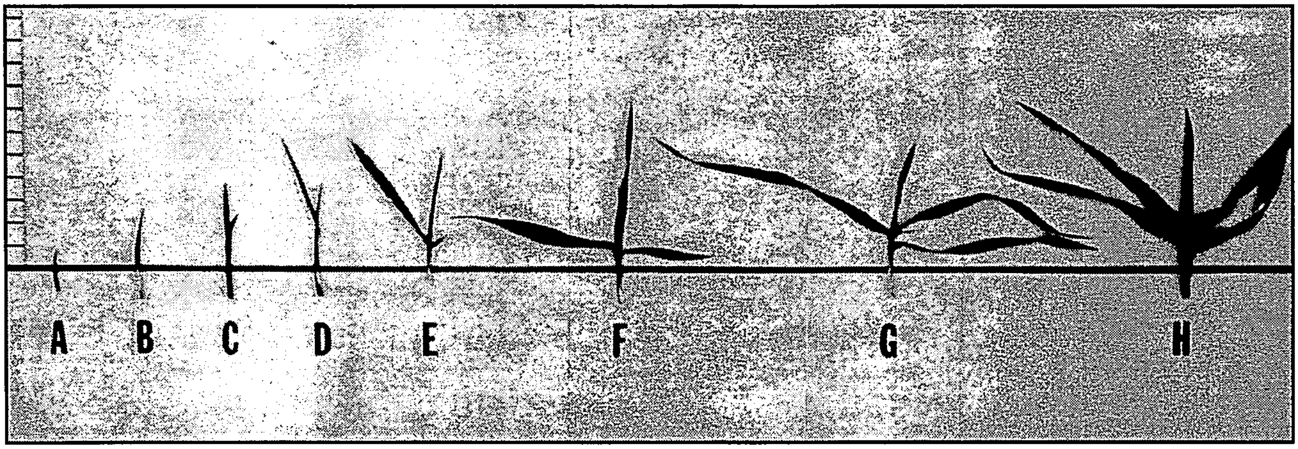

Figure 3. Examples of extents of bromegrass tiller emergence above the soil surface (black line). These range from just the tip showing (as at A), through increasing numbers of opened leaf blades from one (as at D) to five (as at H). Divisions on vertical scale at left are one centimeter apart.

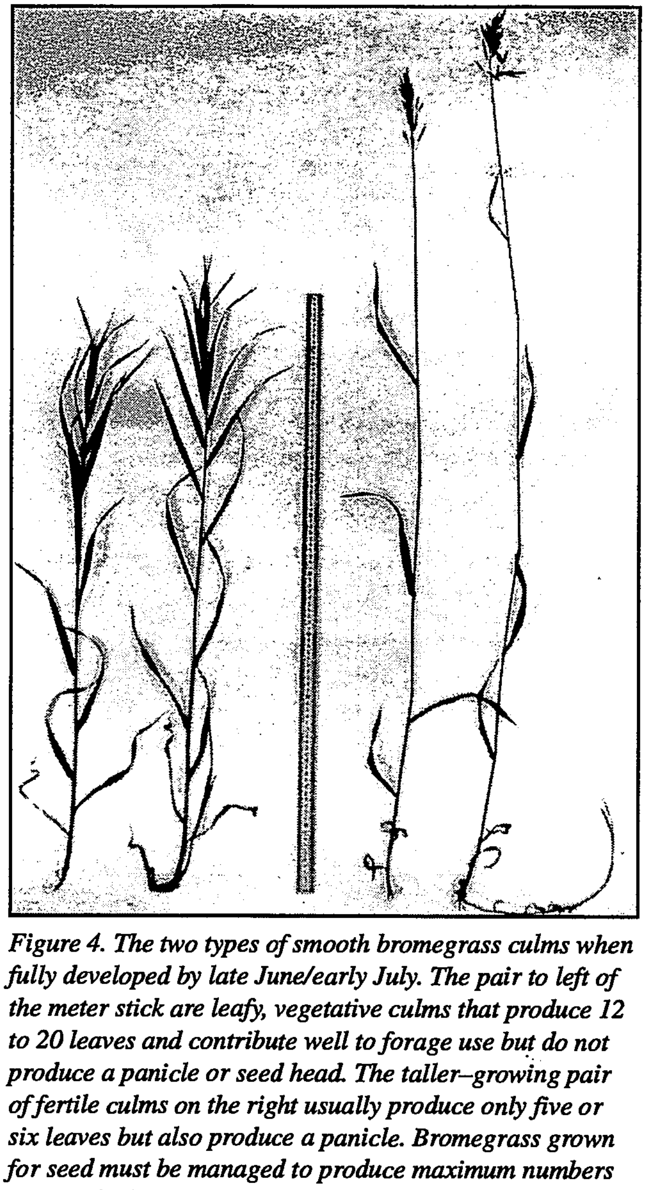

Figure 4. The two types of smooth bromegrass culms when fully developed by late June/early July. The pair to left of the meter stick are leafy, vegetative culms that produce 12 to 20 leaves and contribute well to forage use but do not produce a panicle or seed head. The taller–growing pair of fertile culms on the right usually produce only five or six leaves but also produce a panicle. Bromegrass grown for seed must be managed to produce maximum numbers of panicle–bearing fertile culms.

primordia (transition of growing points from vegetative to reproductive condition) in perennial grasses.

Much of the stimulus that brings about induction of floral primordia is provided by nature, the principal factor being the occurrence in autumn and spring of short daylight periods (photoperiods), or conversely, long daily dark periods (nyctoperiods) (Gall 1947; Newell 1951; Sprague 1948). The other major and critical factor required to promote heading of bromegrass is an adequate and timely supply of N.

Bromegrass Management For Seed Production Elsewhere

It is well known that smooth bromegrass seed yields decline with advancing age of a stand (Anderson *et al.* 1946; Carter 1965; Churchill 1944; Crowle and Knowles 1962; Knowles *et al.* 1951). The above reports and others have noted that bromegrass seed yields may be increased substantially by applications of nitrogen fertilizer; however, excessive N can cause lodging of the crop which in turn can significantly reduce seed yield (Churchill 1944; Harrison and Crawford 1941).

Older stands of bromegrass generally require more N for good seed production than new stands (Canode and Law 1978; Carter 1965). Rates of N required for good seed production vary with growing areas which in turn differ in rainfall amounts and in availability of N present in the soil; thus, recommended annual rates differ among growing areas and generally range from 30 to 100 lb of N/A.

Why Low Bromegrass Seed Yields in Alaska?

Casler and Carlson (1995) identify the major areas of smooth bromegrass seed production in North America as the central Great Plains, the Pacific Northwest states, and the southern Prairie Provinces of Canada. Seed yields in those areas range mostly from 200 to 700 lb/A. Generally higher yields are obtained in the more humid growing areas (Buller *et al.* 1955; Canode and Law 1978; Churchill 1944) than in the drier Great Plains and Prairie Provinces (Crowle and Knowles 1962; Knowles *et al.* 1951), though irrigation can increase yields in the latter areas (Atkins and Smith 1967).

As described in earlier reports (Klebesadel 1970a, 1996), the first foundation seed–production field of Polar bromegrass, planted in rows in 1961 at the Matanuska Research Farm, yielded at the rate of only 198 lb/A in 1962, 106 lb/A in 1963, and 56 lb/A in 1964. Complete fertilizer topdressings were applied in spring of each of those years, supplying N at 63 lb/A. Those very disappointing yields led to several experiments to better understand environmental and cultural factors that influence heading and seed production of bromegrass in Alaska; results of those investigations are included in this bulletin and in earlier reports (Klebesadel 1970a, 1970b, 1971, 1973, 1996).

Time–of–Application of N for Bromegrass Seed Production

Little uniformity exists among recommendations for the most effectual time to apply N to bromegrass for seed production. Churchill (1944) in Michigan recommended spring application, and Harrison and Crawford (1941), also in Michigan, found that bromegrass seed yields responded favorably with N applied in April and May but not when applied in June. Anderson *et al.* (1946) in Kansas found little difference in seed yields following fall or spring applications of N, while Carter (1965) at Fargo, N.D. reported a slight advantage for fall versus spring application. Similarly, Atkins and Smith (1967) and Casler and Carlson (1995) stated (concerning bromegrass seed production): "Fertilizer N should be applied in either fall or very early spring." The marked effectiveness of spring application of N at lower latitudes is dramatically shown by Anderson *et al.* (1946) in Kansas; with no N applied, bromegrass seed yield was 17 lb/A, while N applied 26 March at 60 and 140 lb/A resulted in seed yields of 396 and 570 lb/A, respectively.

At a somewhat more northern latitude, Crowle and Knowles (1962) reported that mid–September N application in Saskatchewan resulted in higher seed yields than application in mid–August, mid–October, or mid–April. Knowles *et al.*

(1951) were in general agreement for a larger area in Western Canada. They reported that preliminary observations indicated autumn N application prior to 1 October may be more desirable than later in autumn or in spring. The foregoing references suggest a trend favoring late–summer–to–autumn N fertilization for growing areas in more northerly latitudes.

Previous Research in Alaska

Factors that influence seed production of bromegrass at far–northern latitudes have been little studied and are not fully understood. Earlier investigations at this location determined the effects of time of seeding (Klebesadel 1970b), and the influence of different artificially altered diurnal photoperiod/nyctoperiod patterns during autumn on subsequent winter survival and heading of several grasses including bromegrass (Klebesadel 1971). Other exploratory studies (Klebesadel 1970a, 1996) determined that the timing of N application, sod disturbance, and aftermath management following seed harvest could influence heading and other components of bromegrass seed yield.

White–top Panicles

Sterile panicles, referred to as "white–top" or "silvertop," are whiter than healthy panicles and are believed incited by a sucking insect called capsus bug (*Capsus stimulans* [Stal]) (Peterson and Vea 1971; also unpublished information, Alaska Agric. and Forestry Exp. Sta.). White–top incidence varies from year to year in seed crops of several grass species in Alaska, often tending toward a higher occurrence in older stands (Klebesadel 1984a, 1996). White–top panicles contain no seed; therefore, a significant occurrence of white–top can materially lower seed yield.

These Experiments

Recognizing that total seed yield is the sum of several contributing factors, and that those factors can be affected beneficially or adversely by different management procedures, as discussed previously, several experiments were conducted to discern how to promote maximum seed production in this far–northern environment. Objectives were to determine the effects of several management practices during the year of planting, and during subsequent years, on panicle production and on other components of seed yield. Polar bromegrass was used in all experiments.

Practices evaluated included various seeding–year forage–harvest schedules and times and rates of N application, several row spacings versus broadcast seeding and, on established stands, (a) rates of nitrogen and phosphorus applied separately and in combinations in late summer versus in spring, (b) influence of N application at various times during the year, and (c) several rates of N applied all in late summer or all in spring, versus split applications (part in late summer, part in spring).

EXPERIMENTAL PROCEDURES

Experiments I through IV were conducted on row plantings of bromegrass seeded in Knik silt loam (Typic Cryochrept) at the Matanuska Research Farm (61.6ºN near Palmer in southcentral Alaska). Experiment V, involving both broadcast and row seedings, was in Bodenburg silt loam (Typic Cryorthent) at the Palmer Research Center seven miles east of the Matanuska Research Farm. All experimental sites had good surface drainage. Pre–plant commercial fertilizer disked into each seedbed supplied N, P_2O_5, and K_2O at 32, 128, and 64 lb/A, respectively. Rows in all experiments except Exp. V were planted 18 inches apart and at the rate of 6 pounds of pure live seed per acre. Randomized complete block experimental designs were used with four replications in all experiments. All forage yields are reported on the oven–dry basis (140ºF).

Experiment I: Effects of different rates and combinations of N and P_2O_5 applied in late summer or in spring, on heading and on other components of seed yield of established bromegrass.

Rows were seeded 15 May 1980, seeding–year aerial growth was clipped to a 2–inch stubble on 20 October 1980, and the experimental area was raked clean. The entire experimental area was topdressed uniformly with N, P_2O_5, and K_2O at 50, 100, and 50 lb/A, respectively, on 16 April 1981. The 1981 seed crop was harvested from the entire area on 24 August and yielded at the rate of only 71 lb/A. After seed harvest the tall aftermath was clipped to a 2–inch stubble on 25 August and that growth was removed immediately.

Several rates and combinations of N and P_2O_5 were topdressed on plots measuring 7.5 by 10 feet on either 26 August 1981 or 4 May 1982 to measure effects of those treatments on the 1982 seed crop harvested 19 to 23 August. One plot in each replication received no fertilizer (check treatment). Specific treatments are identified in figures referred to in the report of this experiment in the Results and Discussion section.

Just prior to seed harvest, a sickle–equipped mower was used to clip 30–inch–wide swaths east–west and north–south and centered on all plot boundaries; the clipped material was raked and removed leaving plots of standing grass growth measuring 5 by 7.5 feet, an area of 37.5 square feet. Ten panicles were selected randomly from each plot before seed harvest; these were used for counts of intra–panicle characteristics. Total number of spikelets was counted on each of those ten panicles (Fig. 1). Two spikelets were then selected randomly from the second whorl of peduncle branches from the base of each of the ten panicles and the number of filled caryopses (seeds) was counted. A 12–inch–wide strip the full width of each plot (= 5 ft^2) was then harvested across one end of each plot leaving a 2–inch stubble; all culms taller than 10 inches in the harvested material were counted as either panicle–bearing or vegetative and the percentage of panicle–bearing culms was calculated for each treatment. All panicles in each plot were counted; seed weights per panicle and per acre were calculated from the total of threshed, cleaned, and weighed seed from each plot. The total number of sterile "white-top" panicles was counted for each plot also; white-top panicles were not included in other calculations.

Experiment II: Effects of four rates of N topdressing applied in late summer versus in spring versus split between late summer and spring on established bromegrass.

Rows seeded 14 June 1983 were mowed to a 2-inch stubble and raked clean on 8 December 1983. No spring fertilizer was applied in 1984. Seed was combine-harvested from all rows 14 August 1984; seed yield from the entire experimental area was at the rate of 262 lb/A. The tall, leafy aftermath growth left after combine harvest was clipped to a 2-inch stubble and raked off. Rectangular plots identical to those in Exp. I were then staked.

"Summer" N topdressings were applied on 28 August 1984 and "spring" N topdressings were applied on 24 April 1985. In addition to a check treatment that received no N on either date, N rates of 45, 90, 135, and 180 lb/A were applied. The proportion of each rate applied on 28 August 1984 was all, ⅔, ⅓, or none, with the remainder of each rate applied to plots on 24 April 1985.

On 14 August 1985, plot borders were clipped and removed prior to seed harvest as in Exp. I. Twenty panicles were selected randomly from each plot for counts of intra-panicle characteristics (as in Exp. I) prior to harvest of all panicles from each plot. On 19 August 1985, a swath 2.5 feet wide and 7.5 feet long and leaving a 2-inch stubble was clipped through the center of each plot to determine forage yield of the aftermath forage remaining after seed harvest. A sample (about 2 lb.) of the harvested herbage was withdrawn, dried to constant weight at 140°F and used to calculate forage yields on the oven-dry basis.

Experiment III: Effects of N application at various times during the year on heading and on other components of seed yield.

The first paragraph describing Exp. II above applies to Exp. III which was conducted on an adjacent area of the rows planted 14 June 1983.

Ammonium nitrate supplying N at 100 lb/A was topdressed on plots measuring 7.5 by 10 feet on four dates in 1984, seven dates in 1985, and three dates in 1986; one treatment received no N. Seed harvests of all plots were taken on 13 August 1985 and 4 August 1986. Prior to each harvest, plot borders were clipped and removed as in Exp. I.

Experiment IV: Effects of N rates and forage harvest in the seeding year on heading and on other components of seed yield the following year.

Rows were planted 17 May 1984 and each plot established on those rows consisted of six rows 10 feet long. Each plot received one of three rates of N (0, 50, and 100 lb/A) in the seeding year, and each plot was subjected to one of four seeding-year forage-harvest schedules (A = 20 July + 5 October, B = 15 August, C = 14 September, and D = 5 October). N application dates for each treatment were A and D = 21 July, B = 16 August, and C = 15 September. At each forage harvest in the seeding year the center two rows of the plot were harvested for yield and the remaining border rows were harvested to a similar 2-inch stubble at the same time but were discarded.

