fertilizer practices for
BROMEGRASS

response of bromegrass to nitrogen source, and to fall and spring applications of different rates of nitrogen, phosphorus and potassium in Alaska's Matanuska Valley

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FERTILIZER PRACTICES FOR BROMEGRASS

SMOOTH BROMEGRASS (*Bromus inermis Leyss.*) is the dominant and most dependable perennial forage crop grown in Alaska. Preliminary studies of the influence of fertilizers upon crude protein yields of bromegrass in Alaska were reported in 1953 (5).[1] Several additional fertilizer experiments on bromegrass stands established from northern-grown commercial seed have been conducted from 1952 to 1960 and are reported here.

METHODS AND MATERIALS

Spring applications of all fertilizers except anhydrous ammonia were broadcast on the soil surface as soon as possible after the disappearance of the snow. Anhydrous ammonia was applied four to six inches below the soil surface in rows six inches apart with a trailer-type applicator equipped with coulters and packing wheels. Summer nitrogen applications were broadcast in late June after the first clipping.

Fall nitrogen topdressings were applied in late September or early October.

Bromegrass forage was harvested from individual plots with a small, sickle bar power mower. The harvested area consisted of a strip thirty inches wide cut down the center of each 15-foot plot. Green and dry weights of each clipping were recorded. Two or three clippings were made per season. Times of harvest were mid-June, mid-July, and mid-August when three clippings were obtained per season, and late June and mid-August when two clippings were obtained. In 1952 representative samples were selected from each plot, ground to pass a 40-mesh Wiley mill screen, and their nitrogen content determined by a modification of the Kjeldahl method.[2]

In 1952 a field trial (triple lattice replicated three times) designed to compare five nitrogen sources was established on a five year old bromegrass stand on Bodenburg silt loam adjacent to Palmer. All plots received 60 and 30 pounds of P_2O_5 and K_2O per acre as treblesuperphosphate and muriate of potash, respectively. All plots receiving nitrogen were topdressed with 100 pounds of N per acre, either all in the spring or half in the spring and half in late June after the first clipping. Yield data are presented in Tables 1, 5, 6, and 7.

A randomized complete block replicated twice, comparing single and split applications of ammonium nitrate and urea, was established on bromegrass sod two years old on the Johnson farm west of Palmer in 1956. All plots received 100 and 30 pounds of P_2O_5 and K_2O per acre, respectively. All received a total of 240 pounds of N per acre for the season. Data from these comparisons are presented in Table 3.

A trial comparing fall and spring applications of nitrogen was initiated in the fall of 1955 (4×2^2 factorial design with six replications). This trial was established on bromegrass sod three years old on Knik silt loam at the Matanuska Experiment Sta-

[1] Numbers in parenthesis refer to references listed in literature cited.

[2] Nitrogen was determined by Margaret Blom chemist. Alaska Agricultural Experiment Station, Palmer. Protein was calculated by applying the 6.25 factor.

Table 1.—Effect of nitrogen and nitrogen source on bromegrass hay yields, Bodenburg silt loam, 1952, including both spring and split applications (means of 15 measurements).

Nitrogen source[1]	Clipping date June 20	July 21	Aug 18	Total for season
	Tons oven-dry hay per acre[2]			
No nitrogen	0.33c[3]	0.18c	0.08c	0.59d
Ammonium nitrate	1.05a	0.39a	0.41a	1.85a
Ammonium sulfate	1.02a	0.42a	0.45a	1.89a
Calcium nitrate	1.10a	0.37a	0.44a	1.91a
Calcium cyanamide	0.63b	0.23b	0.17b	1.03c
Urea	0.88a	0.37a	0.40a	1.65b

[1] All plots received 100 pounds of N per acre except as noted.

[2] Averages of plots receiving single and split nitrogen applications.

[3] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

tion Farm. It also compared four nitrogen sources (ammonium nitrate, ammonium sulfate, anhydrous ammonia, and urea) at two different rates (88 and 176 pounds N per acre). Yield data are presented in Tables 2, 8, 12, and 15.

When anhydrous ammonia was applied in the spring, a supplemental field trial (six replications) was established to determine the effect of sod disturbance by the applicator. All plots of both trials received a uniform application of 80 and 25 pounds of P_2O_5 and K_2O per acre, respectively. The ammonia applicator was used on half the plots, as in those plots receiving anhydrous ammonia of the adjoining experiment, but no nitrogen was applied. Data from this comparison are presented in Table 9.

