Effects of Potassium, Sulfur, Nitrogen Rate, And Nitrogen Source on Bromegrass Forage Yield and Composition

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INTRODUCTION

Production of adequate, high-quality forage is essential for Alaska's livestock industry. Smooth bromegrass *(Bromus inermis)* is the dominant and most dependable perennial forage crop in the Matanuska Valley and other areas of Alaska. Four areas of Knik silt loam on the University of Alaska's Matanuska Research Farm near Palmer were seeded to bromegrass and were used over a period of 18 years to determine the need of high-yielding bromegrass for applications of potassium (K) and sulfur (S). A bromegrass field on the Woods estate two miles south of Palmer was selected in 1976 for a study comparing three rates of two nitrogen (N) sources with and without S. The soil type was Bodenburg silt loam.

EXPERIMENTAL PROCEDURE

In 1967 a 2 × 6 factorial trial replicated six times and involving six K rates (0, 33, 66, 99, 133, and 166 lb K per acre) and two K sources (muriate and sulfate of potash) was laid out in a randomized block design on a three-year-old bromegrass stand and harvested in 1967 and 1968 (location A). In 1969 at another location on this same bromegrass stand a 2 × 6 factorial trial, also replicated six times and involving the same six K rates with and without sulfur, was established and harvested for three years (1969-71) (location B). Sulfur (70 lb per acre) was supplied in ammonium phosphate (16-20-0-14). In 1972 on a three-year-old bromegrass stand about half a mile away the same experimental design and treatments were established and harvested five years (1972-76) (location C). And in 1977 at a different location on this same bromegrass stand this same design and treatments were established and harvested eight years (1977-84) (location D). All plots in 1967 through 1971 received 150 lb N per acre (as ammonium nitrate in 1967 and 1968 and as ammonium phosphate and ammonium nitrate from 1969 through 1971). For each of the 18 years all plots received 44 lb P (100 lb P_2O_5) per acre. In 1967

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and 1968 this was supplied to all plots by treblesuperphosphate. In all other years, plots not receiving sulfur in ammonium phosphate received their P as treblesuperphosphate. Beginning in 1972, the N rate was increased to 200 pounds per acre; half was applied with the other fertilizer ingredients the last of April or early in May and the second half immediately after the first harvest.

In 1977 a 3×2^2 factorial experiment replicated six times involving three N rates (80, 160, and 240 lb N per acre), two N sources (ammonium nitrate [AN] and urea), with and without S, was established in a randomized block design on the Bodenburg silt loam location. Two treatments without N, one of which included S, gave four N rates. All plots received 44 lb P (100 lb P_2O_5) as treblesuperphosphate and 182 lb K per acre (221 lb K_20). Plots receiving S had 25, 50, or 75 lb S per acre (corresponding with the increasing N rates) applied. Sulfur was applied to the AN treatments as sulfate of potash. The additional K was supplied as muriate of potash which was also used on all plots which did not receive S. Sulfur was applied to the urea plots as sulfur-coated urea (38.4 percent N and 12.25 percent S). All fertilizer treatments were broadcast on the soil surface by hand in the early spring of each season when the frost had receded to a 6- to 8-inch depth.

Two clippings were made annually with a small sickle-equipped power mower near the middle of June and the middle of August each year. The harvested area consisted of a strip 30 inches wide cut from the center of each plot 12 feet long. Green and dry weights were recorded for each harvest. Representative samples from each plot were ground to pass a 20-mesh stainless steel laboratory mill screen. Chemical determinations were made as follows: nitrate-N with the nitrate electrode (Smith 1975); total N and P colorimetrically with the Technicon autoanalyzer (TIS 1976); K, calcium (Ca), and magnesium (Mg) using an atomic absorption spectrophotometer following a sulfuric-selenous acid digestion and using lanthanum to control interferences (Perkin-Elmer 1973); and total S using an automatic S analyzer (Smith 1980).

The data were subjected to split-plot type analyses of variance for repeated measures experiment. The main plots of the K and S experiment were a 2×6 randomized complete block with six blocks. Each experimental treatment was measured over 18 years for yield and N concentration and uptake; 16 years for S; 15 years for $N0_3$-N; and 12 years for P, Ca, and Mg. In the analysis of variance the whole plot effects were K, S, and the K $\times$ S interaction. The subplot on repeated measures effects were year and all interactions involving years. In the significance tests for the year and year interaction effects, conservative tests using minimum degrees of freedom for the required F values for significance allowing for auto correlations among years were utilized.

In the N rate, N source, and S experiment the main plots were a $3 \times 2 \times 2$ randomized complete block with six blocks. Each experimental plot was measured over four years. In the analysis of variance the whole plot effects were N, N source, S, and all interactions among these factors. The subplot on repeated measure effects were year and all interactions involving years.

RESULTS AND DISCUSSION

Potassium Rate and Sulfur Experiments

Yield. The effects of S on first-cutting yields over 18 years are shown in Table 1. Sulfur application significantly increased first-cutting yields in 1967-69, 1971, 1975, and 1976, and the average of all 18 years but had no significant effect on these yields the other 12 years. The very low yields in 1969-71 reflect low soil moisture. Moisture stress was so extreme in 1970 that the grass was wilting during the day before the first harvest. That year 1.25 inch water was added from a tank truck immediately after the first cutting.

The effects of K on first-cutting yields over 18 years are presented in Table 2. First-cutting yields were increased significantly by K application every year but 1969-72 and 1977. And only in 1984 was the 166 lb K per acre yield greater than that of the other K rates. The 18-year means indicate a rapid yield increase with 33 and 66 lb K per acre followed by a more gradual increase with increasing K.

The years that K failed to increase yields were at location B and the first year at location D. This may indicate there was enough residual K present from previous field fertilizations to supply the K needed by the grass. The effects of both K and S on second-cutting and total annual bromegrass yields over 18 years are shown in Tables 3, 4, 5, and 6.

The number of years that sulfur application increased significantly the second-cutting and total annual yields was as follows: no K: 5 and 3; 33 lb per acre: 11 and 12; 66 lb per acre: 12 and 11; 99 lb per acre: 11 and 9; 133 lb per acre: 10 and 7; and 166 lb K per acre: 14 and 12 years, respectively, of the 18 years of these trials (table 3 and 4). Sulfur application at all K rates increased the 18-year average of second-cutting yields and of the annual yields except when no K was applied.

Second-cutting bromegrass yields were increased by K every year but 1969-71, 1974, and 1976 when no S was applied and every year but 1969 and 1977 when S was applied. Only in 1980, 1981, 1983, and 1984 did the heaviest K application (166 lb K per acre) with S increase yields above all other K rates. The 18-year average second-cutting was increased with and without S by K and the heaviest K application increased these yields over all other K rates when S was applied (table 5).

Potassium application increased annual total oven-dry yields except in 1969, 1970, and 1971 when no S was applied and in 1969 and 1970 when S was applied. Only in 1980, 1981, and 1984 did the heaviest K rate of 166 lb per acre with S increase total yields above that of all other K treatments. Total annual forage yields averaging all 18 years were increased by K application with or without S, the last K increment increased the 18-year average above all other K treatments only when S was applied.

NO_3-N concentration and uptake. The effects of S on the NO_3-N concentration and uptake over 15 years are shown in Table 7. First-cutting NO_3-N concentration was depressed by S application each year except 1979 when the difference was not large enough to be significant. Sulfur application decreased second-cutting NO_3-N concentration in 1970, 1971, 1974-76, 1983, and 1984 and increased it in 1981. Uptake of NO_3-N was depressed by S application in 10 of the 15 years and increased in 1971. The averages over the 15 years show S application depressed the NO_3-N concentration in both cuttings as well as the total annual NO_3-N uptake.

Table 8 shows that K rates exceeding 33 lb per acre, when no S was applied, increased the first-cutting NO_3-N concentration. Rendig et al. (1976) stated that an inadequate S supply limits the plant's ability to synthesize protein more than it limits N uptake. This may explain the higher NO_3-N concentration where no S was applied over that in plants receiving S.

The effects of K on second-cutting NO_3-N concentration and total seasonal uptake are depicted in Table 9. Second-cutting NO_3-N concentration varied widely from year to year and with K rates with no apparent consistency. However, for 10 of the 15 years the lowest NO_3-N concentration occurred when 33 lb K per acre had been used. In every year but 1970 and 1974 K application increased the total seasonal NO_3-N uptake. Generally the NO_3-N uptake increased with increasing K rates.

Nitrogen concentration and uptake. The effects of S on N concentration and uptake over 18 years are shown in Table 10. First-cutting N concentration was depressed by S application in 1969, 1971, 1975, 1976, 1978-80, and 1984 and increased in 1982. Second-cutting N concentration was decreased by S in all but seven years (1972, 1973, 1977, and 1979-83). The total annual N uptake was increased significantly by S application every year but 1972, 1973, and 1977-81. The 18-year averages show decreases in the N concentration in both cuttings and an increase in the annual uptake with S application.

Table 11 shows the effects of K on first-cutting N concentration and total seasonal N uptake over 18 years. The 18-year average shows a very gradual but irregular increase in annual N uptake with increasing K. Generally each year the first-cutting N concentration was the highest when no K had been applied. This probably results from the reduced growth. Only in 1977 was there no significant difference in N concentration related to the K rate. Further decreases in N concentration with increasing K rates tended to occur in 1982-84. The average of the 18 years of data shows significant decreases in first-cutting N concentration with increasing K only through 66 lb K per acre. The total seasonal N uptake was increased by K application every year except 1969, 1970, and 1974. Only in 1984 was the N uptake significantly greater with the heaviest rate (166 lb per acre) than at all other K rates.

Second-cutting N concentration decreased with each increasing K rate through 66 lb K per acre; with higher K rates the decreases continued, although the differences between two consecutive rates were not large enough to be significant (table 12).

Phosphorus concentration and uptake. The effects of S on P concentration over 12 years is shown in Table 13. Sulfur application decreased the first-cutting P concentration six years (1967, 1971, 1975, 1976, 1978, and 1980) and increased two years (1982 and 1983). Second-cutting P concentration was increased five years (1971 and 1981-84) and decreased four years (1975, 1976, 1979, and 1980) by S. Thus the P concentrations of both bromegrass cuttings were not influenced significantly by S application in 3 of the 12 years.

Effects of different rates of applied K over 12 years (table 14) show that increasing K rates tended to decrease P concentration in first-cutting herbage. Each increasing K rate through 99 lb per acre depressed the P concentration in the second-cutting, although the decrease from 66 to 99 lb K per acre was not large enough to be significant (table 12).

The effects of both K and S on the total annual uptake are shown in Table 15 and 16. Total annual P uptake was increased by S application 2 years when no K was used, 6 years when 33 through 133 lb were used, and 8 years with the highest 166 lb K per acre out of the 14 years (table 15). The 14-year average P uptake was increased by S when K was applied. Application of K generally increased the P uptake both with and without S in all but 5 years without S (1970, 1971, and 1976-78) and four years with S (1970 and 1976-78). P uptake was not influenced much by K rates exceeding 33 lb per acre (table 16).

Potassium concentration. Tables 17, 18, 19, and 20 depict the effects of S and K over 12 years on the K concentration. First-cutting K concentration was either decreased or not influenced significantly by S application. Significant decreases in K concentration occurred once without K, five times with 33 and 166 lb, ten times with 133 lb, eleven times with 66 lb, and twelve times with 99 lb K per acre with S application in those 14 years. The 14-year averages indicate S application depressed first-cutting K concentration when K was applied (table 17).

Second-cutting K concentration generally was not influenced significantly by S application, although Table 18 indicates an increase in 3 years with 99 lb and 2 years with 133 lb and a decrease 1 year with 0 and 33 lb, 4 years with 66 lb, and 2 years with 99 lb K per acre. Each increasing K rate tended to increase the K concentration in both cuttings with and without S (tables 19 and 20). Only in 1979 were all the differences between each increasing K rate significant with the second cutting. Frequently the differences between two consecutive K rates for a specific year were not large enough to be significant. However, the 14-year averages show significant increases in the K concentration in both cuttings with each increasing K rate.

Potassium uptake. The effects of both S and K on the annual K uptake over 16 years are presented in Tables 21 and 22. Uptake of K was not influenced significantly by S application when no K was applied. Applying S increased the K uptake 3 years with 33 lb, 4 years with 66 and 133 lb, 5 years with 99 lb, and 10 years with 166 lb K per acre. Decreases in K uptake with S application occurred once with 66 and 166 lb, twice with 99 lb, and three times with 133 lb K per acre during this 16-year period. Sulfur application had no significant effect on the K uptake except to increase it when 99 or 166 lb K per acre were applied (table 21).

Each increasing K rate increased or tended to increase the K uptake by the bromegrass. Only in 1970 when no S was applied, did the varying K rates produce no significant differences in K uptake. Each increasing K rate with or without S increased the 16-year average K uptake (table 22).

Sulfur concentration. Tables 23 and 24 show the effects of both S and K over the 16 years on first-cutting S concentration. The application of S increased the S concentration of the first-cutting every year but one when 33 or 99 lb per acre of K were used and all but 2 of the 16 years at the other four K rates. First-cutting S concentration averaging all 16 years was increased by S application at all K rates (table 23).

First-cutting S concentration was not influenced significantly by K rate when no S was applied in 1967, 1970, 1971, and 1977 and when S was applied in 1977. All other years, with and without applied

S, first-cutting S concentration tended to decrease with increasing K except when S was applied in 1967; then each increasing K rate through 66 lb per acre increased the S concentration (table 24).

Table 25 presents the effect of S application on the S concentration in the second cutting. Each year S application significantly increased the S concentration.

The effects of K for each of the 16 years presented in Table 26 indicate increasing K rates decreased or tended to decrease second-cutting S concentration except in 1967; that year the reverse seemed to occur. The 16-year average shows a significant decrease in second-cutting S concentration with each increasing K rate through 66 lb per acre and then a more gradual decrease as the K rate increased. Friedrich et al. (1977) using 0, 400, and 800 lb K per acre found a decrease in the S concentration of switchgrass with the first K increment, but no change with the second. McLaren (1976) in Scotland attributes the decrease in the S concentration of grass with increasing K to result from increased dry-matter production which effectively diluted the S content of the plant material.

Sulfur uptake. Tables 27 and 28 show the effects of both S and K over the 17 years on S uptake. Annual S uptake was increased by S application in all but 2 years when no K was applied and one year when 99 and 133 lb K per acre were used. The 17-year average of annual S uptake was increased by S application at all K rates (table 27). The S uptake as related to K rate both with and without S was very erratic so no conclusions can be drawn (table 28).

N to S ratio. The effects of both S and K on first-cutting N/S ratio for each of the 16 years are shown in Tables 29 and 30. Sulfur application decreased the N/S ratio in all but 4 years with 0, and 133 lb, 3 years with 33 and 166 lb, and 2 years with 66 and 99 lb K per acre in the 16 years. We have no explanation for the 1967 N/S ratio increasing significantly with S application when no K was used. The 16-year average of first-cutting N/S ratio was depressed by S application at all K rates (table 29).

First-cutting N/S ratio did not vary significantly with K rate in 9 of the 16 years when no S was applied and in 12 of the 16 years when S was used. The other years this ratio tended to be less at the lower K rates. The 1967 value when no K was applied with S is extremely high compared to any other observation (table 30).

The effects of both S and K on second-cutting N/S ratio are shown in Table 8. Sulfur application depressed and the application of 66 lb or more of K increased the N/S ratio in the second cutting.

Wallihan and Sharpless (1974) concluded that S deficiencies limited protein production and the utilization of N thereby increasing the ratio of N to S in plants. A response to S application was obtained by Bansal et al. (1983) with soybeans, by Eppendorfer (1977) with ryegrass, and by Westermann (1975) with alfalfa when the N/S ratio exceeded 16.5, 16, and 17 to 18, respectively.

Calcium and magnesium concentrations. Table 31 shows the effects of S on the Ca concentration and second-cutting Mg concentration for each year. Sulfur application significantly decreased first-cutting Ca concentration every year but 1967 and second-cutting Ca concentration every year but 1971 and 1973 of the 14 years. Second-cutting Mg concentration was reduced by S 11 years and was increased 2 years. The 14-year average of the Ca concentration in both cuttings and of the second cutting Mg concentration was reduced by S application.

The effects of K on the Ca concentration and the Mg concentration in the second cutting are presented in Table 32. First-cutting Ca concentration was the highest when no K was applied and usually decreased with increasing K rates. Second-cutting Ca concentration decreased with increasing K rates each year. The concentration of Mg in the second-cutting generally decreased with increasing K rates. The decrease between two consecutive K rates was not always large enough to be significant. However, every year the highest Mg concentration occurred when no K was applied and the lowest with the largest K rate (166 lb per acre). The 14-year averages for the Ca concentrations in both cuttings and second-cutting Mg concentration decreased with each increasing K rate.

Tables 33 and 34 show the effects of both S and K on first-cutting Mg concentration. Application of S depressed first-cutting Mg concentration 12 years when no K was applied, 10 years with 33 lb, 9 years with 66 and 99 lb, 6 years with 133 lb, and 4 years with 166 lb K per acre of the 14 years. The 14-year average first-cutting Mg concentration was increased by S application at all K rates (table 33).

Every year, but 1967 when S was applied, the maximum Mg concentration occurred, with and without S, when no K was applied; generally as the K rate increased, the Mg concentration decreased. The 14-year average first-cutting Mg concentration significantly decreased with each increasing K rate through 133 lb K per acre without S application and through 99 lb K per acre when S was applied (table 34).

Calcium and magnesium uptake. The effect of S for each of the 16 years on the Ca and the Mg uptake is shown in Table 35. The Ca uptake was increased 4 years and decreased 6 years of the 16 years by S application. The use of S increased the Mg uptake 5 and decreased it 6 of the 16-years. However the 16-year averages indicate S application increased both the Ca and Mg annual uptake.

Table 36 shows the effects of both S and K on the annual uptake of both Ca and Mg. The first K increment (33 lb per acre) increased the Ca uptake by bromegrass with and without S. Annual Mg uptake gradually decreased with each increasing K increment when no S was added; when S was applied, Mg uptake was the greatest when 33 lb of K per acre was used and the least when 133 lb or more was applied.

Nitrogen Rate, Nitrogen Source, and Sulfur Experiment

Yield. Nitrogen application increased first-cutting bromegrass yields four to six times and second-cutting yields two to seven times. Each increasing N rate increased the yields of both cuttings (table 37).

Table 38 shows the effects of N source on first-cutting yield and of N source at different N rates on second-cutting and total annual yields. First-cutting and total annual yields were greater with AN than with urea at all rates of applied N. Second-cutting yields were greater with AN than with urea when more than 80 lb N per acre were applied.

Sulfur application increased second-cutting bromegrass forage yield. Sulfur response varied with N rate with the first cutting and total annual yield; S application increased the yield when more than 80 lb N per acre were applied (table 39).

Similar responses of N and S have been reported with a wide variety of forages. Ramig et al. (1975) found wheat did not respond to S application when N was deficient or optimum; however, with excess N, addition of S increased wheat forage yields. Friedrich et al. (1977) found no response to high N rates by switchgrass (*Panicum virgatum* L.) unless S was applied. Both Cowling and Jones (1970) and Bolton et al. (1976) grew perennial ryegrass under controlled environments. The former secured S responses after the first harvest at the higher N rates. The latter obtained yield responses to S when the dry matter contained less than 0.20 percent S. Eppendorfer (1977) regarded heavy N rates as inducing S deficiency. Bansal et al. (1983) state that any soil showing large responses to N may not be supplying adequate S from the mineralization of the soil organic matter.

Responses to N rate and N source are similar to those from previous field experiments where AN has generally produced greater bromegrass yields in the Matanuska Valley than has urea (Laughlin 1962, 1963; Laughlin et al. 1973, 1978).

These data seem to indicate that the N in sulfur-coated urea (SCU) is as readily available as that in urea with regard to yield. This corresponds with the conclusion of Vaughn et al. (1979) that SCU is of no greater benefit than urea combined with S in fertilizing California annual grasslands. The observation of Davies (1973) in England that SCU as a single application gave results similar or superior to split applications of AN are not borne out here. Saleem (1980) regarded the residual effects of SCU to be low and did not last beyond one growing season. Our data show no particular residue effect of SCU as compared to AN.