Commercial fertilizer topdressed in spring of the year after planting (applied on 1 May 1985) supplied P_2O_5 and K_2O at 105 and 60 lb/A, respectively. The center two rows of all plots were harvested at near seed maturity on 14 August 1985. All aerial growth was harvested to leave about a 2-inch stubble; the harvested material was placed into cloth bags

Table 1. Polar bromegrass components of seed yield at harvest in 1982 as influenced by rates and combinations of N and P_2O_5 fertilizer applied in late summer of the year before, versus in spring of the year of, seed harvest. (Exp. I)

Treatment no.	Fertilizer N	P_2O_5	Total culms per 5 sq. ft.	Panicle-bearing culms	Spikelets per panicle	Seeds per spikelet	Wt. per 1000 seeds
	lb/A		no.	percent	no.	no.	grams
	Applied 26 Aug 1981:						
1	0	0	278 ef[1]	6 c	14.2 d	1.9 abc	4.20 bc
2	90	0	469 ab	39 b	21.3 abc	2.0 ab	4.05 c
3	180	0	415 a-d	50 ab	25.6 ab	2.0 ab	4.13 bc
4	270	0	475 ab	46 ab	26.1 a	1.8 a-d	4.11 bc
5	360	0	438 abc	51 a	23.9 ab	1.3 d	4.23 bc
6	90	90	435 abc	42 ab	22.9 ab	1.9 abc	4.14 bc
7	180	180	494 a	48 ab	22.6 ab	1.3 d	3.99 c
8	0	90	310 def	10 c	14.4 d	2.1 ab	4.26 bc
9	0	180	260 f	12 c	15.1 d	1.8 a-d	4.39 b
	Applied 4 May 1982:						
10	90	0	376 b-e	10 c	20.8 bc	2.2 ab	4.81 a
11	180	0	434 abc	12 c	23.6 ab	2.4 a	4.75 a
12	90	90	354 c-f	11 c	24.3 ab	2.3 ab	4.71 a
13	180	180	413 a-d	10 c	25.6 ab	2.3 ab	4.71 a
14	0	90	279 ef	10 c	13.2 d	1.9 abc	4.28 bc
15	0	180	378 b-e	9 c	17.7 cd	1.9 abc	4.12 bc

[1] Within each data column, means not followed by a common letter are significantly different (5% level) using Duncan's Multiple Range Test.

and dried with forced air at 90°F.

All culms exceeding 10 inches in length were then separated into panicle–bearing (headed or fertile) and non–panicle–bearing (vegetative or sterile—see Fig. 4) categories and counted. All panicles were then removed from culms, 20 were selected randomly from each plot yield for counts of spikelets–per–panicle, then those panicles were returned to their respective original lots. Each plot yield was threshed, the seed cleaned and weighed, and seed weights per panicle and per acre were calculated. All lots of culms (forage) were dried to constant weight at 140°F and weighed.

Monitored Fate of Tillers

Five to eight tillers were tagged (small, numbered plastic tag on fine nylon string loosely encircling tiller) in certain of the plots on 20 October 1984 and their status was documented on 14 August 1985 just prior to seed harvest. Treatments in which tillers were tagged, development of tillers on tagging date, and their fate the following year are summarized in the table referred to in the Results section for Exp. IV.

Experiment V: Seed yields as influenced by different row spacings versus broadcast seeding.

The experiment was planted on 19 June 1968 at the Palmer Research Center; seed was harvested in the two subsequent years. Six treatments were compared: broadcast seeding, and rows spaced 12, 18, 24, 30, and 36 inches apart. All plots were six feet wide and 16 feet long. All treatments were seeded at the rate of six pounds of pure live seed per acre; thus, increasing amounts of seed was used per row as rows were seeded farther apart.

Dead growth left from the previous year was clipped to a 2–inch stubble and raked off on 28 March 1969 and on 18 March 1970. Spring topdressing on 3 April 1969 supplied N, P_2O_5, and K_2O at 64, 76, and 60 lb/A, respectively, and the same nutrients on 23 April 1970 at 32, 128, and 64 lb/A. A topdressing on 12 August 1969 (after seed harvest) supplied N at 82 lb/A.

Seed was harvested on 8 August 1969 and 26 August 1970. An area four feet wide and 12 feet long was harvested from the center of broadcast–seeded plots. A 12–foot length was harvested from the center of all rows harvested; rows harvested were the middle three in rows 12 inches apart, the middle two in rows 18 inches apart, and only the center one where rows were 24, 30, and 36 inches apart. Appropriate factors were used to convert plot yields to pounds per acre.

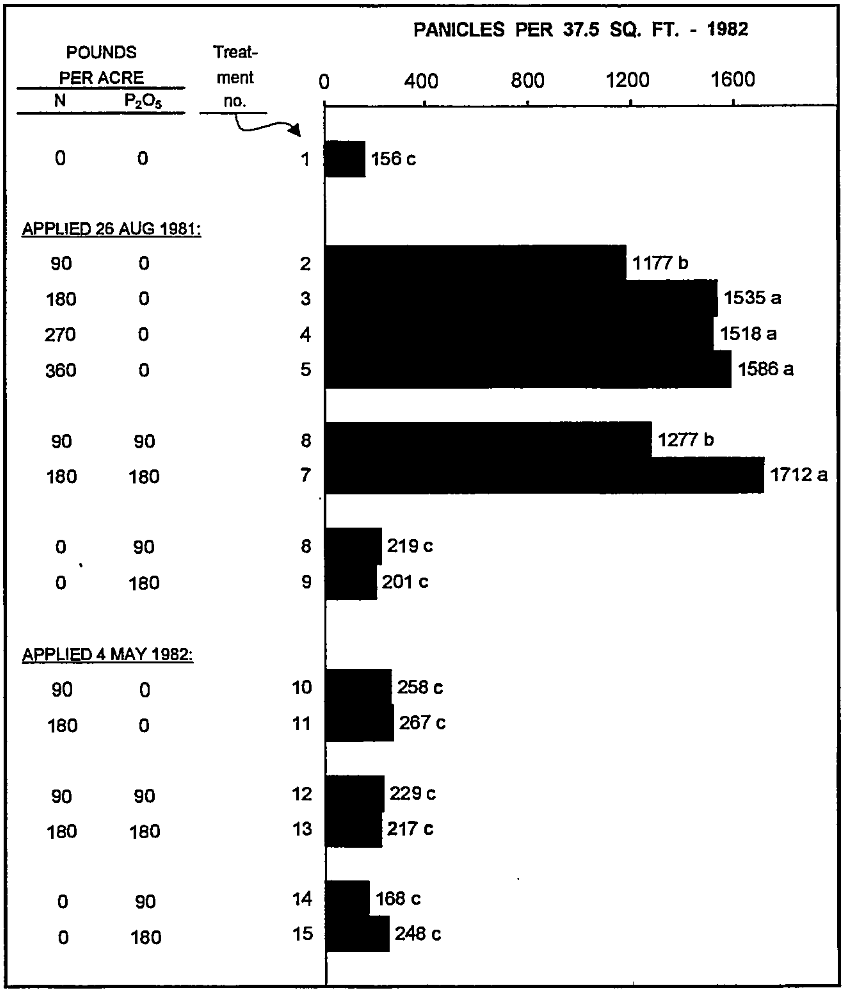

Figure 5. Polar bromegrass panicles per 37.5–square–foot plot in 1982 as influenced by different rates of N and P_2O_5 fertilizer topdressings applied 26 August 1981 or 4 May 1982. Bromegrass was planted 15 May 1980. Graph bars not having a common letter to right of panicle number differ significantly (5% level) using Duncan's Multiple Range Test (Exp. I).

RESULTS

Experiment I: Effects of different rates and combinations of N and P_2O_5 applied in late summer or in spring, on heading and on other components of seed yield of established bromegrass.

Total Culms Produced

The total number of culms produced in 1982 per five square feet (a portion of the larger 37.5 ft^2 plot) ranged from 278 (unfertilized check trtmt.) to 494 (trtmt. 7 that received N and P_2O_5, both at 180 lb/A, in August 1981) (Table 1).

In general, plots that received N at all rates in August of 1981, and those that received N at 180 lb/A in May of 1982, tended to produce significantly more culms (some exceptions) in 1982 than plots that received no N or the lower rate (90 lb/A) in May of 1982.

Nitrogen applications had a stimulatory effect on the production of total culms per unit of area but phosphorus did not. The four N rates applied in late summer were equally effective in stimulating culm density. With spring topdressing, there was a consistent tendency toward greater effectiveness of the 180 over the 90–lb rate, but differences were not statistically significant. The two P_2O_5 rates applied without N did not increase culm numbers over the unfertilized check with either time of application.

Percent of Total Culms Producing Panicles

The percent of total culms that produced panicles in 1982 ranged from 6% (trtmt. 1 = unfertilized check) to 51% (trtmt. 5 = 360 lb N/A applied 26 Aug. 1981) (Table 1). The non–N treatments applied in August 1981 and all treatments (with or without N) applied in early May of 1982 were all about equally low in percent panicle–bearing culms.

The different summer N rates used were generally equally effective, except the 360–lb/A rate resulted in a significantly higher percentage of panicle–bearing culms (51%) than did the 90–lb/A rate (39%). Application of P_2O_5 with N did not affect percent panicle–bearing culms. Mean percent panicle–bearing culms over all summer–applied N rates was 46 while for spring–applied N it was only 11; the latter percentage did not differ from the percent of panicle–bearing culms induced by P_2O_5 applied alone or the percent produced by the unfertilized check treatment.

Panicle Numbers

N applied in late summer was markedly more effective than spring application in stimulating production of panicles (Fig. 5).

The combined effects of numerous culms per unit of area and higher percentages of panicle–bearing culms induced by summer–applied N resulted in markedly more panicles per plot. The three highest rates of summer–applied N resulted in equal densities of panicles, and all three resulted in more panicles than the 90–lb/A rate of N. Spring–applied N, and P_2O_5 applications in summer or spring, were equally non–effective in stimulating panicle production; none of those treatments surpassed the unfertilized check.

Spikelets Per Panicle

Spikelets per panicle ranged from 13.2 (trtmt. 14) to 26.1 (trtmt. 4) (Table 1). All N rates applied in summer or spring were equally effective in stimulating more spikelets per panicle than the unfertilized treatment and more than either of the P_2O_5 rates applied alone or with N. Application of P_2O_5 alone or with N, either in August or in early May, did not affect the number of spikelets per panicle.

Seeds Per Spikelet

The number of seeds per spikelet ranged from 1.3 to 2.4 (Table 1). There was a tendency toward more seeds per spikelet with both rates of spring–applied N; however, differences between those and most other treatments were not statistically significant. Fewest seeds per spikelet (1.3) were obtained with the two summer–applied treatments that had stimulated greatest vegetative growth of the grass during late summer and autumn of the year prior to the year of seed harvest.

Seed Weight Per Panicle

Mean seed weight per panicle ranged from 36 to 166 milligrams (Fig. 6); the heaviest weights resulted from spring–applied N (mean for those four trtmts. = 156 mg.). Applications of the two rates of P_2O_5 alone or with N, in summer or in spring, did not influence seed weight per panicle.

Weight Per 1000 Seeds

Weight per 1000 seeds ranged from 3.99 to 4.81 grams

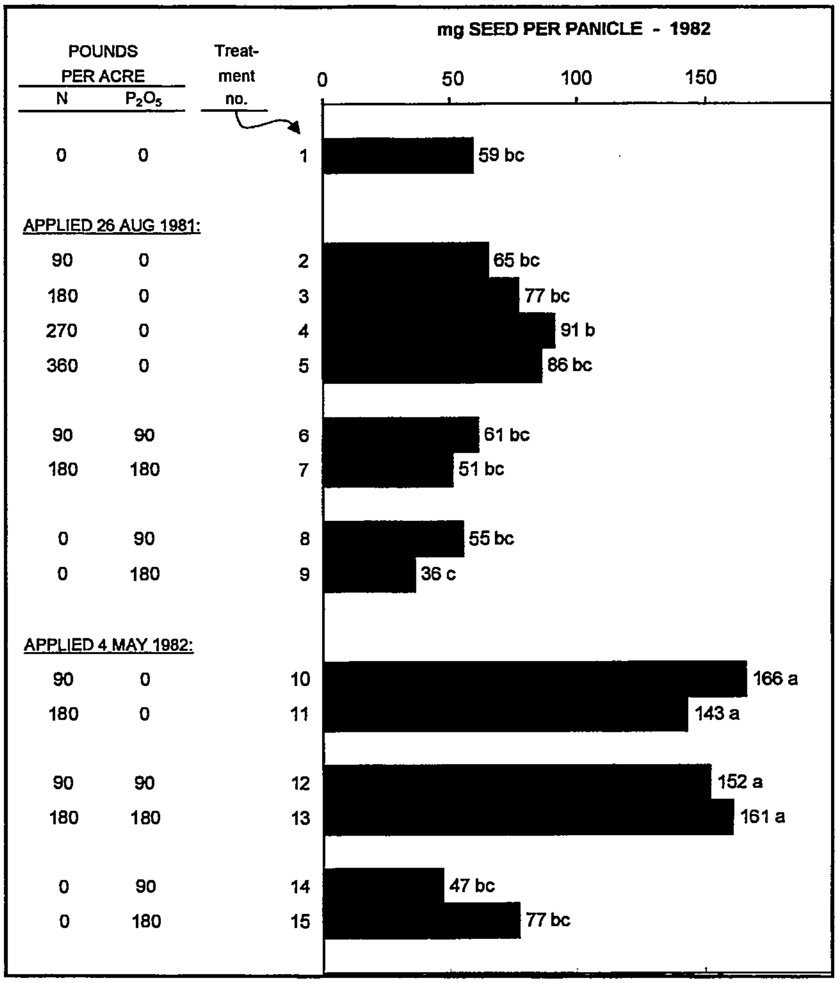

Figure 6. Seed weight per panicle of Polar bromegrass at harvest in August 1982 as influenced by different rates of N and P_2O_5 fertilizer topdressings applied 26 August 1981 or 4 May 1982. Bromegrass was planted 15 May 1980. Graph bars not having a common letter to right of panicle weight differ significantly (5% level) using Duncan's Multiple Range Test (Exp. I).

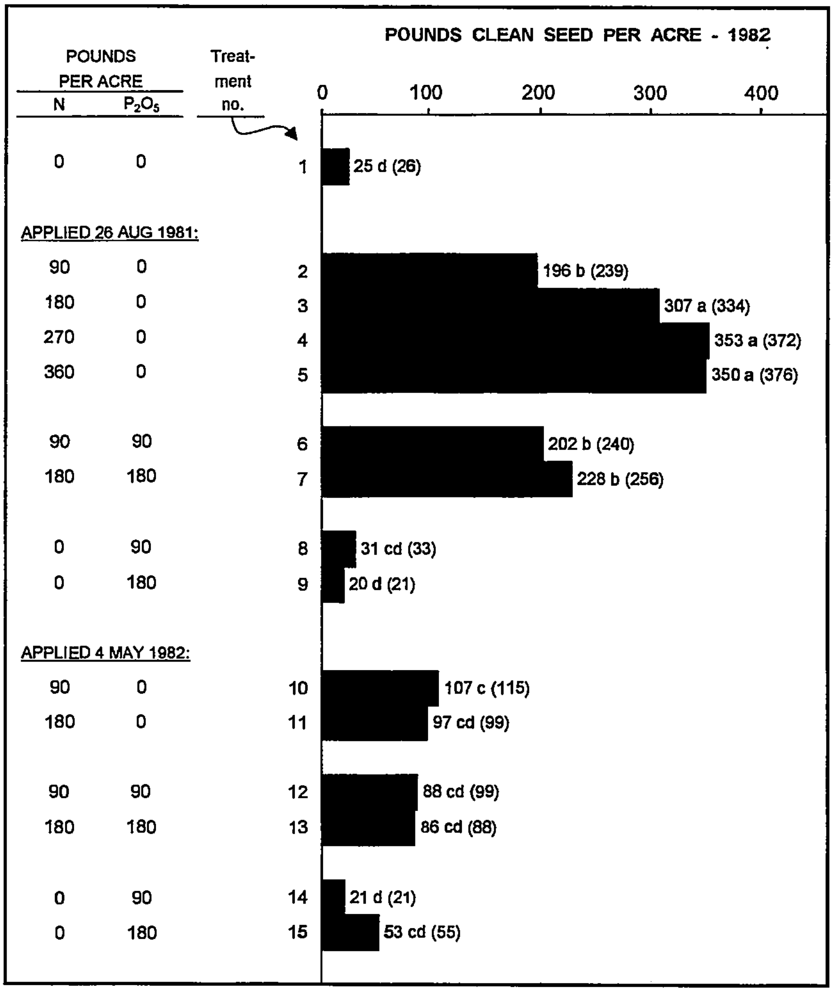

Figure 7. Polar bromegrass seed yields in 1982 (second seed-production year) as influenced by different rates of N and P_2O_5 fertilizer topdressings applied 26 August 1981 or 4 May 1982. Bromegrass was planted 15 May 1980. Graph bars not having a common letter to right of seed yield differ significantly (5% level) using Duncan's Multiple Range Test. Numbers in parentheses are calculated seed yields that would have been obtained with no incidence of white-top (Exp. I).

(Table 1). Both rates of spring-applied N resulted in significantly heavier weights per 1000 seeds (mean = 4.75 grams) than all other treatments; the other treatments were generally similar in weight per 1000 seeds (mean = 4.17 grams).