In the fall of 1957 a trial (3^2 x 2 factorial replicated eight times) was initiated to compare three nitrogen carriers (ammonium nitrate, ammonium sulfate, and urea), three nitrogen rates (100, 200, and 300 pounds of N per acre), and fall versus spring application. This test was establishad on a new bromegrass seeding in barley stubble, both crops having been planted in the spring of 1957 on Knik silt loam. Yield data are presented in Tables 4, 10, 11, 13, 14, and 16.

In the fall of 1957 another trial (3^2 x 2 factorial with eight replications) was initiated to compare three rates each of phosphorus and potassuim (0, 80, and 160 pounds of P_2O_5 and K_2O per acre), and fall versus spring applications. This test was established adjacent to the nitrogen

Table 2.—Effect of nitrogen source on bromegrass hay yields, Knik silt loam, 1956 (means of 24 measurements).

Nitrogen source	Clipping date June 13	July 23	Sept 10	Total
	Tons oven-dry hay per acre[1]			
Ammonium nitrate	1.20a[2]	0.87a	0.40a	2.47a
Ammonium sulfate	1.16a	0.90a	0.41a	2.47a
Anhydrous ammonia	0.65b	0.73c	0.42a	1.80c
Urea	1.12a	0.80b	0.35a	2.27b

[1] Averages of plots receiving 88 and 176 pounds of N per acre.

[2] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

experiment described in the preceding paragraph. Data from this field trial are presented in Tables 17, 18, 19, 20, and 21. With both experiments initiated in 1957 fertilizer treatments were repeated and yields measured each year from 1958 through 1960.

Nitrogen content of the nitrogen sources were as follows: anhydrous ammonia, 82%; ammonium nitrate, 33.5%; ammonium sulfate, 21%; calcium cyanamide, 20%; calcium nitrate, 15.5%; urea 44% in 1952 and 46% in later experiments.

Letters in the tables are used in accordance with Duncan's New Multiple Range Test.

Table 3.—Effect of spring nitrogen application compared with split applications[1] of ammonium nitrate (AN) and urea on bromegrass hay yield, Johnson Farm, Niklason silt loam[2], 1956 (means of 2 measurements).

Source and time applied[3] Spring	Summer	Clipping date June 14	July 16	Sept 6	Total
		Tons oven-dry hay per acre			
AN (all)		1.17a[4]	0.60a	0.51a	2.28a
Urea (all)		0.71b	0.57a	0.46a	1.74b
AN	AN	1.29a	0.49a	0.54a	2.32a
Urea	Urea	0.75b	0.53a	0.62a	1.90b
AN	Urea	1.37a	0.42a	0.58a	2.37a
Urea	AN	0.68b	0.53a	0.55a	1.76b

[1] Half of nitrogen applied in spring and half in early summer.
[2] Tentative soil series.
[3] All plots received 240 pounds N per acre total for season.
[4] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

NITROGEN SOURCE

Yield— Table 1 indicates that all nitrogen carriers increased bromegrass dry-matter yields in 1952. Ammonium nitrate and ammonium sulfate were equally effective every year they were compared (Tables 1, 2, 4, 8, 10 and 11). Calcium nitrate was as effective as ammonium nitrate and ammonium sulfate when these nitrogen sources were compared in 1952 (Tables 1 and 5). Although split nitrogen applications increased yields in second and third clippings, especially in 1952, no significant difference was found between single and split applications when total yields were compared (Tables 3 and 5).

Table 4.—Effect of nitrogen source on bromegrass hay yields, Knik silt loam, 1958 and 1959 (means of 48 measurements).

Nitrogen source	Clipping date 1958 June 10	Aug 20	Total 1958	Clipping date 1959 June 11	Aug 17	Total 1959
	Tons oven-dry hay per acre[1]					
Ammonium nitrate	1.63a[2]	0.51a	2.14a	2.09a	1.52a	3.61a
Ammonium sulfate	1.63a	0.54a	2.17a	2.16a	1.53a	3.69a
Urea	1.40b	0.41b	1.81b	1.61b	1.04b	2.65b

[1] Averages of all nitrogen levels.
[2] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 5.—Effect of a single spring nitrogen application, different nitrogen sources, and split applications[1] on bromegrass hay yields, Bodenburg silt loam, 1952 (means of 3 measurements).