NO_3-N and N concentration. Table 40 shows the effects of N rate on the NO_3-N and total N concentrations in bromegrass forage. First-cutting NO_3-N concentration increased rapidly as the N rate increased when AN was applied and much more slowly when the N source was urea. Second-cutting NO_3-N concentrations reached a maximum when the heaviest N rate (240 lb per acre) was applied; this value was 2.5 times greater with AN than with urea. Total N in the first cutting increased with each increasing N rate. This increase in N concentration in the second cutting was also apparent when

80 to 240 lb N was applied as AN, but only the highest N rate applied as urea increased second-cutting N concentration.

When 160 or 240 lb N were applied, first-cutting NO_3-N concentration was greater with AN than with urea; second-cutting NO_3-N and total N were greater with AN than with urea only at the highest 240 lb N per acre rate. First-cutting total N was greater with AN than with urea at all N rates (table 41).

Table 42 presents the effects of S application on NO_3-N and total N concentration in bromegrass forage. Sulfur application increased first-cutting NO_3-N concentration only when 240 lb N per acre was applied while second-cutting NO_3-N concentration was increased by S at all N rates. First-cutting total N concentration was increased by S application when AN was applied and was decreased when urea was used. Total N concentration in the second cutting was depressed by S application when more than 80 lb N per acre were applied.

These increases in NO_3-N concentration with increasing N rates are similar to increases in the NO_3-N concentration in perennial ryegrass reported by Goh et al. (1979) in New Zealand. Tahtinen (1979) in Finland attributed a decrease in the N concentration of timothy with S fertilization to dilution caused by yield increases. This may also explain the decrease in both NO_3-N and total N in bromegrass with S fertilization on the Matanuska Research Farm (Laughlin et al. 1981). Wallihan and Sharpless (1974) conclude that the deficiency of N or S limits protein production thus limiting utilization of the other element.

Leaves of plants receiving the higher N rates without S application had a lighter color than those receiving S. This follows observations of bromegrass at the Matanuska Research Farm (Laughlin 1970) and of several plants by Mosolov and Volleidt (1955).

P, K, and S concentrations. The effects of N rate on the concentrations of P, K, and S in bromegrass forage are presented in Table 43. Nitrogen application depressed both P and K concentrations in both cuttings. Second-cutting P concentrations were greater when 240 lb N per acre was applied than when 80 or 160 lb per acre were used. First-cutting K concentrations were greater when 160 lb N was applied than with 80 or 240 lb per acre. First-cutting S concentrations were relatively constant at all N rates without S application; when S was applied, the S concentration in the first cutting varied with N rate as follows: 0 and 240>80 and 160. Second-cutting S concentrations with and without S varied as follows: 0>240>80 and 160 lb N per acre.

The decrease in S concentration by N application probably results from the dilution of tissue S by increased yields. McClaren (1976) regarded the reduction in the S concentration of herbage grown in Great Britain with the addition of N and K the result of effectively diluting the S content of the plant material. The increase in S concentration by increasing the N rate from 80 to 240 lb per acre and applying S is similar to that reported by Friedrich et al. (1977) with switchgrass in Wisconsin.

The effects of N source on the P, K, and S concentrations in bromegrass herbage are shown in Table 44. The P and K concentrations in the first cutting were greater with AN than with urea while the second-cutting P and K concentrations were greater with AN than with urea only when S was applied. The S concentration in both cuttings was greater with AN than with urea when S was applied; furthermore second-cutting S concentration was also greater with AN than with urea when 240 lb N per acre were used.

Table 45 shows the effects of S application on bromegrass herbage P, K, and S concentrations. First-cutting P concentration averaging both N sources and second-cutting P concentration when urea supplied the N were increased by S application. Applied S decreased second-cutting K concentration when AN was used and increased the K concentration when urea was the N source. Sulfur application increased the S concentration in both cuttings with both N sources. The increase in S concentration with applied S being less with urea as the N source than with AN leads one to believe the S in the urea is not as readily available as that in sulfate of potash.

The S concentration in herbage receiving SCU did not increase over that receiving no S until 1980. This length of time for an increase in S concentration may reflect slow availability of elemental S which must be converted into sulfates by soil microorganisms before the plant can utilize it (Starkey 1950). Maples et al. (1976), found elemental S applied with urea and in the coating of SCU was not utilized by cotton in Arkansas the first year it was applied. Likewise Samosir and Blair (1983) found S from SCU is not available to flooded rice, at least not in the first crop after application.

Ca and Mg concentrations. The effects of N rate on concentration of Ca and Mg in bromegrass herbage are presented in Table 46. First-cutting Ca concentration, averaging both N sources, varied with N rate as follows: 0>240>80 and 160 lb N per acre. When AN was applied, second-cutting Ca concentration varied with N rate as follows: 80>240>160. When urea was the N source, second-cutting Ca concentration significantly decreased with each increasing N rate. First-cutting Mg concentration significantly increased with both N sources as the N rate increased from 80 to 240 lb per acre. Increasing the AN rate from 160 to 240 lb N per acre increased the second-cutting Mg concentration; urea applied at these rates had no significant effect on second-cutting Mg concentration.

Table 47 shows the effects of N source on the Ca and Mg concentrations in bromegrass herbage. When no S was applied, first-cutting Ca concentration was greater when AN was applied than when urea was used. When S was applied, first-cutting Ca concentration was similar with both N sources. Second-cutting Ca concentration was about the same with the two N sources when 80 lb N was used, but when 160 lb N was applied, second-cutting Ca concentration was greater with urea than with AN. However, when 240 lb N per acre was used, second-cutting Ca concentration was greater with AN than with urea. First-cutting Mg concentration was greater with AN than with urea at all three N rates; second-cutting Mg concentration was also greater with AN than with urea only when the highest 240 lb N per acre rate was applied.

The effects of applied S on the Ca and Mg concentrations in bromegrass herbage are shown in Table 48. Sulfur application depressed first-cutting Ca concentration only when AN supplied the N. Second-cutting Ca concentration was depressed by S application when 240 lb N per acre as AN was applied and when 80 lb N as urea was used. The first-cutting Mg concentration was increased when AN supplied the N while second-cutting Mg concentration was not influenced significantly by S application.

Nutrient uptake. Each increasing N rate increased the annual uptake by bromegrass of N, P, K, S, Ca, and Mg (table 49). Power (1983) doubled P uptake by crested wheatgrass in North Dakota by increasing N rates.

The annual uptake of N, P, K, S, Ca, and Mg was greater with AN than with urea (table 50). Hargrove et al. (1983) state unincorporated urea is often less efficient than other N sources because of the loss of N as ammonia (NH_3). Harper et al. (1983) report greater NH_3 volatilization rates after urea application during warmer than during cooler seasons. They regard rainfall after urea application to decrease NH_3 losses.

The effects of S on annual nutrient uptake are presented in Table 51. At the higher N rates bromegrass nutrient uptake was significantly increased by applied S. The N, K, S, and Mg annual uptake were increased significantly by S application only when 160 and 240 lb N per acre were used. The annual P uptake was increased by S application when 80 or more lb N per acre was applied. Annual Ca uptake was increased by S application only when the N source was urea.

SUMMARY

Eighteen years of data with two cuttings each year of bromegrass fertilized with six K rates with and without S were collected on Knik silt loam and 4 years data with two cuttings each year of bromegrass fertilized with AN, urea, and S are presented. Plant samples were analyzed for NO_3-N, total N, P, K, S, Ca, and Mg and the annual nutrient uptake calculated.

In the first experiment S application frequently increased the first-cutting yield. Second-cutting yield was even more frequently increased by S. Annual N uptake and the K and S concentrations also tended to be increased by application of S. First-cutting NO_3-N was generally decreased while that of the second-cutting was decreased less frequently. First-cutting N concentration and the N to S ratio were also decreased by S.

In most years, K application increased the yields of both cuttings, the annual uptake of NO_3-N, total N, and K, and concentration of K in herbage. When no K was applied, the N, P, K, Ca, and Mg concentrations tended to be the highest. Their concentrations tended to decrease gradually with increasing

rates of applied K. The highest (166 lb per acre) K rate increased total yield and N uptake over all other K rates only once in 18 years.

In the second experiment S application increased first-cutting herbage yields when 80 or more lb N per acre were applied and second-cutting yields at all N rates. Applied S increased the S concentration in both cuttings, especially when N rates exceeded 80 lb per acre. The S concentration was always greater when AN was the N source than with urea. The annual uptake of N, P, K, S, and Mg were also increased by S application when 80 or more lb N per acre were applied. Applied S depressed the NO_3-N, total N, and Ca concentrations and the N to S ratio in both cuttings and the second-cutting Mg concentration.

First-cutting forage yields were increased four to six times and second-cutting yields two to seven times by N application. Yields of both cuttings, the annual N, P, K, S, Ca, and Mg uptake, and first-cutting total N and Mg concentrations were increased by each increasing N rate. Second-cutting total N concentration followed similarly when AN was used, but was increased by only the heaviest 240 lb N per acre application when urea was the N source. Second-cutting Mg concentration was increased by each increasing N rate when more than 80 lb N per acre were applied.

First-cutting yield, N, P, K, and Mg concentrations and annual N, P, K, and S uptake were greater with AN than with urea. Second-cutting yield and first-cutting NO_3-N concentration were greater with AN than with urea when more than 80 lb N per acre were applied. Second-cutting total N and Mg concentrations were also greater with AN than with urea when 240 lb N per acre were used.

Although comparable amounts of N as urea are not as effective as those in AN, presently the lower price combined with the higher N content of urea make it a more economical N source.

Although response to S application was not obtained every year, these results strongly suggest application of S is necessary for sustained high bromegrass forage yields. High yields were maintained with less than 100 lb K per acre each year. However, the amount of K removed with two high-yield cuttings per year was much greater than the amounts applied. Thus, to prevent depletion of available K in the soil, at least 100 lb K should be applied annually.

Table 1. Effect of applied S on first-cutting bromegrass forage yields, 1967-84, Knik silt loam (means of 36 measurements).

Lb S/A	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	18-yr Mean[1]
	(T/A oven-dry)																		
0	1.62b[2]	2.11b	0.44b	0.10a	0.22b	1.87a	2.46a	2.17a	2.11b	0.80b	2.63a	2.99a	1.93a	2.18a	2.03a	1.04a	1.16a	1.68a	1.64b
70	2.16a	2.87a	1.06a	0.33a	1.14a	1.97a	2.52a	2.41a	2.42a	1.14a	2.53a	3.03a	1.74a	1.98a	1.97a	0.99a	1.20a	1.81a	1.85a

[1]Means of 648 measurements.

[2]Letters used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 2. Effect of K application on first-cutting bromegrass forage yields, 1967-84, Knik silt loam (means of 12 measurements).

Lb K/A	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	18-yr Mean[1]
	(T/A oven-dry)																		
0	1.44b[2]	1.66b	0.81a	0.23a	0.50a	1.80a	1.98b	1.66b	1.52b	0.56b	2.40a	2.51b	1.44b	1.75b	1.52b	0.57b	0.67b	1.07c	1.34e
33	1.88ab	2.45a	0.77a	0.19a	0.66a	1.93a	2.45a	2.24a	2.40a	1.07a	2.66a	2.94ab	1.75ab	2.00ab	1.96ab	0.95ab	1.18ab	1.70b	1.73d
66	1.95a	2.68a	0.71a	0.22a	0.74a	1.89a	2.51a	2.31a	2.27a	1.05ab	2.52a	3.11a	1.89ab	1.97ab	1.93ab	1.14a	1.31a	1.66b	1.77cd
99	2.00a	2.57a	0.75a	0.21a	0.68a	1.93a	2.62a	2.46a	2.40a	1.06a	2.57a	3.11a	1.85ab	2.17ab	2.13a	1.10a	1.29a	1.83b	1.82bc
133	1.93ab	2.79a	0.78a	0.23a	0.67a	2.00a	2.74a	2.55a	2.53a	1.04ab	2.76a	3.11a	2.00a	2.22ab	2.18a	1.22a	1.31a	1.86b	1.88ab
166	2.13a	2.80a	0.68a	0.22a	0.81a	1.97a	2.65a	2.55a	2.52a	1.05b	2.57a	3.27a	2.08a	2.38b	2.28a	1.10a	1.32a	2.36a	1.93a

[1]Means of 648 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 3. Effect of applied S at six K application rates on second-cutting bromegrass forage yields 1967-84, Knik silt loam (means of 6 measurements).

Lb S/A	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	18-yr Mean[1]
	(T/A oven-dry)																		
	No K applied																		
0	1.35a[2]	1.18a	0.41b	0.48b	0.83b	1.21a	0.80a	0.56a	0.93b	0.55a	0.67a	1.16b	1.41a	1.23a	0.88a	0.97a	0.96a	0.82a	0.91b
70	1.40a	1.29a	0.74a	1.02a	1.28a	1.38a	0.90a	0.69a	1.32a	0.55a	0.88a	1.48a	1.61a	1.38a	0.95a	0.93a	0.95a	0.82a	1.09a
	33 lb K/A																		
0	1.38b	1.28b	0.33b	0.54b	0.86b	1.45a	1.17a	0.71a	1.52b	0.73b	0.82a	1.64a	2.10a	1.72a	1.28b	1.24b	1.23b	1.07b	1.17b
70	2.08a	2.11a	0.85a	1.18a	1.80a	1.60a	1.33a	0.93a	2.07a	1.02a	0.90a	1.73a	2.05a	1.92a	1.58a	1.79a	1.80a	1.58a	1.57a
	66 lb K/A																		
0	1.54b	1.36b	0.34b	0.61b	0.82b	1.48a	1.23a	0.62b	1.42b	0.74b	0.93a	1.78a	2.26a	1.77b	1.37a	1.25b	1.12b	1.05b	1.20b
70	2.08a	1.99a	0.81a	1.37a	2.05a	1.66a	1.28a	0.93a	2.28a	1.09a	0.85a	1.74a	2.20a	2.18a	1.60a	1.84a	1.63a	1.66a	1.62a
	99 lb K/A																		
0	1.63b	1.44b	0.32b	0.46b	0.79b	1.65a	1.50a	0.62b	1.45b	0.68b	0.86a	1.82a	2.59a	2.06a	1.63a	1.55b	1.48b	1.39b	1.33b
70	2.38a	2.35a	0.91a	1.42a	2.00a	1.77a	1.51a	1.03a	2.47a	1.20a	0.94a	1.93a	2.34a	2.08a	1.62a	2.00a	2.19a	1.76a	1.77a
	133 lb K/A																		
0	1.70b	1.66b	0.36b	0.46b	0.70b	1.83a	1.51a	0.76a	1.71b	0.81b	0.87a	2.00a	2.43a	2.07a	1.76a	1.57b	1.50b	1.38b	1.39b
70	2.27a	2.35a	0.79a	1.33a	1.82a	1.76a	1.46a	0.91a	2.32a	1.11a	0.98a	1.79a	2.37a	2.05a	1.73a	1.97a	2.04a	1.72a	1.71a
	166 lb K/A																		
0	1.72b	1.52b	0.34b	0.53b	0.89b	1.75a	1.55a	0.63b	1.68b	0.75b	1.04a	1.92a	2.25b	1.98b	1.73b	1.47b	1.47b	1.38b	1.37b
70	2.31a	2.26a	0.92a	1.30a	2.20a	1.87a	1.58a	1.04a	2.59a	1.39a	0.92a	1.83a	2.67a	2.57a	2.07a	2.03a	2.53a	2.43a	1.92a

[1]Means of 108 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 4. Effect of applied S at six K application rates on total annual bromegrass forage yields 1967-84, Knik silt loam (means of 6 measurements).

Lb S/A	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	18-yr Mean[1]
	(T/A oven-dry)																		
	No K applied																		
0	2.85a[2]	2.94a	0.92b	0.58b	1.14b	3.06a	2.72a	2.13a	2.43a	1.39a	3.10a	3.60a	2.81a	3.00a	2.46a	1.57a	1.61a	2.04a	2.24a
70	2.78a	2.86a	1.85a	1.38a	1.96a	3.12a	2.95a	2.44a	2.87a	1.35a	3.26a	4.05a	3.09a	3.11a	2.40a	1.48a	1.63a	1.73a	2.46a
	33 lb K/A																		
0	2.95b	3.29b	0.75b	0.62b	1.11b	3.37b	3.58b	2.89a	3.81b	1.99a	3.59a	4.51a	3.92a	3.57b	3.22a	2.17b	2.37b	2.62b	2.80b
70	4.28a	5.01a	1.98a	1.47a	2.88a	3.53a	3.81a	3.22a	4.58a	2.30a	3.44a	4.74a	3.73a	4.08a	3.57a	2.77a	3.01a	3.43a	3.44a
	66 lb K/A																		
0	3.10b	3.43b	0.77b	0.71b	1.01b	3.24a	3.69a	2.73b	3.57b	1.96b	3.41a	4.89a	4.30a	3.87a	3.36a	2.42b	2.41b	2.53b	2.85b
70	4.41a	5.27a	1.80a	1.71a	3.36a	3.69a	3.85a	3.44a	4.73a	2.55a	3.41a	4.85a	3.93a	4.02a	3.46a	2.95a	2.96a	3.49a	3.55a
	99 lb K/A																		
0	3.16b	3.47b	0.75b	0.54b	0.93b	3.47a	4.14a	2.88b	3.63b	1.91b	3.52a	4.88a	4.56a	4.49a	3.91a	2.69a	2.80b	3.26a	3.06b
70	4.84a	5.46a	1.99a	1.76a	3.22a	3.81a	4.12a	3.70a	5.09a	2.63a	3.42a	5.10a	4.07a	3.99a	3.59a	3.05a	3.45a	3.54a	3.71a
	133 lb K/A																		
0	3.39b	4.00b	0.80b	0.58b	0.86b	3.78a	4.27a	3.26a	4.13b	2.03a	3.64a	5.24a	4.58a	4.55a	4.06a	2.83a	2.75b	3.24a	3.22b
70	4.45a	5.60a	1.91a	1.68a	3.00a	3.80a	4.19a	3.51a	4.96a	2.31a	3.75a	4.75a	4.21a	4.01b	3.78a	3.16a	3.42a	3.59a	3.67a
	166 lb K/A																		
0	3.57b	3.97b	0.78b	0.65b	1.14b	3.67a	4.15a	3.05b	3.92b	2.07b	3.73a	5.15a	4.42a	4.44a	3.82b	2.60b	2.76b	3.47b	3.19b
70	4.73a	5.41a	1.84a	1.63a	3.57a	3.87a	4.27a	3.71a	5.38a	2.68a	3.37a	5.15a	4.66a	4.88a	4.53a	3.10a	3.88a	5.06a	3.98a

[1]Means of 108 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 5. Effect of K application with and without S on second-cutting bromegrass forage yields 1967-84, Knik silt loam (means of 6 measurements).

