EFFECTS of FOUR RATES of THREE NITROGEN SOURCES on YIELD and CHEMICAL COMPOSITION of MANCHAR BROMEGRASS FORAGE in the MATANUSKA VALLEY

Winston M. Laughlin

UNIVERSITY OF ALASKA LIBRARY
JUN 4 1981

Agricultural Experiment Station
School of Agriculture and Land Resources Management
University of Alaska

James V. Drew, Director

Technical Bulletin 6

July 1978

THE ELMER E. RASMUSON LIBRARY
UNIVERSITY OF ALASKA

UNIVERSITY OF ALASKA

Foster F. Diebold	-	President
Dr. Howard A. Cutler	-	Chancellor, University of Alaska, Fairbanks
Dr. Keith B. Mather	-	Vice-Chancellor for Research and Advanced Study
Dr. James V. Drew	-	Dean, School of Agriculture and Land Resources Management, and Director, Agricultural Experiment Station

BOARD OF REGENTS

Dr. Hugh B. Fate, Jr., President
Edward B. Rasmuson, Vice President
Don Abel, Jr., Secretary
Mildred Banfield, Treasurer
Jeff Cook
Conrad Frank
Margaret J. Hall
Sam Kito, Jr.
Sharilyn Mumaw
John W. Schaeffer
Charles R. Webber
Dixie R. Brown, Executive Secretary

The Agricultural Experiment Station at the University of Alaska provides station publications and equal educational and employment opportunities to all without regard to race, color, religion, national origin, sex, age, physical handicap, or veteran status.

To simplify terminology, trade names of products or equipment may have been used in this publication. No endorsement of products or firms mentioned is intended, nor is criticism implied of those not mentioned.

Material appearing here may be reprinted provided no endorsement of a commercial product is stated or implied. Please credit the researchers involved, and the University of Alaska Agricultural Experiment Station.

"Technical bulletin (University of Alaska, Fairbanks. Agricultural Experiment Station)"

TABLE OF CONTENTS

ALASKA
S
33
E28
no. 6

THE ELMER E. RASMUSON LIBRARY
UNIVERSITY OF ALASKA

LIST OF TABLES

LIST FIGURES

EFFECTS OF FOUR RATES OF THREE NITROGEN SOURCES ON YIELD AND CHEMICAL COMPOSITION OF MANCHAR BROMEGRASS FORAGE IN THE MATANUSKA VALLEY.[1]

By

Winston M. Laughlin[2], Paul F. Martin[3], and Glenn R. Smith[4]

SUMMARY

In a field study, the effects of four rates of three nitrogen (N) sources on Manchar smooth bromegrass (Bromus inermis Leyss.) grown on Homestead silt loam (Typic Cryorthods) in southcentral Alaska's Matanuska Valley were compared. The three N sources were the commercial fertilizers, ammonium nitrate (AN), aqua ammonia (AA), and urea (U).

Until recent years, all three were imported into Alaska from manufacturers elsewhere in North America or eastern Asia. Now, however, the recently constructed Collier-Carbon manufacturing plant near Kenai, Alaska, can supply bulk urea directly to Alaskan farmers at a price per pound of N considerably less than any other commercial N source. AN has generally been used as the most efficient N source for fertilizer use in Alaska. However, this relatively inexpensive urea requires a reconsideration of crop responses to the major N sources available to Alaskan farmers.

Dry-matter yields, and concentrations of N, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), aluminum (Al), barium (Ba), boron (B), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), strontium (Sr), and zinc (Zn) in bromegrass forage were determined.

Interactions between the N sources and their rates of application were highly significant for practically all measurements. First-cutting forage yields were maximum with 160 lb N/A, considering all N sources. Second-cutting forage yields were larger with each increase in N as AN and U, but not with AA.

AN was superior to U, which in turn was superior to AA in increasing forage yields, N, P, K, Ca, and Mg uptake, Sr content, and recovery of applied N, P, and K. Differences among N sources were more pronounced for the second than for the first cutting.

---

[1] Cooperative investigation of Agricultural Research Service, USDA, and the Alaska Agricultural Experiment Station.

[2] Research Soil Scientist, Agricultural Research Service, USDA, Palmer.

[3] Formerly Research Soil Scientist, Agricultural Research Service, USDA, Palmer (now retired).

[4] Laboratory Technician, Alaska Agricultural Experiment Station, Palmer.

INTRODUCTION

Smooth bromegrass is the dominant and most dependable perennial forage crop in Alaska. Manchar is one of the better performing smooth bromegrass varieties in northern areas. However, relatively large quantities of N are required for maximum yields of perennial forage grasses. Interest in the comparative effects of various N sources on yield and forage quality of smooth bromegrass prompted us to study AA, U, and AN. These three N sources were compared on a two-year-old stand of Manchar smooth bromegrass, located on Homestead silt loam (Typic Cryorthods) northwest of Wasilla in the Matanuska Valley of Southcentral Alaska. We made chemical determinations to provide data showing the effects of the different N sources and rates on the composition of forage produced in Alaska.

EXPERIMENTAL PROCEDURE

Three N sources (AA, U, and AN) at four rates (0, 80, 160 and 240 lb N/A) were applied to the bromegrass stand on May 16, 1967, in a 4 x 3 factorial experimental design and replicated seven times. This field had been limed with high quality marl (3 cubic yards per acre) before bromegrass seedbed preparation. All plots received P_2O_5 and K_2O at 100 and 200 lb/A (44 and 166 lb P and K/A) as treblesuperphosphate and sulfate of potash, respectively. The AN and U fertilizers were broadcast by hand on the soil surface whereas AA was applied by sprinkler. The required amount of ammonium hydroxide was added to a clean, five-pint glass bottle, and the remainder of the bottle was filled with water. The entire contents of the bottle were then transferred to a 3-gallon sprinkling can and sprinkled evenly over each appropriate plot.

Soil on the plot area was sampled on August 11 after the second grass cutting. Samples were analyzed using a modified Morgan's procedure with sodium acetate extractant buffered at pH 4.8 (17). The soil pH was also determined with a commercial pH meter (1:2 soil-water ratio) along with the amount of Kjeldahl N. The original soil sample had a pH of 6.0 with NO_3-N, P, and K levels of 15.4, 5.3, and 137 lb/A, respectively.

Forage yields were obtained by clipping grass on June 26 and August 9, 1967, with a small sickle-equipped power mower, leaving a 1 1/2-inch stubble. A strip 2.5 ft. wide and 12 ft. long was cut from the center of each 6-foot-wide plot. Yields were recorded as oven-dry weights for each harvest. Representative forage samples from each plot were ground to pass a 40-mesh stainless steel screen and analyzed for N using a modification of the Kjeldahl method and collecting the distillate in boric acid (1). The Wisconsin Alumni Research Foundation determined P, K, Ca, Mg, Na, Al, Ba, Fe, Sr, B, Cu, Zn, Mn, and Cr contents by a direct reading emission spectroscopic method (6) and Mo by atomic absorption spectrophotometer (18). Percent recoveries of applied N, P, and K were calculated, as well as the plant uptake of these elements and Ca, Mg, and Na.

All data were evaluated using standard analysis of variance and Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

YIELD

Forage yields increased as N fertilization rates increased (Figure 1), in the order AN>U>AA, according to N source. First-cutting and total-season yields increased significantly as AN fertilizer rate increased up to 160 lb N/A, and second-cutting yields increased for all AN rates. Second-cutting yields increased as each rate of U increased; however, first-cutting yields were not increased by either AA or U at 80 and 240 lb N/A. Yields were similar for U at 80 and 160 lb N/A. First-cutting yields increased significantly with AA at 80 lb N/A, but applying more N did not increase yields further. Only the highest AA rate increased the second-cutting yield. Total season production increased with AA, but not significantly above 80 lb N/A.

These yield differences, as influenced by AN and U on Homestead silt loam receiving adequate rainfall, exceeded those reported earlier on Knik silt loam (Typic Cryorthents) during a dry season, but resembled those on more moist Niklason silt loam (Typic Cryofluvents) (13). Thus, increased soil moisture, with the resulting lower soil temperatures, may inhibit plant use of topdressed urea, although Purvis (19) did not find this in New Jersey. He reported that N losses (as ammonia) were greatest from volatilization when U was applied to heavy grass sods at soil temperatures exceeding 70°F. No such ammonia losses from surface-applied U occurred, if the soil pH was below 6.5 and soil temperature was less than 72°F (19). At the study location, soil pH was less than 6.0 (Table 1), air temperatures rarely reached 70°F, and soil temperatures rarely reached 58°F.

Dotzenko (8), using only U as a N source in Colorado, obtained 3 T/A from two cuttings of irrigated bromegrass receiving 160 lb N/A. At that N rate, we obtained yields of 3.8 and 2.4 T/A with AN and U, respectively. Other investigators reported U fertilization resulted in lower forage yields than those obtained with other N sources (4, 22, 25). The decrease in U efficiency as compared with that of other N sources at the greater N rates (Figure 1) was also reported by Templeman (21) and Wahhab et al. (26). No visible signs of phytotoxicity to the grass, like that reported by Court et al. (7) were observed.

Usually AA is injected into the soil with special equipment rather than sprinkler applied. Poor results with AA may have resulted from ammonia volatilization losses at application. Although air temperatures ranged between 48 and 49°F, an ammonia odor was present during application but persisted only a short time thereafter. Green grass and old straw on plots that received AA turned pale yellow less than ten minutes after AA application. Bromegrass leaves remained yellow less than 24 hours, before foliage reassumed its normal green color. The grass did not appear to be permanently injured.