Carrier and time applied[2] Spring	Summer	Clipping date June 20	July 21	Aug 18	Total
		Tons oven-dry hay per acre			
AN (all)		1.10ab[3]	0.31abc	0.26b	1.67a
AN	AN	0.97ab	0.40a	0.46a	1.83a
AN	Urea	1.18a	0.30bc	0.26b	1.74a
AN	CC	0.87b	0.26c	0.17c	1.30b
CN	Urea	1.14a	0.37ab	0.26b	1.77a

[1] Half of nitrogen applied in spring and half in early summer.

[2] All plots received a total of 100 pounds N per acre for season. Ammonium nitrate—AN, calcium nitrate—CN, calcium cyanamide—CC.

[3] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Calcium cyanamide was inferior to all other nitrogen sources for all clippings (Tables 1 and 5). Bromegrass foliage in plots receiving calcium cyanamide was a lighter yellowish-green color throughout the season than even those plots reeciving no applied nitrogen. When used in combination with ammonium nitrate, calcium cyanamide markedly depresed bromegrass yields in the second and third clippings.

Urea alone or in combination with other nitrogen sources was seldom as effective as ammonium nitrate, ammonium sulfate, or calcium nitrate (Table 1, 2, 3, 4, 8, 10 and 11). One exception is noted when in 1956 bromegrass yields following urea fertilization were not significantly lower than yields from other treatments (Tables 2 and 8). When urea was applied as a summer nitrogen source in 1956 following spring fer-

Table 6.—Effect of nitrogen and nitrogen source on protein content and yield of crude protein of bromegrass, Bodenburg silt loam, 1952 (means of 15 measurements).

Nitrogen source[1]	Clipping date June 20 %[2] protein	June 20 Lbs/ acre	July 21 %[2] protein	July 21 Lbs/ acre	August 18 %[2] protein	August 18 Lbs/ acre	Total protein lbs/acre
	Averages of plots receiving single and split nitrogen applications						
None	10.70b[3]	72c	12.08c	48b	13.37b	24b	144d
AN	12.81a	271a	20.82a	163a	16.34a	134a	568ab
AS	12.86a	266a	21.03a	176a	14.43b	148a	590a
CN	13.04a	291a	21.48a	161a	17.17a	154a	606a
CC	12.92a	167b	14.74b	69b	14.53b	52b	288c
Urea	11.75ab	210ab	20.95a	156a	16.48a	136a	502b

[1] All plots received 100 pounds of N per acre except as noted. Ammonium nitrate—AN, ammonium sulfate—AS, Calcium nitrate—CN, calcium cyanamide—CC.

[2] Dry matter basis.

[3] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 7.— Effect of a single spring nitrogen application, different nitrogen sources, and split applications[1] on protein content and yields of crude protein of bromegrass, Bodenburg silt loam, 1952, (means of 3 measurements).

Nitrogen source[2]		Clipping date June 20		July 21		August 18		Total
Spring	Summer	% protein[3]	Lbs/ acre	% protein[3]	Lbs/ acre	% protein[3]	Lbs/ acre	protein lbs/acre
AN (all)		14.81a[4]	330ab	16.79bc	104b	15.12b	79b	513a
AN	AN	11.97b	235c	22.10a	179a	16.95a	157a	571a
AN	Urea	15.66a	371a	18.49b	111b	14.91b	79b	561a
AN	CC	14.31a	251bc	15.27c	79b	14.75b	47b	377b
CN	Urea	14.31a	333ab	16.48c	119b	15.43ab	82b	534a

[1] Half of nitrogen applied in spring and half in early summer.
[2] All plots received 100 pounds N per acre total for season. Ammonium nitrate—AN, Calcium cyanamide—CC, calcium nitrate—CN
[3] Dry matter basis.
[4] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

tilization with ammonium nitrate, it was as effective as summer-applied ammonium nitrate (Table 3). In 1960 urea was inferior to other nitrogen carriers except in the first clipping when 300 pounds of N had been applied per acre, and in the second clipping following application of 100 pounds of N (Table 10).