Lb K/A	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	18-yr Mean[1]
	(T/A oven-dry)																		
	No S applied																		
0	1.35b[2]	1.18c	0.41a	0.48a	0.83a	1.21c	0.80d	0.56a	0.93b	0.55a	0.67	1.16c	1.41d	1.23d	0.88d	0.97c	0.96b	0.82b	0.91c
33	1.38b	1.28bc	0.33a	0.54a	0.86a	1.45bc	1.17c	0.71a	1.52a	0.73a	0.82ab	1.64b	2.10c	1.72c	1.28c	1.24bc	1.23ab	1.07b	1.17b
66	1.54ab	1.36bc	0.34a	0.61a	0.82a	1.48bc	1.23bc	0.62a	1.42a	0.74a	0.93ab	1.78ab	2.26bc	1.77bc	1.37bc	1.25bc	1.12b	1.05b	1.20b
99	1.63ab	1.44abc	0.32a	0.46a	0.79a	1.65ab	1.50ab	0.62a	1.45a	0.68a	0.86ab	1.82ab	2.59a	2.06ab	1.63ab	1.55a	1.48a	1.39a	1.33a
133	1.70a	1.66a	0.36a	0.46a	0.70a	1.83a	1.51ab	0.76a	1.71a	0.81a	0.87ab	2.00a	2.43ab	2.07a	1.76a	1.57a	1.50a	1.38a	1.39a
166	1.72a	1.52ab	0.34a	0.53a	0.89a	1.75ab	1.55a	0.63a	1.68a	0.75a	1.04a	1.92ab	2.25bc	1.98abc	1.73a	1.47ab	1.47a	1.38a	1.37a
	70 lb S/A																		
0	1.40c	1.29b	0.74a	1.02b	1.28c	1.38b	0.90c	0.69b	1.32d	0.55c	0.88a	1.48b	1.61d	1.38c	0.95c	0.93b	0.95e	0.82c	1.09e
33	2.08b	2.11ab	0.85a	1.18ab	1.80b	1.60ab	1.33ab	0.93ab	2.07c	1.02b	0.90a	1.73ab	2.05c	1.92b	1.58b	1.79a	1.80cd	1.58b	1.57d
66	2.08b	1.99b	0.81a	1.37a	2.05ab	1.66ab	1.28b	0.93ab	2.28bc	1.09b	0.85a	1.74ab	2.20bc	2.18b	1.60b	1.84a	1.63d	1.66b	1.62cd
99	2.38a	2.35a	0.91a	1.42a	2.00ab	1.77a	1.51ab	1.03a	2.47ab	1.20ab	0.94a	1.93a	2.34bc	2.08b	1.62b	2.00a	2.19b	1.76b	1.77d
133	2.27ab	2.35a	0.79a	1.33a	1.82b	1.76a	1.46ab	0.91ab	2.32abc	1.11ab	0.98a	1.79a	2.37ab	2.05b	1.73b	1.97a	2.04bc	1.72b	1.71bc
166	2.31ab	2.26ab	0.92a	1.30ab	2.20a	1.87a	1.58a	1.04a	2.59a	1.39a	0.92a	1.83a	2.67a	2.57a	2.07a	2.03a	2.53a	2.43a	1.92a

[1]Means of 108 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 6. Effect of K application with and without S on total bromegrass forage yields 1967-84, Knik silt loam (means of 6 measurements).

Lb K/A	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	18-yr Mean[1]
	(T/A oven-dry)																		
	No S applied																		
0	2.85c[2]	2.94c	0.92a	0.58a	1.14a	3.06c	2.72d	2.13c	2.43c	1.39b	3.10b	3.60c	2.81c	3.00c	2.46d	1.57c	1.61b	2.04c	2.24d
33	2.95bc	3.29c	0.75a	0.62a	1.11a	3.37abc	3.58c	2.89ab	3.81ab	1.99a	3.59ab	4.51b	3.92b	3.57bc	3.22c	2.17b	2.37a	2.63b	2.80c
66	3.10abc	3.43c	0.77a	0.71a	1.01a	3.24bc	3.69bc	2.73b	3.51b	1.96ab	3.41ab	4.89ab	4.30ab	3.87b	3.36bc	2.42ab	2.41a	2.53bc	2.85bc
99	3.16abc	3.47bc	0.75a	0.54a	0.93a	3.47abc	4.14ab	2.88ab	3.63ab	1.91ab	3.52ab	4.88ab	4.56a	4.49a	3.91a	2.69ab	2.80a	3.26a	3.06ab
133	3.39ab	4.00a	0.80a	0.58a	0.86a	3.78a	4.27a	3.26a	4.13a	2.03a	3.64a	5.24a	4.58a	4.55a	4.06a	2.83a	2.75a	3.24a	3.22a
166	3.57a	3.97ab	0.78a	0.65a	1.14a	3.67ab	4.15ab	3.05ab	3.92ab	2.07a	3.73a	5.15a	4.42ab	4.44a	3.82ab	2.60ab	2.76a	3.47a	3.19a
	70 lb S/A																		
0	2.78c	2.86c	1.85a	1.38a	1.96c	3.12b	2.95b	2.44b	2.87c	1.35b	3.26a	4.05b	3.09c	3.11c	2.40c	1.48b	1.63c	1.73c	2.46d
33	4.28b	5.01b	1.98a	1.47a	2.88b	3.53ab	3.81a	3.22a	4.58b	2.30a	3.44a	4.74a	3.73b	4.08b	3.57b	2.77ab	3.01b	3.43b	3.44c
66	4.41ab	5.27ab	1.80a	1.71a	3.36ab	3.69a	3.85a	3.44a	4.73b	2.55a	3.41a	4.85a	3.93b	4.02b	3.46b	2.95ab	2.96b	3.49b	3.55bc
99	4.84a	5.46ab	1.99a	1.76a	3.22ab	3.81a	4.12a	3.70a	5.09ab	2.63a	3.42a	5.10a	4.07b	3.99b	3.59b	3.05a	3.45ab	3.54b	3.71b
133	4.45ab	5.60a	1.91a	1.68a	3.00b	3.80a	4.19a	3.51a	4.96ab	2.31a	3.75a	4.75a	4.21ab	4.01b	3.78b	3.16a	3.42ab	3.59b	3.67bc
166	4.73ab	5.41ab	1.84a	1.63a	3.57a	3.87a	4.27a	3.71a	5.38a	2.68a	3.37a	5.15a	4.66a	4.88a	4.53a	3.10a	3.88a	5.06a	3.98a

[1]Means of 108 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. 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 applied S on bromegrass NO_3-N concentration and uptake 1970-84, Knik silt loam (means of 36 measurements).

Lb S/A	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	15-yr Mean[1]
	First cutting (% NO_3-N)															
0	.039a[2]	.117a	.141a	.062a	.035a	.065a	.075a	.049a	.049a	.021a	.066a	.039a	.088a	.079a	.077a	.067a
70	.018b	.027b	.088b	.035b	.016b	.024b	.026b	.027b	.019b	.009a	.020b	.015b	.047b	.032b	.032b	.029b
	Second cutting (% NO_3-N)															
0	.126a	.178a	.108a	.034a	.034a	.087a	.110a	.047a	.089a	.073a	.068a	.108b	.123a	.084a	.136a	.094a
70	.041b	.103b	.102a	.029a	.016b	.048b	.044b	.047a	.092a	.072a	.067a	.127a	.134a	.050b	.079b	.070b
	Total annual uptake (lb NO_3-N/A)															
0	1.34a	3.39b	8.70a	3.96a	1.87a	5.17a	3.48a	3.45a	6.02a	3.85a	5.25a	4.76a	5.16a	3.93a	5.64a	4.40a
70	1.12a	4.40a	6.85b	2.56b	1.03b	3.19b	1.57b	2.27b	4.37b	3.46a	3.49b	4.59a	5.81a	2.69b	3.49b	3.39b

[1]Means of 540 measurements.
[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letters are significantly different at the 5% level of probability.

Table 8. Effect of applied S and K on bromegrass first-cutting NO_3-N concentration and second-cutting N to S ratio, Knik silt loam.

Lb K/A	First cutting[1]		Second cutting[2]	
	No S	70 lb S/A	No S	70 lb S/A
	----------(% No_3-N)----------		---------(N/S ratio)--------	
0	.059b[3]	.035a	18.4c	12.3a
33	.058b	.025ab	20.6bc	11.8a
66	.068ab	.023b	21.9a	12.6a
99	.076a	.029ab	22.5a	12.5a
133	.071a	.030ab	21.5ab	12.9a
166	.070a	.030ab	21.6ab	12.8a

[1]Means of 90 measurements.
[2]Means of 96 measurements.
[3]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 9. Effect of K application on second-cutting bromegrass NO_3-N concentration and uptake 1970-84, Knik silt loam (means of 12 measurements).

Lb K/A	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	15-yr Mean[1]
	Second cutting (% NO_3-N in herbage)															
0	.058c[2]	.115c	.100b	.030a	.033a	.064a	.069ab	.044a	.094ab	.100a	.080a	.111ab	.103b	.062ab	.127a	.079b
33	.089ab	.140bc	.103ab	.031a	.021a	.058a	.057b	.039a	.053b	.052b	.050b	.088b	.086b	.050b	.090b	.067c
66	.097a	.150ab	.090b	.028a	.026a	.069a	.080ab	.046a	.078b	.071b	.061ab	.122a	.102b	.059ab	.084b	.078b
99	.068bc	.111c	.100b	.032a	.021a	.065a	.081ab	.055a	.101ab	.072b	.069ab	.136a	.155a	.081a	.130a	.085ab
133	.084abc	.176a	.109ab	.031a	.022a	.077a	.084ab	.052a	.101ab	.068b	.070ab	.133a	.154a	.071ab	.108ab	.089a
166	.104a	.151ab	.129a	.039a	.024a	.073a	.089a	.048a	.115a	.073ab	.072ab	.117ab	.172a	.078ab	.104ab	.093a
	Total annual uptake (lb NO_3-N/A)															
0	0.92a	2.98c	5.86b	2.35c	1.66a	2.80d	1.83b	1.91c	3.85c	3.52b	3.74cd	2.90b	2.68c	2.06b	3.29b	2.82d
33	1.17a	3.98abc	6.25b	2.62bc	1.19a	3.31cd	2.21ab	2.25bc	3.16c	2.53b	3.05d	3.43b	3.93bc	2.61b	3.78b	3.03d
66	1.51a	4.20abc	5.91b	2.80bc	1.44a	3.85cd	2.60ab	2.81abc	4.78b	3.86a	4.14bcd	4.75a	4.59b	2.55b	3.83b	3.57c
99	0.95a	3.22bc	9.34a	3.80ab	1.20a	4.31bc	2.38ab	3.18abc	6.58a	4.20a	4.88abc	5.56a	7.12a	4.26a	5.80a	4.45b
133	1.27a	4.26ab	9.14a	3.76ab	1.54a	5.54a	2.93ab	3.74a	6.19a	3.74ab	5.09ab	5.79a	7.22a	3.98a	5.26a	4.63ab
166	1.59a	4.73a	10.14a	4.26a	1.66a	5.26ab	3.19a	3.26ab	6.62a	4.09a	5.32a	5.65a	7.36a	4.40a	5.43a	4.86a

[1]Means of 180 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 10. Effect of applied S on bromegrass N concentration and uptake 1967-84, Knik silt loam (means of 36 measurements).

Lb S/A	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	18-yr Mean[1]
	First cutting (% N in herbage)																		
0	3.12a[2]	3.30a	3.43a	3.16a	3.57a	2.79a	2.40a	2.29a	2.53a	2.97a	1.88a	2.21a	1.99a	2.52a	2.19a	2.81b	2.44a	2.55a	2.68a
70	3.16a	3.20a	3.13b	3.05a	2.69b	2.76a	2.45a	2.25a	2.31b	2.65b	1.87a	2.04b	1.81b	2.36b	2.09a	2.95a	2.37a	2.37b	2.53b
	Second cutting (% N in herbage)																		
0	2.75a	2.83a	4.12a	3.68a	3.56a	2.83a	2.48a	2.47a	2.65a	3.01a	2.56a	2.60b	2.56a	2.11a	2.67a	2.75a	2.48a	2.52a	2.81a
70	2.59b	2.17b	3.61b	3.11b	3.16b	2.77a	2.41a	2.30b	2.36b	2.87b	2.49a	2.76a	2.55a	2.12a	2.76a	2.78a	2.40a	2.36b	2.64b
	Total annual uptake (lb N/A)																		
0	183b	214b	58b	44b	73b	192a	184a	129b	185b	115b	143a	220a	184a	183a	163a	129b	118b	142b	148a
70	241a	266a	125a	98a	175a	200a	189a	148a	213a	126a	139a	219a	174a	177a	167a	153a	143a	160a	173b

[1]Means of 648 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 11. Effect of K application on first-cutting bromegrass N concentration and uptake 1967-84, Knik silt loam (means of 12 measurements).

Lb K/A	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	18-yr Mean[1]
	First cutting (% N in herbage)																		
0	3.29a[2]	3.50a	3.48a	3.40a	3.58a	2.79ab	2.67a	2.76a	2.84a	3.40a	1.89a	2.34a	2.32a	2.84a	2.61a	3.46a	2.92a	2.90a	2.94a
33	3.04b	3.19b	3.29ab	3.25ab	3.16b	2.74ab	2.45b	2.25bc	2.35b	2.78b	1.77a	2.08b	1.92b	2.42b	2.17b	3.10b	2.51b	2.63b	2.62b
66	3.14ab	3.28b	3.24b	3.06bc	2.99b	2.57b	2.37b	2.31b	2.31b	2.67b	1.85a	2.08b	1.86b	2.44b	2.08bc	2.85c	2.21cd	2.43bc	2.54c
99	3.08ab	3.20b	3.12b	3.07bc	3.09b	2.92a	2.39b	2.12bc	2.32b	2.63b	1.91a	2.12b	1.86b	2.35b	2.06bc	2.73cd	2.40bc	2.40c	2.54c
133	3.20ab	3.18b	3.31ab	2.93c	3.01b	2.80a	2.33b	2.10bc	2.31b	2.63b	1.94a	2.11b	1.72b	2.24b	1.93c	2.51d	2.21cd	2.27cd	2.48c
166	3.09ab	3.15b	3.25b	2.91c	2.95b	2.84a	2.34b	2.06c	2.38b	2.76b	1.88a	2.02b	1.70b	2.35b	1.99bc	2.63cd	2.16d	2.13d	2.48c
	Total annual uptake (lb N/A)																		
0	174c	191b	102a	69a	111b	177b	154b	126a	152c	92b	132b	194b	158b	166b	135c	100b	93c	106c	135c
33	208b	242a	94a	70a	130a	192ab	185a	140a	206ab	124a	139ab	216a	172ab	179ab	164b	144a	136ab	161b	161b
66	218ab	252a	86a	76a	128ab	183b	184a	142a	197b	125a	138ab	218a	183a	178ab	162b	145a	124b	144b	160b
99	222ab	245a	89a	68a	123ab	205a	198a	141a	206ab	126a	142ab	232a	189a	184ab	172ab	155a	148a	161b	167ab
133	223ab	256a	89a	70a	115b	208a	198a	143a	218a	121a	153a	228a	185a	179ab	174ab	154a	137ab	151b	167ab
166	229a	254a	89a	72a	137a	210a	199a	140a	216ab	136a	142ab	229a	187a	195a	184a	149a	143ab	180a	172a

[1]Means of 216 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 12. Effect of K application on the second-cutting N concentration (means of 216 measurements) and on the second-cutting P concentration of bromegrass 1967-84, Knik silt loam (means of 144 measurements).

Lb K/A	N	P
	(%)	
0	3.06a[1]	.365a
33	2.83b	.331b
66	2.69c	.317c
99	2.65cd	.312cd
133	2.59de	.305d
166	2.55e	.305d

[1]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 13. Effect of applied S on bromegrass P concentration 1967, 1971, 1975-84, Knik silt loam (means of 36 measurements).

Lb S/A	1967	1971	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	12-yr Mean[1]
	First cutting (% P in herbage)												
0	.275a[2]	.291a	.247a	.282a	.240a	.241a	.190a	.360a	.294a	.426b	.339b	.397a	.298a
70	.247b	.253b	.189b	.246b	.228a	.194b	.186a	.281b	.282a	.471a	.378a	.381a	.278b
	Second cutting (% P in herbage)												
0	.232a	.286b	.253a	.253a	.243a	.353a	.374a	.352a	.388b	.354b	.364b	.378b	.319a
70	.216a	.334a	.222b	.232b	.231a	.340a	.339b	.326b	.411a	.412a	.432a	.414a	.326a

[1]Means of 432 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 14. Effect of K application on P concentration in first-cutting bromegrass herbage in 1967, 1971, 1975-84, Knik silt loam (means of 12 measurements).

Lb K/A	1967	1971	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	12-yr Mean[1]
	(% P in herbage)												
0	.293a[2]	.327a	.313a	.332a	.250a	.264a	.232a	.384a	.392a	.544a	.437a	.452a	.352a
33	.265ab	.272b	.219b	.274b	.233a	.218b	.192b	.347b	.294b	.453b	.365b	.399b	.294b
66	.240b	.259b	.201bc	.233c	.234a	.209b	.185b	.305cd	.285b	.437bc	.341b	.390b	.277c
99	.256b	.277b	.198bc	.250bc	.228a	.212b	.182b	.320bc	.264bc	.449b	.363b	.381b	.282bc
133	.248b	.247b	.198bc	.254bc	.231a	.202b	.168b	.277d	.245c	.406c	.325c	.344c	.262d
166	.264ab	.251b	.180c	.242bc	.228a	.199b	.168b	.288cd	.249c	.402c	.322c	.338c	.261d

[1]Means of 144 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. 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 applied S at six K application rates on annual P uptake by bromegrass 1967-68, 1970-71, 1975-84, Knik silt loam (means of 6 measurements).

Lb S/A	1967	1968	1970	1971	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	18-yr Mean[1]
	(lb P/A in herbage)														
	No K applied														
0	15.6a[2]	20.0a	4.9b	7.2b	15.5a	8.7a	16.2a	23.9a	19.4a	25.5a	19.4a	13.7a	13.2a	17.1a	15.7a
70	16.2a	19.4a	12.6a	13.5a	14.4a	8.5a	15.6a	22.7a	18.9a	21.3b	20.3a	14.8a	16.6a	15.2a	16.4a
	33 lb K/A														
0	16.8a	22.2b	3.9b	6.4b	19.4a	11.3a	17.2a	26.2a	22.7a	26.5a	21.7a	16.5b	16.5b	20.4b	17.7b
70	20.2a	33.3a	10.1a	17.6a	18.6a	11.3a	16.0a	23.6a	21.0a	26.7a	24.1a	23.8a	25.9a	28.8a	21.5a
	66 lb K/A														
0	15.6a	21.8b	4.1b	5.8b	15.7a	9.7a	16.7a	26.7a	24.5a	26.1a	22.6a	18.1b	17.2b	20.1b	17.5b
70	17.7a	40.7a	9.8a	20.6a	18.9a	11.8a	15.2a	22.2b	19.5b	22.2b	22.4a	24.1a	21.7a	27.1a	21.0a
	99 lb K/A														
0	15.0b	21.7b	3.3b	5.1b	17.6a	10.0a	15.9a	26.3a	25.9a	30.3a	24.8a	20.4b	19.4b	25.1a	18.6b
70	21.2a	35.9a	9.2a	19.1a	18.6a	12.0a	15.7a	25.2a	22.8a	25.2b	23.3a	26.9a	28.6a	28.1a	22.3a
	133 lb K/A														
0	15.9a	25.0b	3.7b	4.6b	18.1a	10.5a	17.5a	27.5a	23.6a	29.5a	24.4a	20.5b	18.0b	22.8b	18.7b
70	18.9a	39.4a	10.2a	16.7a	19.3a	10.5a	16.5a	22.9b	21.8a	22.0b	24.0a	25.5a	25.5a	27.1a	21.4a
	166 lb K/A														
0	16.8b	26.9b	3.8b	6.4b	17.0a	10.5a	17.0a	26.3a	23.0a	29.3a	23.7b	19.6b	17.8b	24.7b	18.8b
70	21.2a	40.0a	9.3a	19.8a	20.0a	11.6a	15.1a	24.1a	23.5a	27.0a	27.8a	25.6a	28.7a	36.0a	23.6a

[1]Means of 84 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 16. Effect of K application with and without S application on the P uptake by bromegrass 1967-68, 1970-71, 1975-84, Knik silt loam (means of 6 measurements).