TABLE 1: EFFECT OF N SOURCE AND RATE ON THE SOIL pH, KJELDAHL N, AND AVAILABLE NO_3-N, P, AND K IN HOMESTEAD SILT LOAM ON AUGUST 11, 1967.

	pH (water)	Kjeldahl N	lb/A Available NO_3-N	lb/A Available P	lb/A Available K
Nitrogen lb/A	Effect of N rate (means of 21 measurements)				
0	5.87a	0.161b	3.2b	5.1a	269a
80	5.83a	0.174a	3.1b	5.7a	185bc
160	5.70a	0.164b	3.0b	5.8a	191b
240	5.77a	0.171a	7.2a	6.4a	151c
	Effect of N source (means of 28 measurements)				
Ammonium nitrate	5.74a	0.162a	5.6a	5.7a	172b
Urea	5.80a	0.166a	3.8b	5.8a	196b
Aqua ammonia	5.84a	0.168a	3.0b	5.7a	229a
C.V.	4.0%	2.0%	35.7%	31.9%	29.1%

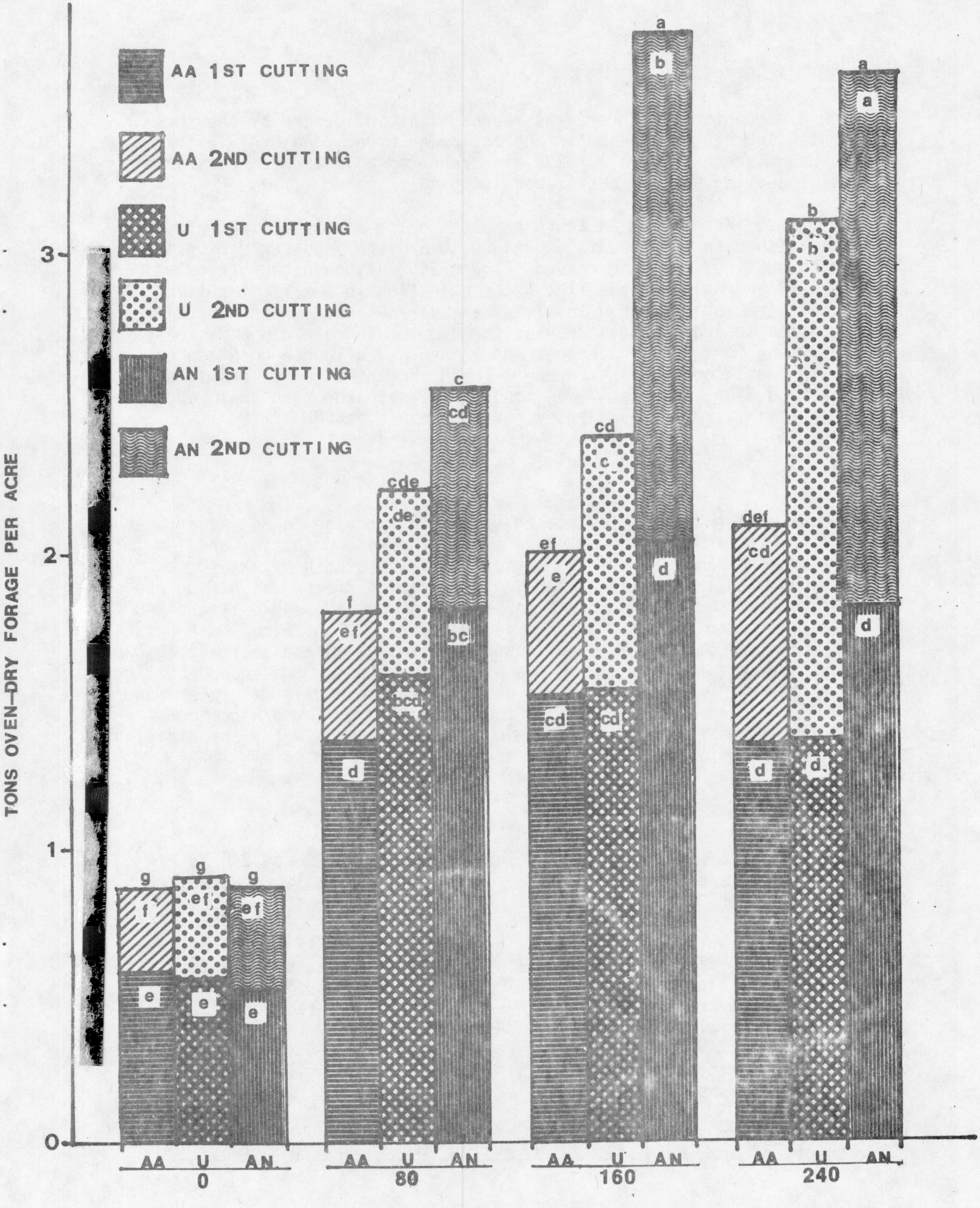

FIGURE 1: EFFECT OF N RATE AND SOURCE ON OVEN-DRY YIELD OF BROMEGRASS FORAGE (1967). (IN ALL BAR GRAPHS, BAR SEGMENTS REPRESENTING A GIVEN CUTTING THAT CONTAIN THE SAME LETTER INDICATE THESE VALUES ARE NOT SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL OF PROBABILITY, ACCORDING TO DUNCAN'S MULTIPLE RANGE TEST).

NITROGEN PERCENTAGE

The N percentages in bromegrass herbage, as influenced by the three different N sources, decreased in the following order: AN>U>AA (Figure 2). Vicente-Chandler and Figarella (23) also reported a lower N concentration in grass receiving U than in that receiving AN.

With each increase in AN the N percent in the first-cutting forage increased with each increase in N over 80 lb N/A the N concentration of the second-cutting forage increased (Figure 2). Although the other two N sources (U and AA) increased the N concentration in the first-cutting forage, differences between N levels at the various rates were irregular and sometimes insignificant. Only at the 240 lb N/A rate did U increase second-cutting forage N percentage, and AA had no influence on N concentration in the second-cutting forage. The N concentration of bromegrass that received 240 lb N/A as AN was considerably greater than that reported by Ramage et al. (20) in New Jersey for 400 lb N/A as AN.

NITROGEN UPTAKE

First-cutting N uptake increased with each increase in AN rates up to 160 lb N/A (Figure 3). However, N uptake in the second cutting and for the total season increased at all AN rates. Urea increased N uptake for the total season with the 80 and 240 lb N/A; however, differences in N uptake were insignificant above 80 lb N/A for the first cutting and only the 240-lb/A rate increased N uptake for the second cutting. AA increased N uptake for both cuttings but had no significant effect on N uptake above 80 lb N/A for the first cutting and only at the highest N rate for the second cutting. Also, significantly more total N was absorbed at the 240-lb N/A rate than at 80 lb N/A. Vicente-Chandler and Figarella (23) in Puerto Rico found similar results with napier-grass and concluded U and AA were less efficient suppliers of N than AN, ammonium sulfate, or sodium nitrate.

NITROGEN RECOVERY

Recoveries[1] of N at the application rates of 80, 160 and 240 lb N/A as shown in Figure 4 were, respectively, 96, 107, and 88% for AN; 68, 40 and 48% for U; and 32, 23, and 20% for AA.

Viets (24), working with several grasses, recovered 7 to 50% of N when AN was applied to fine-textured soils and 80% when it was applied to a fine sandy loam in Washington. Using 50, 100, 200, and 400 lb N/A as AN on orchard grass and reed canary grass, Ramage et al. (20) recovered 60, 74, 62, and 59%, respectively, of the applied N. In this study, recovery of more N than applied as AN at the 160-lb rate may have resulted from decomposition of soil organic matter. Broadbent (5) found similar results with ammonium sulfate applications.

---

[1] $\% \text{ recovery of applied N} = \frac{(\text{N uptake - N uptake of no N treatment})\ 100}{\text{N applied}}$

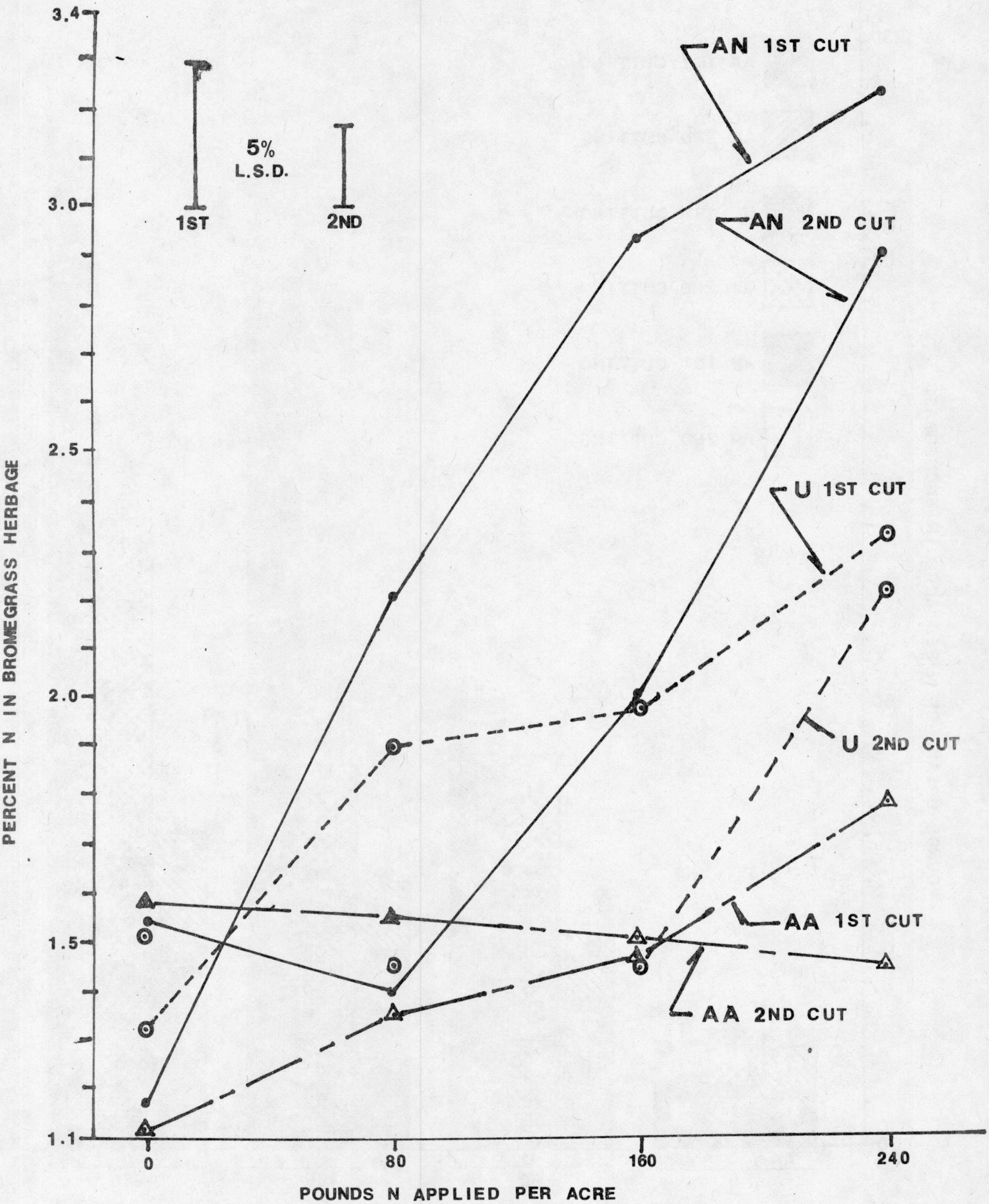

FIGURE 2: EFFECT OF N RATE AND SOURCE ON N PERCENTAGE IN BROMEGRASS FORAGE (1967).
(IN ALL LINE GRAPHS, SEGMENTS SHOWN REPRESENT THE DIFFERENCES NECESSARY FOR SIGNIFICANCE AT THE 5% LEVEL OF PROBABILITY).