Seed Yields

Total seed yields ranged from 20 to 353 lb/A (Fig. 7); yields were significantly higher where N rates exceeding 90 lb/A were applied in August of the year before the year of seed harvest; however, no significant increases in seed yield occurred with N rates higher than 180 lb/A (trtmts. 4 and 5 vs. 3). Application of P_2O_5 with the 180 lb/A rate of N in late summer (trtmt. 7) resulted in significantly lower seed yield than where that N rate had been applied alone (trtmt. 3). Application of N in spring or P_2O_5 rates alone on either date generally resulted in no more seed than the unfertilized check treatment, and the slightly increased yields from spring application of N were due not to an increase in panicles (Fig. 5) but to greater weight of seed per panicle (Fig. 6).

If there had been no white-top panicles, seed yields would have been higher because of the considerable incidence of that problem, especially in some of the higher-yielding treatments (Fig. 8). Calculated yields of seed that would have been obtained without white-top appear in parentheses in Figure 7.

White-top Panicles

Incidence of white-top ranged from 1.5% to 17.5% of total panicles (Fig. 8). Greatest incidence occurred where N had been topdressed in August of the previous year at the 90 lb/A rate, with or without P_2O_5, and with summer application of the 180 lb/A rate of both N and P_2O_5. White-top incidence was significantly lower at higher rates of N without P_2O_5, similar to its occurrence with several other treatments. Spring-applied N at 90 lb/A tended to result in more white-top than 180 lb N/A.

Incidence of white-top therefore was highest where some N had been applied but not at the highest rates. Application of P_2O_5 with the 90-lb/A rate of N in spring, or with the 180-lb/A rate in summer of the prior year, tended to increase incidence of white-top over the rate of occurrence where those N rates were applied without P_2O_5.

Peterson and Vea (1971) in Minnesota noted that white-top in Kentucky bluegrass (*Poa pratensis* L.) was more abundant following heavy applications of N fertilizer. In an earlier report (Klebesadel 1996), no clear relationship was evident between white-top incidence and fertility treatments, although white-top occurrence in that report also was not greatest at highest N rates.

Experiment II: Effects of four rates of N topdressing applied in late summer versus in spring versus split between late summer and spring on established bromegrass.

Panicle Numbers

With the knowledge from Exp. I that N applied in August (of the year prior to a seed crop) resulted in markedly increased panicle numbers, and that N applied in spring of the year of a seed crop resulted in increased seed weight per panicle, Exp. II was designed to investigate the effects of combining both beneficial effects by applying different rates of N at both times.

As shown in Figure 9, N applications of 45, 90, 135, and 180 lb/A in spring (24 Apr. 1985) again, as in Exp. I, resulted in very few more panicles than the check treatment; the slightly increased numbers were not significantly different than with no N applied.

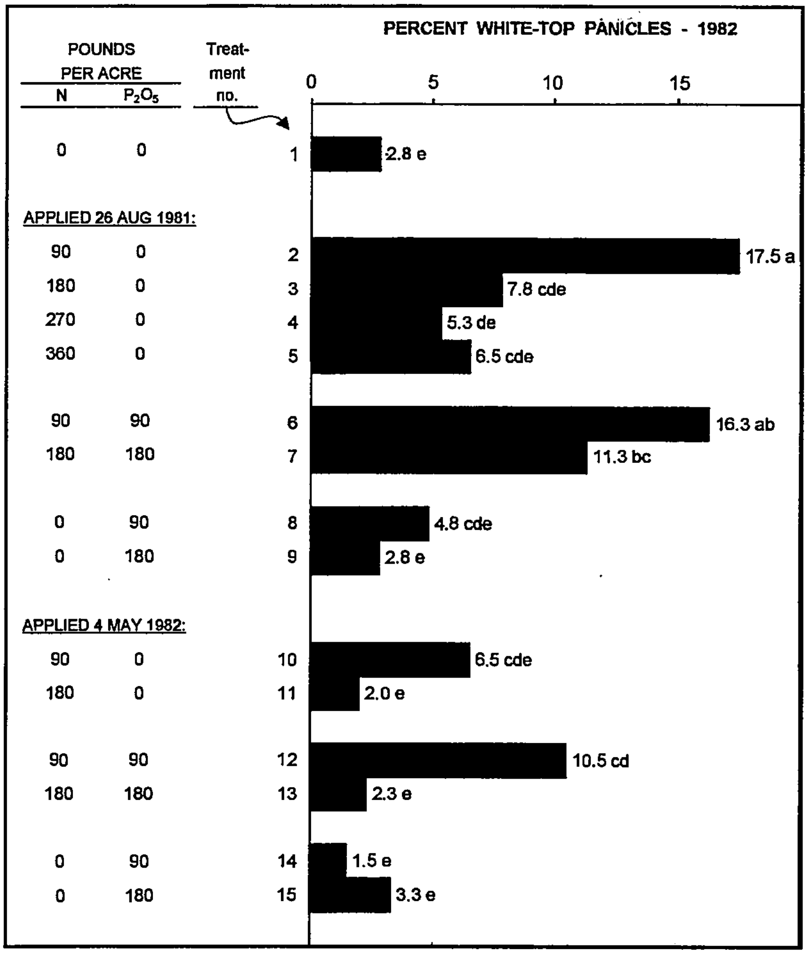

Figure 8. Percent sterile "white–top" panicles in 1982 Polar bromegrass seed crop as influenced by different N and P_2O_5 fertilizer topdressings applied 26 August 1981 or 4 May 1982. Bromegrass was planted 15 May 1980. Graph bars not having a common letter to right of percent value differ significantly (5% level) using Duncan's Multiple Range Test (Exp. I).

In contrast, the same rates of N applied 28 August 1984 (with no N applied the following spring) resulted in vastly increased panicle numbers (Fig. 9). Each increasing N rate applied all in August, up to the 180 lb/A rate, resulted in a significant increase in panicle numbers. The 180 lb/A rate resulted in over 17 times as many panicles as the no–N check treatment, and 10 times more than 180 lb/A applied in spring.

Cover Photo

The photo on the cover, taken 14 August 1985, shows the marked difference in panicle production resulting from different times of N application. For this seed crop, both plots received N at the rate of 135 lb/A, all in a single application. That N was applied on the left plot on 24 April 1985, and on the right plot on 28 August 1984. Note the abundance of dark green leafiness but scarcity of heads in the left, spring–fertilized plot. The left plot thus had a much higher proportion of leafy, non–headed (sterile) culms than headed ones. Pictured is agronomy aide Jana Griffin.

As 2/3 and 1/3 of each of the four rates was applied in August, and the balance in April, panicle numbers decreased in every case by a significant margin except for one instance at the 135 lb/A rate (90 lb/A in Aug. + 45 lb/A in Apr. did not result in significantly fewer than 135 lb/A in Aug. + 0 in Apr.).

Inasmuch as the spring–applied N had virtually no effect on panicle numbers produced, Figure 10 was drawn to show the cumulative effect of increasing rates of N from 0 to 180 lb/A, applied 28 August 1984, on numbers of panicles produced in 1985 (where more than one treatment supplied the same rate of N in August, the mean number of panicles was calculated). That graph line is steepest from 0 to the 90 lb/A rate and, though increased numbers of panicles continue with each N increment to the 180–lb/A rate, the rate of increase lessened above 90 lb/A.

These results indicate that maximum practical seed yields should be realized with N applied either (a) about 150 lb/A in August immediately after seed harvest, or (b) 100 lb/A, as above, plus about 50 lb/A in early spring. These rates are somewhat higher than results reported elsewhere; Canode and Law (1978) noted that fall application of N of up to 120 lb/A increased seed yields of older stands. Knowles *et al.* (1951) recommended 40 to 80 lb N/A for western Canada and Atkins and Smith (1967) suggest the same for the Great Plains. Canode (1968) reported no increases in bromegrass seed yields with N rates above 60 lb/A applied in fall in eastern Washington state.

Spikelets Per Panicle

Spikelets per panicle ranged from 18.9 (trtmt. 1) to 30 (trtmt. 16)(Table 2). The unfertilized treatment 1 with 18.9 spikelets per panicle had significantly fewer than any of the other 16 treatments that all received N from 45 to 180 lb/A.

Treatments 2 through 5, receiving N at 45 lb/A, averaged 25.2 spikelets per panicle, and different times of N application did not influence spikelet numbers significantly.

With N applied at 90 and 135 lb/A, significantly fewer spikelets per panicle almost always resulted when all of the N was applied in spring than with the other three treatments at each of those rates.

The six treatments with the most spikelets per panicle (trtmts.6,10,11,12,15,16) averaged 28.5 and all involved at least 45 lb N/A applied 28 August 1984.

The numbers of spikelets per panicle in this experiment were all fewer than those reported by Harrison and Crawford (1941) in Michigan (their range over 16 trtmts. = 32 to 48 spikelets per panicle).

Table 2. Polar bromegrass spikelets per panicle and aftermath forage yields in August 1985 as influenced by N rates applied 28 August 1984 and/or 24 April 1985 as split or single applications on rows planted 14 June 1983 (Exp. II).

Treatment no.	N applied 28 Aug. 1984	N applied 24 April 1985	Seed Spikelets per panicle	Forage Oven-dry yield
	lb/A	lb/A	no.	Tons/A
1	0	0	18.9 g	0.87 h
2	45	0	25.4 cdef	1.58 fg
3	30	15	26.2 cdef	1.66 efg
4	15	30	24.0 f	1.56 g
5	0	45	25.2 def	2.05 defg
	Mean		25.2	1.71
6	90	0	28.1 abcd	1.94 defg
7	60	30	26.5 cdef	1.93 defg
8	30	60	27.0 bcde	2.14 b-f
9	0	90	25.0 ef	2.20 bcde
	Mean		26.7	2.05
10	135	0	28.3 abc	2.18 bcde
11	90	45	27.3 a-e	2.07 c-g
12	45	90	29.7 ab	2.47 abcd
13	0	135	24.1 f	2.65 abc
	Mean		27.4	2.34
14	180	0	27.0 bcde	2.21 bcde
15	120	60	27.3 a-e	2.15 b-f
16	60	120	30.0 a	2.79 a
17	0	180	26.2 cdef	2.67 ab
	Mean		27.7	2.46

[1] Within each data column, means not followed by a common letter are significantly different (5% level) using Duncan's Multiple Range Test.

The differences in spikelets–per–panicle numbers between the present study and results in Michigan may be due to (a) innate characteristics of the different bromegrass strains used or (b) dissimilar growing conditions. One of the major climatic differences between the two study locations is precipitation received—for the months of March thru June, the Alaska site normally receives 2.8 inches while the Michigan site receives 11.9 inches (U.S. Dep. Agric.1941) and in the study year reported did receive that amount (Harrison and Crawford 1941).

Seeds Per Spikelet

Mean seeds per spikelet ranged from 1.9 to 2.4 and the overall mean was 2.2. No patterns of response were apparent and differences among treatments were not significant.

Seed Weight Per Panicle

Seed weight per panicle ranged from 106 milligrams (where no N was applied) to 179 milligrams where N was applied at 135 or 180 lb/A on 24 April 1985 (Fig. 11). As increasing proportions of each N rate were applied in April 1985, the seed weight per panicle in August 1985 increased regularly, though not always by a significant amount. The heaviest panicles were produced with all of each N rate applied in April. No significant increases in seed weight per panicle resulted from N rates higher than 90 lb/A.

Seed Yields

Seed yields in August 1985 ranged from 34 lb/A where no N had been applied to 583 lb/A where N had been applied at 180 lb/A on 28 August 1984 (Fig. 12). The five highest–yielding treatments that did not differ significantly resulted in yields from 528 to 583 lb/A. Two of those treatments involved N application only in August (135 and 180 lb/A) while the other three were split applications.

Aftermath Forage Yields

Oven–dry forage yields harvested on 19 August after seed harvest ranged from 0.87 T/A (unfertilized check trtmt.) to 2.79 T/A (trtmt. 16) (Table 2). Within each four–treatment set that received the same rate of N (whether all in Aug. 1984, all in April 1985, or split between the two dates) there was a general trend toward higher yields as more of each rate was applied in spring; however, few differences within each rate were significant.

A general trend also existed for higher forage yield with increasing rates of applied N (regardless of time of application). Mean forage yields for 45, 90, 135, and 180 lb N/A were 1.71, 2.05, 2.34, and 2.46 T/A. All 16 N treatments resulted in significantly higher forage yield than the unfertilized check treatment. No analyses of herbage quality were conducted; however, there were undoubtedly differences in quality in favor of plots that received N in spring, and especially at the higher rates that resulted in very leafy herbage (see cover photo) but poor seed yields. Herbage harvested for the first time in mid–August (from established bromegrass) is generally of modest nutritional quality (Klebesadel 1970b). Moreover, if the aftermath, after combine–harvest of seed, is intended for hay, that forage should be harvested as soon as possible as herbage quality is declining rapidly at that time (Knowles *et al.* 1951).

Experiment III: Effects of N application at various times during the year on heading and on other components of seed yield.

All applications of N in this experiment were at the rate of 100 lb/A. N was applied on 10 dates (7 in 1985, 3 in 1986) prior to the 1986 seed harvest on 4 August.

Panicle Numbers and Seed Yields

Panicle numbers per plot (Fig. 13) and seed yields (Fig. 14) were both influenced markedly by the different times of N application. Panicles were most abundant with N applied on 15 or 27 August of 1985, the year prior to the seed crop, and seed yield was highest with N application on 27 August. Panicle numbers and seed yields were progressively smaller as N application dates were increasingly earlier or later than those August dates.

Considering the difference in seed yield in 1986 between the optimum date of N application in 1985 (27 Aug.) and the latest date in 1985 (25 Sep.), the latter date of N application resulted in a 127 lb/A lower seed yield. Thus, over the 29 days between the two N application dates, seed yield in 1986 averaged 4.4 pounds less for each day that N application was delayed after 27 August in 1985.

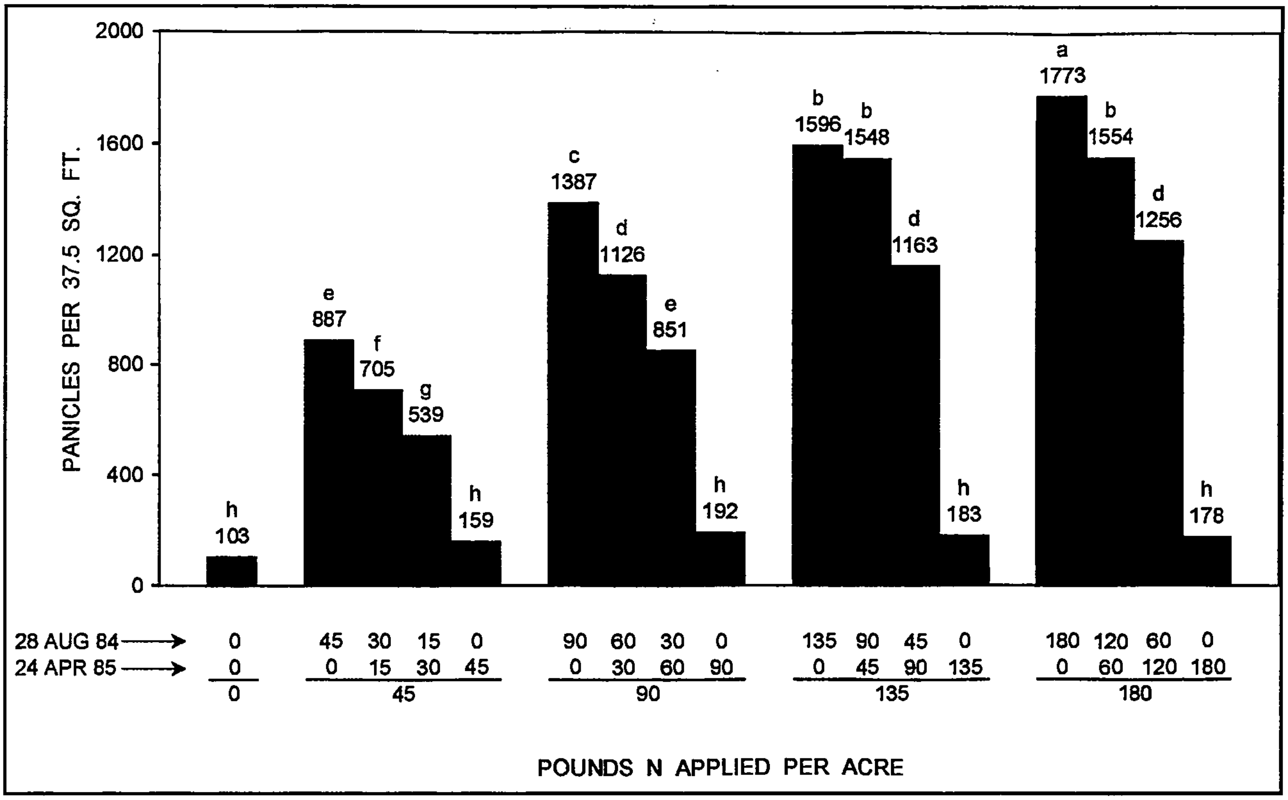

Figure 9. Panicles per 37.5 square foot plot of Polar bromegrass in August, 1985 as influenced by four rates of N topdressing applied 28 August 1984 or 24 April 1985 or split between the two dates. Graph bars not having a common letter above the panicle number above each bar differ significantly (5% level) using Duncan's Multiple Range Test. Rows planted 14 June 1983 (Exp. II).