Lb K/A	1967	1968	1970	1971	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	14-yr Mean[1]
	(lb P/A in herbage)														
	No S applied														
0	15.6a[2]	20.0c	4.9a	7.2a	15.5b	8.7a	16.2a	23.9a	19.4b	25.5b	19.4b	13.7c	13.2b	17.1c	15.7b
33	16.8a	22.2bc	3.9a	6.4a	19.4a	11.3a	17.2a	26.2a	22.7b	26.5b	21.7ab	16.5bc	16.5ab	20.4bc	17.7a
66	15.6a	21.8bc	4.1a	5.8a	15.7ab	9.7a	16.7a	26.7a	24.5a	26.1b	22.6ab	18.1ab	17.2ab	20.1bc	17.5ab
99	15.0a	21.7bc	3.3a	5.1a	17.6ab	10.0a	15.9a	26.3a	25.9a	30.3a	24.8a	20.4ab	19.4a	25.1a	18.6a
133	15.9a	25.0ab	3.7a	4.6a	18.1ab	10.5a	17.5a	27.5a	23.6a	29.5ab	24.4a	20.5a	18.0a	22.8ab	18.7a
166	16.8a	26.9a	3.8a	6.4a	17.0ab	10.5a	17.0a	26.3a	23.0ab	29.3ab	23.7a	19.6ab	17.8a	24.7a	18.8a
	70 lb S/A														
0	16.2b	19.4d	12.6a	13.5c	14.4b	8.5a	15.6a	22.7a	18.9b	21.3b	20.3b	14.8b	16.6c	15.2b	16.4c
33	20.2ab	33.3c	10.1a	17.6abc	18.6ab	11.3a	16.0a	23.6a	21.0ab	26.7a	24.1ab	23.8a	25.9a	28.8a	21.5b
66	17.7ab	40.7a	9.8a	20.6a	18.9a	11.8a	15.2a	22.2a	19.5b	22.2b	22.4b	24.1a	21.7b	27.1a	21.0b
99	21.2a	35.9bc	9.2a	19.1ab	18.6ab	12.0a	15.7a	25.2a	22.8ab	25.2ab	23.3b	26.9a	28.6a	28.1a	22.3ab
133	18.9ab	39.4ab	10.2a	16.7bc	19.3a	10.5a	16.5a	22.9a	21.8ab	22.0b	24.0ab	25.5a	25.5ab	27.1a	21.4b
166	21.2a	40.0a	9.3a	19.8ab	20.0a	11.6a	15.1a	24.1a	23.5a	27.0a	27.8a	25.6a	28.7a	36.0a	23.6a

[1]Means of 84 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 17. Effect of applied S with six K application rates on first-cutting K concentration in bromegrass herbage in 1967, 1971, 1973-84, Knik silt loam (means of 6 measurements).

Lb S/A	1967	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	14-yr Mean[1]
	(% K in herbage)														
	No K applied														
0	1.34a[2]	1.11a	0.80a	0.63a	0.67a	0.78a	1.02a	0.68a	0.61a	0.74a	0.53a	0.86a	0.80a	0.70a	0.80a
70	1.53a	0.59b	0.91a	0.71a	0.73a	0.74a	1.11a	0.82a	0.64a	0.87a	0.64a	1.07a	0.86a	0.76a	0.86a
	33 lb K/A														
0	1.90a	1.75a	1.44a	1.15a	1.34a	1.48a	1.44a	1.21a	0.94a	1.45a	1.24a	2.15a	1.59a	1.55a	1.47a
70	1.94a	1.08b	1.39a	1.12a	1.15a	1.18b	1.36a	1.12a	0.85a	1.32a	1.03a	1.81b	1.32b	1.10b	1.27b
	66 lb K/A														
0	2.32a	1.99a	1.98a	1.51a	1.86a	1.81a	1.99a	1.89a	1.65a	2.27a	1.95a	2.54a	1.99a	2.23a	2.00a
70	2.08a	1.36b	1.72b	1.39a	1.34b	1.42b	1.84a	1.37b	1.22b	1.60b	1.28b	2.28b	1.38b	1.34b	1.54b
	99 lb K/A														
0	2.52a	2.31a	2.46a	2.00a	2.19a	2.05a	2.14a	2.25a	1.90a	2.54a	2.18a	2.93a	2.37a	2.45a	2.31a
70	2.55a	1.76b	2.14b	1.69b	1.78b	1.72b	2.21a	1.85b	1.57b	1.95b	1.48b	2.54b	1.98b	1.59b	1.92b
	133 lb K/A														
0	2.61a	2.21a	2.66a	2.01a	2.37a	2.23a	2.70a	2.33a	1.91a	2.89a	2.31a	3.02a	2.58a	2.60a	2.46a
70	2.84a	2.08a	2.30b	1.96a	1.98b	2.02a	2.30b	2.03b	1.65b	2.09b	1.61b	2.57b	1.92b	1.72b	2.08b
	166 lb K/A														
0	2.92a	2.19a	3.12a	2.25a	2.46a	2.28a	2.75a	2.61a	2.00a	3.01a	2.50a	3.22a	2.56a	2.55a	2.60a
70	3.01a	2.34a	2.89a	2.24a	2.40a	2.25a	2.62a	2.40a	1.92a	2.31b	1.86b	2.73b	2.26b	1.94b	2.37b

[1]Means of 84 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 18. Effect of applied S at six K application rates on second-cutting K concentration in bromegrass herbage in 1967, 1971, 1973-84, Knik silt loam (means of 6 measurements).

Lb S/A	1967	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	14-yr Mean[1]
	(% K in herbage)														
	No K applied														
0	0.87a[2]	1.34a	0.84a	0.56a	0.62a	0.72a	0.94a	0.77a	0.85a	0.76a	0.88a	0.92a	0.73a	0.84a	0.83a
70	0.93a	0.80b	0.83a	0.56a	0.59a	0.66a	0.94a	0.94a	1.10a	0.94a	1.00a	0.90a	0.70a	0.86a	0.84a
	33 lb K/A														
0	1.23a	2.43a	0.92a	0.82a	0.99a	1.05a	1.12a	1.07a	1.20a	1.00a	1.25a	1.32a	1.12a	1.18a	1.19a
70	1.21a	1.83b	0.90a	0.70a	0.88a	0.97a	1.13a	1.17a	1.45a	1.17a	1.37a	1.31a	0.86a	1.06a	1.14a
	66 lb K/A														
0	1.62a	2.78a	1.02a	1.14a	1.56a	1.63a	1.50a	1.56b	1.80a	1.60a	1.82a	1.96a	1.68a	1.60a	1.66a
70	1.40a	2.22g	1.00a	0.86b	1.19b	1.39a	1.42a	1.87a	1.80a	1.53a	1.96a	1.88a	1.23b	1.39a	1.51b
	99 lb K/A														
0	1.60a	2.63a	1.19a	1.38a	1.74a	1.88a	1.68a	2.24a	2.10a	1.86b	2.07b	2.33b	1.96a	2.16a	1.92a
70	1.80a	2.89a	1.26a	1.08b	1.63a	1.62a	1.50a	2.42a	2.35a	2.14a	2.45a	2.76a	1.87a	1.88b	1.98a
	133 Lb K/A														
0	1.73a	3.12b	1.36a	1.46a	1.93a	1.92a	1.83a	2.66a	2.49a	2.23a	2.31b	2.93a	2.14a	2.32a	2.17b
70	1.98a	3.43a	1.37a	1.32a	2.01a	1.97a	1.74a	2.82a	2.61a	2.43a	2.69a	3.00a	2.05a	2.31a	2.27a
	166 lb K/A														
0	1.85a	3.23b	1.39b	1.56a	2.10a	2.18a	1.86a	3.15a	2.98a	2.60a	2.63a	3.05b	2.23a	2.40a	2.37b
70	1.97a	3.62a	1.67a	1.57a	2.11a	2.17a	1.98a	3.41a	2.84a	2.68a	2.82a	3.74a	2.46a	2.48a	2.54a

[1]Means of 84 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 19. Effect of K application with and without S application on first-cutting K concentration in bromegrass 1967, 1971, 1973-84, Knik silt loam (means of 6 measurements).

Lb S/A	1967	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	14-yr Mean[1]
	(% K in herbage)														
	No S applied														
0	1.34e[2]	1.11d	0.80e	0.63d	0.67e	0.78d	1.02d	0.68e	0.61d	0.74d	0.53f	0.86e	0.80d	0.70d	0.80f
33	1.90d	1.75c	1.44d	1.15c	1.34d	1.48c	1.44c	1.21d	0.94c	1.45c	1.24e	2.15d	1.59c	1.55c	1.47e
66	2.32c	1.99bc	1.98c	1.51b	1.86c	1.81b	1.99b	1.89c	1.65b	2.27b	1.95d	2.54c	1.99b	2.23b	2.00d
99	2.52bc	2.31a	2.46b	2.00a	2.19b	2.05ab	2.14b	2.25b	1.90ab	2.54b	2.18bc	2.93b	2.37a	2.45ab	2.31c
133	2.61b	2.21ab	2.66b	2.01a	2.37ab	2.23a	2.70a	2.33b	1.91ab	2.89a	2.31ab	3.02ab	2.58a	2.60a	2.46b
166	2.92a	2.19abc	3.12a	2.25a	2.46a	2.28a	2.75a	2.61a	2.00a	3.01a	2.50a	3.22a	2.56a	2.55a	2.60a
	70 lb S/A														
0	1.53d	0.59e	0.91e	0.71d	0.73d	0.74d	1.11d	0.82d	0.64d	0.87d	0.64e	1.07d	0.86d	0.76f	0.86f
33	1.94c	1.08d	1.39d	1.12c	1.15c	1.18c	1.36d	1.12c	0.85d	1.32c	1.03d	1.81c	1.32c	1.10e	1.27e
66	2.08c	1.36d	1.72c	1.39c	1.34c	1.42c	1.84c	1.37c	1.22c	1.60c	1.28cd	2.28b	1.38c	1.34cd	1.54d
99	2.55b	1.76c	2.14b	1.69b	1.78b	1.72b	2.21b	1.85b	1.57b	1.95b	1.48bc	2.54ab	1.98b	1.59bc	1.92c
133	2.84a	2.08b	2.30b	1.96b	1.98b	2.02a	2.30b	2.03b	1.65b	2.09ab	1.61ab	2.57a	1.92b	1.72ab	2.08b
166	3.01a	2.34a	2.89a	2.24a	2.40a	2.25a	2.62a	2.40a	1.92a	2.31a	1.86a	2.73a	2.26a	1.94a	2.37a

[1]Means of 84 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 20. Effect of K application with and without S application on second-cutting K concentration in bromegrass 1967, 1971, 1973-84, Knik silt loam (means of 6 measurements).

Lb K/A	1967	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	14-yr Mean[1]
	(% K in herbage)														
	No S applied														
0	0.87c[2]	1.34d	0.84c	0.56c	0.62e	0.72d	0.94c	0.77e	0.85f	0.76d	0.88e	0.92e	0.73d	0.84d	0.83f
33	1.23b	2.43c	0.92bc	0.82c	0.99d	1.05c	1.12c	1.07e	1.20e	1.00d	1.25d	1.32d	1.12c	1.18c	1.19e
66	1.62a	2.78b	1.02bc	1.14b	1.56c	1.63b	1.50b	1.56d	1.80d	1.60c	1.82c	1.96c	1.68b	1.60b	1.66d
99	1.60a	2.63bc	1.19ab	1.38ab	1.74bc	1.88b	1.68ab	2.24c	2.10c	1.86c	2.07bc	2.35b	1.96ab	2.16a	1.92c
133	1.73a	3.12a	1.36a	1.46a	1.93ab	1.92ab	1.83a	2.66b	2.49b	2.23b	2.31b	2.93a	2.14a	2.32a	2.17b
166	1.85a	3.23a	1.39a	1.56a	2.10a	2.18a	1.86a	3.15a	2.98a	2.60a	2.63a	3.05a	2.23a	2.40a	2.37a
	70 lb S/A														
0	0.93c	0.80e	0.83d	0.56d	0.59d	0.66d	0.94e	0.94e	1.10e	0.94d	1.00e	0.90e	0.70d	0.86d	0.84f
33	1.21bc	1.83d	0.90d	0.70d	0.88d	0.97c	1.13de	1.17e	1.45d	1.17d	1.37d	1.31d	0.86d	1.06d	1.14e
66	1.40b	2.22c	1.00cd	0.86cd	1.19c	1.39b	1.42cd	1.87d	1.80c	1.53c	1.96c	1.88c	1.23c	1.39c	1.51d
99	1.80a	2.89b	1.26bc	1.08bc	1.63b	1.62b	1.50bc	2.42c	2.35b	2.14b	2.45b	2.76b	1.87b	1.88b	1.98c
133	1.98a	3.43a	1.37b	1.32ab	2.07a	1.97a	1.74ab	2.82b	2.61ab	2.43a	2.69ab	3.00b	2.05b	2.31a	2.27b
166	1.97a	3.62a	1.67a	1.57a	2.11a	2.17a	1.98a	3.41a	2.84a	2.68a	2.82a	3.74a	2.46a	2.48a	2.54a

[1]Means of 84 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 21. Effect of applied S with six K application rates on annual K uptake by bromegrass 1967-68, 1970-71, 1973-84, Knik silt loam (means of 6 measurements).

Lb S/A	1967	1968	1970	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	16-yr Mean[1]
	(lb K/A in herbage)																
	No K applied																
0	64a[2]	67a	11a	27a	44a	26a	32a	21a	62a	51a	41a	45a	32a	28a	24a	31a	38a
70	68a	64a	18a	29a	53a	32a	39a	19a	70a	71a	55a	58a	37a	28a	25a	29a	43a
	33 lb K/A																
0	93b	105b	19a	50b	91a	61a	90a	50a	97a	104a	84a	89a	80a	73a	63a	72a	76a
70	136a	132a	35a	89a	93a	65a	96a	50a	89a	108a	88a	101a	84a	82a	63a	73a	86a
	66 lb K/A																
0	123b	144b	24b	54b	122a	77a	120a	68a	127a	169a	149a	150a	127a	108a	89a	100a	109a
70	155a	183a	52a	125a	114a	85a	119a	73a	117a	149a	119b	125a	109a	117a	76a	94a	113a
	99 lb K/A																
0	128b	167b	20b	49b	166a	107a	145b	76a	142a	220a	183a	199a	166a	139a	119a	149a	136b
70	211a	229a	66a	159a	150a	113a	172a	89a	136a	211a	165a	164b	137b	164a	132a	125a	151a
	133 lb K/A																
0	146b	215b	22b	50b	188a	122a	182a	85a	181a	257a	203a	234a	188a	168a	128a	159a	158a
70	213a	265a	75a	173a	166a	125a	197a	92a	162a	221b	183a	181b	158b	179a	138a	143a	167a
	166 lb K/A																
0	171b	226b	30b	68b	205a	128b	180b	94b	186a	289a	221a	247a	195a	163b	132b	173b	169b
70	236a	302a	78a	223a	209a	154a	243a	121a	132b	283a	227a	243a	209a	210a	185a	221a	205a

[1]Means of 96 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 22. Effect of K application with and without S application on the annual K uptake by bromegrass 1967-68, 1970-71, 1973-84, Knik silt loam (means of 6 measurements).

Lb K/A	1967	1968	1970	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	16-yr Mean[1]
	(lb K/A in herbage)																
	No S applied																
0	64d[2]	67e	11a	27b	44e	26c	32d	21d	62d	51f	41e	45e	32e	28d	24c	31d	38f
33	93c	105d	19a	50a	91d	61b	90c	50c	97c	104e	84d	89d	80d	73d	63b	72c	76e
66	123b	144c	24a	54a	122c	77b	120b	68bc	127b	169d	149c	150c	127c	108c	89b	100b	109d
99	128b	167b	20a	49ab	166b	107a	145b	76abc	142b	220c	183b	199b	166b	139b	119a	149a	136c
133	146b	215a	22a	50a	188ab	122a	182a	85ab	181a	257b	203ab	234a	188ab	168a	128a	159a	158b
166	171a	226a	30a	68a	205a	128a	180a	94a	186a	289a	221a	247a	195a	163ab	132a	173a	169a
	70 lb S/A																
0	68c	64f	18d	29e	53d	32d	39d	19d	70c	71e	55e	58d	37d	28e	25d	29d	43f
33	136b	132e	35cd	89d	93c	65c	96c	50c	89c	108d	88d	101c	84c	82d	63c	73c	86e
66	155b	183d	52bc	125c	114c	85c	119c	73bc	117b	149c	119c	125c	109c	117c	76c	94c	113e
99	211a	229c	66ab	159b	150b	113b	172b	89b	136b	211b	165b	164b	137b	164b	132b	125b	151c
133	213a	265b	75ab	173b	166b	125b	197b	92b	162a	221b	183b	181b	158b	179b	138b	143b	167b
166	236a	302a	78a	223a	209a	154a	243a	121a	132b	283a	227a	243a	209a	210a	185a	221a	205a

[1]Means of 96 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 23. Effect of applied S with six K application rates on first-cutting bromegrass S concentration 1967, 1970-84, Knik silt loam (means of 6 measurements).

Lb S/A	1967	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	16-yr Mean[1]
	(% S in herbage)																
	No K applied																
0	.113a[2]	.162b	.127b	.175b	.172b	.154b	.190b	.156b	.166a	.192b	.186b	.217b	.173b	.192b	.181b	.164b	.170b
70	.095a	.285a	.322a	.237a	.235a	.260a	.258a	.305a	.187a	.226a	.267a	.310a	.293a	.343a	.299a	.291a	.263a
	33 lb K/A																
0	.098b	.143b	.102b	.180b	.145b	.121b	.132b	.109b	.154b	.158a	.156b	.180b	.131b	.138b	.134b	.144b	.139b
70	.183a	.263a	.242a	.222a	.262a	.204a	.212a	.221a	.182a	.178a	.202a	.234a	.211a	.286a	.251a	.260a	.226a
	66 lb K/A																
0	.107b	.150b	.105b	.147b	.128b	.106b	.115b	.104b	.153a	.146a	.138b	.163b	.125b	.124b	.131b	.123b	.129b
70	.213a	.235a	.202a	.202a	.200a	.185a	.187a	.194a	.161a	.162a	.179a	.226a	.188a	.218a	.200a	.209a	.198a
	99 lb K/A																
0	.133b	.142b	.117b	.148b	.137b	.099b	.117b	.090b	.147b	.148a	.132b	.147b	.125b	.140b	.133b	.156b	.132b
70	.235a	.230a	.192a	.203a	.185a	.170a	.170a	.180a	.175a	.154a	.158a	.214a	.179a	.243a	.229a	.210a	.195a
	133 lb K/A																
0	.115b	.137b	.108b	.142b	.132b	.100b	.110b	.091b	.151a	.156a	.127b	.154b	.120b	.108b	.128b	.122b	.125b
70	.247a	.217a	.180a	.188a	.177a	.161a	.166a	.155a	.164a	.158a	.154a	.188a	.164a	.218a	.216a	.194a	.184a
	166 lb K/A																
0	.115b	.145b	.105b	.133b	.127b	.094b	.110b	.092b	.142a	.137a	.126b	.151b	.119b	.116b	.128b	.128b	.123b
70	.235a	.208a	.167a	.203a	.177a	.162a	.173a	.179a	.166a	.159a	.153a	.202a	.164a	.216a	.197a	.191a	.184a

[1]Means of 96 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 24. Effect of K application with and without S application on first-cutting S concentration 1967, 1970-84, Knit silt loam (means of 6 measurements).