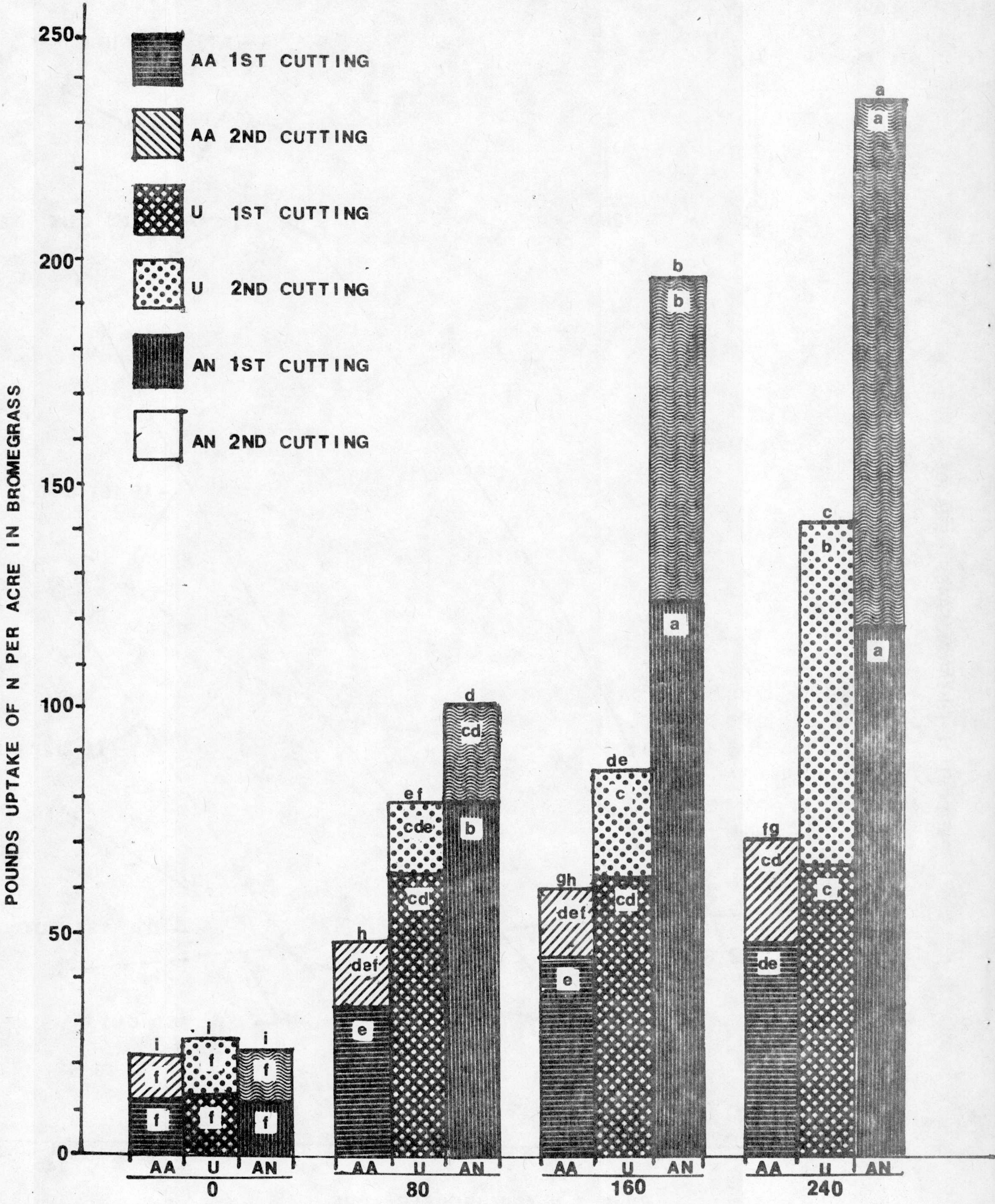

FIGURE 3: EFFECT OF N RATE AND SOURCE ON N UPTAKE BY BROMEGRASS (1967).

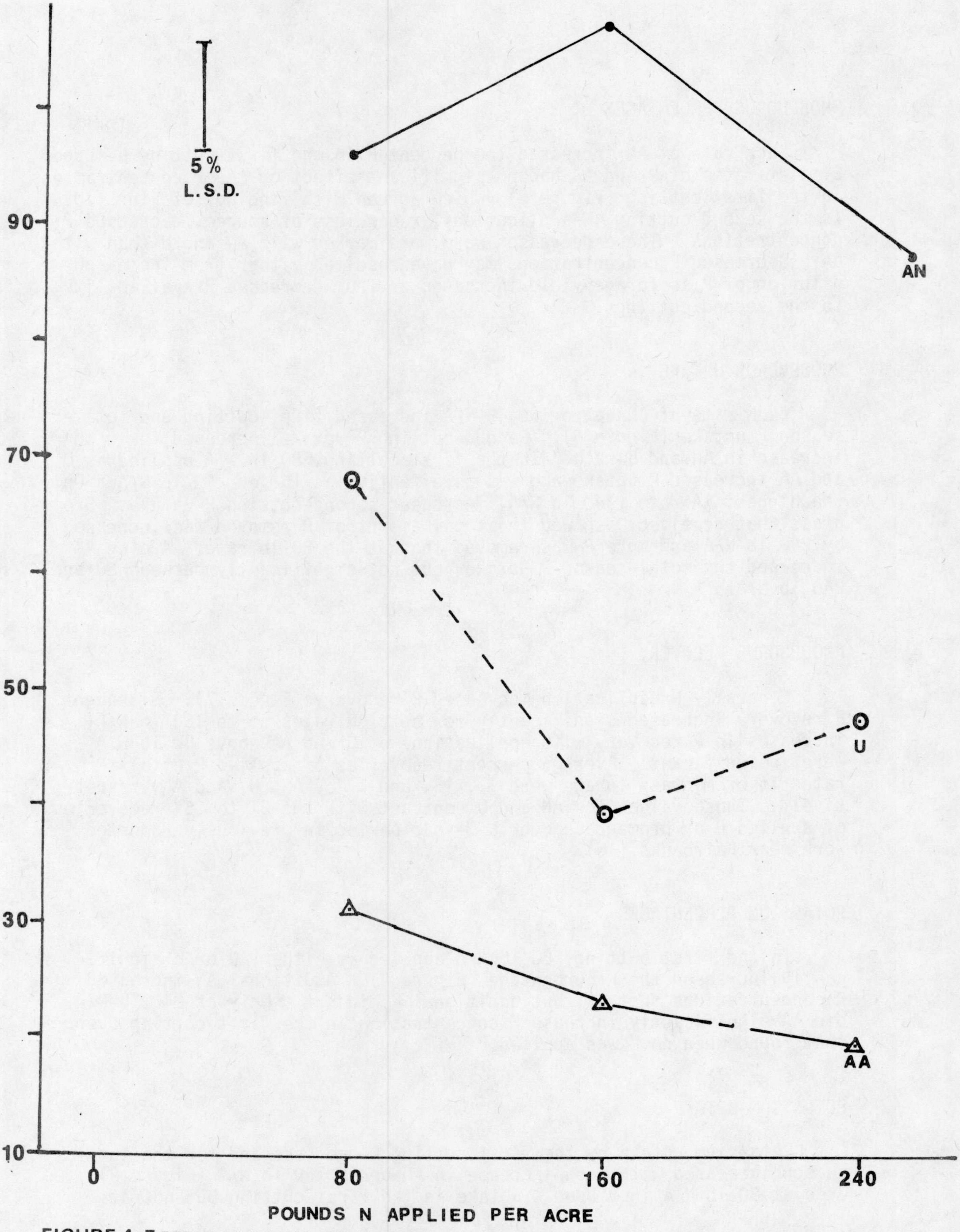

FIGURE 4: EFFECT OF N RATE AND SOURCE ON RECOVERY OF APPLIED N BY BROMEGRASS (1967).

$$\text{(\% RECOVERY OF APPLIED N} = \frac{\text{(N UPTAKE - N UPTAKE OF NO TREATMENT) 100)}}{\text{N APPLIED}}$$

THE ELMER E. RASMUSON LIBRARY
UNIVERSITY OF ALASKA

PHOSPHORUS PERCENTAGES

Each rate of AN increased the percent P in the first-cutting herbage. Similar rates of U and AA had no significant effect on the P concentrations in the first cutting (Figure 5), which agreed with findings of Fine (10). In the second cutting, N applications, regardless of source, decreased P concentrations. These decreases were more marked with AN and U than with AA. Decreased P concentrations may have resulted either from increased dilution of P as forage yield increased or from decreased P availability to the second cuttings.

PHOSPHORUS UPTAKE

Each rate of AN up to 160 lb N/A increased first-cutting and total-season P uptake (Figure 6). Second-cutting P uptake increased for each increase in AN and U rate. In the first cutting, 80 lb N/A applied as U and AA increased P uptake and was as effective as 160 or 240 lb N/A. Only the highest AA rate (240 lb N/A) increased second-cutting P uptake. Bromegrass that received U showed the total amount of P removed was increased by 240 lb N/A and more P was removed than at the 80-lb rate. Adding AA increased the total-season P uptake, but not significantly between 80 and 240 lb N/A.

PHOSPHORUS RECOVERY

Generally N application increased P recovery (Figure 7). Although P recovery increased significantly for both AN rates up to 160 lb N/A, increases in P recovery with applications of U and AA above 80 lb N/A were insignificant. Average percent recoveries of applied P at all N rates in bromegrass forage were 31, 13, and 17 by AN, U, and AA, respectively. Those values for AN and U contrast with the 21 to 36% recoveries of applied P by bromegrass over a 3-year period in previously reported work near Fairbanks (16).

POTASSIUM PERCENTAGES

In the first cutting, 80 lb N/A applied as either AN or U significantly increased the K percentage (Figure 8). Additional AN increased K concentrations further, but additional U did not. Only at 240 lb N/A did AA significantly increase K concentration in the first cutting over that found when no N was applied.