Anhydrous ammonia was inferior to all other nitrogen carriers in 1956 (Tables 2 and 8). Moreover, Table 9 reveals a highly significant reduction of first clipping bromegrass yields after the sod was disturbed by the ammonia applicator and when no nitrogen was applied. This depression was not evident in the second and third clippings.

Protein Content and Yield—Protein content and yield of all 1952 clippings were improved by applications of ammonium nitrate, ammonium sulfate, and calcium nitrate (Tables 6 and 7). Although the increase in the protein content of the first clipping from urea and the third clipping from ammonium sulfate was not significantly greater than the no-nitrogen treatment, the protein yield of these clippings and the protein content of the other clippings were increased by a significant margin by these nitrogen carriers.

Note in Table 6 that the protein content of the first and second clippings and the protein yield of the

Table 8.—Effect of nitrogen source and fall versus spring application on bromegrass hay yields harvested June 13, 1956, Knik silt loam (means of 12 measurements).

Nitrogen source	Time of application Fall	Spring
	Tons oven-dry hay/acre[1]	
Ammonium nitrate	1.12abc[2]	1.28a
Ammonium sulfate	1.08bc	1.25ab
Anhydrous ammonia	0.76d	0.53c
Urea	0.95c	1.30a

[1] Average of plots receiving 88 and 176 pounds N per acre.
[2] Any two values within the table not followed by the same letter are significantly different at the 5% level of probability.

Table 9.—Effect of sod disturbance by anhydrous applicator on bromegrass yields, Knik silt loam, 1956 (means of 6 measurements).

Treatment[1]	Clipping date June 13	July 23	Sept 10	Total
	Tons oven-dry hay per acre			
Applicator used	0.35a[2]	0.30a	0.16a	0.81a
Applicator not used	0.59b	0.30a	0.15a	1.04a

[1] No nitrogen added.
[2] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

first clipping that received calcium cyanamide were greater than where no nitrogen was applied. However, calcium cyanamide resulted in a lower protein content in the second and third clippings and also lower protein yields of all clippings than any of the other nitrogen carriers. The protein content of the third clipping and the protein

Table 10.—Effect of nitrogen source and nitrogen rate on bromegrass yields, 1959 and 1960 (means of 16 measurements).

Nitrogen source	Pounds N per acre	Total 1959	Clipping date 1960 June 13	Aug 16	Total 1960
		Tons oven-dry hay per acre			
Ammonium nitrate	100	2.64d[1]	2.71bc	1.21d	3.92c
	200	3.94b	2.98a	1.42bc	4.40b
	300	4.24a	2.90ab	2.04a	4.94a
Ammonium sulfate	100	2.78d	2.62c	1.12d	3.74cd
	200	3.91b	2.99a	1.47b	4.46b
	300	4.42a	2.81abc	2.20a	5.01a
Urea	100	2.00e	2.21d	1.25cd	3.46e
	200	2.85d	2.68bc	0.09e	3.58d
	300	3.19c	2.85abc	1.08de	3.93c

[1] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 11.—Effect of nitrogen source and time of application on bromegrass yields, Knik silt loam, 1959 and 1960 (means of 24 measurements).

Nitrogen source	Time applied	Clipping date June 11, 1959	Aug 17, 1959	June 13, 1960
		Tons oven-dry hay per acre		
Ammonium nitrate	Fall	2.01b[2]	1.48a	2.77b
	Spring	2.16ab	1.55a	2.96a
Ammonium sulfate	Fall	2.07b	1.48a	2.76b
	Spring	2.25a	1.58a	2.85ab
Urea	Fall	1.66c	0.88c	2.38c
	Spring	1.57c	1.20b	2.77b

[1] Averages of plots receiving 88 and 176 pounds N per acre.
[2] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

yield of the second and third clippings as influenced by calcium cyanamide did not differ significantly from those that received no nitrogen. Calcium cyanamide resulted in a protein yield far below other nitrogen sources in all bromegrass clippings.

Table 12.—Effect of two nitrogen rates on bromegrass hay yields, Knik silt loam, 1956 (means of 48 measurements)

Pounds N per acre	Clipping date June 13	July 23	Sept 10	Total
	Tons oven-dry hay per acre			
88	0.98b[1]	0.63b	0.24b	1.85b
176	1.09a	1.02a	0.55a	2.66a

[1] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

NITROGEN RATE

Each nitrogen increment improved yields (Tables 10, 12, 13, and 14). Less increase at the higher nitrogen levels occurred with the first than with the second and third clippings. The maximum nitrogen rate for economical yields was 200 pounds per acre.