Lb S/A	1967	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	16-yr Mean[1]
	(% S in herbage)																
	No S applied																
0	.113a[2]	.162a	.127a	.175ab	.172a	.154a	.190a	.156a	.166a	.192a	.186a	.217a	.173a	.192a	.181a	.164a	.170a
33	.098a	.143a	.102a	.180a	.145b	.121b	.132b	.109b	.154a	.158b	.156b	.180b	.131b	.138b	.134b	.144ab	.139b
66	.107a	.150a	.105a	.147bc	.128b	.106b	.115b	.104b	.153a	.146b	.138bc	.163bc	.125b	.124bc	.131b	.123b	.129c
99	.133a	.142a	.117a	.148bc	.137b	.099b	.117b	.090b	.147a	.148b	.132bc	.147c	.125b	.140b	.133b	.156a	.132bc
133	.115a	.137a	.108a	.142c	.132b	.100b	.110b	.091b	.151a	.156b	.127c	.154bc	.120b	.108c	.128b	.122b	.125c
166	.115a	.145a	.105a	.133c	.127b	.094b	.110b	.092b	.142a	.137b	.126c	.151c	.119b	.116bc	.128b	.128b	.123c
	70 lb S/A																
0	.095d	.285a	.322a	.237a	.235a	.260a	.258a	.305a	.187a	.226a	.267a	.310a	.293a	.343a	.299a	.291a	.263a
33	.183c	.263a	.242b	.222ab	.262b	.204b	.212b	.221b	.182a	.178b	.202b	.234b	.211b	.286b	.251b	.260b	.226b
66	.213b	.235b	.202c	.202bc	.200b	.185bc	.187bc	.194bc	.161a	.162b	.179bc	.226bc	.188bc	.218c	.200d	.209c	.198c
99	.235ab	.230b	.192cd	.203bc	.185b	.170c	.170c	.180bc	.175a	.154b	.158c	.214bcd	.179c	.243c	.229bc	.210c	.195c
133	.247a	.217b	.180cd	.188c	.177b	.161c	.166c	.155c	.164a	.158b	.154c	.188d	.164c	.218c	.216cd	.194c	.184d
166	.235ab	.208b	.167d	.203bc	.177b	.162c	.173c	.179c	.166a	.159b	.153c	.202cd	.164c	.216c	.197d	.191c	.184d

[1]Means of 96 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 25. Effect of applied S on second-cutting bromegrass S concentration 1967, 1970-84, Knit silt loam (means of 36 measurements).

Lb S/A	1967	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	16-yr Mean[1]
	(% S in herbage)																
0	.094b[2]	.104b	.124b	.172b	.158b	.139b	.109b	.119b	.207b	.168b	.160b	.162b	.165b	.130b	.123b	.128b	.141b
70	.171a	.207a	.236a	.223a	.210a	.218a	.198a	.219a	.229a	.202a	.186a	.205a	.242a	.241a	.234a	.228a	.216a

[1]Means of 576 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 26. Effect of K application on second-cutting bromegrass S concentration 1967, 1970-1984, Knit silt loam (means of 36 measurements).

Lb K/A	1967	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	16-yr Mean[1]
	(% S in herbage)																
0	.098c[2]	.192a	.220a	.229a	.225a	.225a	.205a	.224a	.254a	.231a	.214a	.241a	.263a	.237a	.223a	.210a	.218a
33	.127b	.166b	.179b	.216a	.206b	.204b	.177b	.187b	.235b	.206b	.188b	.204b	.214b	.193b	.194b	.199a	.193b
66	.132b	.148c	.171b	.188b	.177c	.171c	.144c	.160c	.211c	.174c	.170bc	.174c	.188c	.166cd	.171c	.172b	.170c
99	.128b	.137c	.171b	.193b	.172c	.160cd	.136c	.155c	.206c	.169c	.164cd	.173c	.196c	.184c	.169c	.162b	.167cd
133	.153a	.154c	.170b	.178b	.165c	.160cd	.131c	.144c	.204c	.166c	.153cd	.152e	.181c	.163d	.154c	.162b	.162d
166	.157a	.136c	.172b	.182b	.160c	.150d	.127c	.145c	.200c	.164c	.149d	.158de	.178c	.169cd	.160c	.162b	.161d

[1]Means of 192 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 27. Effect of applied S with six K application rates on annual S uptake by bromegrass 1967-68, 1970-84, Knit silt loam (means of 6 measurements).

Lb S/A	1967	1968	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	17-yr Mean[1]
	(lb S/A in herbage)																	
	No K applied																	
0	6.1a[2]	4.3a	1.5b	3.3b	11.3b	9.6b	6.8b	8.3b	4.5b	11.3b	14.2b	10.7b	13.0b	9.4b	5.9b	5.2b	6.4b	7.8b
70	5.3a	4.3a	7.3a	11.8a	15.4a	14.4a	13.0a	14.6a	8.0a	13.5a	19.1a	15.4a	17.8a	14.2a	9.1a	9.8a	9.7a	11.9a
	33 lb K/A																	
0	5.6b	4.0b	1.3b	2.8b	12.0b	11.1b	7.5b	9.8b	4.7b	12.2b	15.3b	12.9b	12.6b	9.5b	5.9b	6.1b	7.5b	8.3b
70	14.9a	16.8a	6.8a	13.4a	16.5a	16.3a	14.1a	20.2a	10.6a	13.7a	18.5a	15.0a	19.1a	16.6a	14.5a	15.7a	17.8a	15.3a
	66 lb K/A																	
0	6.4b	4.4b	1.5b	2.3b	10.0b	10.0b	6.1b	7.6b	4.1b	11.2b	14.9b	12.6b	12.3b	9.1b	5.8b	6.1b	6.2b	7.7b
70	16.9a	19.3a	6.9a	14.6a	15.3a	15.6a	13.2a	17.9a	10.5a	12.1a	16.4a	14.3a	16.9a	14.1a	12.8a	12.7a	14.5a	14.4a
	99 lb K/A																	
0	6.4b	4.7b	1.1b	2.2b	10.7b	11.6b	5.9b	7.8b	3.6b	11.2b	14.3b	13.4a	13.3b	10.8b	7.0b	7.0b	9.3b	8.3b
70	20.3a	23.0a	6.5a	13.4a	16.3a	15.7a	13.2a	17.8a	10.3a	12.6a	17.2a	13.4a	16.4a	14.7a	14.8a	15.3a	14.7a	15.0a
	133 lb K/A																	
0	7.2b	6.0b	1.3b	2.0b	11.6b	11.6b	7.0b	8.8b	3.9b	11.7b	16.1a	12.2b	13.4b	10.6b	6.4b	6.9b	7.7b	8.5b
70	19.8a	22.2a	6.8a	12.3a	14.4a	14.9a	11.6a	16.3a	7.8a	13.3a	15.9a	13.7a	14.2a	14.3a	13.7a	14.1a	14.9a	14.1a
	166 lb K/A																	
0	7.6b	4.4b	1.2b	2.6b	10.8b	10.9b	6.2b	7.9b	4.1b	11.5b	14.6b	11.8b	13.0b	9.9b	5.7b	6.6b	8.5b	8.1b
70	21.2a	27.8	6.1a	14.4a	15.7a	15.3a	12.3a	18.2a	9.8a	12.0a	17.2a	14.5a	18.2a	16.8a	14.0a	15.7a	20.0a	15.8a

[1]Means of 102 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 28. Effect of potassium application with and without sulfur application on the annual S uptake by bromegrass 1967-68, 1970-84, Knit silt loam (means of 6 measurements).

Lb K/A	1967	1968	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	17-yr Mean[1]
	(lb S/A in herbage)																	
	No S applied																	
0	6.1b[2]	4.3bc	1.5a	3.3a	11.3b	9.6c	6.8b	8.3c	4.5ab	11.3b	14.2d	10.7e	13.0ab	9.4bc	5.9c	5.2c	6.4d	7.8b
33	5.6b	4.0c	1.3a	2.8b	12.0a	11.1b	7.5a	9.8a	4.7a	12.2a	15.3b	12.9b	12.6bc	9.5bc	5.9c	6.1b	7.5c	8.3ab
66	6.4b	4.4bc	1.5a	2.3cd	10.0d	10.0c	6.1c	7.6d	4.1bc	11.2b	14.9bc	12.6bc	12.3c	9.1c	5.8c	6.1b	6.2d	7.7b
99	6.4b	4.7b	1.1a	2.2cd	10.7c	11.6a	5.9c	7.8cd	3.6c	11.2b	14.3d	13.4a	13.3a	10.8a	7.0a	7.0a	9.3a	8.3ab
133	7.2a	6.0a	1.3a	2.0d	11.6ab	11.6a	7.0b	8.8b	3.9c	11.7b	16.1a	12.2cd	13.4a	10.6a	6.4b	6.9a	7.7c	8.5a
166	7.6a	4.4bc	1.2a	2.6bc	10.8c	10.9b	6.2c	7.9cd	4.1bc	11.5b	14.6cd	11.8d	13.0ab	9.9b	5.7c	6.6a	8.5b	8.1ab
	70 lb S/A																	
0	5.3f	4.3f	7.3a	11.8d	15.4b	14.4e	13.0b	14.6d	8.0c	13.5a	19.1a	15.4a	17.8b	14.2bc	9.1d	9.8d	9.7d	11.9d
33	14.9e	16.8e	6.8ab	13.4b	16.5a	16.ea	14.1a	20.2a	10.6a	13.7a	18.5b	15.0a	19.1a	16.6a	14.5a	15.7a	17.8b	15.3ab
66	16.9d	19.3d	6.9ab	14.6a	15.3b	15.6b	13.2b	17.9b	10.5a	12.1c	16.4d	14.3b	16.9c	14.1c	12.8c	12.7c	14.5c	14.4bc
99	20.3b	23.0b	6.5bc	13.4b	16.3a	15.7b	13.2b	17.8b	10.3a	12.6b	17.2c	13.4c	16.4d	14.7b	14.8a	15.3a	14.7c	15.0abc
133	19.8c	22.2c	6.8ab	12.3c	14.4c	14.9d	11.6d	16.3c	7.8c	13.3a	15.9e	13.7c	14.2e	14.3bc	13.7b	14.1b	14.4c	14.1c
166	21.2a	27.8a	6.1a	14.4a	15.7b	15.3cd	12.3c	18.2b	9.8b	12.0c	17.2c	14.5b	18.2b	16.8a	14.0b	15.7a	20.0a	15.8a

[1]Means of 102 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 29. Effect of applied S with six K application rates on the N/S ratio in first-cutting bromegrass 1967, 1970-84, Knit silt loam (means of 6 measurements).

Lb S/A	1967	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	16-yr Mean[1]
	No K applied																
0	23.1b[2]	21.7a	29.3a	15.2a	15.7a	18.7a	15.4a	22.0a	11.5a	12.9a	13.7a	13.7a	14.9a	17.3a	16.6a	18.0a	17.5a
70	37.3a	12.0b	10.8b	12.5a	11.8b	10.4b	10.9b	11.2b	10.1a	9.8a	8.0b	8.8b	9.1b	10.6b	9.7b	9.9b	12.1b
	33 lb K/A																
0	33.5a	22.3a	36.1a	15.6a	16.6a	18.8a	18.8a	27.9a	11.9a	13.7a	12.8a	14.6a	16.9a	21.3a	18.1a	18.6a	19.8a
70	16.2b	12.2b	11.5b	12.7a	12.8b	11.3b	10.8b	11.6b	9.4a	11.1a	9.2b	9.6b	10.1b	11.4b	10.4b	10.0b	11.3b
	66 lb K/A																
0	30.9a	20.8a	35.3a	17.5a	18.1a	21.9a	22.0a	28.0a	12.4a	15.2a	14.0a	15.4a	17.4a	22.7a	17.7a	21.3a	20.7a
70	15.0b	13.0b	12.0b	12.8b	12.1b	12.6b	11.6b	12.8b	11.2a	12.1a	10.0b	10.6b	10.6b	14.2b	10.1b	11.1b	12.0b
	99 lb K/A																
0	29.0a	22.2a	32.0a	21.0a	17.9a	22.2a	21.5a	32.1a	12.4a	15.0a	15.1a	16.6a	17.1a	21.6a	18.4a	16.8a	20.7a
70	12.9b	12.9b	13.2b	13.9b	12.9b	12.2b	12.8b	13.4b	11.4a	13.1a	11.0b	10.8b	11.2b	10.9b	10.4b	10.8b	12.1b
	133 lb K/A																
0	27.9a	22.7a	33.6a	20.0a	17.8a	21.3a	22.2a	31.4a	12.9a	14.2a	13.9a	14.8a	16.7a	21.9a	18.1a	19.4a	20.6a
70	14.3b	13.2b	14.1b	14.7b	13.2b	13.2b	13.5b	15.9b	11.9a	12.9a	10.9a	11.8a	11.4b	12.2b	10.1b	11.4b	12.8b
	166 lb K/A																
0	28.5a	20.5a	33.1a	22.2a	19.0a	23.0a	22.9a	31.8a	13.4a	14.6a	13.9a	15.8a	17.5a	22.6a	16.7a	17.9a	20.8a
70	16.0b	14.0b	14.8b	13.3b	12.9b	12.2b	13.3b	14.7b	11.2a	12.8a	10.9a	11.7b	11.7b	12.2b	11.1b	10.8b	12.7b

[1]Means of 96 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 30. Effect of K application with and without S application on the N/S ratio in first-cutting bromegrass 1967, 1970-84, Knik silt loam (means of 6 measurements).

Lb K/A	1967	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	16-yr Mean[1]
	No S applied																
0	23.1b[2]	21.7a	29.3c	15.2c	15.7a	18.7b	15.4c	22.0c	11.5a	12.9a	13.7a	13.7a	14.9a	17.3b	16.6a	18.0ab	17.5b
33	33.5a	23.3a	36.1a	15.6c	16.6a	18.8b	18.8bc	27.9b	11.9a	13.7a	12.8a	14.6a	16.9a	21.3a	18.1a	18.6ab	19.9a
66	30.9ab	20.8a	35.3ab	17.5bc	18.1a	21.9ab	22.0ab	28.0b	12.4a	15.2a	14.0a	15.4a	17.4a	22.7a	17.7a	21.3a	20.7a
99	29.9b	22.2a	32.0bc	21.0a	17.9a	22.2ab	21.5ab	32.1a	12.4a	15.0a	15.1a	16.6a	17.1a	21.6a	18.4a	16.8b	20.7a
133	27.9b	22.7a	33.6ab	20.0ab	17.8a	21.3ab	22.2ab	31.4ab	12.9a	14.2a	13.9a	14.9a	16.7a	21.9a	18.1a	19.4ab	20.6a
166	28.5b	20.5a	33.1ab	22.2a	19.0a	23.0a	22.9a	31.8a	13.4a	14.6a	13.9a	15.8a	17.5a	22.6a	16.7a	17.9ab	20.8a
	70 lb S/A																
0	37.3a	12.0a	10.8b	12.5a	11.8a	10.4a	10.9a	11.2b	10.1a	9.8a	8.0a	8.8a	9.1a	10.6b	9.7a	9.9a	12.1ab
33	16.2b	12.2a	11.5ab	12.7a	12.8a	11.3a	10.8a	11.6b	9.4a	11.1a	9.2a	9.6a	10.1a	11.4ab	10.4a	10.0a	11.3b
66	15.0b	13.0a	12.0ab	12.8a	12.1a	12.6a	11.6a	12.8ab	11.2a	12.1a	10.0a	10.6a	10.6a	14.2a	10.1a	11.1a	12.0ab
99	12.9b	12.9a	13.2ab	13.9a	12.9a	12.2a	12.8a	13.4ab	11.4a	13.1a	11.0a	10.8a	11.2a	10.9ab	10.4a	10.8a	12.1ab
133	14.3b	13.2a	14.1ab	14.7a	13.2a	13.2a	13.5a	15.9a	11.9a	12.9a	10.9a	11.8a	11.4a	12.2ab	10.1a	11.4a	12.8a
166	16.0b	14.0a	14.8a	13.3a	12.9a	12.2a	13.3a	14.7ab	11.2a	12.8a	10.9a	11.7a	11.7a	12.2ab	11.1a	10.8a	12.7a

[1]Means of 96 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 31. Effect of applied S on Ca concentration and on second-cutting Mg concentration in bromegrass 1967, 1971, 1973-84, Knik silt loam (means of 36 measurements).

Lb S/A	1967	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	14-yr Mean[1]
	First cutting (% Ca in herbage)														
0	.350a[2]	.345a	.326a	.297a	.229a	.316a	.262a	.364a	.435a	.355a	.359a	.328a	.343a	.305a	.330a
70	.346a	.302b	.302b	.224b	.185b	.214b	.221b	.314b	.389b	.301b	.291b	.252b	.294b	.257b	.278b
	Second cutting (% Ca in herbage)														
0	.430a	.367a	.330a	.407a	.296a	.370a	.515a	.375a	.444a	.378a	.418a	.386a	.350a	.321a	.385a
70	.381b	.353a	.317a	.311b	.244b	.300b	.469b	.350b	.382b	.332b	.382b	.324b	.272b	.271b	.335b
	Second cutting (% Mg in herbage)														
0	.170b	.138b	.213a	.254a	.215a	.202a	.327a	.290a	.355a	.242a	.238a	.199a	1.81a	.196a	.230a
70	.191a	.171a	.194b	.223b	.195b	.194a	.287b	.254b	.290b	.210b	.201b	.171b	.154b	.178b	.208b

[1]Means of 504 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 32. Effect of K application on first-cutting Ca concentration and on second-cutting Ca and Mg concentration in bromegrass 1967, 1971, 1973-84, Knik silt loam (means of 36 measurements).

Lb K/A	1967	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	14-yr Mean[1]
	First cutting (% Ca in herbage)														
0	.397a[2]	.434a	.350a	.335a	.269a	.358a	.266a	.379a	.508a	.402a	.432a	.395a	.443a	.371a	.381a
33	.362b	.358b	.323ab	.283b	.225b	.284b	.266a	.364a	.458b	.358b	.351b	.322b	.340b	.310b	.329b
66	.338bc	.318c	.330ab	.256bc	.206bc	.259bc	.225b	.355a	.408c	.323c	.314c	.285c	.294c	.289b	.300c
99	.339bc	.297cd	.319b	.244cd	.191cd	.234cd	.235b	.319b	.388cd	.302cd	.290cd	.245d	.272c	.242c	.280d
133	.337bc	.269d	.288c	.225d	.177de	.228d	.226b	.317b	.350e	.297cd	.292cd	.252d	.276c	.244c	.270e
166	.316c	.268d	.272c	.222d	.175e	.227d	.229b	.299b	.362de	.285d	.272d	.239d	.287c	.229c	.263f
	Second cutting (% Ca in herbage)														
0	.514a	.513a	.334ab	.457a	.385a	.433a	.547a	.435a	.562a	.524a	.566a	.517a	.432a	.434a	.475a
33	.441b	.383b	.346ab	.394b	.309b	.385b	.543ab	.420a	.453b	.431b	.458b	.402b	.369b	.366b	.407b
66	.397c	.354bc	.355a	.375bc	.259c	.332c	.504bc	.359b	.406c	.341c	.393c	.338c	.302c	.275c	.356c
99	.372cd	.332cd	.325ab	.340cd	.235cd	.297cd	.459cd	.339bc	.362d	.308cd	.353cd	.318c	.286cd	.263cd	.328d
133	.370cd	.299de	.270c	.306de	.226cd	.287cd	.450d	.308c	.364cd	.281de	.324de	.294cd	.251de	.225de	.304e
166	.338d	.278e	.312bc	.283e	.206d	.274d	.448d	.312c	.329d	.243e	.303e	.262d	.227e	.212e	.288f
	Second cutting (% Mg in herbage)														
0	.237a	.267a	.250a	.357a	.325a	.347a	.399a	.396a	.478a	.356a	.345a	.318a	.293a	.308a	.334a
33	.214a	.177b	.239a	.285b	.249b	.255b	.354b	.326b	.354b	.277b	.259b	.222b	.208b	.230b	.261b
66	.176b	.143c	.202b	.237c	.198c	.181c	.308c	.259c	.318c	.213c	.212c	.175c	.161c	.178c	.212c
99	.163bc	.135c	.198b	.208d	.168d	.153d	.274d	.238cd	.282d	.192cd	.186cd	.154c	.132d	.156cd	.188d
133	.152bc	.107d	.168c	.180e	.153d	.135de	.256d	.211d	.263d	.169d	.172d	.129d	.110de	.130de	.167e
166	.141c	.100d	.162c	.163e	.137d	.116e	.252d	.201e	.239e	.149e	.143e	.112d	.102e	.122e	.144f

[1]Means of 504 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 33. Effect of applied S with six K application rates on bromegrass first-cutting Mg concentration 1967, 1971, 1973-84, Knik silt loam (means of 36 measurements).