Seed Weight Per Panicle

The minor discrepancies in values between the graph of panicle numbers (Fig. 13) and that of seed yield (Fig. 14) were caused by differences in seed weight per panicle as influenced by different times of N application as shown in Figure 15.

Seed weight per panicle was highest, 164 and 156 milligrams, respectively, with N applications on 19 April and 14 May in the year of the seed crop (Fig. 15). Seed weight per panicle decreased regularly as N applications were made progressively earlier or later than those two most favorable dates. This effect agrees with results of Exp. I wherein spring N applications resulted in higher seed weights per panicle than applications in August of the prior year.

Incidence of White–top

The different times of N application affected the incidence of sterile white–top panicles in the 1986 seed crop (Fig. 16). Percent white–top panicles ranged from 1.8 for application on 16 June

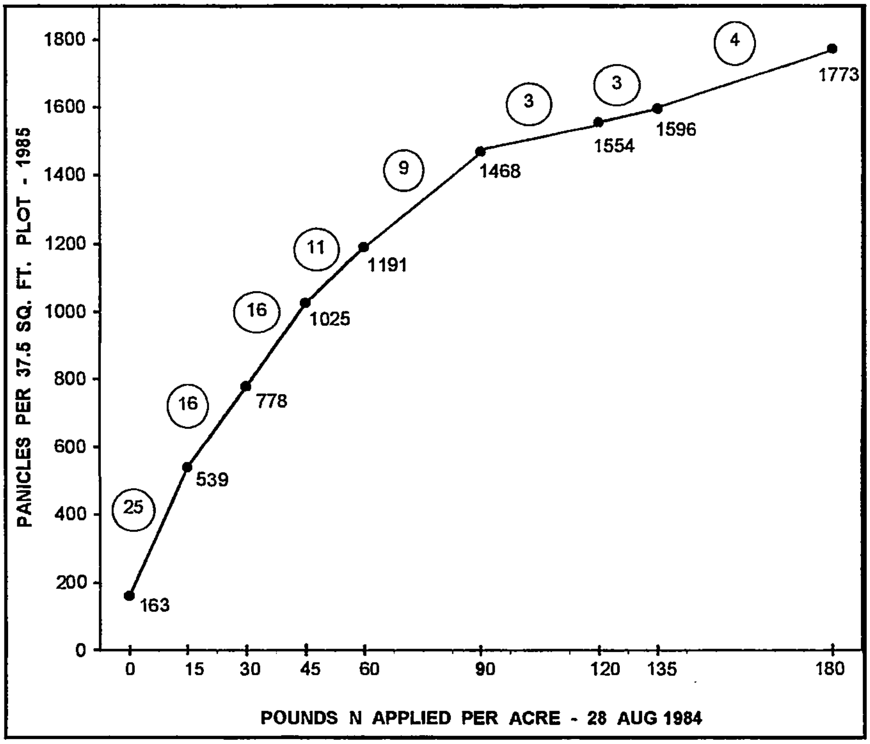

Figure 10. Influence of N rates applied 28 August 1984 on Polar bromegrass panicle numbers per 37.5–square–foot plot in 1985. Means were calculated where more than one treatment supplied the same rate of N. Circled values between points are the increase in number of panicles per plot for each pound of N applied per acre (Exp. II).

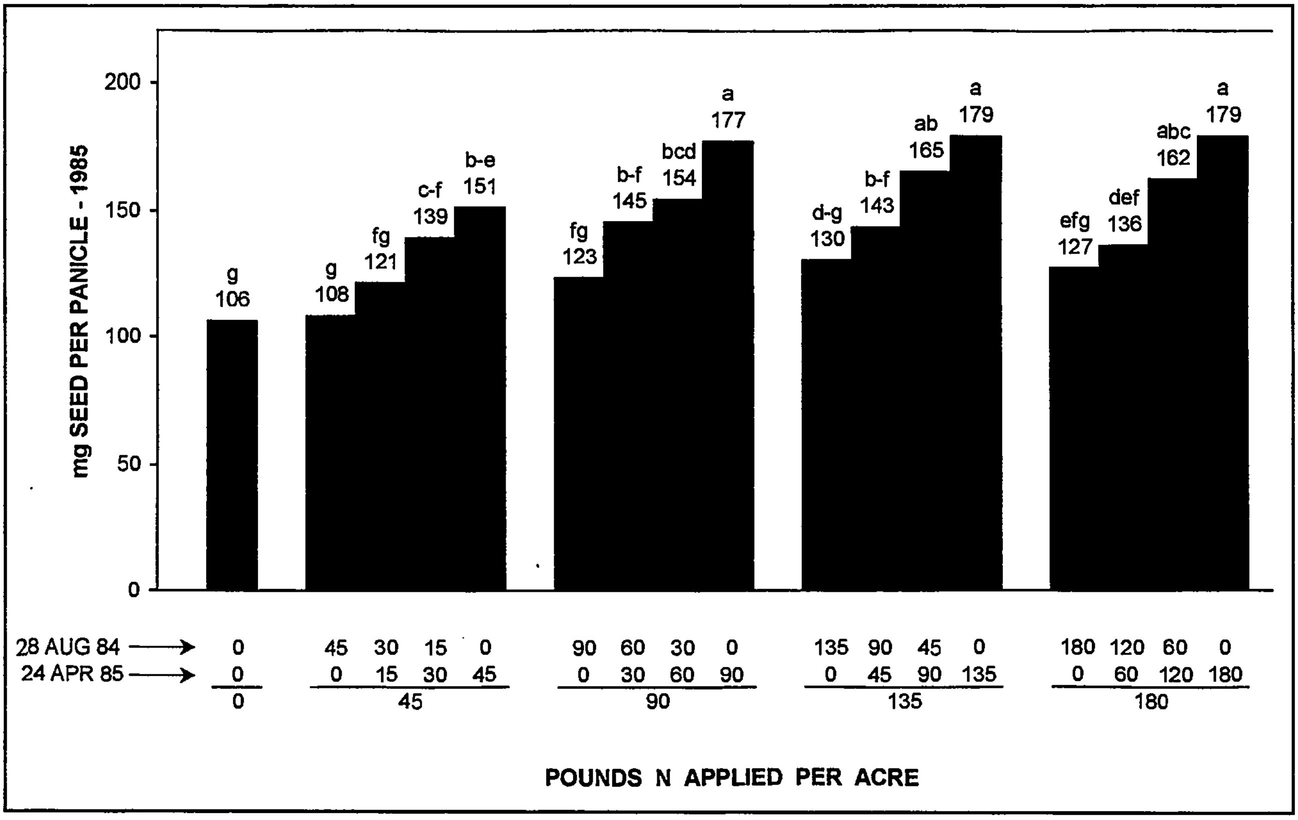

Figure 11. Milligrams of seed per panicle of Polar bromegrass at seed harvest on 14 August 1985 as influenced by four rates of N topdressing applied 28 August 1984 or 24 April 1985 or split between the two dates. Graph bars not having a common letter above the panicle–weight value above each bar differ significantly (5% level) using Duncan's Multiple Range Test. Rows planted 14 June 1983 (Exp. II).

1986 to 37.0 for application on 15 August 1985. Incidence of white–top became less as N application dates were progressively earlier or later than the 15 August 1985 application.

No obvious explanation is available for the pattern of white–top incidence as influenced by N application dates, nor why the 16 June 1986 application caused a lesser incidence of white–top than even the check treatment. The very high incidence of white–top for all seven dates of application in 1985 (all above 26%), as well as the 23% incidence with N applied 19 April 1986, indicates that this malady can reduce seed yields markedly.

Experiment IV: Effects of N rates and forage harvest in the seeding year on heading and on other components of seed yield the following year.

In previous experiments in this report and an earlier bulletin (Klebesadel 1996) it was found that management actions in the year prior to the year of seed production could influence seed yields significantly in established stands of bromegrass. An earlier report (Klebesadel 1970b) showed the marked influence of planting date on seed production of Polar and pumpelly bromegrasses in the following year. Experiment IV was designed to evaluate certain other management variables in the seeding year to learn if they might affect, and hopefully enhance, seed yields in the first year of seed production (second year of stand).

The intent of Exp. IV was to evaluate two factors: First, the effects of additional N applied at different times and rates during the seeding year to supplement the 32 lb/A applied in the preplant seedbed application. That seedbed fertilizer logically would be mostly taken up during the growing season in producing plant growth, leaving little N available to late–season tillers; other experiments in this study had shown N supply during the latter portion of the growing season to be a critical factor in promoting heading and thus seed production in the following year.

Second, it had been standard practice previously at this station to plant bromegrass seed–production fields in spring and remove topgrowth as forage at any convenient time before or after autumn killing frost. Thus, a forage crop was obtained late during the year of establishment, and the seed fields overwintered as clean stubble for unimpeded grass growth in spring (fertilizer topdressings were then applied in spring as recommended by reports from studies at lower latitudes).

Late removal of seeding–year topgrowth resulted in heavy shading of the new tillers emerging late in the growing season; it is known from other work (Watkins 1940; Klebesadel 1996) that shading has a suppressing effect on later heading. Moreover, leaving the aerial growth in place until late in the growing season resulted in minimal development of those tillers, inasmuch as growth emphasis was directed principally into the primary tall growth of the plants.

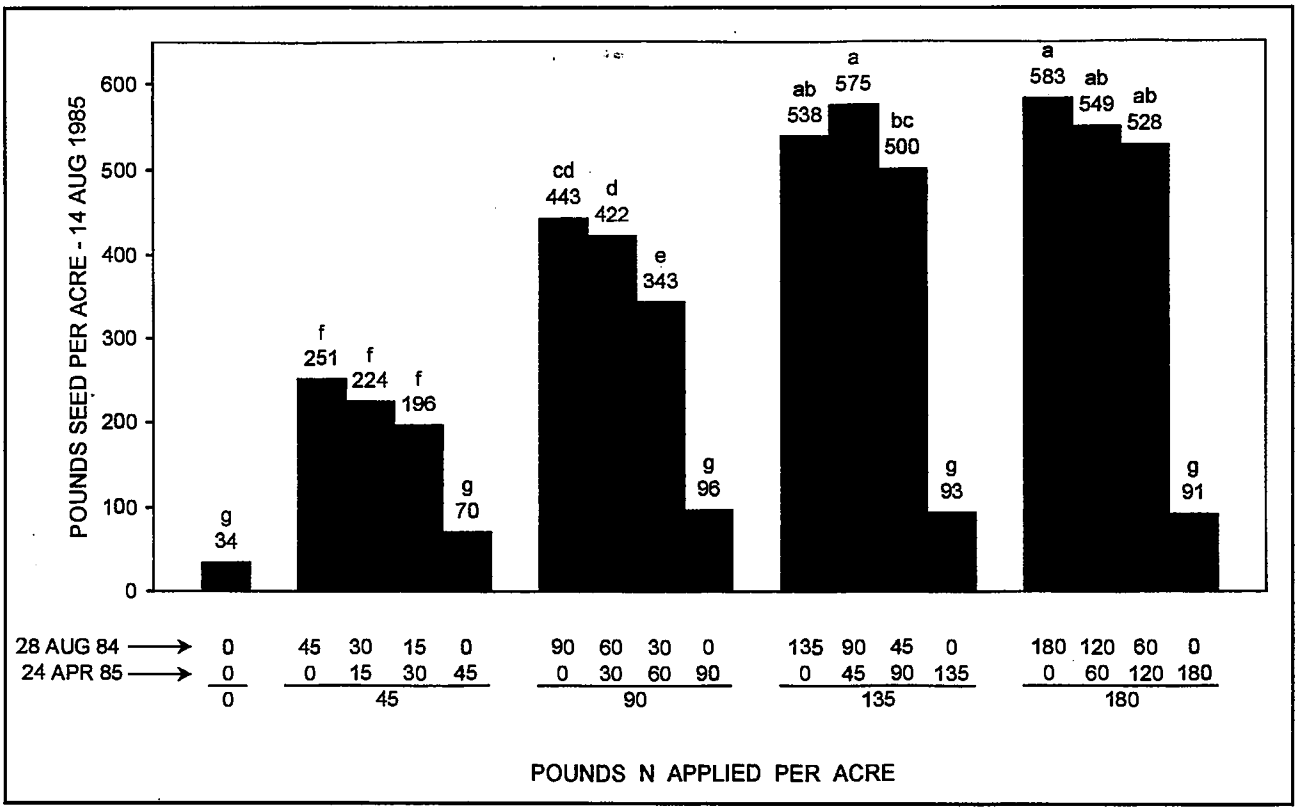

Figure 12. Seed yield of Polar bromegrass on 14 August 1985 as influenced by four rates of N topdressing applied 28 August 1984 or 24 April 1985 or split between the two dates. Graph bars not having a common letter above the seed–yield amount above each bar differ significantly (5% level) using Duncan's Multiple Range Test. Rows planted 14 June 1983 (Exp. II).

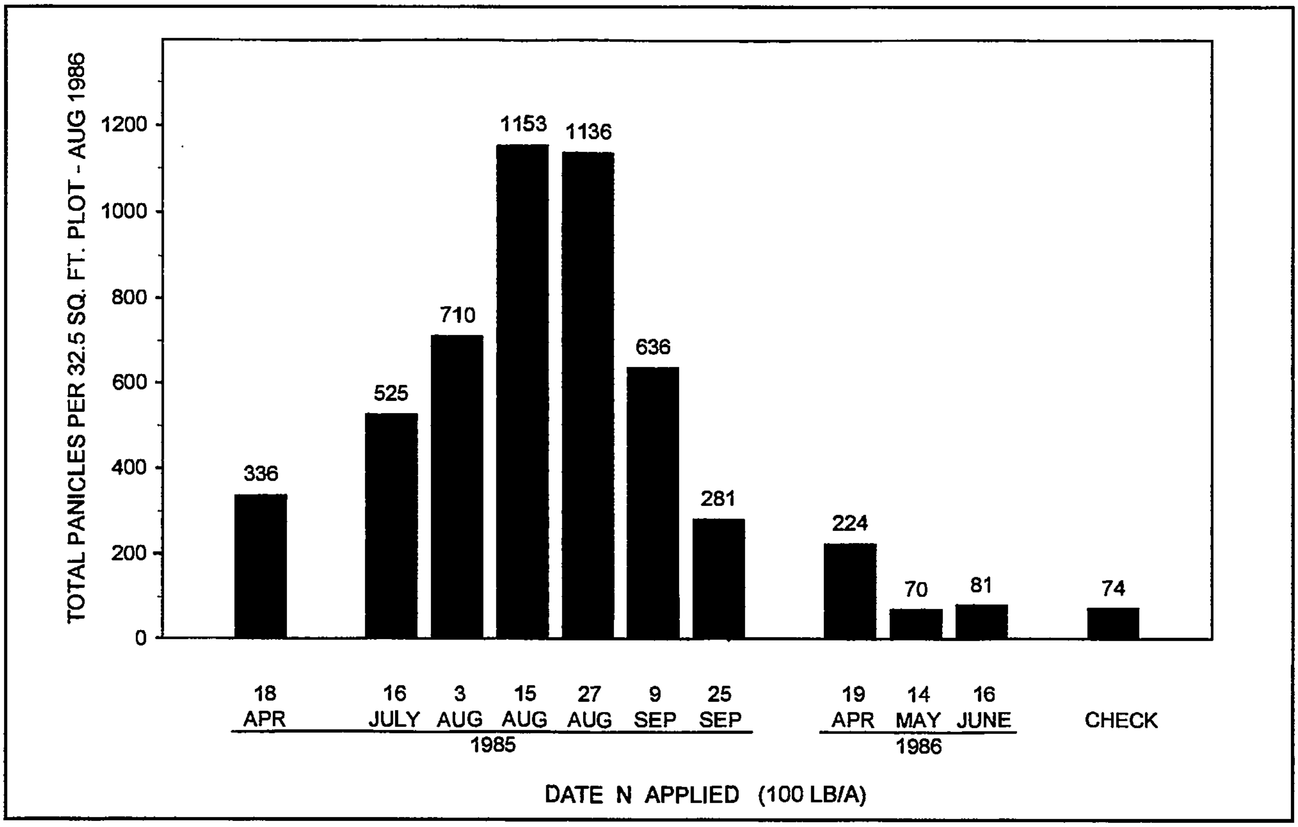

Figure 13. Numbers of Polar bromegrass panicles per 32.5 square foot plot at 1986 seed harvest as influenced by different times of N application during 1985 and 1986 on rows planted 14 June 1983 (Exp. III).