A careful study of these data also indicates a possible increasing yield response to nitrogen as the age of the bromegrass sod increases. The additional 200 pounds of nitrogen increased yields 0.25, 1.60, (Table 13) and 1.15 (Table 14) tons per acre on first, second, and third year sod respectively. In 1956 an additional 88 pounds of nitrogen increased yields by 0.81 tons per acre on fourth year bromegrass (Table 12).

FALL VERSUS SPRING NITROGEN

Spring nitrogen applications were somewhat superior to fall applications (Table 15) although the seasonal response varied from year to year, by clipping and by nitrogen source. Table 8 indicates that the first clipping in 1956 showed no real differences between fall and spring applications of ammonium nitrate and ammonium sulfate. However, spring application of urea in 1956 (Table 8), 1959 and 1960 (Table 11) was much superior to fall application (with the exception of the first clipping of 1959). Spring nitrogen applications with the other nitrogen sources were in general significantly superior to fall appli-

Table 13.—Effect of three nitrogen rates on bromegrass hay yields, Knik silt loam, 1958-1960 (means of 48 measurements).

Pounds N per acre	Clipping date 1958 June 10	Aug 20	Total 1958	Clipping date 1958 June 11	Aug 17	Total 1959	June 13, 1960
	Tons oven-dry hay per acre						
100	1.46b[1]	0.42c	1.88b	1.60b	0.81c	2.41c	2.51b
200	1.62a	0.49b	2.11a	2.14a	1.39b	3.53b	2.88a
300	1.59a	0.54a	2.13a	2.13a	1.88a	4.01a	2.85a

[1] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

cations as evidenced by yields presented in Tables 8 and 11.

First clippings in 1958 and 1959 and total yield for 1958 showed no significant differences between fall and spring nitrogen applications (Table 16). The second clipping in both years revealed the superiority of spring nitrogen treatments.

No significant differences between fall and spring nitrogen applications occurred in 1959 at the 300 pound rate and in 1960 at the 100 pound rate as shown by the August clipping in each year. All other comparisons for the August harvest reveal that spring applications were superior to fall applications.

Table 14.—Effect of three nitrogen rates and time of nitrogen application on bromegrass hay yields, Knik silt loam, 1959 and 1960 (means of 24 measurements).

Pounds N per acre	Time of N application	Clipping date Aug 17, 1959	Aug 16, 1960	Total 1960
		Tons oven-dry hay per acre		
100	Fall	0.74e[1]	1.21d	3.67c
	Spring	0.88d	1.17de	3.72c
200	Fall	1.26c	1.11e	3.78c
	Spring	1.53b	1.42c	4.45b
300	Fall	1.83a	1.72b	4.52b
	Spring	1.92a	1.84a	4.87a

[1] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 15.—Effect of time of nitrogen application on bromegrass hay yields, Knik silt loam, 1956 (means of 48 measurements).

Time of N application	Clipping date June 13	July23	Sept 10	Total
	Tons oven-dry hay per acre			
Fall	0.98b[1]	0.80b	0.36b	2.14b
Spring	1.09a	0.85a	0.43a	2.37a

[1] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

PHOSPHORUS

Phosphorus Rate—In 1958 no significant yield increases occurred as the phosphorus level was increased (Table 17). Each increment of phosphorus in 1959 significantly improved the yields of both bromegrass clippings.

Addition of phosphorus in 1960 had no significant influence on first clipping yields (Table 18). Second clipping and total 1960 seasonal yields were improved by phosphorus in the absence of potassium but were reduced when potassium was also applied.

Potassium Rate— The addition of potassium in 1958 had no significant influence on bromegrass dry matter yields (Table 19). Yields in 1959 and 1960 were increased by potassium although 80 pounds of K_2O per acre were not significantly different from 160 (Tables 19 and 20).

Fall versus Spring Application— No significant difference in bromegrass yields occurred between fall and spring applications of either phosphorus or potassium with any clipping from 1958 through 1960 (Tables 20 and 21).

Table 16.—Effect of time of nitrogen application on bromegrass hay yields, Knik silt loam, 1958 and 1959 (means of 72 measurements).