POTASSIUM UPTAKE

Potassium uptake by the first cutting bromegrass and for the total season increased with each increase in AN up to 160 lb N/A (Figure 9). Urea at 80 lb N/A increased K uptake in the first cutting but not at

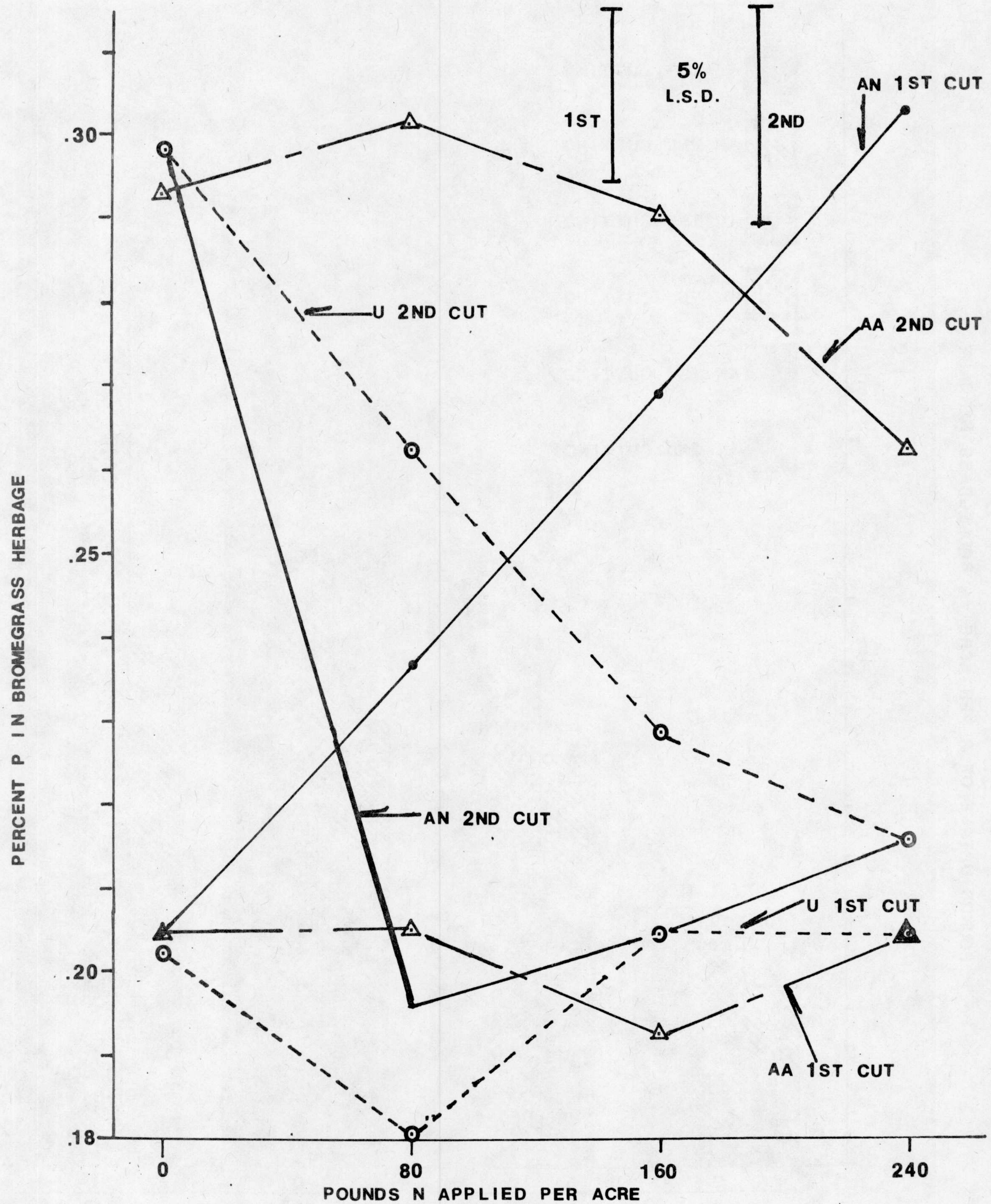

FIGURE 5: EFFECT OF N RATE AND SOURCE ON P PERCENTAGE IN BROMEGRASS FORAGE (1967).

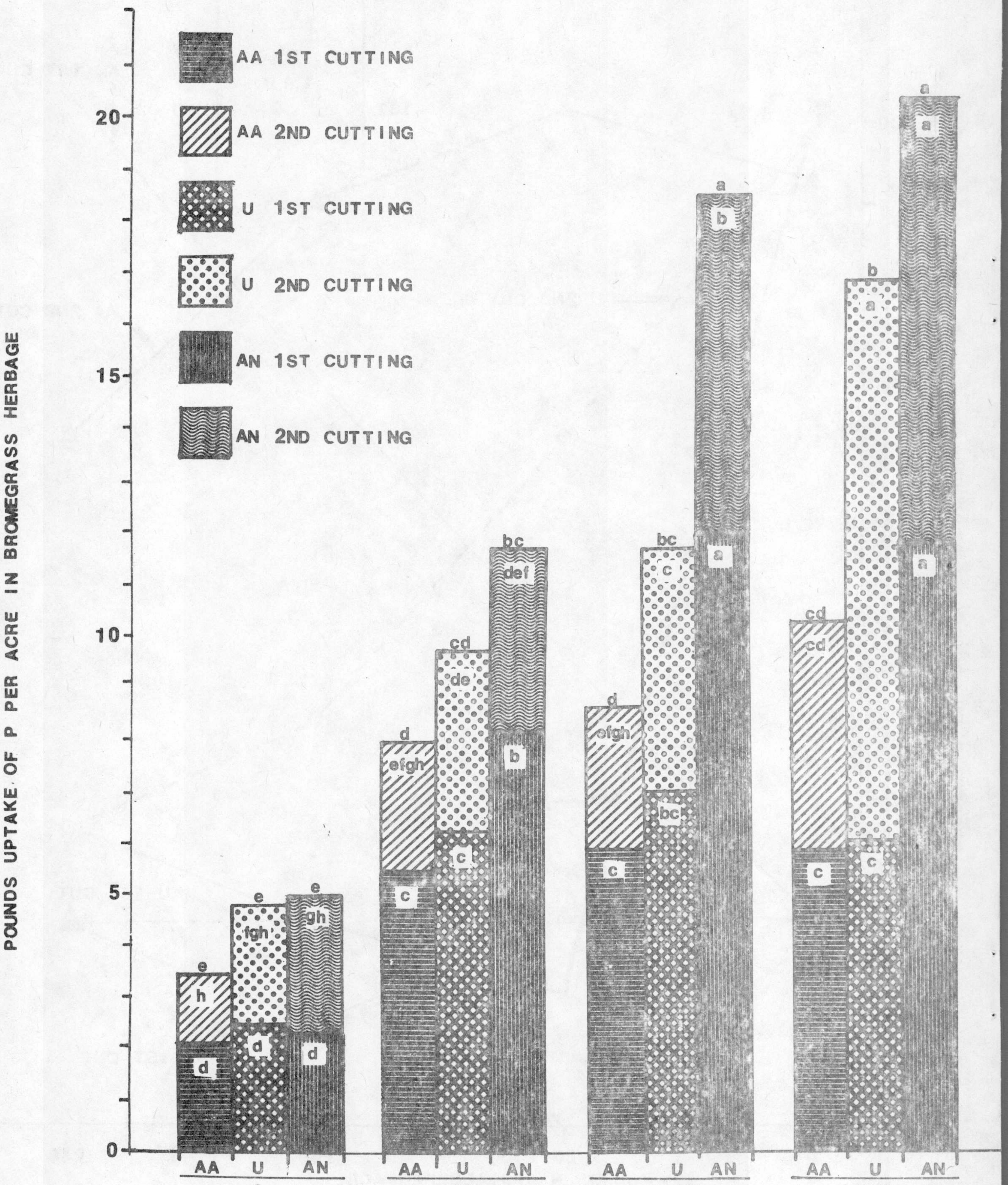

FIGURE 6: EFFECT OF N RATE AND SOURCE ON P UPTAKE BY BROMEGRASS (1967).

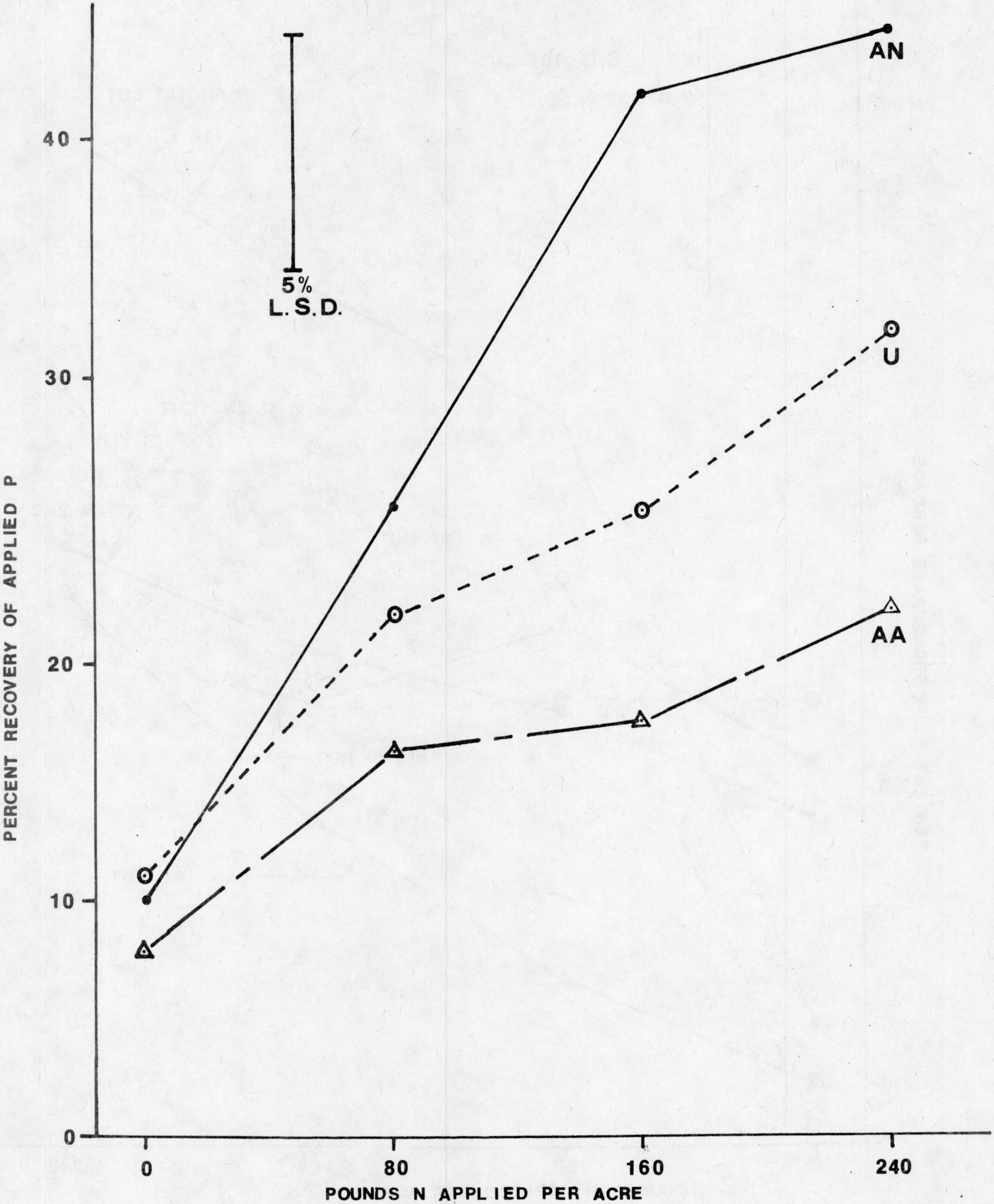

FIGURE 7: EFFECT OF N RATE AND SOURCE ON RECOVERY OF APPLIED P BY BROMEGRASS (1967).