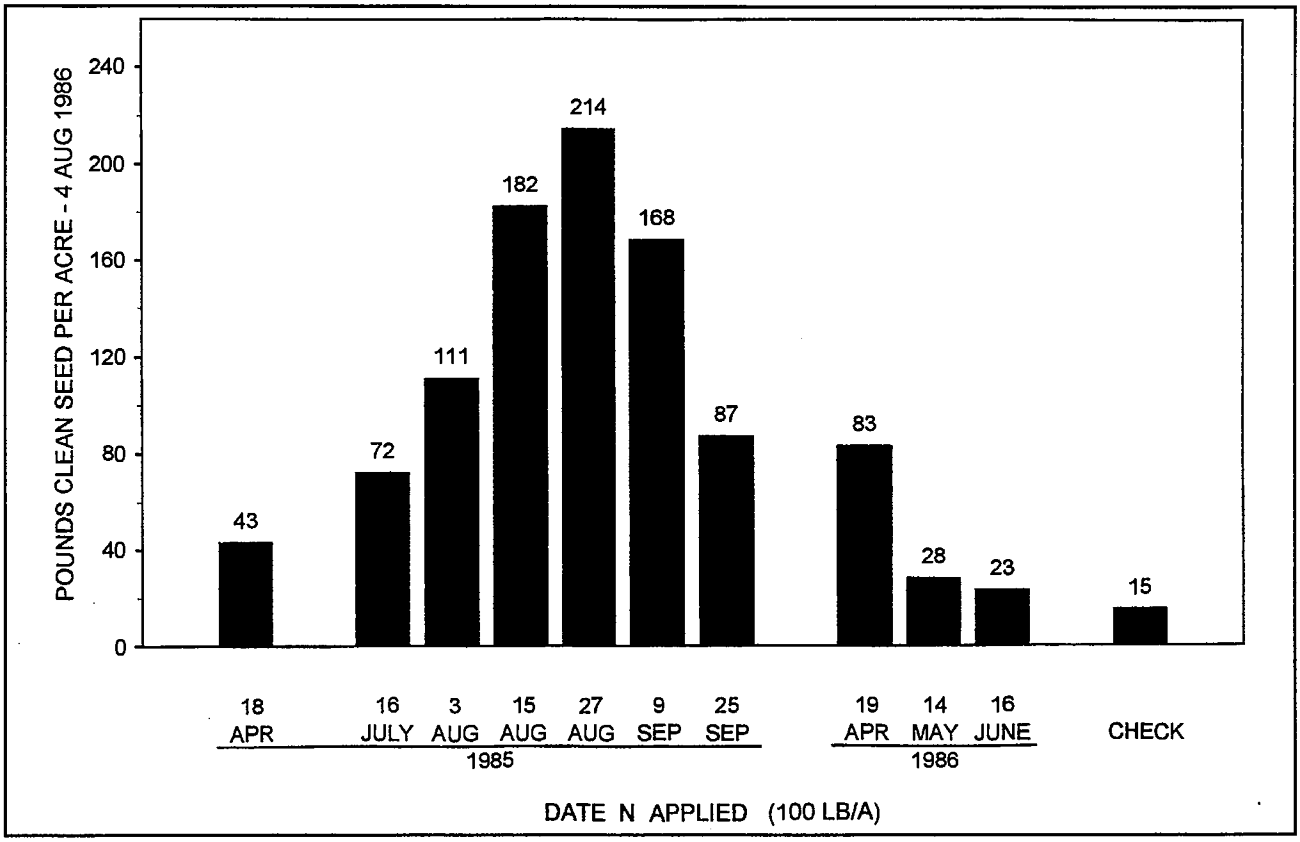

Figure 14. Pounds clean Polar bromegrass seed per acre in the 1986 seed harvest as influenced by different times of N application during 1985 and 1986 on rows planted 14 June 1983 (Exp. III).

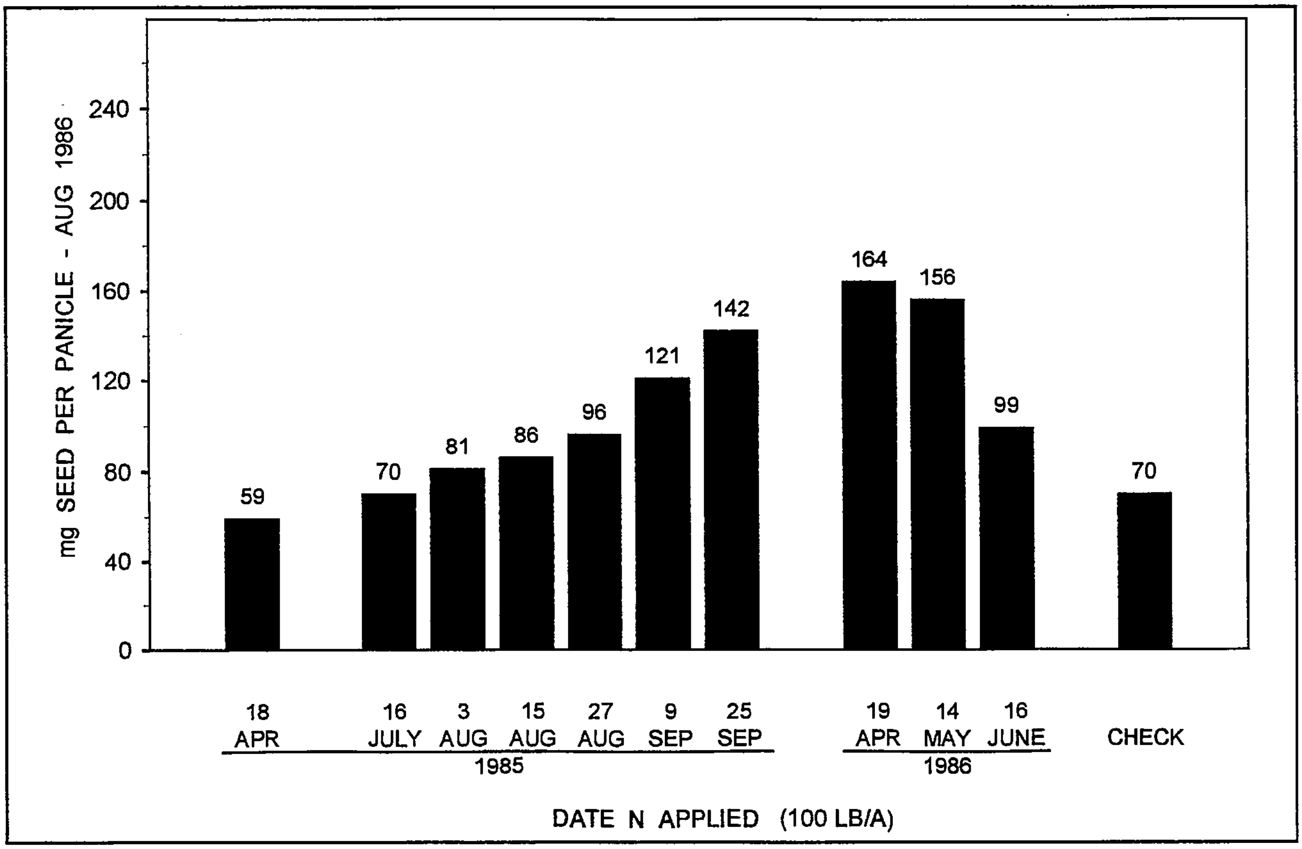

Figure 15. Mean milligrams seed per Polar bromegrass panicle in the 1986 seed crop as influenced by different times of N application during 1985 and 1986 on rows planted 14 June 1983 (Exp. III).

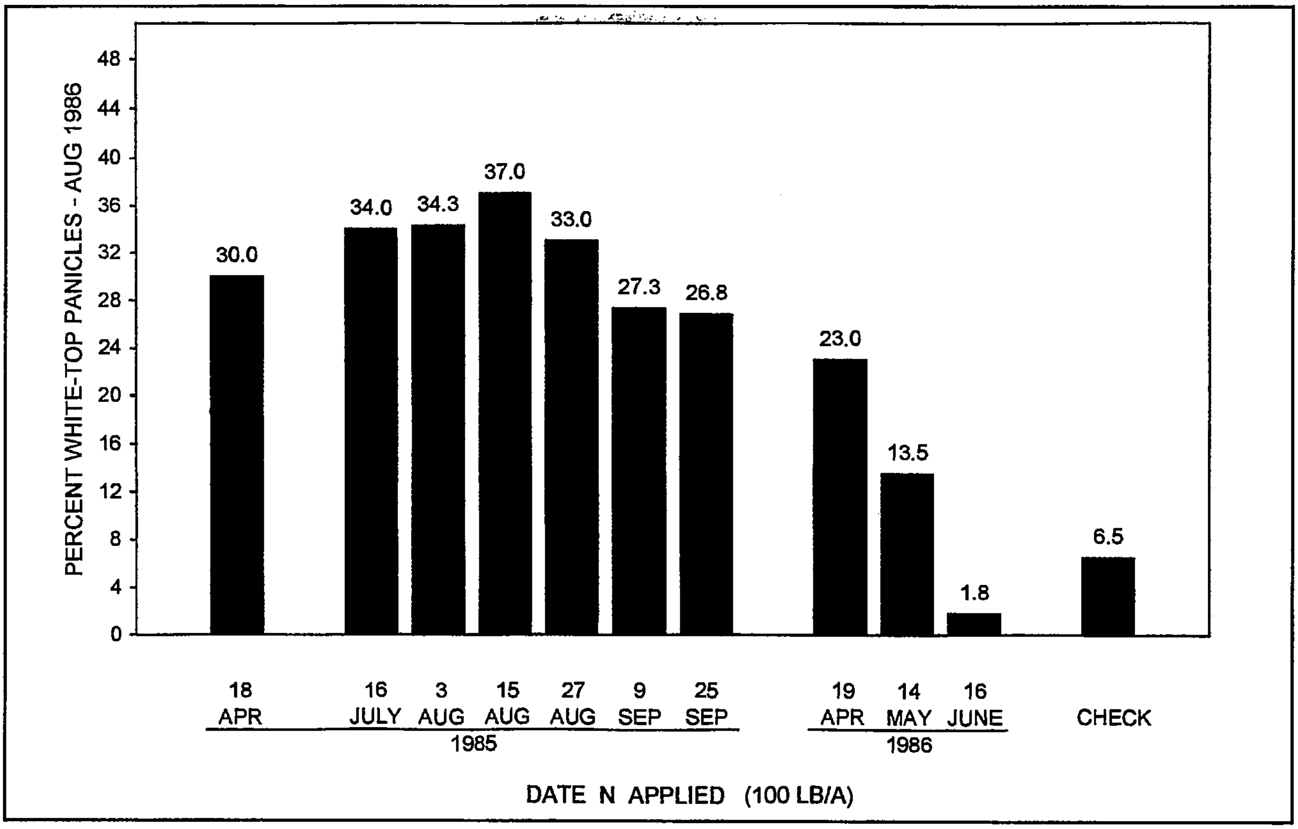

Figure 16. Percent sterile "white–top" panicles in the 1986 Polar bromegrass seed crop as influenced by different times of N application during 1985 and 1986 on rows planted 14 June 1983 (Exp. III).

Earlier work (Fig. 13 in Klebesadel 1993b) not concerned with seed production showed that removal of seeding–year aerial growth near 15 August, as opposed to near killing frost, resulted in a dense, robust, leafy growth of unshaded, unelongated tillers prior to freeze–up. It was reasoned that those tillers in a seed–production field, with adequacy of applied N, should be ideally developed for beneficial exposure to autumn photoperiod/nyctoperiod influences that promote development of inflorescence primordia and thus increased heading and seed yield the following year.

Seeding–Year Forage Yields

Seeding–year forage yields ranged from 1.37 T/A (trtmt. 1, with no added N and harvests 20 July and 5 Oct.) to 1.94 T/A (trtmt. 12, with N at 100 lb/A applied 21 July and forage harvest on 5 October (Table 3). These yields compare well with seeding–year forage yields of Manchar and Polar bromegrass reported earlier (Klebesadel 1993b).

No forage–quality factors were measured in the present study, but in the earlier study (Klebesadel 1993b) crude protein in seeding–year forage declined from about 23% for that harvested on 10 August to about 12% with harvest on 1 October. The topdressings of additional N with treatments 11 and 12 on 21 July in the present experiment logically would have increased crude protein levels in the forage harvested 5 October.

At the first forage harvest on 20 July (trtmts. 1, 2, 3) the grass ranged from 12 to 22 inches tall. Though most bromegrass culms do not produce panicles in the seeding year, the first of those few produced were just being exserted with most of the remainder in boot stage. Only about 50 panicles were visible over the entire experimental area. On that date it was noted that a considerable number of tillers were emerging through the soil surface from laterally spreading rhizomes (Fig. 2), some up to six inches distant from the seeded row.

On 15 August, when treatments 4, 5, and 6 were harvested, the grass was 30 to 38 inches tall with about 10 to 20 panicles visible over each 9–by 30–foot main plot. On that date, plots that had been harvested on 20 July had regrown to 16 to 18 inches tall.

At the 14 September forage harvest of treatments 7, 8, and 9 an estimated 30 to 35 panicles were visible per main plot, with the grass about as tall as was noted on 15 August.

Of special interest is the starkly different types of regrowth that developed after forage harvests on 20 July (a tall regrowth of elongated culms) versus 15 August (no elongation of culms in the very short, leafy regrowth). At the 5 October first harvest of treatments 10, 11, and 12, and the reharvest of treatments 1, 2, and 3 (that previously had been harvested on 20 July) regrowth on the latter plots appeared taller than on the unharvested plots due to some lodging of the growth on those previously unharvested plots (Fig. 17). In contrast, no culm elongation occurred in the regrowth of plots harvested 15 August (trtmts. 4, 5, 6); those rows showed only a proliferation of leaves on the many short tillers that had emerged (Fig. 17).

Table 3. Influence of forage harvest and N fertilization in the seeding year on second-year characteristics of seed production of Polar bromegrass seeded in rows 17 May 1984 (Exp. IV).

1984					1985					
					Per 22.5 sq. ft.					
Treatment no.	Forage harvest dates	Forage yield[1]	N application		Total culms	Vegetative culms	Panicle-bearing culms	Culms headed	Seed weight per panicle	Aftermath forage yield[1]
	dates	T/A	lb/A	date	no.	no.	no.	percent	milligrams	T/A
1	20 July + 5 Oct	0.24 + 1.13 = 1.37 e	0	—	790 c[2]	271 d	519 cde	65 abc	130 cde	1.08 ab
2	20 July + 5 Oct	0.24 + 1.20 = 1.44 cde	50	21 July	1108 b	457 cd	651 bcd	60 abcd	154 bc	1.56 ab
3	20 July + 5 Oct	0.24 + 1.27 = 1.51 bcde	100	21 July	1176 ab	512 abcd	664 bc	57 bcd	163 b	1.45 ab
4	15 Aug	1.40 de	0	—	1175 ab	408 cd	767 b	66 ab	126 de	1.53 ab
5	15 Aug	1.40 de	50	16 Aug	1451 ab	439 cd	1012 a	70 ab	123 e	1.73 a
6	15 Aug	1.40 de	100	16 Aug	1501 a	422 cd	1079 a	72 a	138 bcde	1.76 a
7	14 Sep	1.81 abc	0	—	740 c	259 d	481 de	65 abc	120 e	0.92 b
8	14 Sep	1.81 abc	50	15 Sep	1255 ab	492 bcd	763 b	62 abcd	147 bcde	1.53 ab
9	14 Sep	1.81 abc	100	15 Sep	1297 ab	617 abc	680 bc	53 cde	194 a	1.74 a
10	5 Oct	1.79 abcd	0	—	1197 ab	779 a	418 e	37 f	160 b	1.82 a
11	5 Oct	1.87 ab	50	21 July	1155 ab	572 abc	583 cde	51 de	147 bcde	1.51 ab
12	5 Oct	1.94 a	100	21 July	1342 ab	754 ab	588 cde	44 ef	152 bcd	1.79 a

[1] Oven-dry basis.

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

Gall (1947) and Evans and Wilsie (1946) reported that bromegrass requires 15- to 16-hour photoperiods for culm elongation. Prevailing photoperiods at this location at the time of the 20 July and 15 August harvests were 18 hr. 10 min. and 15 hr. 56 min., respectively (List 1958). With a time lag for new tillers to begin growth after harvest and to become responsive to photoperiodic influences, it is apparent that photoperiods were sufficiently long to promote tiller elongation after the 20 July harvest, but not after the 15 August harvest.

Seeding–Year Tiller Development

Notes taken on all plots on 20 October 1984, after all seeding–year harvests had been taken and new tiller growth had ceased, were as follows:

	Forage harvests during 1984			
Visual estimates of percent of total area of plots covered by:	20 July + 5 Oct	15 Aug	14 Sep	5 Oct
Bare ground	87	40	80	84
Bare stubble	10	0	5	15
Green tiller leaves	3	60	15	1

Total Culms Produced

Treatments 1 and 7 that had no additional N applied in 1984 (beyond the seedbed application) resulted in significantly fewer total culms in 1985 than all other treatments (Table 3). Treatment 2 had significantly fewer total culms than treatment 6. Differences among the other treatments were not significant. However, except for treatments harvested only once on 5 October, treatments that received no added N in the seeding year (trtmts. 1, 4, 7) tended to have fewer total culms than treatments that received added N.