Time of N application	Clipping date 1958 June 10	Clipping date 1958 Aug 20	Total 1958	Clipping date 1959 June 20	Clipping date 1959 Aug 17	Total 1959
			Tons oven-dry hay per acre			
Fall	1.60a[1]	0.46b	2.06a	2.18a	1.04b	3.22b
Spring	1.51a	0.51a	2.02a	2.27a	1.17a	3.44a

[1] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

DISCUSSION

This work shows that ammonium nitrate, ammonium sulfate, and calcium nitrate are equally effective as sources of nitrogen for bromegrass in Alaska. Urea was invariably inferior to these carriers, while calcium cyanamide was much inferior.

Morris and Jackson (8) also found the first three mentioned carriers equally effective and much superior to calcium cyanamide in promoting growth of rye. Nowakowski (11) found at Rothamsted that ammonium nitrate, ammonium sulfate, calcium nitrate, and urea produced similar first cutting yields of permanent grass and Italian ryegrass. However, ammonium sulfate gave lower second cutting yields than other nitrogen carriers.

Widdowson, Penny, and Cooke (16) found that calcium nitrate gave lower potato yields than ammonium sulfate. They reported that urea delayed emergence and reduced plant establishment. Parish and Feillafe (12) reported ammonium sulfate superior to urea for sugar cane. Gil Benavides (2), comparing ammonium nitrate, ammonium sulfate, and urea reported the highest corn yields from ammonium nitrate and the lowest from urea. Pearson, et al (13) reported no consistent corn yield difference between ammonium nitrate, sodium nitrate, urea, and anhydrous ammonia, but noted nitrogen recovery from urea tended to be lower than from other sources.

Table 17.—Effect of three rates of phosphorus fertilization on bromegrass hay yields, Knik silt loam, 1958 and 1959 (means of 48 measurements).

Pounds P_2O_5 per acre	Clipping date 1958 June 12	Clipping date 1958 Aug 21	Total 1958	Clipping date 1959 June 10	Clipping date 1959 Aug 17	Total 1959
			Tons oven-dry per acre			
0	1.50a[1]	0.27a	1.77a	1.60c	1.50c	3.10c
80	1.61a	0.26a	1.87a	1.89b	1.63b	3.52b
160	1.62a	0.23a	1.85a	1.99a	1.83a	3.82a

[1] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 18.—Effect of three rates of phosphorus and potassium fertilization on bromegrass hay yields, Knik silt loam, 1960 (means of 16 measurements).

Pounds P_2O_5 per acre	Pounds K_2O per acre	Clipping date 1960 June 13	Aug 15	Total
		Tons oven-dry hay per acre		
0	0	2.29d[1]	1.05e	3.34e
	80	2.91ab	1.69a	4.60ab
	160	2.91ab	1.64a	4.55ab
80	0	2.36d	1.22de	3.58de
	80	2.70bcd	1.52ab	4.22c
	160	3.09a	1.59ab	4.68a
160	0	2.50cd	1.27cd	3.77d
	80	2.78bc	1.43bcd	4.21c
	160	2.85b	1.44bcd	4.29bc

[1] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Templeman (14) reported urea less effective than conventional fertilizer and that response to urea became less efficient as application rates increased. Meyer, Olson and Rhodes (7) reported nitrogen losses from surface applications of all nitrogen carriers. The greatest loss was reported from fertilizers containing urea. Losses were greatest on neutral to alkaline soils under conditions of limited rainfall, were magnified by crop residue on the soil surface, and were accentuated by cool temperatures which limit nitrification. Greater bromegrass yields following spring application of urea compared to fall application as revealed in this report may be explained by poor nitrification caused by low temperatures.

Kurtz, Owens, and Huck (4) indicate similar crop uptake of nitrogen from all nitrogen sources when applied at low rates, but indicate some cases of nitrogen losses particularly at higher rates. They reported that urea was rapidly hydrolyzed to ammonium ions within one to two weeks when soil temperatures rose above freezing. This raised the pH which in turn stimu-

Table 19.—Effect of three potassium rates on bromegrass hay yields, Knik silt loam, 1958-1960 (means of 48 measurements).