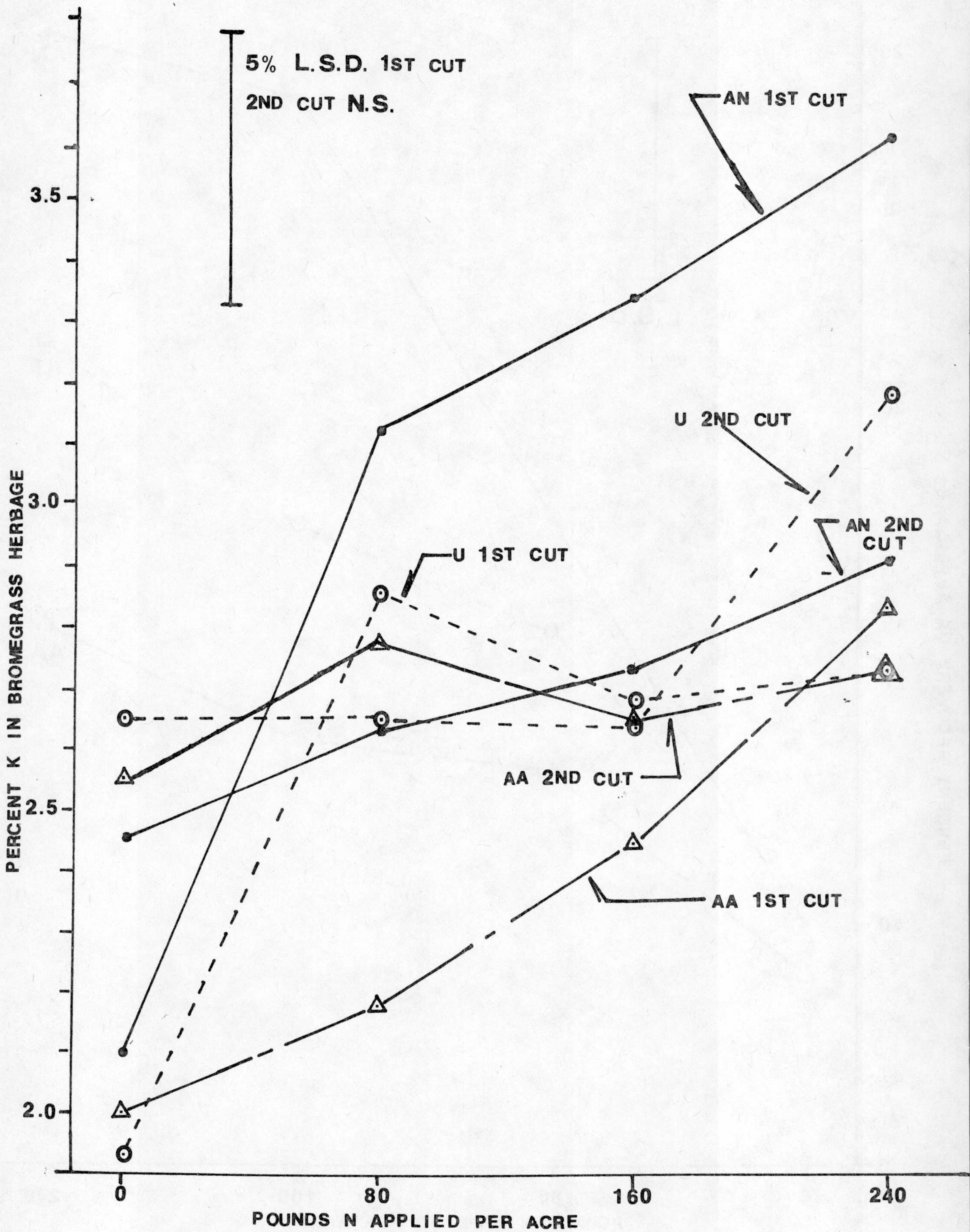

FIGURE 8: EFFECT OF N RATE AND SOURCE ON K PERCENTAGE IN BROMEGRASS FORAGE (1967).

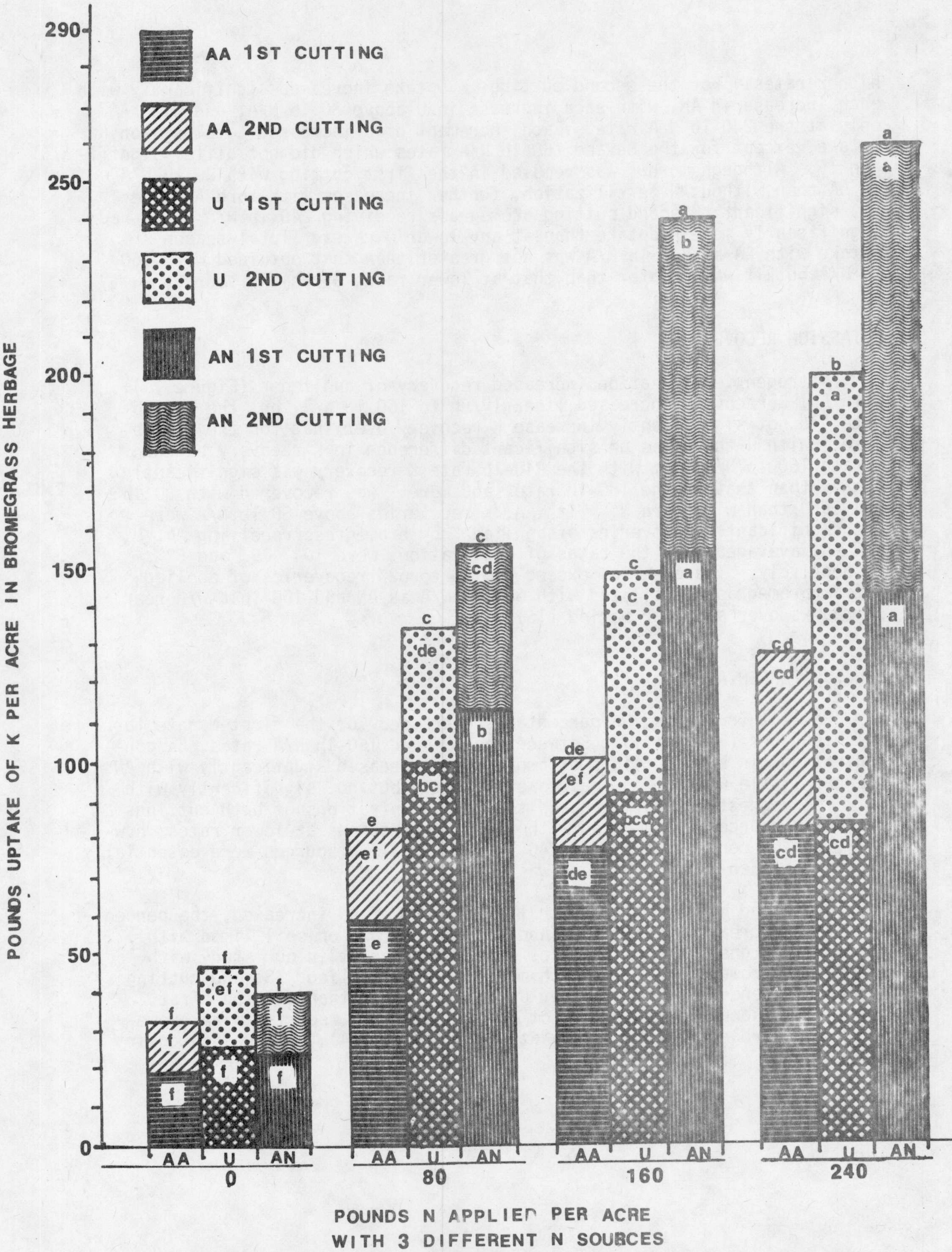

FIGURE 9: EFFECT OF N RATE AND SOURCE ON K UPTAKE BY BROMEGRASS (1967).

higher rates. For the second cutting, K uptake increased significantly with each increase in AN, with each increase in U above 80 lb N/A, and with AA only at the 240-lb N/A rate. Each increment of U increased total-season K uptake, except for the 80 and 160 lb N/A rates which did not differ significantly. Although more K was removed in the first cutting with 80 lb N/A of AA than without N fertilization, further increases with more AA were not significant. Second-cutting bromegrass receiving 240 lb N/A as AA had significantly more K uptake than at any lower N rates. Total-season K uptake with AA at 240 lb N/A was not greater than that obtained with 160 lb N/A but it was greater than that at lower rates of this N source.

POTASSIUM RECOVERY

Nitrogen fertilization increased recovery of applied K (Figure 10). With AN, K recovery increased linearly up to 160 lb N/A, but the 240-lb rate did not significantly increase K recovery over that for the 160-lb rate. With U there was no significant difference in K recovery between 80 and 160 lb N/A, but with the 240-lb rate K recovery was significantly higher than that at the 160-lb rate, and more K was recovered with 80 lb N/A as U than with zero N. With AA, K recoveries above 80 lb N/A were not significant. Recoveries of applied K by bromegrass receiving AN, U, and AA, averaged over the rates of application, were 104, 79, and 52% respectively. These values exceed the 30 to 62% recoveries of applied K from bromegrass fertilized with 300 lb N/A as AN and 160 lb K_2O/A near Fairbanks over a 3-year period (16).

CALCIUM PERCENTAGES

For both cuttings, Ca percentages decreased for the first N rate for all N sources (Figure 11). Between the 80- and 160-lb N/A rates, Ca concentrations in both cuttings of bromegrass increased signficantly with AN, changed little with U, and decreased slightly but not significantly with AA. The highest N rate increased the Ca concentrations of both cuttings for all N sources as compared with the concentrations at lower rates; however, the Ca concentrations at 240 lb N/A for all N sources were essentially no greater than those when no N was applied.

Drake and White (9) found that as amounts of AN increased, the percentage of Ca increased in tomatoes and buckwheat grown on soil limed with coarse limestone. Those increases were not apparent in our study with bromegrass grown on soil to which marl had been applied. Second-cutting bromegrass generally had a higher Ca concentration than did the first, but this seasonal increase was not as great as that reported with bromegrass at Fairbanks (16), timothy at Anchor Point (14), or bluejoint near Palmer (15).