Lb S/A	1967	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	14-yr Mean[1]
	(% Mg in herbage)														
	No K applied														
0	.151a[2]	.178b	.235a	.201a	.223a	.258a	.176a	.251a	.361a	.292a	.268a	.262a	.245a	.218a	.237a
70	.138a	.212a	.187b	.157b	.193b	.198b	.152b	.200b	.273b	.190b	.198b	.193b	.200b	.187b	.191b
	33 lb K/A														
0	.124a	.130a	.185a	.132a	.172a	.158a	.154a	.199a	.250a	.203a	.172a	.157a	.157a	.163a	.168a
70	.135a	.144a	.155b	.117a	.146b	.127b	.133b	.163b	.217b	.165b	.142b	.130b	.143a	.140b	.147b
	66 lb K/A														
0	.117a	.112a	.157a	.116a	.152a	.130a	.138a	.178a	.212a	.173a	.145a	.138a	.135a	.135a	.146a
70	.126a	.104a	.148a	.096b	.118b	.107b	.119a	.152b	.183b	.137b	.113b	.107b	.103b	.118a	.124b
	99 lb K/A														
0	.110a	.096a	.148a	.109a	.136a	.116a	.132a	.167a	.197a	.150a	.130a	.115a	.118a	.132a	.133a
70	.126a	.098a	.127b	.098a	.106b	.098a	.120a	.137b	.152b	.125b	.105b	.093b	.093b	.090b	.112b
	133 lb K/A														
0	.112a	.100a	.118a	.098a	.122a	.106a	.129a	.157a	.165a	.138a	.113a	.105a	.105a	.105a	.120a
70	.122a	.071ab	.120a	.087a	.100b	.088a	.114a	.134b	.137b	.118b	.102a	.100a	.085b	.097a	.105b
	166 lb K/A														
0	.105a	.099a	.125a	.096a	.121a	.105a	.120a	.142a	.150a	.120a	.108a	.098a	.097a	.112a	.114a
70	.121a	.078b	.098b	.086a	.096b	.084b	.111a	.139a	.148a	.120a	.097a	.093a	.083a	.093a	.103b

[1]Means of 84 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 34. Effect of K application with and without S application on bromegrass first-cutting Mg concentration 1967, 1971, 1973-84, Knik silt loam (means of 6 measurements).

Lb K/A	1967	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	14-yr Mean[1]
	(% Mg in herbage)														
	No S applied														
0	.151a[2]	.178a	.235a	.201a	.223a	.258a	.176a	.251a	.361a	.292a	.268a	.262a	.245a	.218a	.237a
33	.124b	.130b	.185b	.132b	.172b	.158b	.154b	.199b	.250b	.203b	.172b	.157b	.157b	.163b	.168b
66	.117b	.112bc	.157c	.116bc	.152c	.130c	.138bc	.178c	.212c	.173c	.145c	.138b	.135c	.135c	.146c
99	.110b	.096c	.148c	.109c	.136cd	.116cd	.132c	.167c	.197c	.150d	.130cd	.115c	.118cd	.132cd	.133d
133	.112b	.100c	.118d	.098c	.122d	.106d	.129c	.157cd	.165d	.138de	.113d	.105c	.105d	.105e	.120e
166	.105b	.099c	.125d	.096c	.121d	.105d	.120c	.142d	.150d	.120e	.108d	.098c	.097d	.112de	.114e
	70 lb S/A														
0	.138a	.212a	.187a	.157a	.193a	.198a	.152a	.200a	.273a	.190a	.198a	.193a	.200a	.187a	.191a
33	.135a	.144b	.155b	.117b	.146b	.127b	.133ab	.163b	.217b	.165b	.142b	.130b	.143b	.140b	.147b
66	.126a	.104c	.148b	.096c	.118c	.107c	.119bc	.152bc	.183c	.137c	.113c	.107c	.103c	.118c	.124c
99	.126a	.098cd	.127c	.098bc	.106cd	.098cd	.120bc	.137c	.152d	.125c	.105c	.093c	.093c	.090d	.112d
133	.122a	.071e	.120c	.087c	.100cd	.088cd	.114bc	.134c	.137d	.118c	.102c	.100c	.085c	.097d	.105d
166	.121a	.078de	.098d	.086c	.096d	.084d	.111c	.139c	.148d	.120c	.097c	.093c	.083c	.093d	.103d

[1]Means of 84 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 35. Effect of applied S on annual Ca and Mg uptake by bromegrass 1967-68, 1970-71, 1973-84, Knik silt loam (means of 36 measurements).

Lb S/A	1967	1968	1970	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	16-yr Mean[1]
	(lb Ca/A in herbage)																
0	24.1b[2]	25.8b	6.1b	7.6b	24.3a	17.8a	17.8a	12.6a	22.5a	34.3a	35.1a	28.3a	25.8a	16.4a	16.4a	17.1a	20.8b
70	30.2a	35.4a	13.1a	19.4a	23.6a	16.0b	18.9a	11.3a	19.6b	31.0b	29.9b	24.8b	22.9b	15.9a	16.5a	17.3a	21.6a
	(lb Mg/A in herbage)																
0	8.97b	11.50b	2.77b	2.85b	12.96a	8.39a	12.26b	6.20a	12.87a	20.28a	22.96a	15.84a	12.54a	7.83a	7.56a	9.04a	10.93b
70	13.32a	17.51a	7.04a	8.50a	11.90b	8.90a	13.91a	6.54a	11.46b	17.93b	18.63b	13.74b	10.86b	7.84a	7.89a	9.60a	11.60a

[1]Means of 576 measurements.

[2]Letters are used in accordance with Duncan's multiple range test. Any two values comparing the two S rates not followed by the same letter are significantly different at the 5% level of probability.

Table 36. Effect of K application with and without S on the annual Ca and Mg uptake by bromegrass, Knik silt loam (means of 96 measurements).

	Ca uptake		Mg uptake	
Lb K/A	No S	S	No S	S
	(lb/A)			
0	20.6b[1]	19.6d	12.82a	12.17b
33	22.8a	24.1a	12.49a	13.92a
66	21.0b	22.2b	10.87b	11.92b
99	20.5b	22.0bc	10.51b	11.24b
133	20.5b	20.2cd	9.81bc	10.08c
166	19.1b	21.6bc	9.06c	10.25c

[1]Letters are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 37. Effects of N rate on bromegrass forage yield, 1977-80, Bodenburg silt loam (means of 96 measurements).

Lb N/A	1st cut	2nd cut	Total
	(T/A oven-dry)		
0[1]	0.44d[2]	0.26d	0.70d
80	2.03c	0.70c	2.73c
160	2.73b	1.51b	4.24b
240	2.97a	1.87a	4.84a

[1]Means of 48 measurements.
[2]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 38. Effects of N source on bromegrass forage yield, 1977-80, Bodenburg silt loam.

		2nd cut[2] (lb N/A)			Total[2] (lb N/A)		
		(lb N/A)					
N Source	1st cut[1]	80	160	240	80	160	240
	(T/A)						
AN	2.81a[3]	0.73a	1.75a	2.06a	3.03a	4.75a	5.19a
Urea	2.34b	0.67a	1.27b	1.68b	2.44b	3.72b	4.49b

[1]Means of 144 measurements. (All N rate averaged together).
[2]Means of 48 measurements.
[3]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 39. Effects of applied S on bromegrass forage yield, 1977-80, Bodenburg silt loam.

	1st cut[1]					Total[1]			
	(lb N/A)					(lb N/A)			
	0[3]	80	160	240	2nd cut[2]	0[3]	80	160	240
	(T/A)								
No S	0.46a[4]	2.04a	2.53b	2.71b	1.32b	0.70a	2.75a	4.02b	4.48b
S	0.43a	2.02a	2.93a	3.23a	1.40a	0.70a	2.72a	4.46a	5.20a

[1]Means of 48 measurements.
[2]Means of 144 measurements. (All N rates averaged together).
[3]Means of 24 measurements.
[4]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 40. Effects of N rate on NO_3-N and total N concentration in bromegrass herbage, 1977-80, Bodenburg silt loam.

	NO_3-N[1]				N		
	1st cut		2nd cut			2nd cut[1]	
Lb N/A	AN	Urea	AN	Urea	1st cut	AN	Urea
	(%)						
0	.021		.020		1.58d	1.77	
80	.026c[3]	.018b	.018b	.018b	1.73c	1.50c	1.55b
160	.095b	.024ab	.022b	.019b	2.10b	1.63b	1.59b
240	.206a	.036a	.079a	.032a	2.34a	2.10a	1.75a

[1]Means of 48 measurements.
[2]Means of 96 measurements.
[3]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 41. Effects of N source on the NO_3-N and N concentrations in bromegrass herbage, 1977-80, Bodenburg silt loam.

	NO_3-N						N			
	1st cut[1]			2nd cut[1]				2nd cut[1]		
	(lb N/A)			(lb N/A)				(lb N/A)		
N Source	80	160	240	80	160	240	1st cut[2]	80	160	240
	(%)									
AN	.026a[3]	.095a	.206a	.018a	.022a	.079a	2.26a	1.50a	1.63a	2.10a
Urea	.018a	.024b	.036b	.018a	.019a	.032b	1.85b	1.55a	1.59a	1.75b

[1]Means of 48 measurements.
[2]Means of 144 measurements.
[3]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 42. Effect of applied S on the NO_3-N and N concentrations in bromegrass herbage, 1977-80, Bodenburg silt loam.

	NO_3-N					N					
	1st cut[1]					1st cut[3]		2nd cut[1]			
	(lb N/A)					(N Source)		(lb N/A)			
	0	80	160	240	2nd cut	AN	Urea	0	80	160	240
	(%)										
No S	.019a[4]	.020a	.061a	.088b	.034a	2.18b	1.94a	1.78a	1.50a	1.67a	1.98a
S	.023a	.023a	.058a	.154a	.029b	2.34a	1.76b	1.77a	1.50a	1.55b	1.87b

[1]Means of 48 measurements.
[2]Means of 144 measurements.
[3]Means of 72 measurements.
[4]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 43. Effects of N rate on the P, K, and S concentrations in bromegrass herbage 1977-80, Bodenburg silt loam.

	P[1]		K[1]		S[2]			
					1st cut		2nd cut	
Lb N/A	1st cut	2nd cut	1st cut	2nd cut	No S	S	No S	S
	(%)							
0[2]	.274a[3]	.291a	2.51c	2.81a	.121a[4]	.168a[4]	.146a[4]	.128a[4]
80	.260b	.254c	2.78b	2.66b	.116a	.126c	.121c	.129c
160	.260b	.248c	2.85a	2.67b	.117a	.146b	.118c	.129c
240	.256b	.265b	2.77b	2.71b	.122a	.172a	.129b	.160b

[1]Means of 96 measurements.
[2]Means of 48 measurements.
[3]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.
[4]Means of 24 measurements.

Table 44. Effects of N source on P, K, and S concentrations in bromegrass herbage, 1977-80, Bodenburg silt loam.

	P			K			S						
		2nd cut			2nd cut		1st cut		2nd cut				
									----------(lb N/A)----------				
N source	1st cut[1]	No S	S	1st cut	No S	S	No S	S	80[3]	160[3]	240[3]	No S	S
	----------						(%)						
AN	.269a[4]	.252a	.248b	2.93a	2.71a	2.50b	.120a	.174a	.123a	.125a	.153a	.122a	.146a
Urea	.248b	.250a	.272a	2.67b	2.71a	2.80a	.117a	.123b	.126a	.122a	.136b	.123a	.132a

[1]Means of 144 measurements.
[2]Means of 72 measurements.
[3]Means of 48 measurements.
[4]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 45. Effects of applied S on the P, K, and S concentrations in bromegrass herbage, 1977-80, Bodenburg silt loam.

	P			K			S			
		2nd cut[2]			2nd cut[2]		1st cut[2]		2nd cut[2]	
		-------(N Source)-------			----------(N Source)----------					
	1st cut[1]	AN	Urea	1st cut[1]	AN	Urea	AN	Urea	AN	Urea
	----------				%					
No S	.254b[3]	.252a	.250b	2.82a	2.71a	2.71b	.120b	.117b	.122b	.123b
S	.263a	.248a	.272a	2.78a	2.50b	2.80a	.174a	.123a	.146a	.132a

[1]Means of 144 measurements.
[2]Means of 72 measurements.
[3]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 46. Effects of N rate on the Ca and Mg concentrations in bromegrass herbage, 1977-80, Bodenburg silt loam.

	Ca			Mg			
		2nd cut[2]		1st cut[2]		2nd cut[2]	
		----------		----------(N Source)----------			
Lb N/A	1st cut[1]	AN	Urea	AN	Urea	AN	Urea
	----------		%				
0[2]	.363a[3]	.516		.137		.174	
80	.304c	.422a	.432a	.104c	.096c	.134b	.139a
160	.308c	.349c	.382b	.121b	.101b	.135b	.131a
240	.326b	.376b	.352c	.138a	.111a	.174a	.136a

[1]Means of 96 measurements.
[2]Means of 48 measurements.
[3]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 47. Effects of N source on the Ca and Mg concentrations in bromegrass herbage, 1977-80, Bodenburg silt loam.

	Ca					Mg					
	1st cut[1]		2nd cut[2]			1st cut[2]			2nd cut[2]		
			(lb N/A)								
N Source	No S	S	80	160	240	80	160	240	80	160	240
	(%)										
AN	.329a[3]	.306a	.422a	.349b	.376a	.104a	.121a	.138a	.134a	.135a	.174a
Urea	.308b	.309a	.432a	.382a	.352b	.096b	.101b	.111b	.139a	.131a	.136b

[1]Means of 72 measurements.
[2]Means of 48 measurements.
[3]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 48. Effects of applied S on the Ca and Mg concentrations in bromegrass herbage, 1977-80, Bodenburg silt loam.

	Ca								Mg		
			(N Source)								
			AN			Urea					
	1st cut[2]		2nd cut[1]						1st cut[2]		
	(N Source)		(lb N/A)						(N Source)		
	AN	Urea	80	160	240	80	160	240	AN	Urea	2nd cut[3]
	(%)										
No S	.329a[4]	.308a	.426a	.349a	.404a	.451a	.381a	.347a	.117b	.105a	.142a
S	.306b	.309a	.418a	.349a	.348b	.413b	.383a	.356a	.124a	.101a	.141a

[1]Means of 24 measurements.
[2]Means of 72 measurements.
[3]Means of 144 measurements.
[4]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 49. Effects of N rate on N, P, K, S, Ca, and Mg uptake by bromegrass, 1977-80, Bodenburg silt loam (means of 96 measurements).

Lb N/A	N	P	K	S	Ca	Mg
	(lb per acre)					
0[1]	23d[2]	3.9d	37d	2.1d	5.7d	2.1d
80	91c	14.1c	154c	6.6c	17.3c	5.9c
160	163b	21.9b	240b	11.0b	28.8b	10.1b
240	211a	25.3a	267a	14.4a	32.4a	13.2a

[1]Means of 48 measurements.

[2]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 50. Effect of N source on the N, P, K, S, Ca, and Mg uptake by bromegrass, 1977-80, Bodenburg silt loam (means of 144 measurements).

Lb N/A	N	P	K	S	Ca	Mg
	(lb per acre)					
AN	184a[1]	22.8a	245a	12.6a	28.3a	11.4a
Urea	127b	18.1b	196b	8.7b	22.7b	8.1b

[1]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

Table 51. Effects of applied S on N, P, K, S, Ca, and Mg uptake by bromegrass, 1977-80, Bodenburg silt loam.

	N				P				K				S				Mg				Ca (N Source)	
	0	80	160	240	0	80	160	240	0	80	160	240	0	80	160	240	0	80	160	240	AN	Urea
	(lb/A)																					
No S	22a[1]	92a	157b	197b	3.8a	13.9b	20.6b	23.1b	36a	156a	230b	252b	1.8a	6.3a	9.3b	11.2b	2.0a	5.9a	9.7b	12.3b	28.3a	21.2b
S	23a	90a	170a	226a	4.0a	14.3a	23.2a	27.6a	38a	152a	250a	282a	2.4a	6.9a	12.7a	17.6a	2.2a	5.8a	10.4a	14.2a	28.3a	24.2a

[1]Letters in tables are used in accordance with Duncan's multiple range test. Any two values within a column not followed by the same letter are significantly different at the 5% level of probability.

REFERENCES

Bansal, K.N., D.P. Motiramani, and A.R. Pal. 1983. Studies on sulfur in vertisols. *Plant Soil 70:*133-140.

Bentley, C.F., L. Gareau, R. Renner, and L.W. McElroy. 1956. Fertilizer and nutritive values of hays. I. Sulphur-deficient grey wooded soils. *Can. J. Agric. Sci. 36:*315-325.

Bolton, J., T.Z. Nowakowski, and W. Lazarus. 1976. Sulfur-nitrogen interaction effects on the yield and composition of the protein-N, non-protein-N, and soluble carbohydrates in perennial ryegrass. *J. Sci. Food Agric. 27:*553-560.

Cowling, D.W., and L.H.P. Jones. 1970. A deficiency in soil sulfur supplies for perennial ryegrass in England. *Soil Sci. 110:*346-354.

Davies, L.H. 1973. Two grass field trials with a sulfur-coated urea to examine its potential as a slow release nitrogen fertilizer in the U.K. *J. Sci. Food Agric. 24:*63-67.

Eppendorfer, W.H. 1977. Effects of varying amounts of sulphur and nitrogen on yield, N/S ratio and amino acid composition of successive cuts of Italian ryegrass. *K. Vet-Landbohojsk Arsskr. 1977:*42-57. (*Biolg. Abst. 64:*24202. 1977).

Friedrich, J.W., D. Smith, and L.E. Schrader. 1977. Herbage yield and chemical composition of switchgrass as affected by N, S, and K fertilization. *Agron. J. 69:*30-33.

Goh, K.M., R.J. Haynes, and K.K. Kee. 1979. Ionic balance and composition of perennial ryegrass *(Lolium perenne)* as influenced by nitrogen and sulfur fertilization. *N. Z. J. Agric. Res. 22:*319-328.

Hargrove, W.L., R.A. Rawniker, and B.R. Bock. 1983. Ammonia volatilization from urea in no-tillage. *Agron. Abst.* 1983 Ann. Meetings. p. 170-171.

Harper, L.A., V.R. Catchpoole, R. Davis, and K.L. Weir. 1983. Ammonia volatilization: Soil, plant and microclimate effects on diurnal and season fluctuations. *Agron. J. 75:*212-218.

Laughlin, W.M. 1962. Fertilizer practices for bromegrass. Alaska Agric. Expt. Sta. Bull. 32. 15 pp.

Laughlin, W.M. 1963. Bromegrass response to rate and source of nitrogen applied in fall and spring in Alaska. *Agron. J. 55:*60-62.

Laughlin, W.M. 1970. Lack of sulfur limits plant growth. *Agroborealis 2*(1):21.

Laughlin, W.M., P.F. Martin, and G.R. Smith. 1973. Nitrogen fertilization of Polar bromegrass. *Agroborealis 5:*12.

Laughlin, W.M., P.F. Martin, and G.R. Smith. 1978. Effects of four rates of three nitrogen sources on yield and chemical composition of Manchar bromegrass forage in the Matanuska Valley. Alaska Agric. Expt. Sta. Tech. Bull. 6. 28 pp.

Laughlin, W.M., G.R. Smith, and M.A. Peters. 1981. Sulfur, manganese, molybdenum, and magnesium influences on bromegrass forage yield and composition in Southcentral Alaska. *Comm. in Soil Sci. Plant Analy. 12:*299-317.

Maples, R., J.L. Keogh, and W.E. Sabbe. 1976. Sulfurcoated urea as a nitrogen source for cotton. Arkansas Agric. Expt. Sta. Bull. 807. 23 pp.

McLaren, R.G. 1976. Effects of fertilizers on the sulphur content of herbage. *J. Br. Grasl. Soc. 31:*99-103.

Mosolov, I.N., and L.P. Volleidt. 1955. Kvoprosu o fiziologicheskoi roli sery v rasteniyakh. (The physiological role of sulfur in plants). *Doklady Akad. Nauk SSSR 105:*1045-1048. (*Biolog. Abst. 32:*24734. 1958).

Perkin-Elmer Corp., Norwalk, Conn. 1973. Analysis of plant tissue-acid-digestion procedure. Analytical methods for atomic absorption spectrophotometry. Perkin-Elmer Corp., Norwalk, Conn.