Pounds K_2O per acre	Clippings in 1958 Jun 12	Aug 21	Total	Clippings in 1959 Jun 10	Aug 17	Total	Clippings 1960 Aug 15	Total
				Tons oven-dry hay per acre				
0	1.55a[1]	0.24a	1.79a	1.68b	1.50b	3.18b	1.18b	3.25b
80	1.54a	0.26a	1.80a	1.86a	1.69a	3.55a	1.54a	4.27a
160	1.63a	0.26a	1.89a	1.93a	1.77a	3.70a	1.56a	4.43a

[1] Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

lated the activity of nitrifying organisms. On the other hand ammonium sulfate depressed the pH.

Volk (15) reported nitrogen losses from surface applications of ammonium nitrate, ammonium sulfate and urea to limed and unlimed turf and to bare sandy soil. Losses were greatest from urea, with greater losses from large than from small pellets. Low and Piper (6), in addition to reporting a poorer plant response to urea caused by loss of nitrogen to the atmosphere, also indicated an occasional phytotoxicity to urea. This they attributed to a rapid production of ammonia, which may be reduced by mixing urea with acid salts to neutralize the ammonia. Most workers do not recommend surface applications of urea, but indicate little loss when the fertilizer is incorporated in the soil.

Nakazawa (9) reported that calcium cyanamide produced better growth of *Crytomeria japonica* than ammonium sulfate. Other workers have reported calcium cyanamide to be an inferior source of nitrogen. Bjalfve (1) found the nitrification of calcium cyanamide proceeds more rapidly at low than at high application rates. Killingmo (3) and Nommik (10) reported the formation of dicyandiamide in the breakdown of calcium cyanamide. The latter worker reported the rate of ammonification to be highly dependent upon temperature and that during breakdown of high concentrations a nitrogenous compound was produced which decomposed very slowly. He believed this compound to be dicyandiamide. Slow breakdown of calcium cyanamide in the cool temperatures prevalent in Alaska may be responsible for the poor bromegrass performance reported here and for the yellowing of the foliage.

Table 20.—Effect of three potassium rates and time of application on bromegrass hay yields June 13, 1960, Knik silt loam (means of 24 measurements).

Pounds K_2O per acre	Time of application Fall	Spring
	Tons oven-dry hay/acre	
0	2.30c[1]	2.46c
80	2.87ab	2.72bc
160	3.03a	2.86ab

[1] Any two values not followed by the same letter are significantly different at the 5% level of probability.

Morris and Jackson (8) reported higher total rye forage yields by adding the nitrogen in two rather than in one application. Data collected in Alaska indicate such split nitrogen applications had no beneficial influence on total bromegrass yields, but did increase relative size of the second and third clippings.

Table 21.—Effect of time of application of phosphorus and potassium on bromegrass hay yields, 1958-1960, Knik silt loam (means of 72 measurements).

Time of fertilization	Clippings in 1958 Jun 12	Aug 21	Total	Clippings in 1959 Jun 10	Aug 17	Total	Clippings in 1960 Jun 13	Aug 15	Tot
	Tons oven-dry hay per acre[1]								
Fall	1.57	0.25	1.82	1.79	1.66	3.45	2.74	1.42	4.16
Spring	1.58	0.26	1.84	1.86	1.65	3.51	2.68	1.44	4.12

[1] No significant yield differences

SUMMARY AND CONCLUSIONS

From 1952 through 1960 five replicated experiments employing various experimental designs were conducted on established brome grass stands to compare several nitrogen carriers, and rates and time of application of nitrogen, phosphorus, and potassium.

Ammonium nitrate, ammonium sulfate, and calcium nitrate were equally effective as suppliers of nitrogen to bromegrass. Anhydrous ammonia and calcium cyanamide were inferior to all other nitrogen carriers.

Urea was seldom as effective as ammonium nitrate, ammonium sulfate, or calcium nitrate. This was especially true with high nitrogen levels and with fall applications.

Split nitrogen applications (half in the spring and half in early summer) produced higher second and third cutting yields, but no more dry matter for the entire season than did the same amount of nitrogen applied only in the spring.

Under the conditions of these experiments, bromegrass without irrigation responded economically to nitrogen applications up to 200 pounds per acre. The older the stand the greater the nitrogen response.

Spring applications of nitrogen were generally superior to equal quantities applied in the fall.

Bromegrass yields showed little response to phosphorus and potassium applications that exceeded 80 pounds P_2O_5 or K_2O per acre.

Fall and spring phosphorus and potassium applications produced essentially equal dry matter yields.

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