Percent of Total Culms Producing Panicles

Among all treatments, the lowest percentage of culms producing panicles in 1985, 37%, occurred with treatment 10, which received no additional N during the seeding year and was harvested once on 5 October (Table 3). In contrast, treatment 6, which had herbage removed on 15 August 1984 and N added then at 100 lb/A resulted in 72% of culms producing panicles, almost twice the percentage of treatment 10 and more than in any of the other experiments reported here. Treatment 5, managed identical to treatment 6 except for a lighter N topdressing, produced 70% headed culms, virtually as many as treatment 6.

Panicle Numbers

Panicles per plot ranged from 418 (trtmt. 10) to 1079 (trtmt. 6) (Table 3). It bears mention that treatment 10, the least favorable one, was closest in management (no additional N during seeding year + late harvest of aerial growth) to prior standard operational procedure for seed fields at this station. Treatment 6 resulted in more than 2½ times more panicles per plot than that previously standard practice (trtmt. 10). Plots that were harvested for forage 15 August 1984 and had 50 or 100 lb N/A applied in the seeding year (trtmts. 5 and 6) had significantly more panicles per plot than all other treatments.

Seed Weight Per Panicle

Mean seed weight per panicle ranged from 120 to 194 milligrams (Table 3). Treatment 9, at 194 milligrams, significantly surpassed all other treatments. With N at the heaviest rate (100 lb/A), applied the latest of all dates (15 Sep.), there undoubtedly was considerable carryover of N supply from 1984 to spring growth of tillers in 1985. Thus, the high

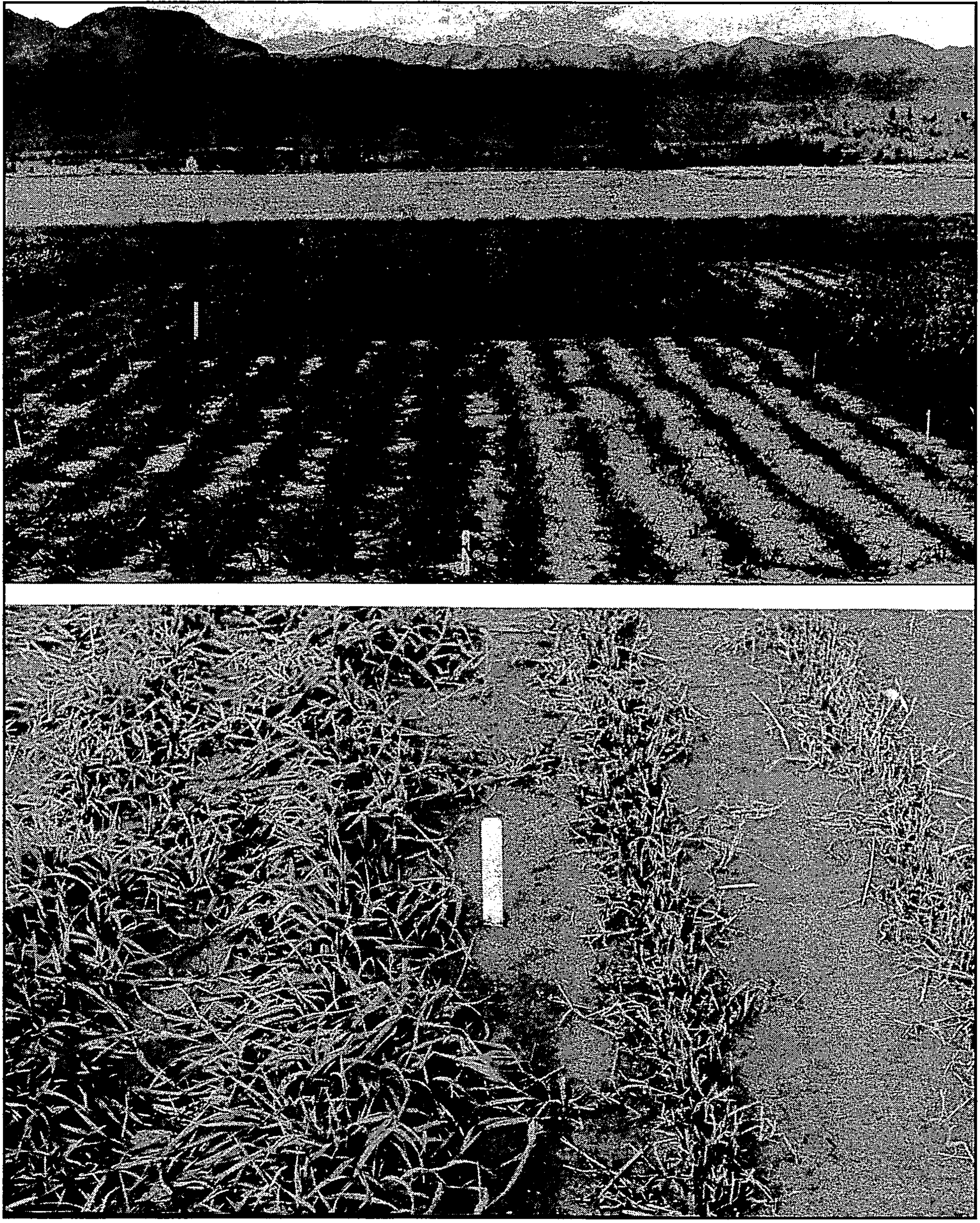

Figure 17. (Upper): Photo 15 September 1984 of Polar bromegrass seed rows planted 17 May 1984 and harvested for forage on 15 August (left foreground) and 14 September (right foreground). Rows left of center in background have regrown tall since harvest on 20 July; rows right of center in background were not harvested until 5 October and show some lodging on this date. (Lower): Photo 10 October 1984 of rows harvested once for forage on 15 August (left) and twice on 20 July and 5 October (right). The proliferation of short but leafy tiller growth during the late portion of the growing season on rows harvested 15 August (with additional N topdressed then) favored seed production the following year (Fig. 18).

seed weight per panicle in treatment 9 is consistent with earlier experiments in this report where spring–applied N resulted in high seed weights per panicle. Two other treatments with the highest rate of applied N (200 lb/A) also tended to be highest of the 3–treatment groups in seed weight per panicle (trtmts. 3, 6).

Seed Yields

Seed yields in 1985 ranged from 248 (trtmt. 7) to 638 lb/A (trtmt. 6) (Fig. 18). Within each 3–treatment group (categorized by time of forage harvest in the seeding year), seed yields always increased where higher rates of N had been added in 1984, although differences were not always statistically significant.

Seed yields are determined by the cumulative influence of all of the components of yield; however, the dominant factor was the number of panicles per unit of area, followed by seed weight per panicle. An example of how these two components combine for effect on seed yield is seen in treatment 9. Although treatment 9 had a slightly lower density of panicles than treatment 8 (Table 3), treatment 9 resulted in a higher seed yield (Fig. 18) than treatment 8 due to a significantly higher seed weight per panicle (Table 3).

The lowest seed yield (248 lb/A) occurred with treatment 7. An earlier bulletin on seeding–year management of bromegrass for forage (Klebesadel 1993b) reported that seeding–year harvest in early–to–mid September was more harmful to subsequent winter survival of bromegrass than earlier or later dates. Forage harvest on 14 September may have predisposed treatment 7 to poorer winter survival of floral primordia. However, treatments 8 and 9, also harvested for forage on 14 September of the seeding year (but supplied immediately thereafter with N), surpassed several of the other treatments in seed production.

Aftermath Forage Yields

Forage yields (Table 3) of the tall aftermath growth include both the non–headed and the headed culms (but with panicles removed). Yields ranged from 0.92 (trtmt. 7) to 1.82 T/A (trtmt. 10). The only significant differences were that treatment 7 resulted in significantly lower yield than treatments 5, 6, 9, 10, and 12.

Monitored Fate of Tillers

Forty–four tillers were tagged on 20 October 1984, when growth had ceased, to learn if stage of pre–winter development in the various treatments was related to heading or non–heading the following year. At least 10 were tagged within each seeding–year forage harvest treatment, five in the unfertilized plot, and five in the plot that received N at 100 lb/A (Table 4).

A surprising number (18) of the tagged tillers died between tagging and evaluation; most died during winter. More died (6 of 10) in treatments 1 and 3 (where plants had been

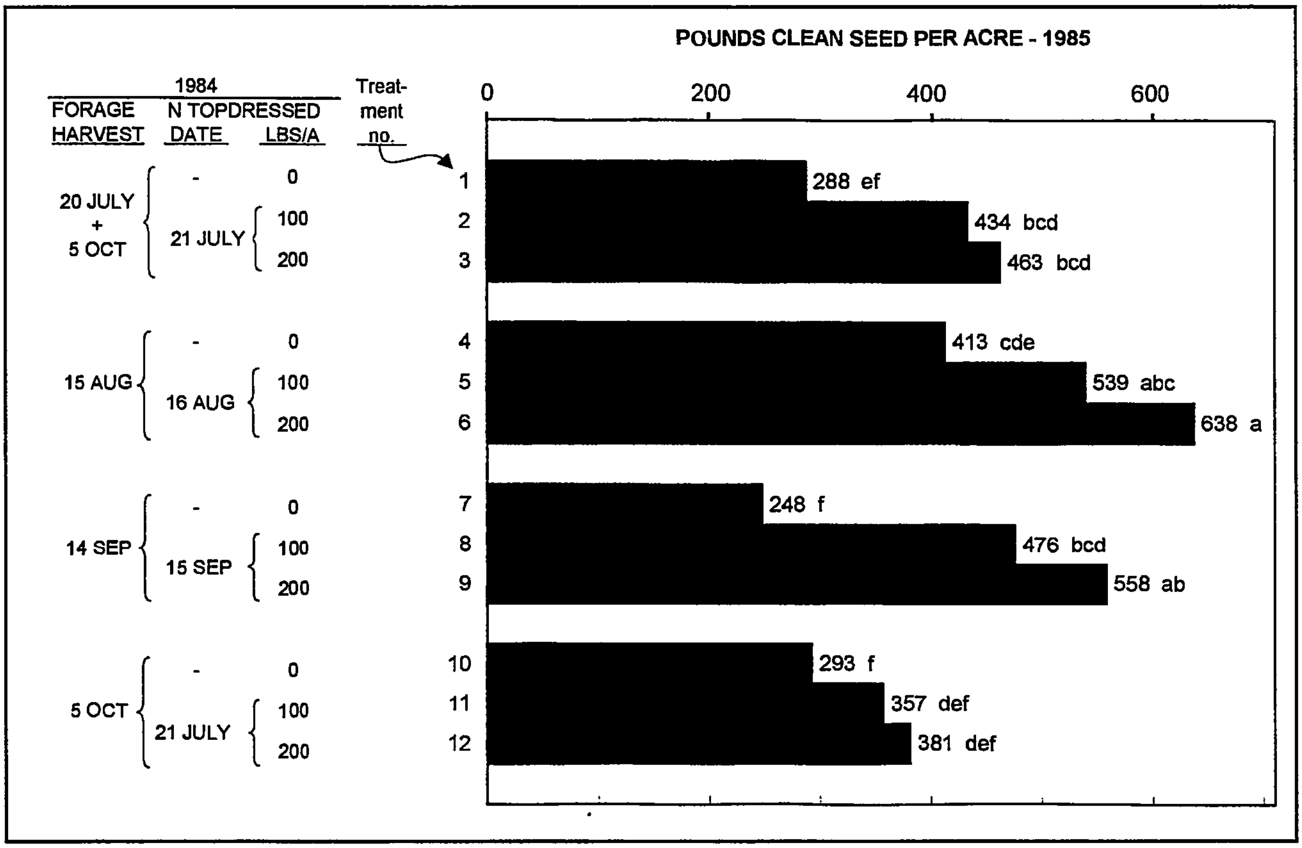

Figure 18. Seed yields of Polar bromegrass in first harvest year (1985) as influenced by twelve different management treatments during the seeding year. Rows planted 17 May 1984. (Exp. IV).

Table 4. Fate in 1985 of Polar bromegrass tillers of various sizes and extents of development when tagged 20 October 1984 (Exp. IV).

	1984						1985	
				Development at tagging				
Treatment number[1]	Tiller letter I.D.	Seeding–year forage harvested	N in seeding year[2]	Stage in Fig. 3[3]	Open leaves	Died between tagging and evaluation	Developed as vegetative culm	Developed as headed culm
		dates	lb/A		no.			
1	a	7/20 + 10/5	0	F	3	yes	—	—
	b	7/20 + 10/5	0	C	0	—	yes	—
	c	7/20 + 10/5	0	D	1	—	—	yes
	d	7/20 + 10/5	0	C	0	—	yes	—
	e	7/20 + 10/5	0	H	5	yes	—	—
3	a	7/20 + 10/5	100	E	2	—	—	yes
	b	7/20 + 10/5	100	C	0	yes	—	—
	c	7/20 + 10/5	100	F	3	yes	—	—
	d	7/20 + 10/5	100	D	1	yes	—	—
	e	7/20 + 10/5	100	F	3	yes	—	—
4	a	8/15	0	G	4	—	—	yes
	b	8/15	0	E	2	—	—	yes
	c	8/15	0	G	4	—	—	yes
	d	8/15	0	G	4	yes	—	—
	e	8/15	0	F	3	—	—	yes
	f	8/15	0	E	2	—	—	yes
6	a	8/15	100	H	5	—	—	yes
	b	8/15	100	H	5	—	—	yes
	c	8/15	100	E	2	—	—	yes
	d	8/15	100	C	0	—	yes	—
	e	8/15	100	F	3	—	yes	—
	f	8/15	100	H	5	—	—	yes
	g	8/15	100	E	2	yes	—	—
	h	8/15	100	H	5	yes	—	—
7	a	9/14	0	F	3	—	—	yes
	b	9/14	0	C	0	—	—	yes
	c	9/14	0	D	1	yes	—	—
	d	9/14	0	F	3	—	—	yes
	e	9/14	0	B	0	—	—	yes
9	a	9/14	100	E	2	yes	—	—
	b	9/14	100	D	1	—	—	yes
	c	9/14	100	F	3	—	—	yes
	d	9/14	100	F	3	yes	—	—
	e	9/14	100	B	0	(tag disappeared)		
10	a	10/5	0	C	0	yes	—	—
	b	10/5	0	E	2	yes	—	—
	c	10/5	0	B	0	—	yes	—
	d	10/5	0	E	2	—	—	yes
	e	10/5	0	E	2	—	yes	—
12	a	10/5	100	E	2	yes	—	—
	b	10/5	100	D	1	yes	—	—
	c	10/5	100	D	1	yes	—	—
	d	10/5	100	E	2	yes	—	—
	e	10/5	100	B	0	(tag disappeared)		

[1] Treatment number as identified in Table 3.

[2] In addition to pre–plant seedbed N at 32 lb/A (see Table 3 for dates of application).

[3] Letters used to identify stage of tiller development when tagged are those in Figure 3.

harvested for forage twice in the seeding year) and in treatments 10 and 12 where 6 of 9 died (where forage was harvested late on 5 October) than in the other treatments. There was a tendency for more to die where N had been applied at 100 lb/A (12 of 21 tillers = 57%) than in plots where no N was added during the seeding year (6 of 20 tillers = 30%). Harrison and Romo (1994) also reported a high winter mortality of tagged tillers in an older stand of bromegrass in Saskatchewan.

Only six of the 44 tagged tillers developed into vegetative, non–headed culms in 1985, while 18 developed into headed culms. A higher percentage (64%) of tagged tillers developed into headed culms in treatments 4 and 6 (where seeding–year forage harvest was taken on 15 August) than in the other treatments.

Most of the tillers that developed into vegetative culms had no opened leaf blades when tagged near freeze–up (4 of 6); though one had two leaves and the other had three.

Tagged tillers that developed into headed culms the following year had from 0 to 5 leaves when tagged, and most that headed (13 of 17) had two or more leaves. Thus, this exploratory tagging showed that tillers did not have to have several leaves opened before freeze–up in order to produce panicles the following year (although most that headed had reached that stage); two that had no opened leaf blades eventually headed.

Another class of tillers not considered in the tagging reported here are those whose tips remained below the soil surface in autumn and emerged after growth started in spring. More extensive tagging of tillers should be done both in autumn and in spring. Monitoring their eventual development should contribute to a better understanding of the relationship of tiller development to heading and to seed production.

Canode and Law (1978) noted with bromegrass: "Large tillers produced the highest percentage of seed heads ...small tillers produced the lowest percentage of seed heads." However, those tillers were rated in spring (late March) and were divided into size groups on the basis of diameter of tiller stem–base rather than number of opened leaf blades or extent of pre–winter emergence from the soil surface as depicted in Figure 3.