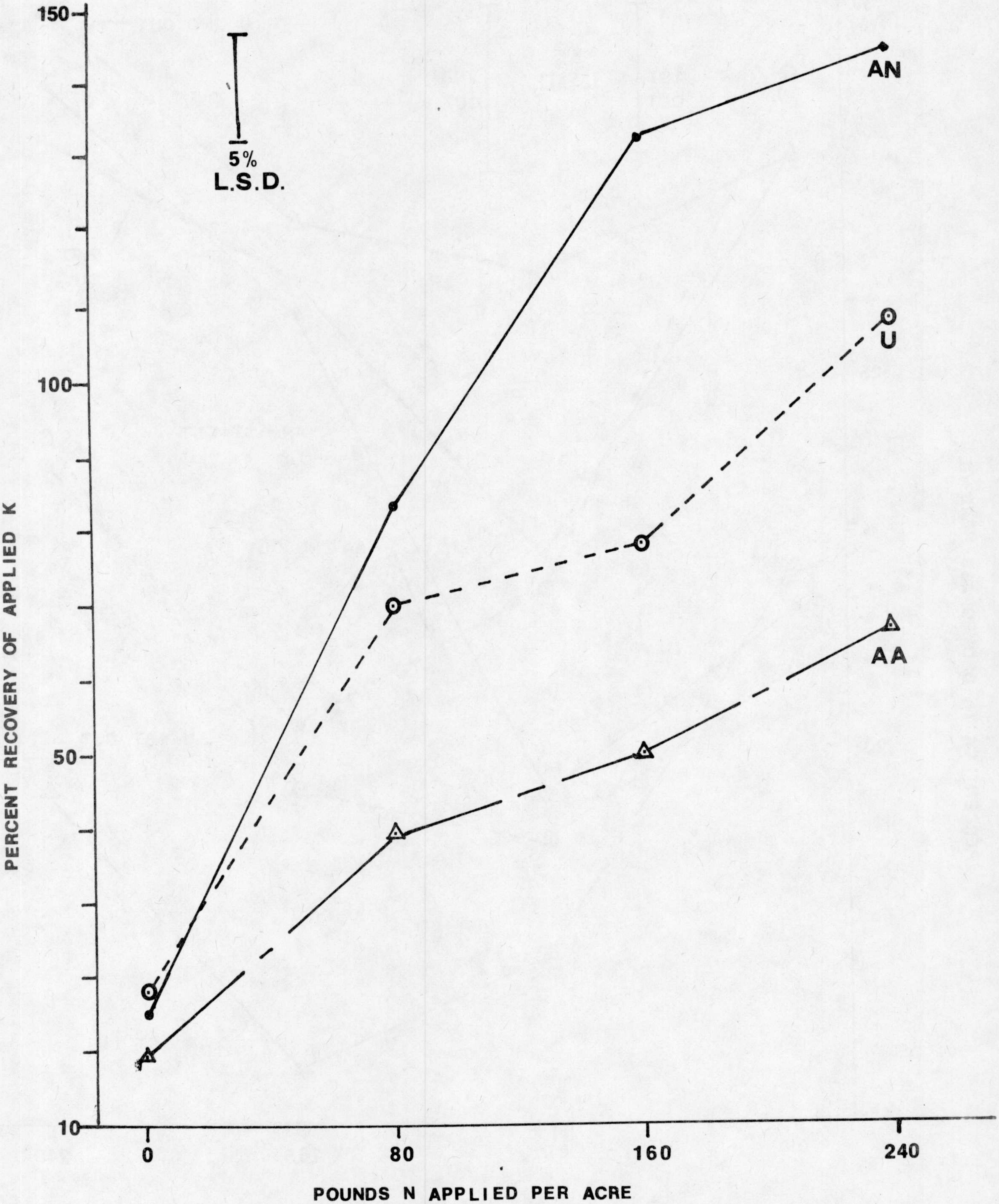

FIGURE 10: EFFECT OF N RATE AND SOURCE ON RECOVERY OF APPLIED K BY BROMEGRASS (1967).

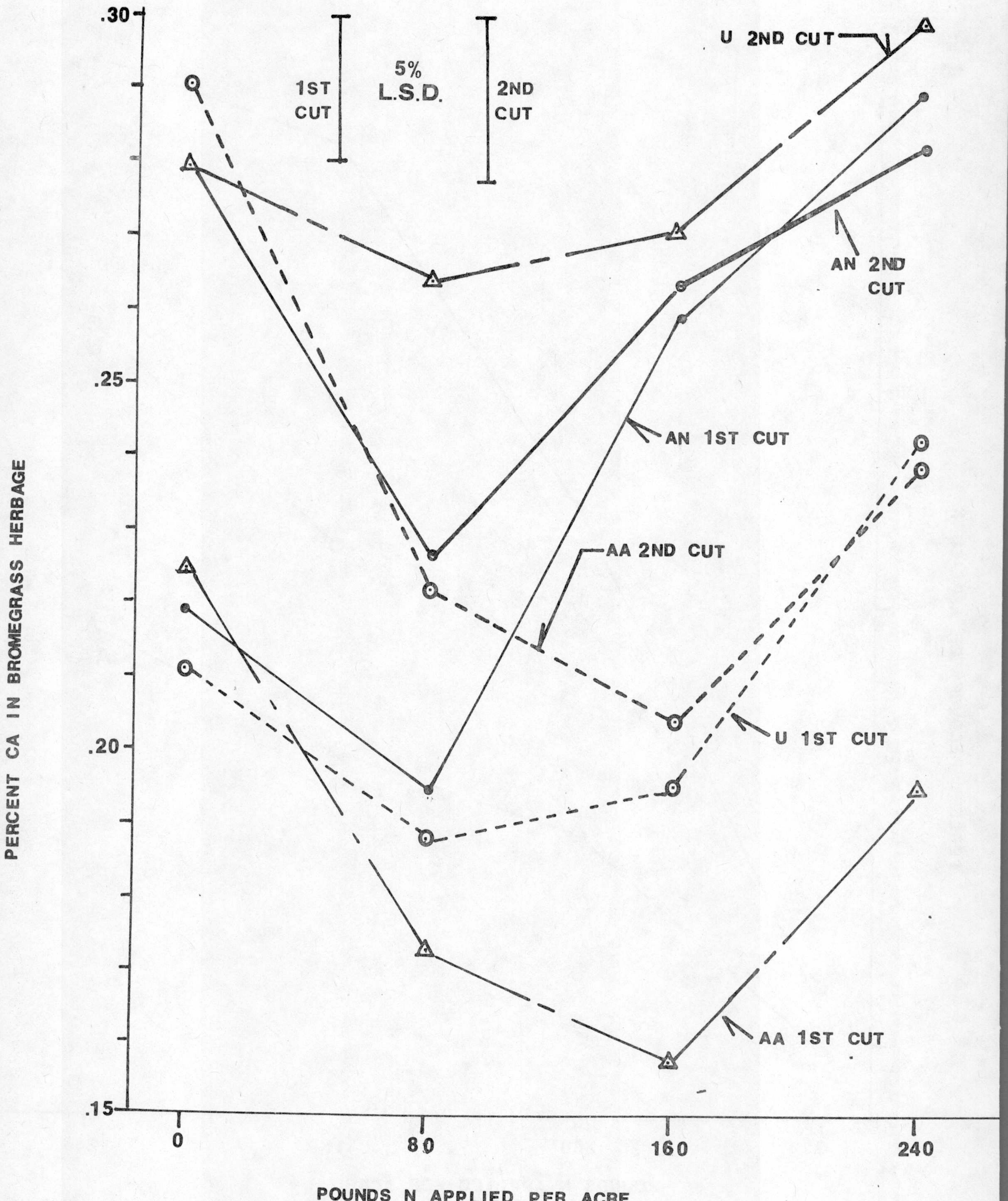

FIGURE 11: EFFECT OF N RATE AND SOURCE ON Ca PERCENTAGE IN BROMEGRASS FORAGE (1967).

CALCIUM UPTAKE

Each increase in AN up to 160 lb N/A increased Ca uptake for the first cutting (Figure 12). However, Ca uptake was not increased for the first cutting by more than 80 lb N/A supplied by either U or AA. Calcium uptake in the second cutting and for the total season was increased by each increase in AN. Each increase in U increased Ca uptake both for the second cutting and for the total season, except total-season Ca uptake did not differ significantly between the 80- and 160-lb N/A rates. When N was supplied by AA, Ca uptake was less than that with the other N sources.

MAGNESIUM PERCENTAGES

For both cuttings, Mg percentages decreased slightly to markedly for the first N increment regardless of N source (Figure 13). For the 160 lb N/A as AN, the Mg concentration increased for both cuttings. Further increases in Mg percentages occurred with the highest rate (240 lb N/A) as U or AN. For 240 lb N/A as AN, Mg concentration in both cuttings exceeded that of unfertilized bromegrass; however, this was not true for the other two N fertilizer sources. This increase in Mg concentration with high N resembled that obtained by Alston (2) with oats on limed soil. In first-cutting bromegrass that received AA, Mg concentration remained constant as the N application increased from 80 to 240 lb N/A. The Mg concentration in second-cutting bromegrass was greater than that of the first cutting for all N sources. The Mg percentages in this bromegrass were considerably lower than those determined previously in Alaska forages (14, 15, 16).

MAGNESIUM UPTAKE

Each increase in AN up to 160 lb N/A increased the amount of Mg removed by the first cutting; however, Mg uptake was not increased further by the highest N rate (Figure 14). Each increase in AN above 80 lb N/A increased the Mg uptake in the second cutting and for the total season. For first-cutting bromegrass, Mg uptake for U or AA was significantly increased by the 80-lb N/A rate, but not at higher rates. For the second cutting receiving U or AA, Mg uptake generally increased, but only at the 240-lb N rate was Mg uptake greater than that at lower N rates. Applications of both U and AA increased the seasonal Mg uptake over the no-N treatment, but only with U at 240 lb N/A was Mg greater than that at the lower rates.

SODIUM PERCENTAGE AND UPTAKE

Sodium percentages varied erratically from 0.009 to 0.15% and were unrelated to either N sources or rates. Sodium uptake by the bromegrass paralleled that of the dry-matter yields, with 0.2 to 2 lb Na/A removed by the two cuttings during the season.