Power, J.F. 1983. Recovery of nitrogen and phosphorus after 17 years from various fertilizer materials applied to crested wheatgrass. *Agron. J. 75:*249-254.

Ramig, R.E., P.E. Rasmussen, R.R. Allmaras, and C.M. Smith. 1975. Nitrogen-sulfur relations in soft winter wheat. I. Yield response to fertilizer and residual sulfur. *Agron. J. 67:*219-224.

Rendig, V.V., C. Oputa, and E.A. McComb. 1976. Effects of sulfur deficiency on non-protein nitrogen, soluble sugars, and N/S ratios in young corn (*Zea mays* L.) plants. *Plant Soil 44:*423-437.

Saleem, M.A.M. 1980. Effect of sulfur-coated urea and urea on the productivity and nitrogen utilization of *Cynodon* cultivar IB 8. *East Afr. Agric. For. J. 43:*25-30.

Samosir, S., and G.J. Blair. 1983. Sulfur nutrition of rice. III. A comparison of fertilizer sources for flooded rice. *Agron. J. 75:*203:206.

Smith, G.R. 1975. Rapid determination of nitrate-nitrogen in soils and plants with the nitrate electrode. *Anal. Lett. 8:*503-508.

Smith, G.R. 1980. Rapid determination of total sulfur in plants and soils by combustion sulfur analysis. *Anal. Lett. 13:*465-471.

Starkey, R.L. 1950. Relations of microorganisms to transformations of sulfur in soils. *Soil Sci. 70:*55-65.

Tahinen, H. 1977. The effect of sulphur on the yield and chemical composition of timothy. *Ann. Agric. Fenn. 16:*220-226.

Technicon Industrial Systems. 1976. Technicon industrial methods 396-75 A/A and 334-74 A/A. Technicon Ind. Syst., Tarrytown, N.Y.

Vaughn, C.E., M.B. Jones, and J.E. Ruckman. 1979. Effects of sulfur-coated urea on California annual grassland yield and chemical composition. *Agron. J. 71:*297-300.

Wallihan, E.F., and R.G. Sharpless. 1974. Effect of sulfur supply on the optimum concentration of nitrogen in leaves of the rice plant. *Soil Sci. 118:*304-307.

Westermann, D.T. 1975. Indexes of sulfur deficiency in alfalfa. II. Plant analyses. *Agron. J. 67:*265-268.

APPENDIX

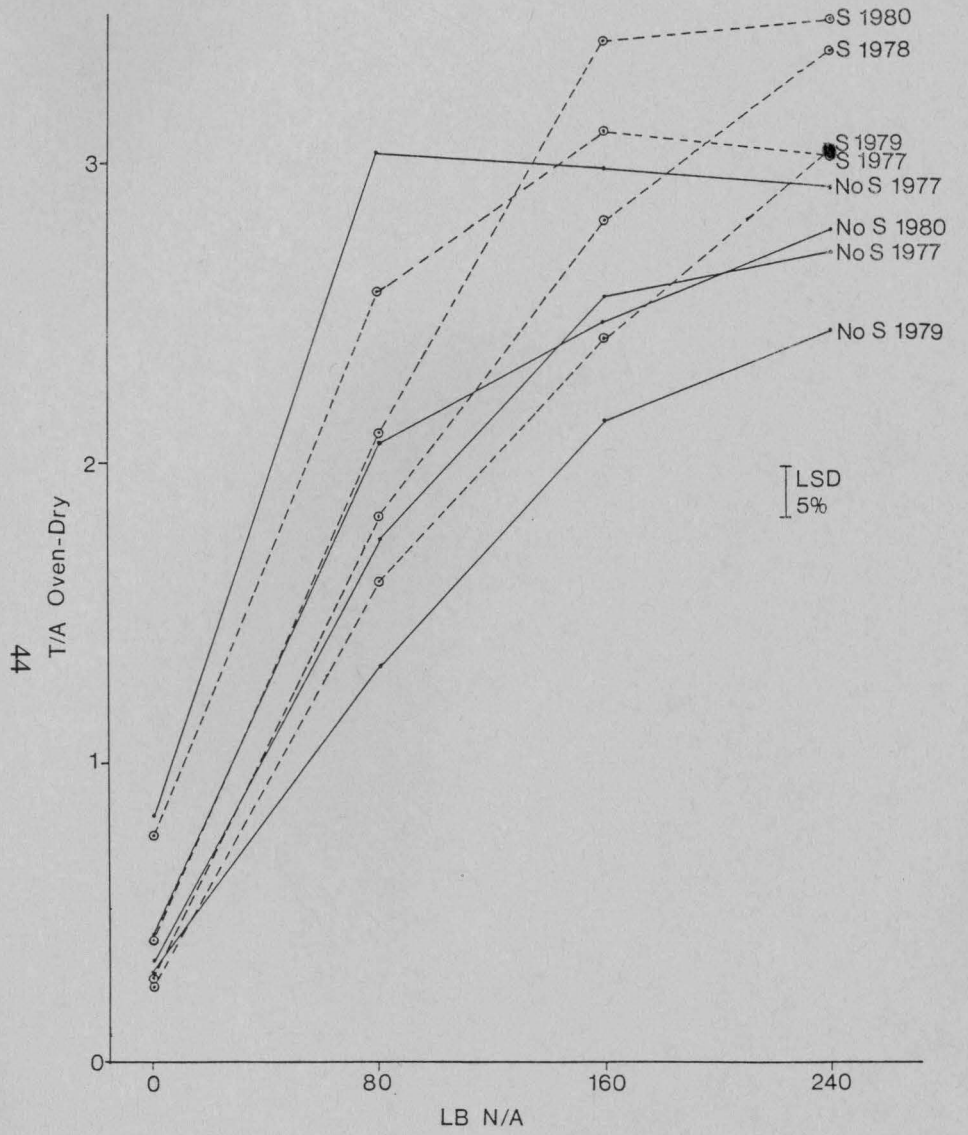

Figure 1. Effect of nitrogen and sulfur on first-cutting bromegrass oven-dry yields. Bodenburg silt loam. 1977-1980.

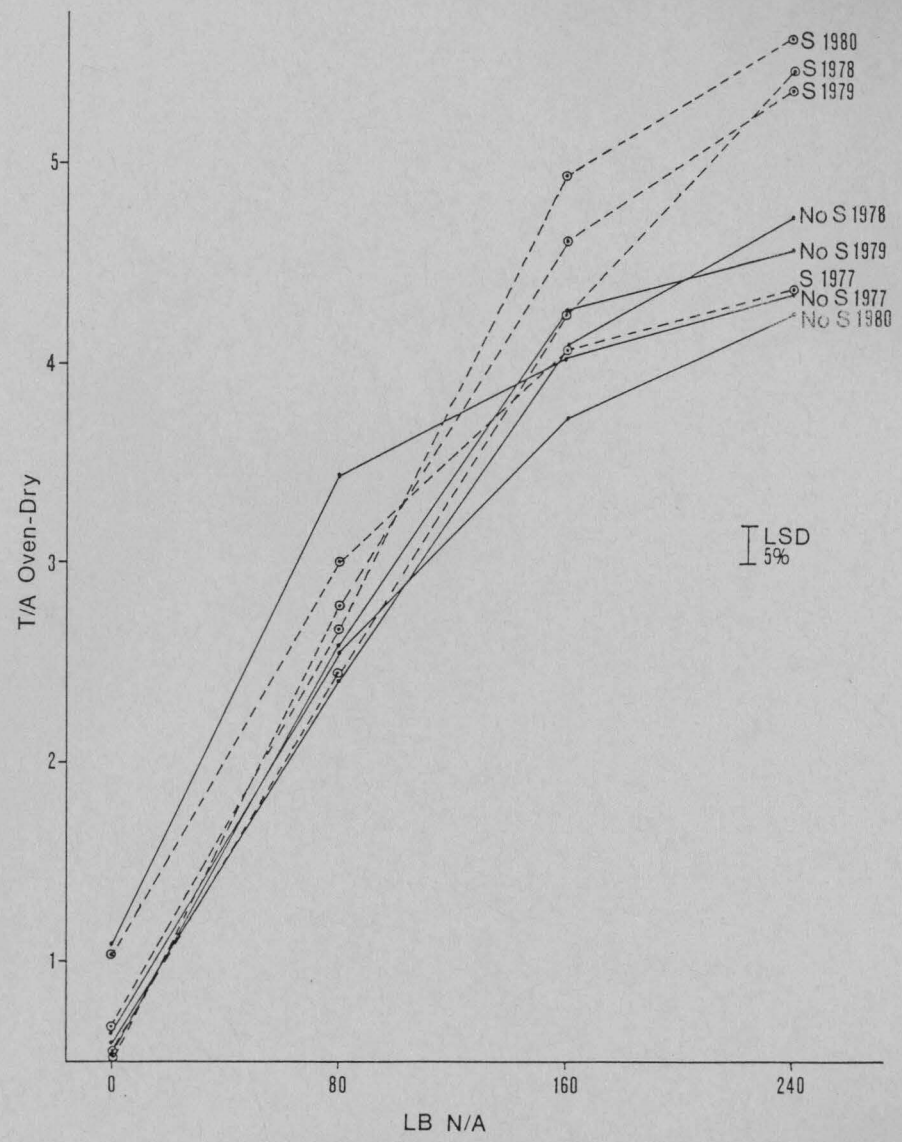

Figure 2. Effect of nitrogen and sulfur on seasonal bromegrass oven-dry yields. Bodenburg silt loam. 1977-1980.

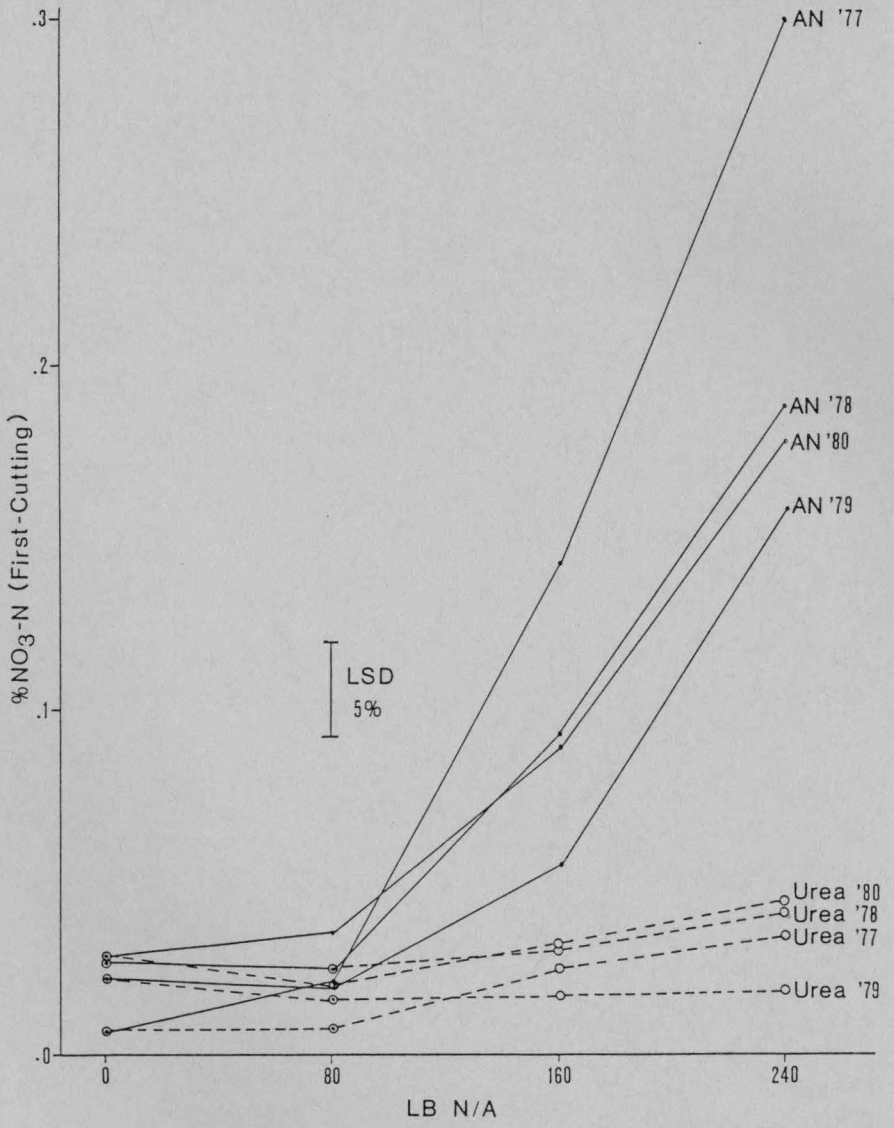

Figure 3. Effect of nitrogen on second-cutting bromegrass oven-dry yields. Bodenburg silt loam. 1977-1980.

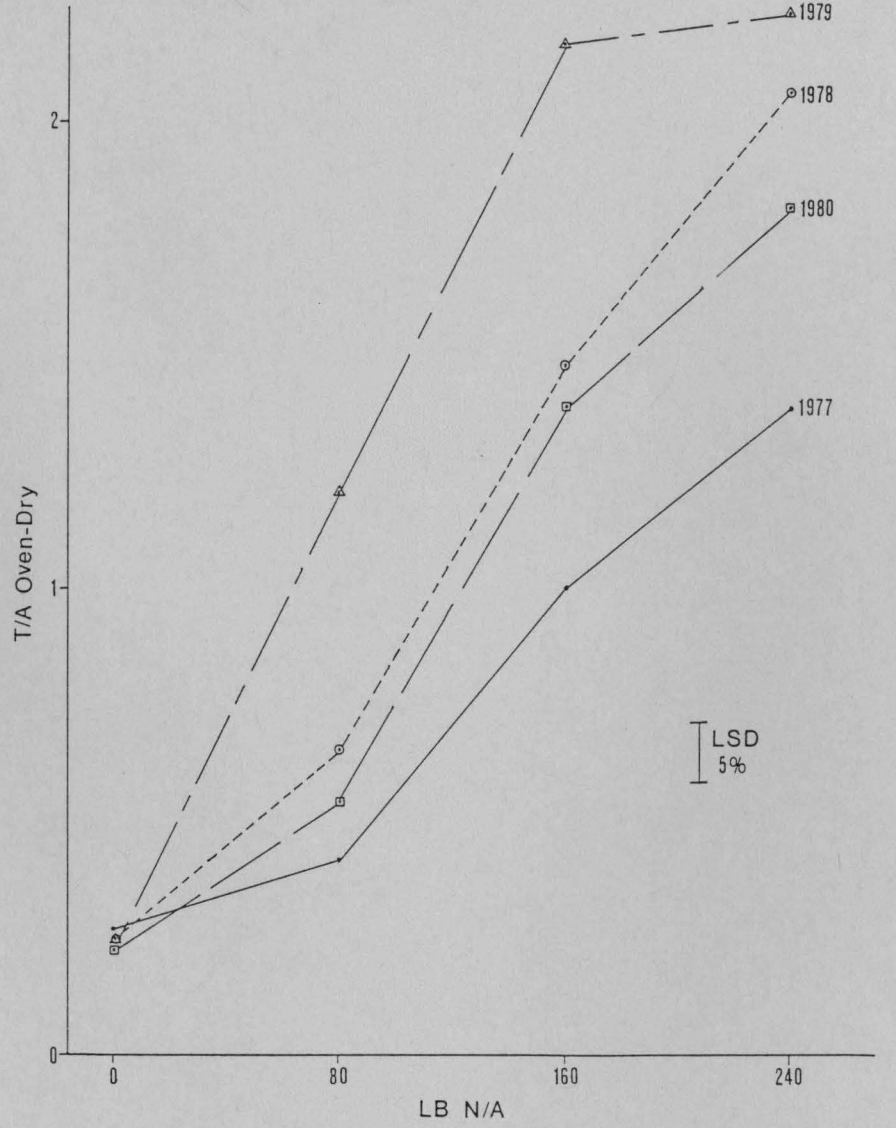

Figure 4. Effect of nitrogen rate and source on first-cutting bromegrass NO_3-N concentration. Bodenburg silt loam. 1977-1980.

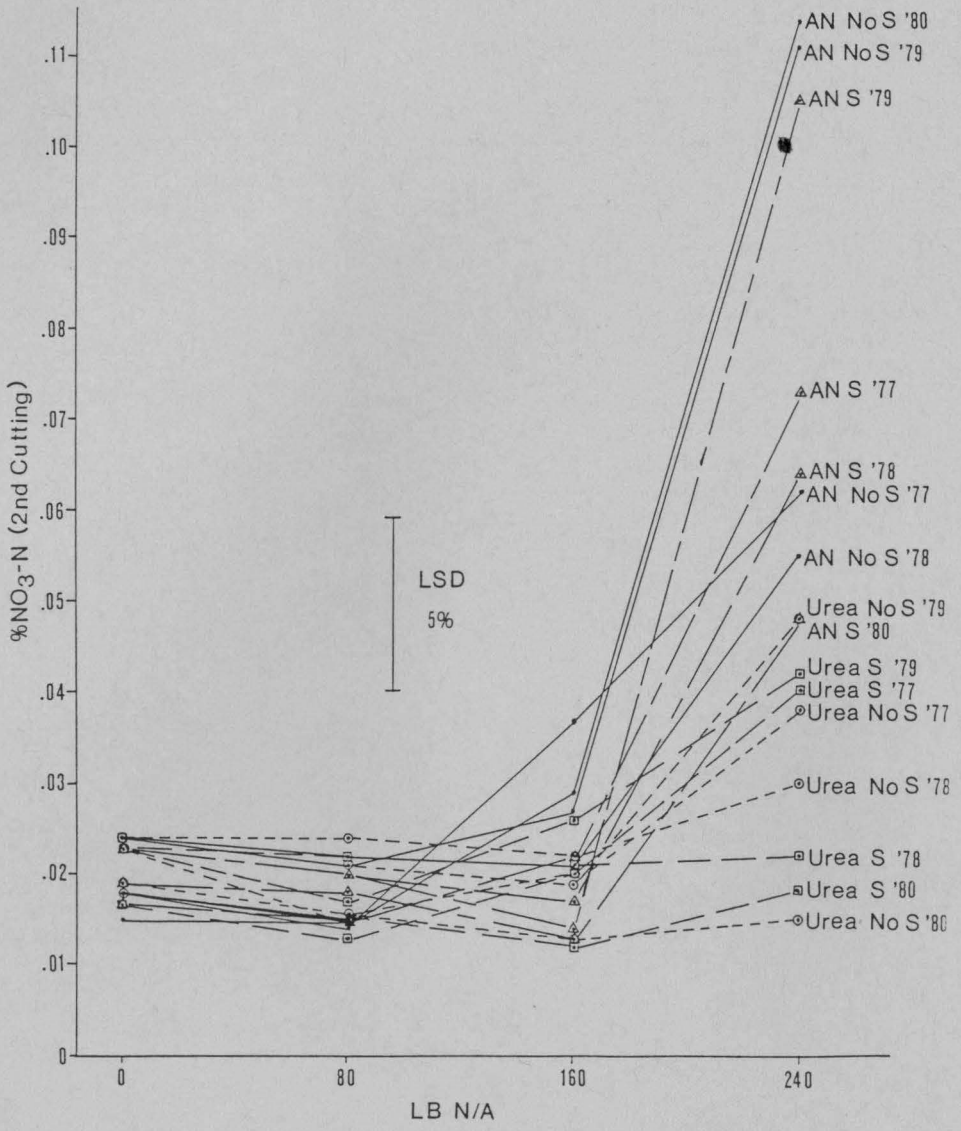

Figure 5. Effect of nitrogen rate and source with and without sulfur on second-cutting bromegrass nitrate nitrogen concentration. Bodenburg silt loam. 1977-1980.