Experiment V: Seed yields as influenced by different row spacings versus broadcast seeding.

Highest seed yield (596 lb/A) in 1969 was obtained from rows spaced 24 inches apart (Fig. 19). Seed yields were progressively lower from rows progressively wider apart or closer together than 24 inches. Lowest yield in 1969 (399 lb/A) was obtained from broadcast seeding.

Yield differences among treatments were smaller in 1970, but the lowest yield (102 lb/A) was obtained from rows seeded 12 inches apart. Seed yields generally increased in 1970 with progressively wider row spacing.

Mean seed yield for all planting configurations was 500 lb/A in 1969 but only 32% of that (158 lb/A) in 1970

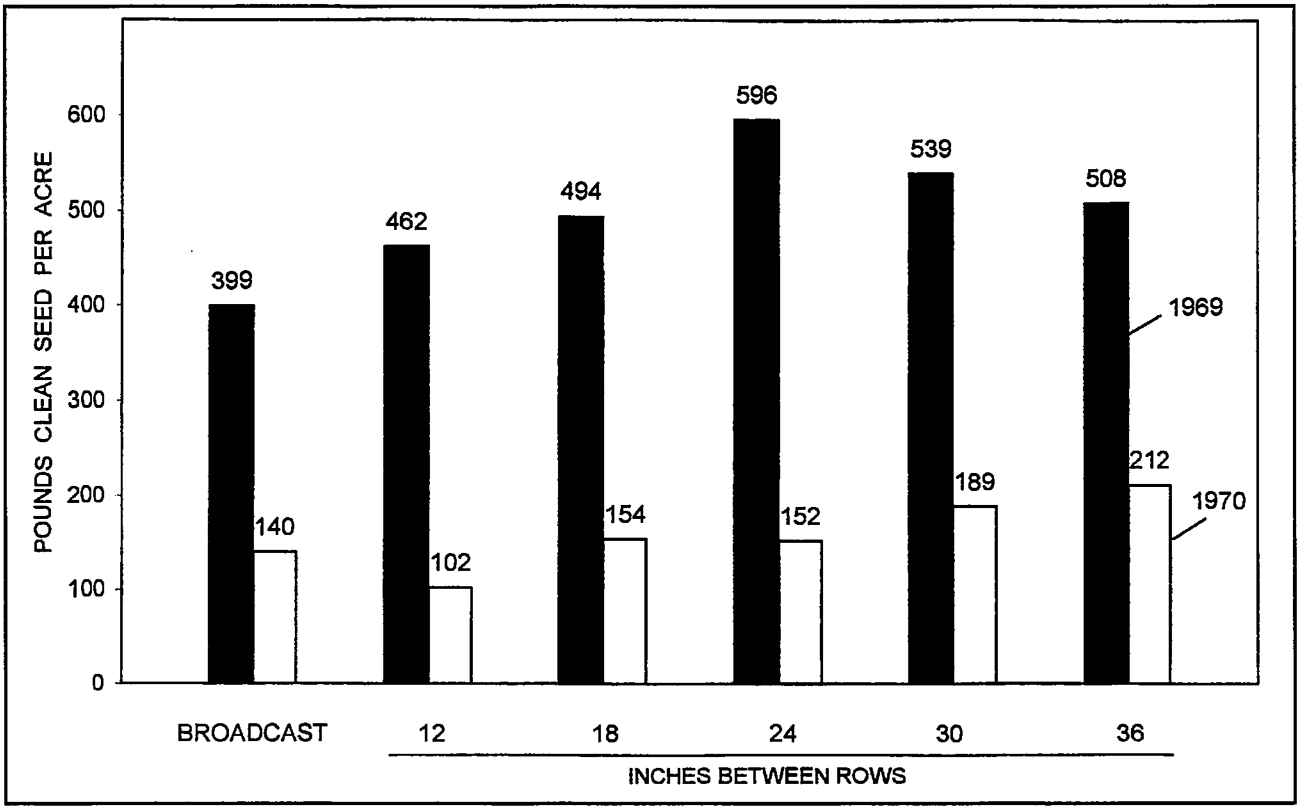

Figure 19. Seed yields of Polar bromegrass in two years (1969 and 1970) as influenced by broadcast seeding versus five different spacings between rows planted 19 June 1968 (Exp. V).

(Fig. 19). The normal tendency for decline in seed yield with advancing age of stands is generally recognized (Anderson *et al.* 1946; Carter 1965; Churchill 1944; Crowle and Knowles 1962; Knowles *et al.* 1951). However, the low 1970 yields (second year of seed production) represented a severe decline to uneconomic production levels. The low production in 1970 was somewhat puzzling inasmuch as N was applied at 82 lb/A on 12 August 1969, a rate and timing that in other experiments in this report promoted much higher seed yields the following year.

It is believed that moisture deficit was a major factor in suppressing seed yields in 1970. Total annual precipitation was considerably below normal in 1968, 1969, and 1970. The good seed yields in 1969, despite generally below average precipitation in most months, probably was helped by good rainfall totals in May and July of 1969 (1.67 and 2.83 inches, respectively). Moreover, the quite thick (3 to 4 feet) silt mantle over gravel at the Palmer location undoubtedly served as a good soil–moisture reservoir for a time (resulting in high 1969 yields) until the consecutive 3–year precipitation deficit resulted in depletion of soil moisture to the extent that seed yields suffered in 1970. Specifically, monthly precipitation totals for August and September, 1969, and April and May, 1970 (months that would contribute to effectiveness of the August 1969 N topdressing, and spring growth and seed yields in 1970), were only 0.49, 0.86, 0.54, and 0.27 inches, respectively.

Experiment Not Reported

A more comprehensive experiment than Exp. I with Polar bromegrass (15 trtmts) was conducted for seed production of native pumpelly bromegrass (26 trtmts). That experiment, in addition to summer versus spring application of different rates of N and P_2O_5, alone and together, (as in Exp. I) also evaluated the influence of potassium (K_2O) applied alone at two rates (90 and 180 lb/A) as well as with N, with P_2O_5, and with both of the latter nutrients.

Potassium had no effect on panicle density, seed weight per panicle, or seed yield. Inasmuch as the effects of N and P_2O_5 on panicle density, seed weight per panicle, and seed yield were virtually similar to those of Polar in Exp. I, the pumpelly brome experiment is not reported in detail here.

The one salient difference between Exp. I and the one with pumpelly brome was a considerably higher incidence of white–top panicles in the worst–afflicted treatments with the native bromegrass. With Polar in Exp. I, summer–applied N rates at 90 and 180 lb/A resulted in mean incidence of 17% and 10%, respectively. In contrast, the same summer–applied N rates with pumpelly brome averaged 41% and 26%, respectively.

One factor possibly contributing to the above differences in white–top occurrence between the two bromegrasses was that the pumpelly bromegrass was in its third seed–production year (planted in 1979—experiment in 1981–82) while Polar in Exp. I was in its second–seed production year (planted in 1980—experiment in 1981–82).

DISCUSSION

Time of N Application

In the introduction of this bulletin, several investigators in the conterminous 48 states (below 49°N) are cited whose reports state that N to stimulate seed production of bromegrass may be applied with equal effectiveness in autumn or in early spring.

Farther north in Canada (49° to 55°N), reports indicate that N application "in mid–September" or "prior to 1 October" may be more effective in increasing bromegrass production than later in autumn or in spring.

Results in the present report show conclusively that spring–applied N was ineffectual in promoting increased panicle numbers at this high latitude (61.6°N); its only contribution toward enhancing seed yield was to increase seed weight per panicle. Not only did an appropriate rate of N have to be applied in the year before seed is to be produced, N was most effective if applied in mid–to–late August at this northern latitude where growing seasons are shorter than in Canadian and U.S. bromegrass seed–producing areas.

Autumn and Spring Induction Conditions

It is generally agreed by several investigators that certain conditions are required for the microscopic growing point or primordium, hidden near the base of a bromegrass tiller (Fig. 2), to be induced to change from a vegetative primordium to a floral primordium that will produce a panicle. Those conditions include exposure of the tiller to short photoperiods/long nyctoperiods of specifically appropriate duration, and for the tiller to be supplied with an adequate level of N.

At high–latitude locations, as in southcentral Alaska, the unique interrelationship of seasonal photoperiod pattern and growing season apparently presents photoperiodic conditions conducive to bromegrass floral induction only in autumn (Hodgson 1966; Klebesadel 1970a, 1996). Mean dates of first autumn occurrence of temperatures of 32°, 28°, 24°, and 20°F at the Matanuska Research Farm are 12 September, 22 September, 7 October, and 20 October, respectively (Watson 1959). The killing temperature for bromegrass aerial growth is not known precisely; however, the above temperature pattern and general field observations indicate that frost killing of bromegrass vegetation normally occurs not long after the autumn equinox (when photoperiods and nyctoperiods are both 12 hours). Prior to freeze–up, however, plants are exposed to short photoperiods/long nyctoperiods of durations appropriate for inducing and initiating floral primordia (Fig. 20).

In contrast, spring growth of grasses in this area does not begin until late April when much longer photoperiods, between 15 and 16 hours, generally exceed those required for induction of floral primordia. In more southern areas, in contrast, grasses begin spring growth when photoperiods are significantly shorter (Fig. 20), so actively growing grasses are exposed to inductive conditions there both in autumn and in spring (Clarke and Elliott 1974).

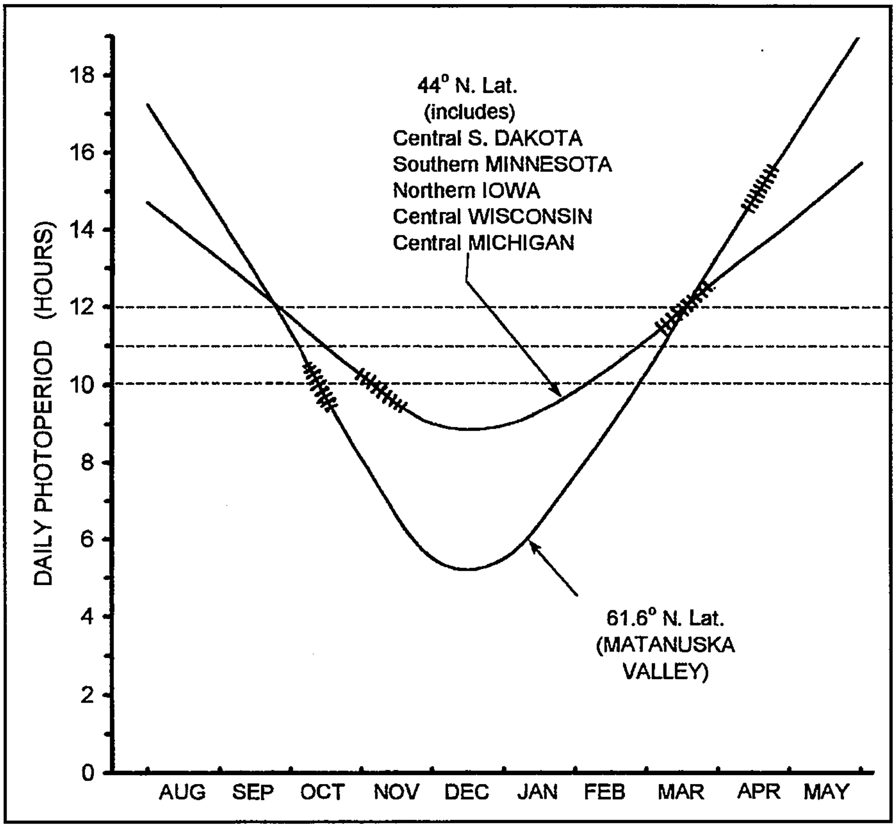

Figure 20. Track of daily photoperiod (daylight duration) at two widely separated latitudes where bromegrass seed is grown; short hatched lines across photoperiod lines indicate time when bromegrass ceases growth in autumn and begins growth in spring. Note that photoperiods are short at both latitudes when growth ceases in autumn. Photoperiods are also relatively short at the more southern latitude when new tiller growth begins in spring. In contrast, when tillers begin growth in spring in southcentral Alaska, photoperiods are near 15–hour duration, too long (and/or nyctoperiods too short) to cause growing points to be converted from vegetative to fertile status that would produce panicles. Dashed horizontal lines identify 10, 11, and 12–hour photoperiods, durations believed (by Newell 1951) to be in the critical range for induction of floral primordia.

Bromegrass Differences in Critical Photoperiod/Nyctoperiod Stimulus

Reports from this station (Klebesadel 1971, 1973) demonstrated that by exposing a normally nonhardy, southern–type cultivar of smooth bromegrass to artificially shortened photoperiods (lengthened nyctoperiods) for about eight weeks prior to freeze–up (creating pre–winter photoperiod/nyctoperiod conditions resembling those that occur at more southern latitudes), that grass not only developed adequate freeze tolerance for good winter survival, but also produced many panicles the following year.

Others (Howell and Weiser 1970) have noted the similarities between the environmental stimuli (shortening photoperiods and lowering temperatures) that control both the development of freeze tolerance and flower initiation in plants. Thus, the artificially altered pre–winter photoperiods referred to above (Klebesadel 1971, 1973) not only caused the whole plants, including primordia, to develop freeze tolerance adequate to survive the Alaska winter, but also induced growth primordia to produce panicles the following year.

In contrast, the artificially shortened pre–winter photoperiods caused subarctic–adapted pumpelly bromegrass to produce only 1/15 as many panicles the following year as were produced where it had been grown under normally shortening subarctic photoperiods. The start of the shortened–photoperiod treatment on 25 August abruptly shortened the normally occurring photoperiods from 15 hours on that date to 9 hours, and continued that daily photoperiod until frost killed bromegrass aerial growth near 20 October. Thus pumpelly bromegrass plants deprived of exposure to all durations of photoperiod between 15 and 9 hours (that would have occurred with gradually shortening normal daily photoperiods between 25 August and 20 October) produced very few panicles.

These disparate results with different bromegrasses under similar photoperiodic regime indicate dissimilar photoperiodic requirements for induction of floral primordia in different bromegrasses, and that those requirements may differ considerably among cultivars or ecotypes, especially those adapted at diverse latitudes.

Lamp (1952) cited many reports that document the considerable variation in vegetative growth and reproductive activity of different clones and ecotypes of smooth bromegrass. As a far–northern example, Romanova and Vasiliskov (1974) reported that at 67° 44' N in northwestern Russia one variety of smooth bromegrass produced seed heads routinely while two other ecotypes (from ca. 59° to 60°N) remained vegetative. One of those was induced to produce panicles by shortening daily photoperiods (to 8 to 14 hours) for over 20 days, while the other could not be induced to produce any seed heads.

Time of Panicle Initiation

All references cited herein concerning bromegrass seed production at mid–temperate latitudes are based on smooth bromegrass which, according to many authorities, may undergo induction in autumn but commences floral initiation only in spring at those more southern latitudes.

Newell (1951) in Nebraska moved bromegrass plants at different times from shortening photoperiods in the field to indoor conditions with long photoperiods (that promote culm elongation and emergence of panicles). Plants brought into the greenhouse in August produced no panicles, those brought indoors in mid–September produced some panicles, but most were produced on plants transferred indoors in mid–November and mid–December. Those results inform that brome plants were most effectively induced to produce panicles by the daily photoperiods occurring at that latitude after mid–September and prior to mid–November (= photoperiods decreasing from about 12 ½ to 10 hours) (see List 1958).

Various investigators have examined growing points of smooth bromegrass periodically from autumn to spring to determine when actual initiation occurs (i.e., discernible visible changes in the growing point or primordium that confirm that it will produce a panicle). Canode *et al.* (1972) at Pullman, WA noted first indications of floral initiation on 12 February; Gall (1947) and Lamp (1952) reported initiation in early to mid–April at Chicago, IL; Sass and Skogman (1951) similarly observed its occurrence from early to mid–April at Ames, IA; Rumburg *et al.* (1980) in Colorado, and Clarke and Elliott (1974) in Alberta, found no floral initiation in smooth brome in autumn but did in spring.

In contrast to those findings with smooth bromegrass, Clarke and Elliott (1974) in Canada and Hodgson (1966) in Alaska reported autumn initiation of floral primordia in northern ecotypes of the closely related native pumpelly bromegrass.

The phenomenon of pre–winter initiation, with well differentiated floral parts that overwintered successfully and developed to maturity the following year, was reported by Sorensen (1941) to be standard behavior in numerous grasses and other species in northeast Greenland (70° to 77°N). Twenty–seven species and taxonomic varieties of grasses (no bromegrasses mentioned as occurring there) all underwent floral initiation during the year prior to seed–head emergence and seed production. He concluded that "highly advanced development of the floral organs" during the year prior to the year of seed–head emergence was an adaptational behavior that permitted heading and flowering very early in the growing season which, in turn, enabled those far–northern ecotypes to produce and mature seed during the brief growing period there.