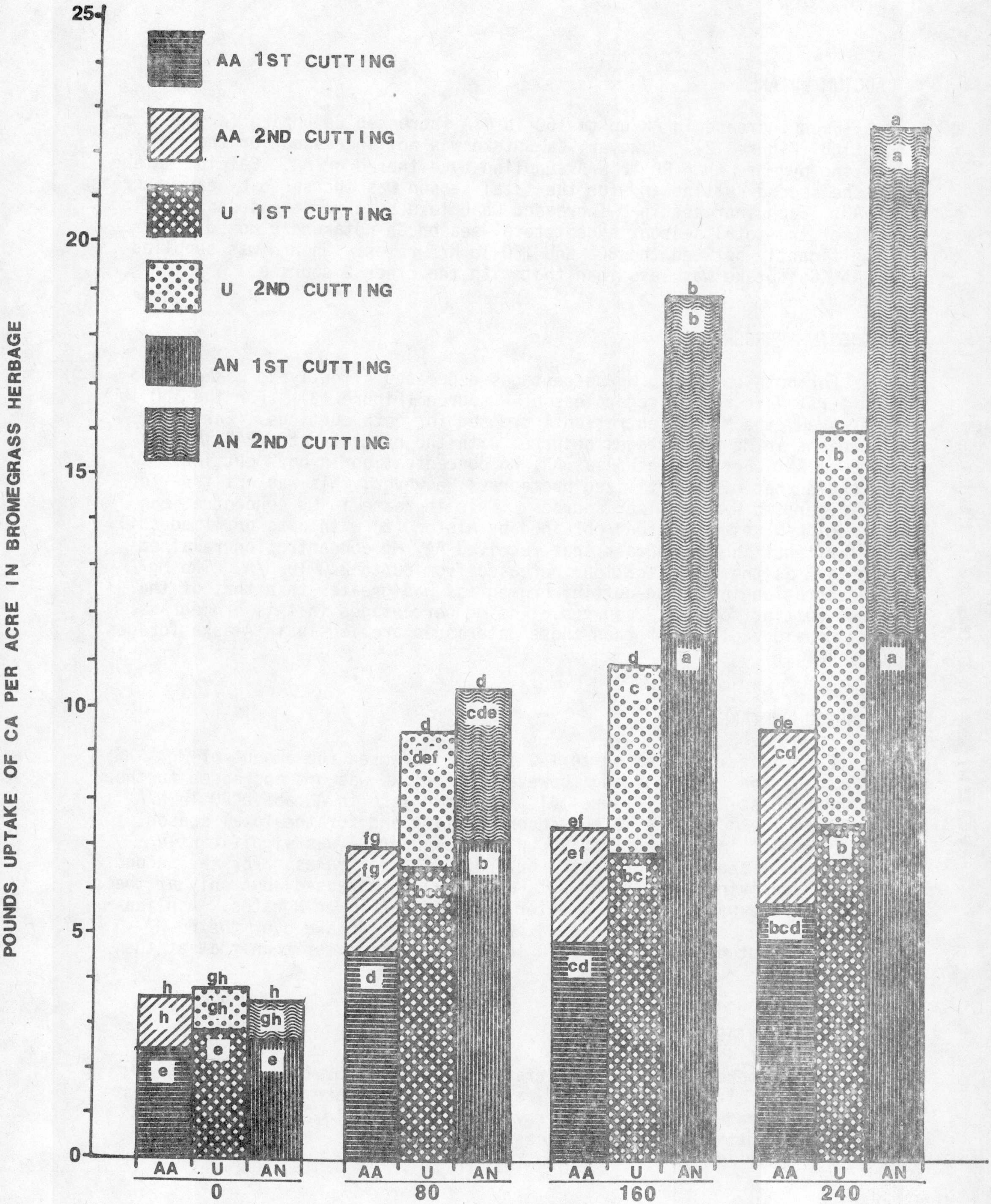

FIGURE 12: EFFECT OF N RATE AND SOURCE ON Ca UPTAKE BY BROMEGRASS (1967).

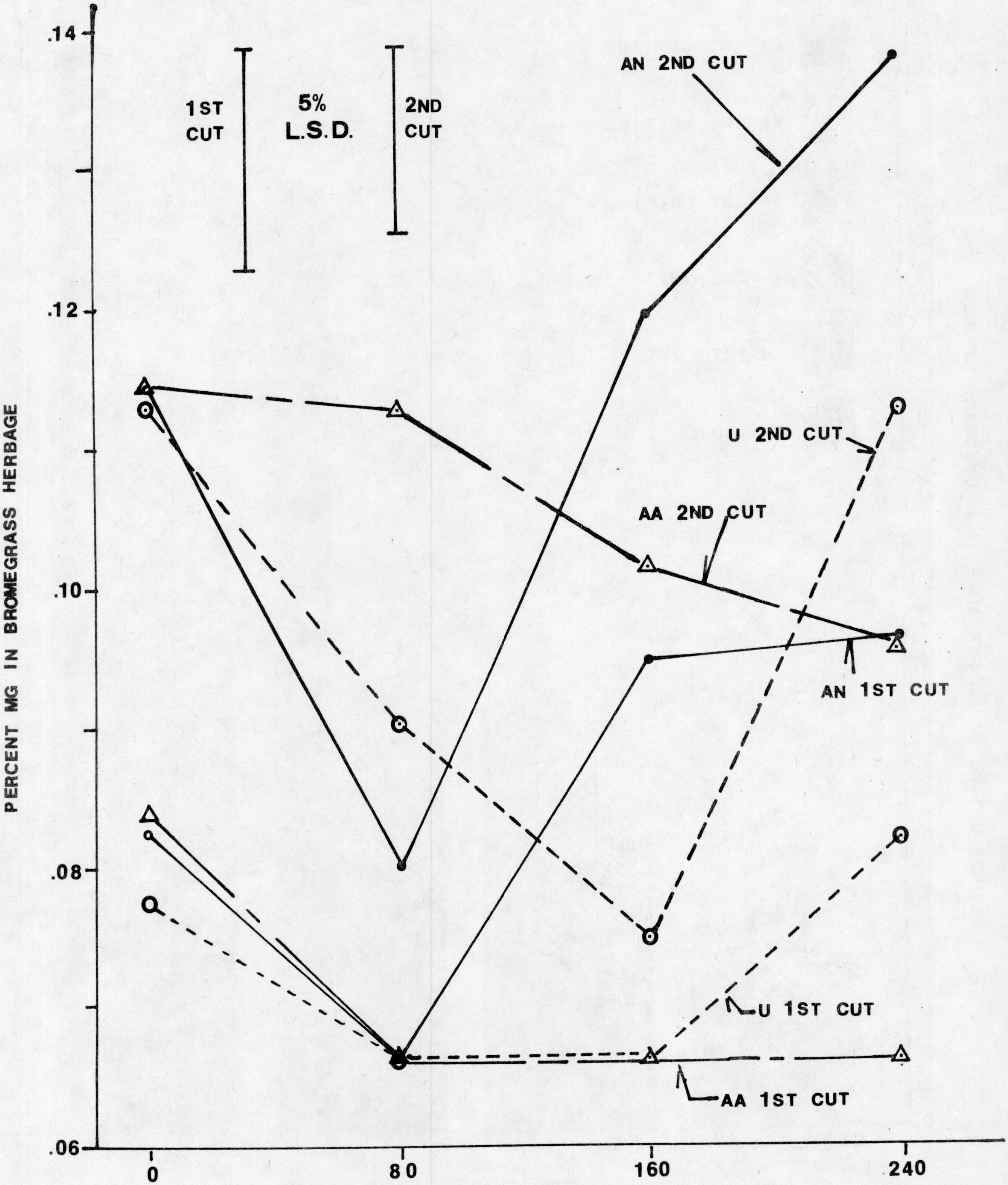

FIGURE 13: EFFECT OF N RATE AND SOURCE ON Mg PERCENTAGE IN BROMEGRASS FORAGE (1967).

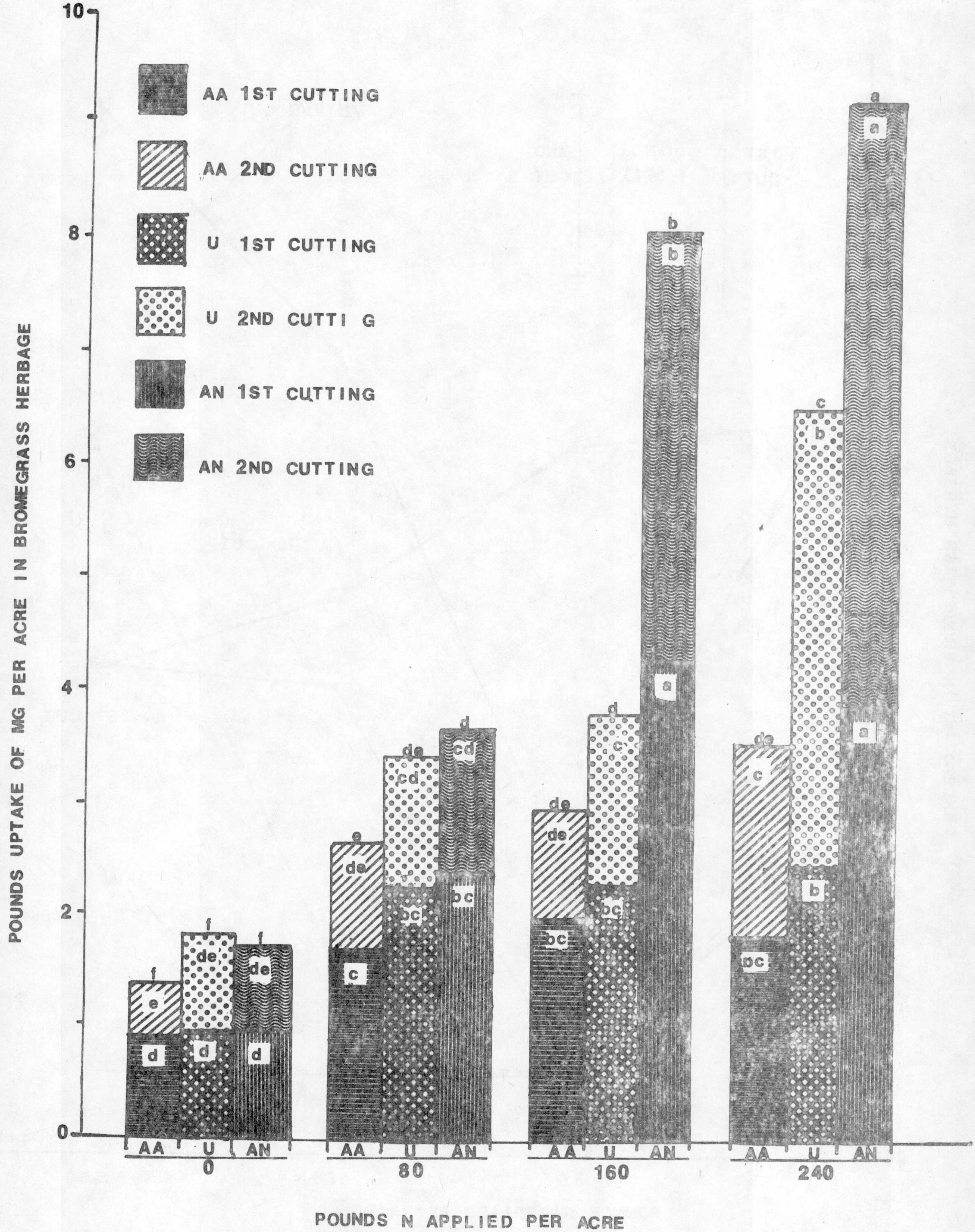

FIGURE 14: EFFECT OF N RATE AND SOURCE ON Mg UPTAKE BY BROMEGRASS (1967).

ALUMINUM

The highest N application rate reduced Al in the second cutting (Table 2), but there were no significant differences in Al content in bromegrass between 80 and 240 lb N/A. First-cutting Al concentrations were not related to N rates, and Al concentrations in both cuttings were unaffected by N source.

BARIUM

Barium concentrations were decreased by the 80- and 160-lb N/A rates in the first cutting, but were not affected by N rates in the second cutting (Table 2). The first-cutting Ba concentrations were highest for the AN application but those for the second cutting were not affected by N sources.

BORON

B concentrations were decreased by the 80- and 160-lb N/A rates in the first cutting (Table 2). In the second cutting, the 160- and 240-lb N rates were decreased B content in the forage. First-cutting B concentrations were not affected significantly by N sources, but second-cutting B concentrations were higher for AA than for AN treatments.

CHROMIUM

All samples of both cuttings contained less than 3 ppm Cr.

COPPER

Cu concentrations in bromegrass increased as N rates increased and were highest when AN was used as the N source (Table 2). The first cutting contained the highest Cu content (2.9 ppm) which was 2 ppm lower than the minimum amount associated with Cu deficiencies in ruminants (11).