Heading As Related to Latitude of Adaptation

Manchar bromegrass, selected for ideal adaptation in the Pacific Northwest states, is adequately winterhardy for good vegetative survival during all but the most severe winters in this area, yet it has been noted that it consistently produces very few panicles at this latitude (Klebesadel 1970b). At more southern latitudes where it is better adapted, Manchar is described as "a high yielder of seed," and yields from 400 to over 600 pounds per acre are not uncommon according to Stark and Klages (1949). Manchar is commonly grown in the northern states where spring initiation is common, but it is very poorly adapted for successful production of panicles at the latitude of southcentral Alaska. In a similar vein, Knowles and White (1949) in Canada reported considerably lower seed yields from southern–type bromegrass strains than from northern types at three locations in western Canada.

An indication of heading disparities of differently adapted bromegrass strains at this station can be seen from two previously unreported row–seeded experiments (1 with 3 replications, 1 with 2) that were located in a sheltered site (leeward of a wooded tract that kept the insulating snow cover from blowing away, thus favoring the more southerly adapted, less winterhardy cultivars during winter). The two–experiment mean numbers of panicles for 16 feet of row for native pumpelly, Polar, Manchar, and the even more southerly adapted Achenbach were 796, 926, 341, and 143, respectively. In more–exposed, normal field environments, Manchar has headed considerably less (Klebesadel 1970b) and Achenbach has usually sustained greater winter injury, usually total winterkill.

Those observations concur with determinations of comparative winterkill of subarctic–adapted versus introduced smooth bromegrasses in the field in Alaska (Klebesadel 1970b), as well as laboratory–determined comparative injury of rhizomes of different bromegrasses subjected to different levels of freeze stress (Klebesadel 1993a). In both studies, from least–injured to most injured those grasses were: native Alaskan pumpelly brome, the Alaska cultivar Polar, Manchar (adapted in northern areas of the conterminous 48 states), and Achenbach, a southern–type cultivar from Kansas.

Winter Survival of Primordia

Referring to smooth bromegrass, Sass and Skogman (1951) in Iowa stated: "The rare inflorescence primordia that are formed in late autumn do not survive the winter." Implicit in that observation is the contention that floral primordia are more susceptible to cold injury than other overwintering plant tissues that do survive without injury.

By subjecting Southland smooth bromegrass, a southern–type, nonhardy cultivar poorly adapted at this Alaska latitude, to short photoperiods (9 hr)/long nyctoperiods (15 hr) for eight weeks prior to winter, not only was good winter survival promoted, but many panicles were produced the following year (Klebesadel 1971, 1973). This suggests that not only did the short photoperiods/long nyctoperiods cause successful late–summer/autumn induction of inflorescence primordia, but the artificially altered pre–winter day/night regime also promoted development of adequate levels of freeze tolerance in overwintering tissues (Hodgson 1964; Klebesadel 1993c), including the inflorescence primordia, for successful winter survival of those incipient panicles.

Clarke and Elliott (1974), in Canada, reported that autumn–initiated infloresences of pumpelly brome survived winters and developed into full panicles the following year.

Experiments reported here utilized Polar, a cultivar predominantly of hybrid origin; 11 of the 16 clones in its genetic background represent hybridization between temperate–latitude–adapted smooth bromegrass that typically initiates floral primordia in spring, and northern–adapted pumpelly bromegrass that normally exhibits pre–winter initiation of floral primordia (Clarke and Elliott 1974; Hodgson 1966). Therefore, an adequate supply of N, provided by mid–to–late summer application, undoubtedly served to stimulate induction (and probably initiation) of panicle primordia of Polar prior to winter. This phenomenon, common both to the grass and to this latitude, resulted in greater panicle density and higher yields in the seed crop of the following year.

Monitoring Development of Floral Primordia

In addition to external stimuli acting upon plants to cause heading, Lamp (1952) stated that a tiller must also achieve a certain minimum stage of growth or development, referred to as "ripeness–to–flower," before the growing point can be induced to become a floral primordium. More study is needed of this concept for its applicability to seed production in Alaska.

More extensive tagging of tillers at various stages of development and monitoring their eventual fate in Alaska than the exploratory results reported here should be informative. A complicating factor in determining the relative influence on heading of environmental and management influences is the unknown extent to which those stimuli influence the tiller itself versus the extent to which effects of those stimuli are transmitted to the tiller from the parent plant to which it is attached.

More extensive microscopic examination of shoot apexes should be done during autumn, winter, and early spring at this and at more southern latitudes. It could be informative to conduct a cooperative experiment of such examinations at two widely separated latitudes using identical genetic material (vegetatively propagated) of bromegrasses adapted at different latitudes.

High Latitude and High Altitude Plant Responses Related?

Rumburg *et al.* (1980) reported increased heading of bromegrass with October (compared with May) N fertilization in an irrigated, high mountain meadow in northern Colorado. They believed, however, that induction of floral primordia nonetheless occurred in spring because, due to minimal late–season growth, "bromegrass shoots (late–summer tillers) did not reach required maturity for floral induction until additional early spring growth occurred." They reasoned that earlier spring growth (visible on 12 May) on the fall–fertilized plots exposed that growth to critical photoperiodic conditions that then induced primordia in spring. Lesser heading on May–fertilized plots occurred because "a shortage of available N delayed maturity of shoots in spring–fertilized plots just enough to prevent their coinciding with necessary environmental conditions of cold temperatures or daylength and, thus, they were destined to remain vegetative."

However, daily photoperiods at their study site near Walden, CO (about 41° 45' N) on 12 May when "new growth was visible" were about 14 ½ hours (List 1958), well beyond the critical photoperiod duration for induction of infloresences (Newell 1951). The late initiation of spring growth at their high–altitude site (2480 meters a.s.l. = 8258 feet) is quite analogous to the high–latitude location of the present experiments where spring bromegrass growth begins too late to be exposed to critical photo–inductive conditions (Fig. 20). Photoperiods from mid–to–late October at the Colorado site range from 11 to 10 ½ hours, quite appropriate for photoperiodic induction (Newell 1951).

An alternative explanation to that set forth by Rumburg *et al.* (1980) for the effectiveness of October–applied N in Colorado is that actual induction of floral primordia occurred prior to winter with the enhanced supply of N along with appropriate photoperiodic conditions. They dismissed that scenario, stating that "grasses in this study grew little after July haying," and with the supporting observation that there was "no visible evidence to suggest floral initiation" on 14 October. Little information exists to support or discount the possibility of induction occurring prior to freeze–up with actual initiation (visible tissue differentiation at the growing point) not occurring until spring. The Colorado report states that at the spring fertilization on 12 May, from 50 to 80% of bromegrass shoots from fall–fertilized plots had developing inflorescences.

Age of Stand

A widely accepted principle noted in most reports of bromegrass seed production is the good seed yield during the first one or two years after planting followed by a relatively rapid decline in yields with aging life of a stand. An earlier report from this station (Klebesadel 1996) concluded that although several management actions could promote modest seed–yield increases in four to five–year–old stands, the yields obtained were nonetheless lower than initial yields and generally too low to be considered practical.

Experiments IV and V are the only experiments in the present study that report seed yields in the first production year (second year of the stand). The generally higher seed yields of the best treatments in those two experiments and lower yields in the others reported here, which represent older grass stands, are consistent with observations elsewhere.

A summary of the wide ranges in seed yields in experiments reported here follows:

Experiment	Pounds seed per acre Lowest	Pounds seed per acre Highest	Seed production year
I	20[1]	353	2nd
II	34[1]	583	2nd
III	15[1]	214	3rd
IV	248	638	1st
V–a	399	596	1st
V–b	102	212[2]	2nd

[1] No N applied.

[2] Year of severe moisture deficit.

The very low "lowest" yields in Exps. I through III were without benefit of N fertilization, a critical factor in promoting seed yields. However, the low "highest" yield in the second seed–production year of Exp. V (Exp. V–b = 1970) was low despite good N fertilizer supply, due to moisture deficit as explained in the Results section of Exp. V.

In the first, second, and third years of production, the five experiments reported here confirm that higher seed yields can be obtained from younger stands. However, they also reveal that several management practices, even in the early years of production, can influence markedly the heading and seed production of bromegrass at this high latitude. The extremely wide ranges of seed yields in these experiments illustrate that inappropriate grower actions can ensure virtual crop failure while appropriate and timely actions can maximize crop and monetary returns.

Adequacy of Water

The one apparently major influence on seed production that was not studied as a variable in these experiments is the supply of soil moisture to plants. Crowle and Knowles (1962) state that adequacy of moisture is the major factor affecting bromegrass seed production. The total requirement for moisture supply, and whether critical moisture–adequacy needs exist at certain growth stages in the reproductive process is not known precisely. Atkins and Smith (1967), summarizing cultural practices for grass seed production in the Great Plains, recommend that irrigation water should be applied to field capacity just before heading or when heading starts. Moreover, they state that grass plants must have an ample supply of water during flowering.

The very modest total annual rainfall in Alaska's major agricultural areas (mean = 15.56 inches at this study site), and especially the typically very low precipitation amounts received during the first half of the growing season (during culm elongation, heading, flowering, and seed–fill) suggest (a) that this is a topic worthy of study in this area, and (b) that supplemental sprinkler irrigation, along with the other desirable management practices identified herein, could result in higher yields than reported here and certainly would ensure high seed yields in years of inadequate precipitation.

Canode (1968) in eastern Washington noted a relationship between moisture supply and bromegrass seed yield. He reported a high yield (1101 lb/A) in the first production year when precipitation was 6.3 inches above normal, but only 48% of that yield in the second year when precipitation was near normal (= 22 inches). As further evidence of soil moisture effects, he noted a higher seed yield in the fifth year of production when precipitation was 2.8 inches above normal than in the fourth year when precipitation was normal.

Components of Seed Yield

Seed yield is the product of two main components: (a) the number of panicles per unit of field area and (b) the mean seed weight per panicle. Seed weight per panicle, in turn, is the product of "sub–components" that include (a) spikelets per panicle, (b) seeds per spikelet, and (c) weight of seeds (presented in this report as mean weight per 1000 seeds).

Percent of Culms Producing Panicles

The high percentages of culms producing panicles (37 to 72%) in Exp. IV (Table 3), in the first year of seed production, contrasts with the somewhat lower percentages in the second year of production in Exp. I (9 to 51%, Table 1). The very low percentages (of the ranges) in Exp. I are from treatments that received no N.

Rumburg *et al.* (1980) found 50 to 80% of new shoots had developing inflorescences on 12 May in October–fertilized bromegrass at high altitude in Colorado; however, with dilution by later–emerging growth the headed culms were 25% on 25 July, compared with 1.8% and 1.7% on spring–fertilized and non–fertilized plots, respectively.

Seeds Per Spikelet

Knobloch (1944), reporting on a detailed study of the structure of smooth bromegrass stated: "The pedunculate spikelet...consists of a rachilla bearing two glumes and two to ten florets. The upper one or two florets may be sterile..." That statement suggests that as many as eight florets per spikelet could be seed–bearing, yet where seeds per spikelet were counted in the present study (Exp. I, Table 1), the lowest and highest means were 1.3 and 2.4, respectively.

Increasing the number of seeds per spikelet appears to be a facet of bromegrass seed production that could materially increase yields; the unfilled florets that could become seed–bearing seemingly represent an unrealized potential. Future studies should address that possibility, for moisture adequacy at certain developmental stages, such as during panicle development and/or at or near pollination time, may be of critical importance in producing more seeds per spikelet.

Weight Per 1000 Seeds

The weight per 1000 seeds was heaviest with N applied in spring (Table 1). Mean weight per 1000 seeds (over all treatments) was 4.33 grams.

Canode (1968) noted a regular and significant decrease in weight per 100 seeds of Manchar bromegrass with each year of increasing stand age from the first to the fifth harvest year; he also reported significantly lower weights per 100 seeds with each closer row spacing from 36 to 24 to 12 inches. With both stand age and row spacing, seed weight decreased with density of bromegrass stand.

White–top Panicles

Differences in the incidence of white–top panicles as influenced by time and rate of fertilizer topdressings were considerable, ranging from relatively insignificant (1 to 2%) to over 40% of total panicles produced (Exp. II). The patterns of incidence, as influenced by treatments, are somewhat confusing, yet provide some grist for speculation.

The patterns seen might suggest that factors such as succulence and/or "taste" of bromegrass culm tissues may influence capsus bug sucking activity, thus resulting in differential incidence of white–top.

In Exp. I (Fig. 8), percent affected panicles was highest where the lowest rate of N (90 lb/A) was applied. That rate of N resulted in more succulent growth in the seed–production year than treatments where no N was applied, and all no–N treatments were low in white–top incidence.

However, where higher rates of N were applied without

P_2O_5 (trtmts. 3, 4, 5, 11–Fig. 8) incidence of white–top was much lower; those higher N rates without P_2O_5 might imply a high N/P ratio in plant tissues that could render them unpalatable to the insect. In support of that hypothesis, P_2O_5 applied with the higher N rates, which logically would impart a more balanced N/P ratio in plant tissues, caused percent of panicles affected by white–top to be increased markedly (trtmt. 7–Fig. 8). Anderson *et al.* (1946) reported better palatability of bromegrass with P_2O_5 added than with N alone.

Waddington and Storgaard (1971) reported 21 to 31% white–top (referred to as "blind panicles") in a three–year study with Lincoln bromegrass in Manitoba. The "white, sterile seed panicles" ascribed to frost damage by Knowles *et al.* (1951) may in fact have been the same insect–incited damage called "white–top" here.

Rows Versus Broadcast Stand

The effect of row spacing on seed production of a rhizomatous grass changes with the age of the stand. With the continuing spreading growth of rhizomes with each succeeding growing season, narrowly spaced, uncultivated rows quickly coalesce to become a solid stand and generally become less productive of panicles and seed sooner than rows seeded farther apart. Thus, a row spacing that gives highest seed yield in the first year of production may change in rank as years advance and rows spread to cause the stand to become more dense. Miller and Steiner (1995) noted that "lower plant densities favor reproductive development."

The superiority of rows over broadcast stand for seed production, as seen in Exp. V, has been reported by others. Canode (1968) seeded Manchar bromegrass rows 12, 24, and 36 inches apart for seed production at Pullman, WA. In the first two–year average the 36–inch rows resulted in significantly lower yield than the two narrower spacings. However, with continued grass spread and more rapidly increased stand density in the narrower row spacings, the four–year average yield from the 12–inch row spacing was 575 lb/A compared to 661 and 637 lb/A from 24– and 36–inch row spacings, respectively. Buller *et al.* (1955) reported higher bromegrass seed yields from 36–inch rows than from broadcast stands in a two–year comparison in Pennsylvania. Similarly, Churchill (1944) in Michigan obtained higher bromegrass seed yields from rows 28 inches apart than from broadcast stands.

Carter (1965) at Fargo, ND (20 in. mean annual precipitation) reported consistently highest seed yields over seven years from cultivated rows two feet apart (mean = 357 lb/A); cultivated rows three feet apart averaged 250 lb/A while solid seeding (7–inch drills) was lowest at 178 lb/A.

CONCLUSIONS

To be economic, costs of grower inputs (equipment, fuel, operator time, fertilizer, etc.) necessarily must be considered in relation to the value of seed produced. These are factors that vary with time and with individual growers; this report does not attempt to analyze economic aspects of bromegrass seed production.

However, results presented here reveal that bromegrass seed production can be influenced markedly by management variables and that much higher seed yields than heretofore realized at this location are possible. These results and those in previous reports (Klebesadel 1970a, 1970b, 1971, 1973, 1996) should assist growers of bromegrass seed in Alaska to achieve high yields by following specific, appropriate management practices.

This study provides a better understanding of the unique responses of this crop to north–latitude environmental influences, and how new and appropriate management practices must be implemented to cope with the heading/environment relationship peculiar to far–northern latitudes. That understanding reveals also why management procedures developed for bromegrass seed growers at more southern latitudes are inappropriate for use in Alaska. Of utmost significance, the timing of N application for bromegrass seed production in the northern conterminous states is wholly inappropriate for promoting heading and maximizing seed production at this latitude.

A currently vague and unstudied, but probably vitally important, influence in promoting high yields of bromegrass seed in Alaska is the extent to which adequacy of soil moisture, and hence the supply to plants, affects seed yield. The very low seed yield in the very dry second year of production in Exp. V, reinforced by the contention of Crowle and Knowles (1962) that moisture is the major factor affecting bromegrass seed yield, lend credence to the importance of that factor.

The typically very modest rainfall in Alaska agricultural areas during the early months of the growing season (when culm elongation, heading, anthesis, and seed fill occur) may severely limit seed yields. Beyond a basic minimal supply of soil moisture for general plant growth, critical moisture–adequacy requirements may occur at specific developmental stages that could have a major impact on ultimate seed yield. If so, future research could show that supplemental sprinkler irrigation at certain plant developmental stages could materially enhance seed yield.

The considerable incidence of white–top in these and earlier–reported experiments (Klebesadel 1996) indicate that its occurrence can reduce seed yields markedly, with significant economic impact for growers, and that effectual control strategies should be devised and employed.

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