IRON

First-cutting Fe concentrations were not related to N rates (Table 2). In the second cutting Fe concentrations were decreased as N application increased. Source of N had no influence on Fe concentrations in either cutting.

TABLE 2: EFFECT OF N SOURCE AND RATE ON THE Al, Ba, B, Cu, Fe, Mn, Mo, Sr, AND Zn IN FIRST AND SECOND CUTTINGS OF MANCHAR BROME ON HOMESTEAD SILT LOAM, 1967.

	ppm Al		ppm Ba		ppm B	
	1st	2nd	1st	2nd	1st	2nd
Nitrogen lb/A	Effect of N rate (means of 12 measurements)					
0	153a[1]	209a	12.4a	17.0a	5.0a	4.7a
80	47a	62b	7.6c	15.4a	3.6b	4.0ab
160	61a	37b	9.9b	15.5a	3.7b	3.5b
240	145a	25b	12.4a	15.4a	4.1ab	3.2b
	Effect of N source (means of 16 measurements)					
Ammonium nitrate	120a	43a	11.6a	16.0a	2.7a	3.3b
Urea	107a	95a	10.1b	15.5a	4.0a	3.9ab
Aqua ammonia	78a	112a	10.0b	16.7a	4.6a	4.3a
C.V.[2]	127%	133%	18.8%	13.2%	30.3%	26.8%

	ppm Cu		ppm Fe		ppm Mn	
	1st	2nd	1st	2nd	1st	2nd
Nitrogen lb/A	Effect of N rate (means of 12 measurements)					
0	1.0c	0.9b	186a	221a	49.1a	80.4a
80	1.7b	1.0b	82a	89b	39.6b	69.6b
160	2.2b	1.0b	95a	66b	39.3b	62.4c
240	2.9a	1.7a	180a	50b	43.0ab	50.4d
	Effect of N source (means of 16 measurements)					
Ammonium nitrate	2.6a	1.4a	158a	71a	48.4a	62.3b
Urea	1.8b	1.1b	137a	106a	37.9b	61.4b
Aqua ammonia	1.4b	1.0b	113a	142a	40.0b	73.5a
C.V.	33.1%	31.7%	84.0%	87.3%	22.2%	12.3%

	ppm Mo		ppm Sr		ppm Zn	
	1st	2nd	1st	2nd	1st	2nd
Nitrogen lb/A	Effect of N rate (means of 12 measurements)					
0	0.12a	0.14a	10.4b	11.7a	12.3b	15.8a
80	0.13a	0.08b	10.2a	11.0a	12.7b	14.2a
160	0.14a	0.11ab	10.2a	11.0a	14.0b	13.0a
240	0.12a	0.10b	11.8a	12.4a	17.1a	15.2a
	Effect of N source (means of 16 measurements)					
Ammonium nitrate	0.10a	0.11a	11.6a	12.4a	16.9a	15.7a
Urea	0.14a	0.10a	10.5b	11.1b	13.6b	12.9b
Aqua ammonia	0.14a	0.10a	9.9b	11.0b	11.6c	15.2a
C.V.	50.6%	39.9%	14.4%	14.2%	17.2%	19.6%

1 Column means by the same letter are not significantly different at the 5% level of probability, according to Duncan's Multiple Range Test.

2 Coefficient of variation indicates the dispersion of the individual values around the mean. The larger the value, the greater the variation within the experiment.

MANGANESE

Eighty and 160 lb N/A applications reduced Mn concentrations in the first cutting (Table 2) and each increase in N reduced second-cutting Mn concentrations. In the first cutting, Mn concentrations was greatest with AN; in the second cutting, it was greatest with AA.

MOLYBDENUM

In the first cutting, Mo concentration was not affected by N rates applied (Table 2). Second-cutting Mo concentration was highest where no N was applied and was reduced by the 80- and 240-lb N/A application rates. This decrease may be related to that reported by Barshad (3), who suggested high N rates decreased Mo in plants growing on soils containing high Mo levels.

The N sources did not influence the Mo concentration in forage for either cutting. Mo values obtained for this study were about 1/10 those reported for other vegetation (11). According to Jensen and Lesperance (12), 5 to 30 ppm Mo is toxic to livestock. They found 8 ppm Mo in bromegrass grown in soil which had received 5 lb Mo/A.

STRONTIUM

The Sr content of the first-cutting brome increased slightly with the largest (240 lb N/A) N application (Table 2). Second-cutting Sr concentration was unaffected by N rates. Both bromegrass cuttings receiving AN contained more Sr than that fertilized with either U or AA.

ZINC

Like Sr, Zn content of the first cutting increased at the 240-lb N/A rate, but that in the second cutting was unaffected by N (Table 2). The amount of Zn in the second cutting was independent of N application rates.

The amount of Zn in the first cutting decreased with N sources as follows: AN>U>AA. Using U produced second-cutting bromegrass with less Zn than using either AN or AA.

Although Zn content values were only slightly lower than those reported by Fletcher and Brink (11) in British Columbia, they were well below the 50 ppm Zn regarded as minimal to adequate for ruminant nutrition.

Table 1 presents soil pH, Kjeldahl N, and available NO_3-N, P, and K in soil, after two cuttings of bromegrass, as influenced by soil treatments. The decrease in available K as N applications increased, reflected the incoming yield of bromegrass as it decreased soil K. The heaviest K rate significantly increased the soil's NO_3-N content. Soil pH and available P were unaffected by N rate or source.

After the last harvest, more available NO_3-N was present in plots that had received AN than in those fertilized with either U or AA. The higher available K in soil from plots that received AA reflected less K removal because of the relatively lower bromegrass yields. Kjeldahl N contents were not affected by N source.

When we compared the values in Table 1 with those of the original composite soil samples taken before fertilizer application, we found that available K increased slightly, NO_3-N decreased, and available P remained unchanged. These comparisons, along with the uptake data, showed bromegrass almost completely utilizing applied N and K.

The Collier Carbon plant near Kenai, Alaska, currently can supply bulk U directly to Alaskan farmers at a lower price than any other commercial N source. However, since both P and K are also usually required in grass fertilization, bulk U must be applied by a separate operation or mixed with appropriate P and K fertilizers immediately before application. Farmers must take extreme care in mixing U with other fertilizers, since absorption of atmospheric moisture and consequent caking of the fertilizer can result. U reacts especially rapidly with ammonium nitrate.

Thus, in choosing among N sources, farmers must consider several factors including cost per unit of N, availability of application equipment, application costs, compatibility with other fertilizers, as well as anticipated crop responses.

ACKNOWLEDGMENT

We thank Mrs. Erma Liebing for final drafting of the figures and for typing the manuscript.

LITERATURE CITED

1. Association of Official Analytical Chemists. 1970. Official methods of analysis, 11th Ed. Washington, D.C.

2. Alston, A. M. 1966. The influence of N and Mg fertilizers and $CaCO_3$ on the absorption of Mg by oats. J. Agric. Sci. 66:61-66.

3. Barshad, I. 1951. Factors affecting the molybdenum content of pasture plants: II. Effect of soluble phosphates, available nitrogen, and soluble sulfates. Soil Sci. 71:387-398.

4. Burton, G. W., and J. E. Jackson. 1962. Effect of rate and frequency of applying six nitrogen sources on coastal bermudagrass. Agron. J. 54:40-43.

5. Broadbent, F. E. 1966. Effect of fertilizer nitrogen on the release of soil nitrogen. Soil Sci. Soc. Amer. Proc. 29:692-696.

6. Christensen, R. E., R. M. Beckman, and J. J. Birdsell. 1968. Some mineral elements of commercial spices and herbs as determined by direct reading emission spectroscopy. J. Amer. Soc. Anal. Chem. 51:1003-1010.

7. Court, M. N., R. C. Stephen, and J. S. Waid. 1964. Toxicity as a cause of the inefficiency of urea as a fertilizer. II. Experimental. J. Soil Sci. 15:49-65.

8. Dotzenko, A. D. 1961. Effect of different nitrogen levels on the yield, total nitrogen content and nitrogen recovery of six grasses. Agron. J. 53:131-133.

9. Drake, M., and J. M. White. 1961. Influence of nitrogen on uptake of calcium. Soil Sci. 91:66-69.

10. Fine, L. O. 1955. The influence of nitrogen and potassium on the availability of fertilizer phosphorus. S. Dak. Agr. Exp. Sta. Bull. 453. (N.C. Regional Publ. 67), 22 pp.

11. Fletcher, K., and V. C. Brink. 1969. Content of certain trace elements in range forages from South Central British Columbia. Can. J. Plant Sci. 49:517-520.

12. Jensen, E. H., and A. L. Lesperance. 1971. Molybdenum accumulation by forage plants. Agron. J. 63:201-204.

13. Laughlin, W. M. 1962. Fertilizer practices for bromegrass. Ak. Agr. Exp. Sta. Bull. 32. 15 pp.

14. Laughlin, W. M. 1965. Effect of fall and spring applications of four rates of potassium on yield and composition of timothy in Alaska. Agron. J. 57:555-558.

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

16. Laughlin, W. M., and S. Restad. 1964. Effect of potassium rate and source on yield and composition of bromegrass in Alaska. Agron. J. 56:484-487.

17. Martin, P. F. 1970. Laboratory methods and procedures. IN: Alaska Agricultural Experiment Station "quick" soil tests. Ak. Agr. Exp. Sta. Mimeo. 11 pp.

18. Perkin-Elmer Corporation. 1966. Analytical methods for atomic absorption spectrophotometry. Norwalk, Conn.

19. Purvis, E. R. 1961. Urea is satisfactory nitrogen source under most conditions. N.J. Agr. 43:5-7.

20. Ramage, C. H., C. Eby, R. E. Mather, and E. R. Purvis. 1958. Yield and chemical composition of grasses fertilized heavily with nitrogen. Agron. J. 50:59-62.

21. Templeman, W. G. 1961. Urea as fertilizer. J. Agr. Sci. 57:237-239.

22. Tsai, P., and T. R. Sheng. 1961. A study on the relative availability of ammonium sulphate, ammonium chloride and urea to sugar cane. Rep. Taiwan Sugar Exp. Sta. 24:55-65.

23. Vicente-Chandler, J., and J. Figarella. 1962. Effects of five nitrogen sources on yield and composition of napier grass. J. Agric. Univ. of Puerto Rico. 46:102-106.

24. Viets, F. G., Jr. 1960. Recovery of fertilizer nitrogen on irrigated and dryland soils of the western United States. Trans. 7th Int. Congr. of Soil Sci. 2:486-493.

25. Volk, G. M. 1961. Gaseous loss of ammonia from surface-applied nitrogenous fertilizers. J. Agric. Food Chem. 9:280-283.

26. Wahhab, A., M. Khan, and M. Ishaq. 1960. Nitrification of urea and its loss through volatilization of ammonia under different soil conditions. J. Agric. Sci. 55:47-51.