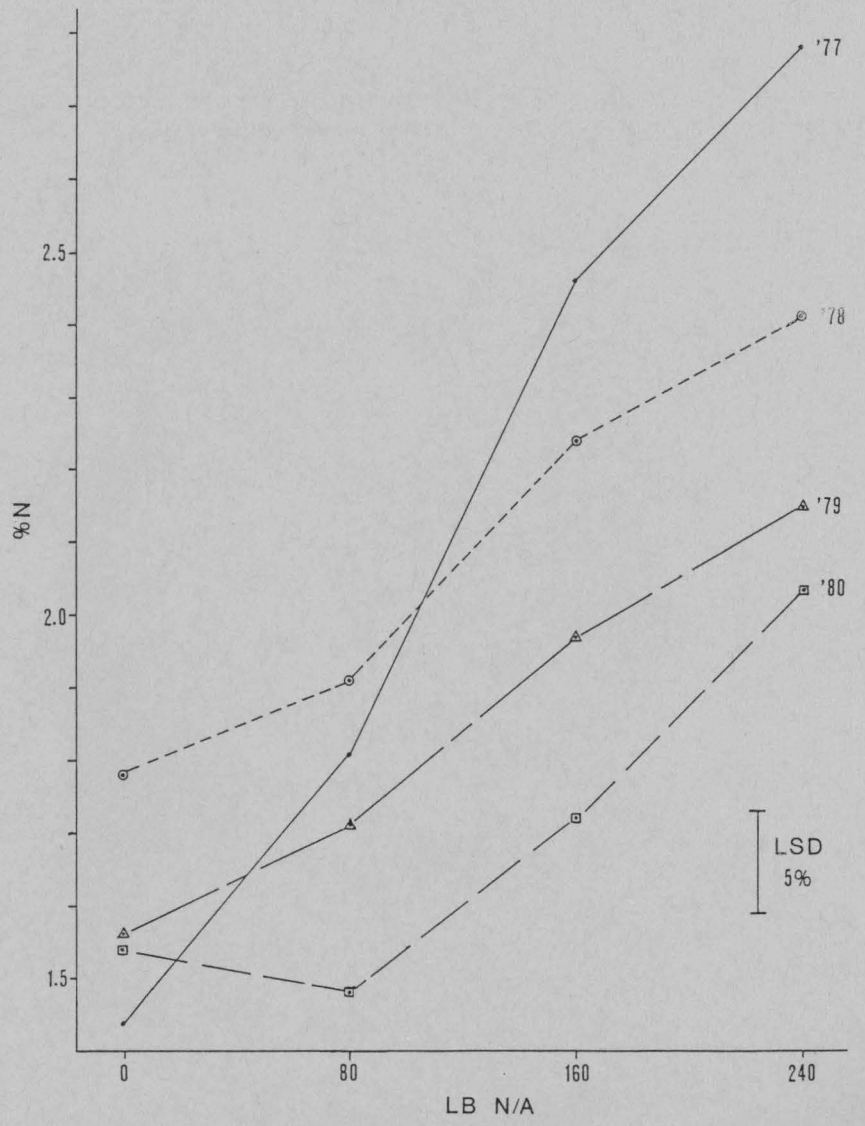

Figure 6. Effect of nitrogen on first-cutting nitrogen concentration in bromegrass. Bodenburg silt loam. 1977-1980.

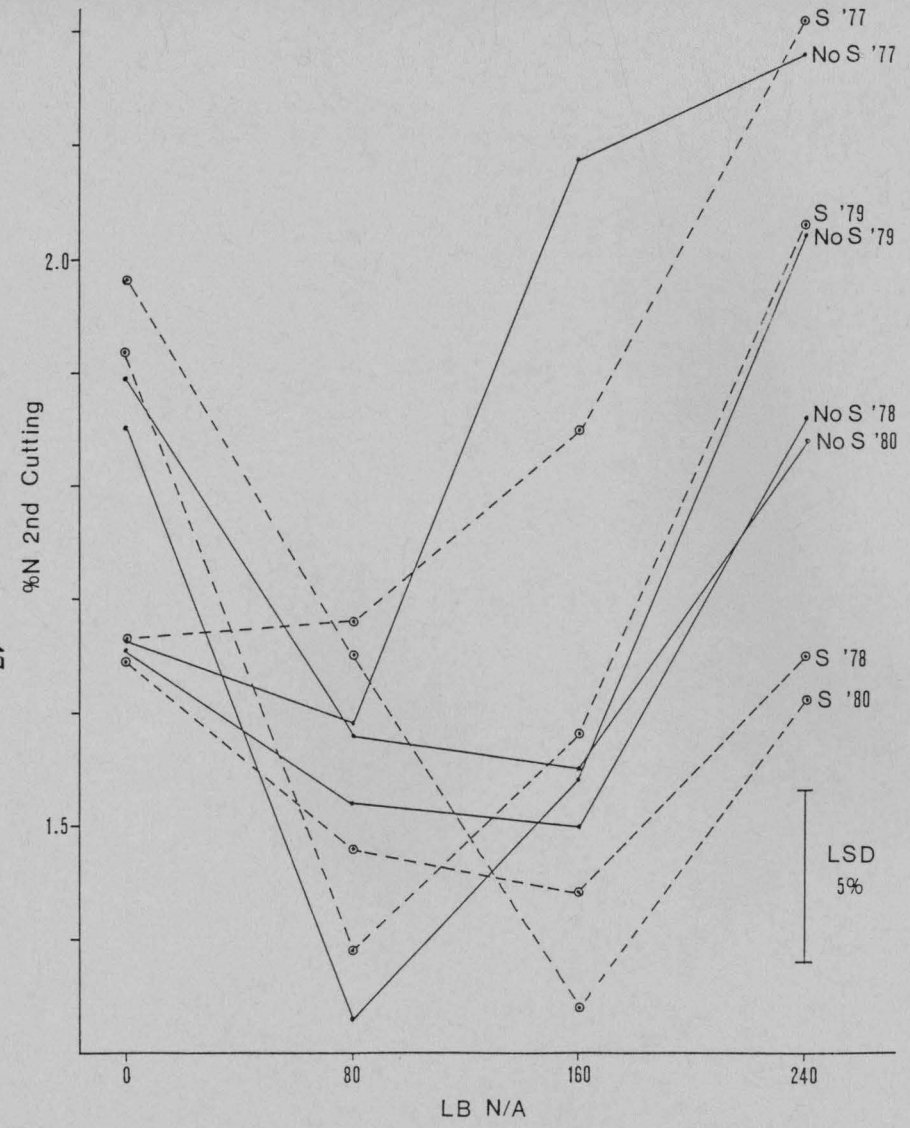

Figure 7. Effect of nitrogen rate and sulfur on second-cutting nitrogen concentration in bromegrass. Bodenburg silt loam. 1977-1980.

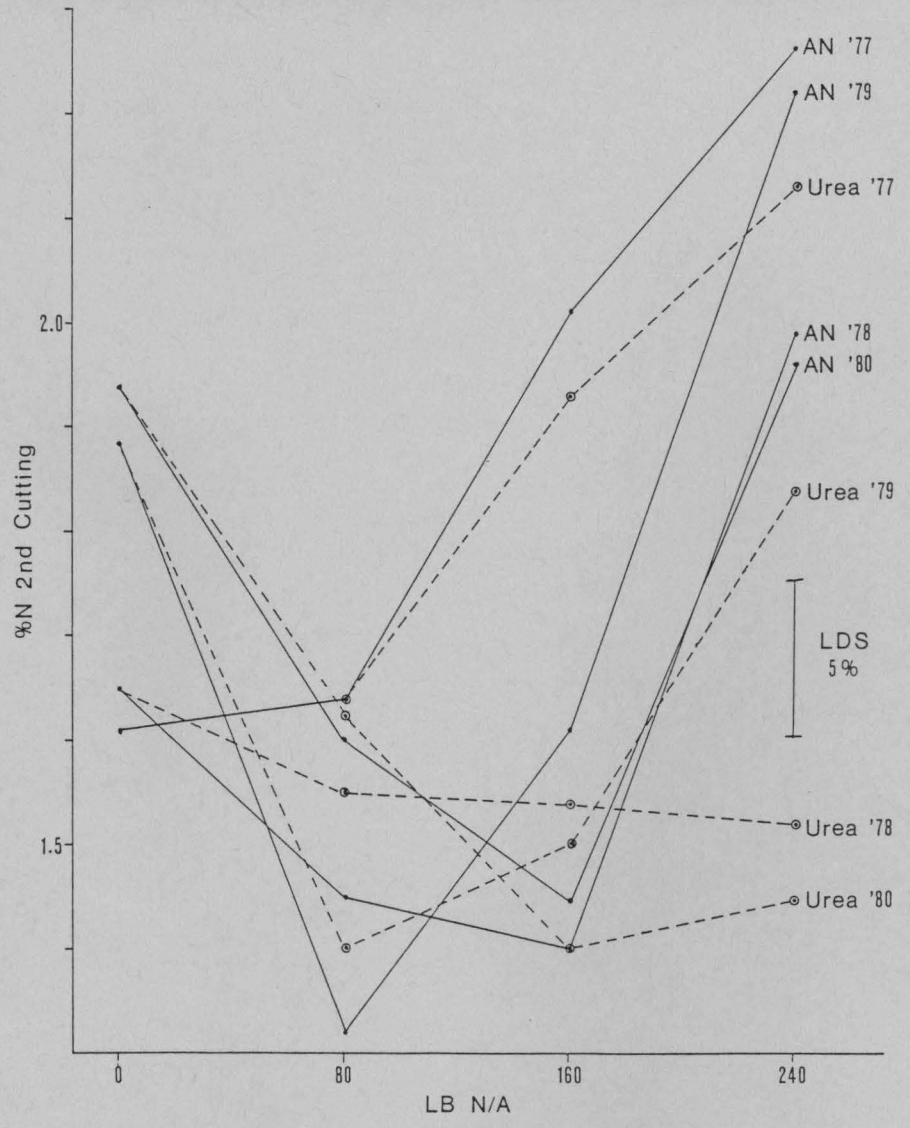

Figure 8. Effect of nitrogen rate and source on second-cutting nitrogen concentration in bromegrass. Bodenburg silt loam. 1977-1980.

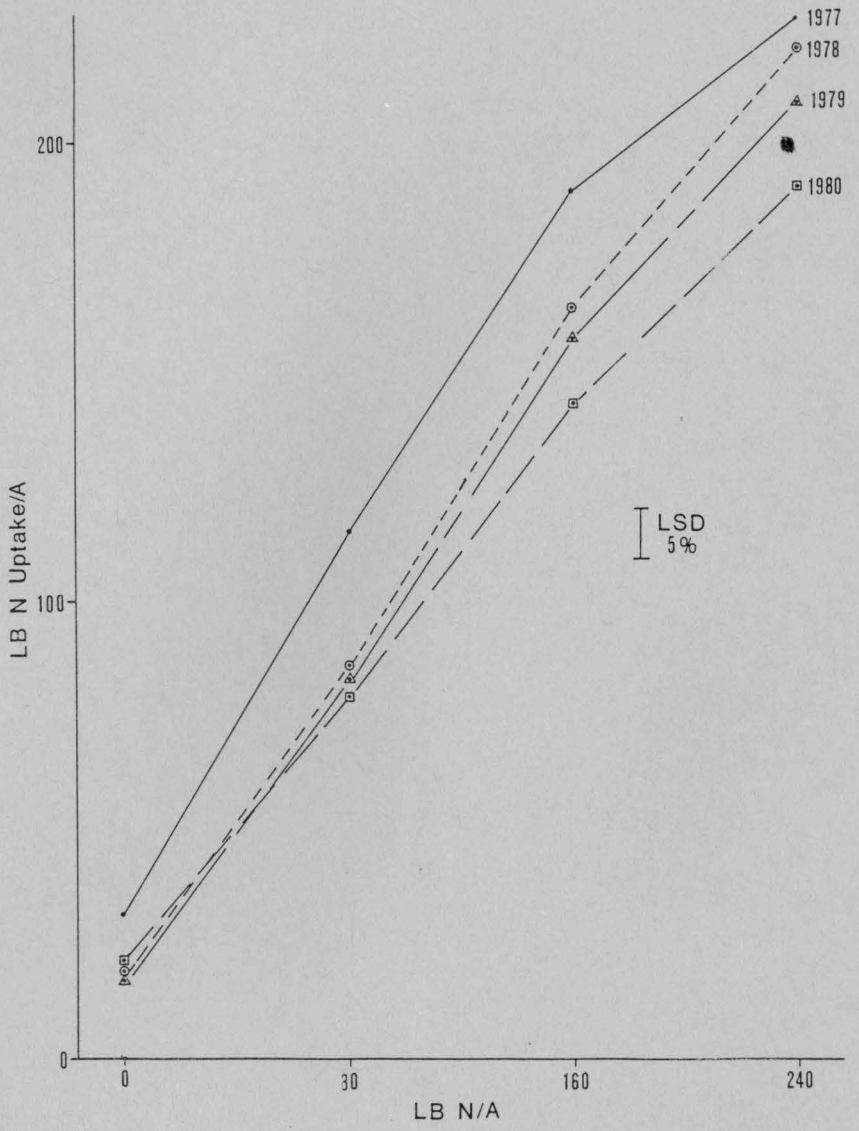

Figure 9. Effect of nitrogen on nitrogen uptake by bromegrass. Bodenburg silt loam. 1977-1980.

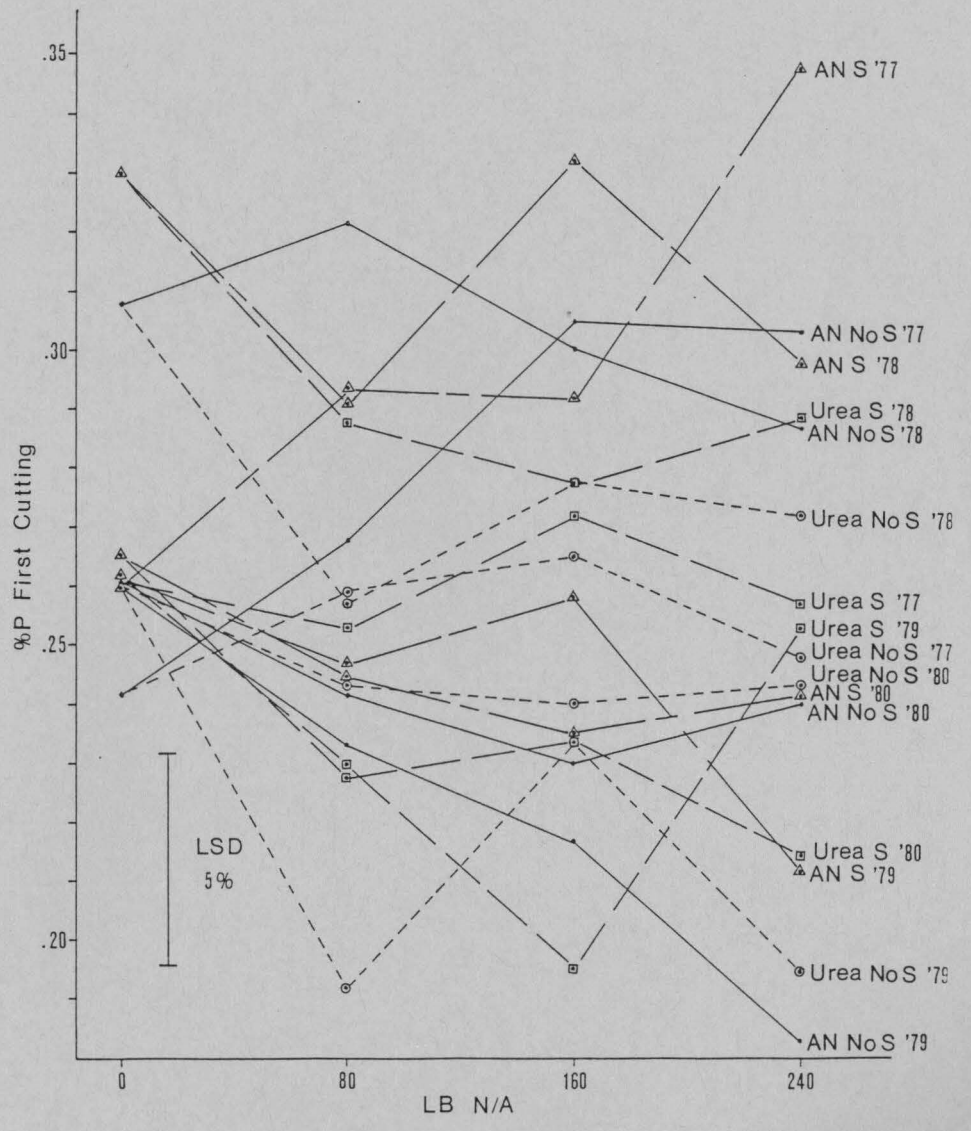

Figure 10. Effect of nitrogen rate and source with and without sulfur on first-cutting phosphorus concentration in bromegrass. Bodenburg silt loam. 1977-1980.

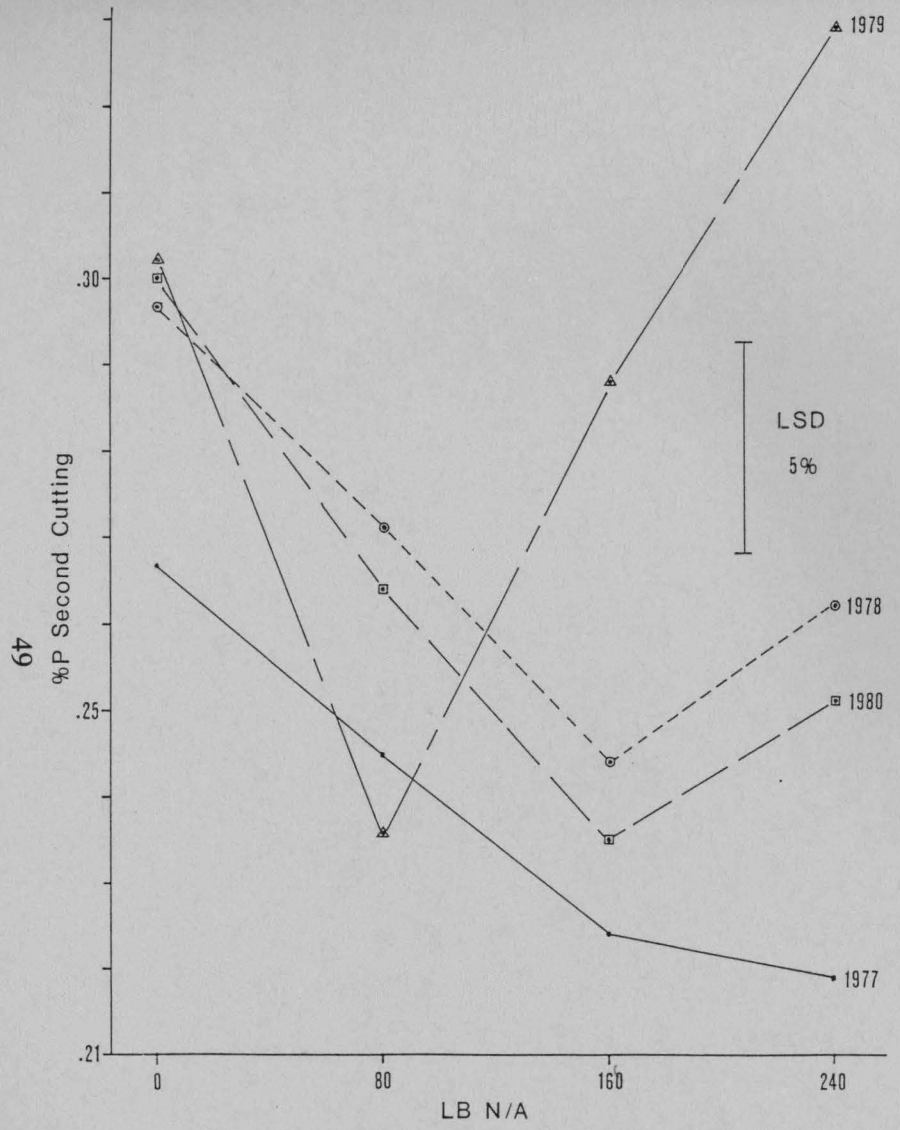

Figure 11. Effect of nitrogen on second-cutting phosphorus concentration in bromegrass. Bodenburg silt loam. 1977-1980.

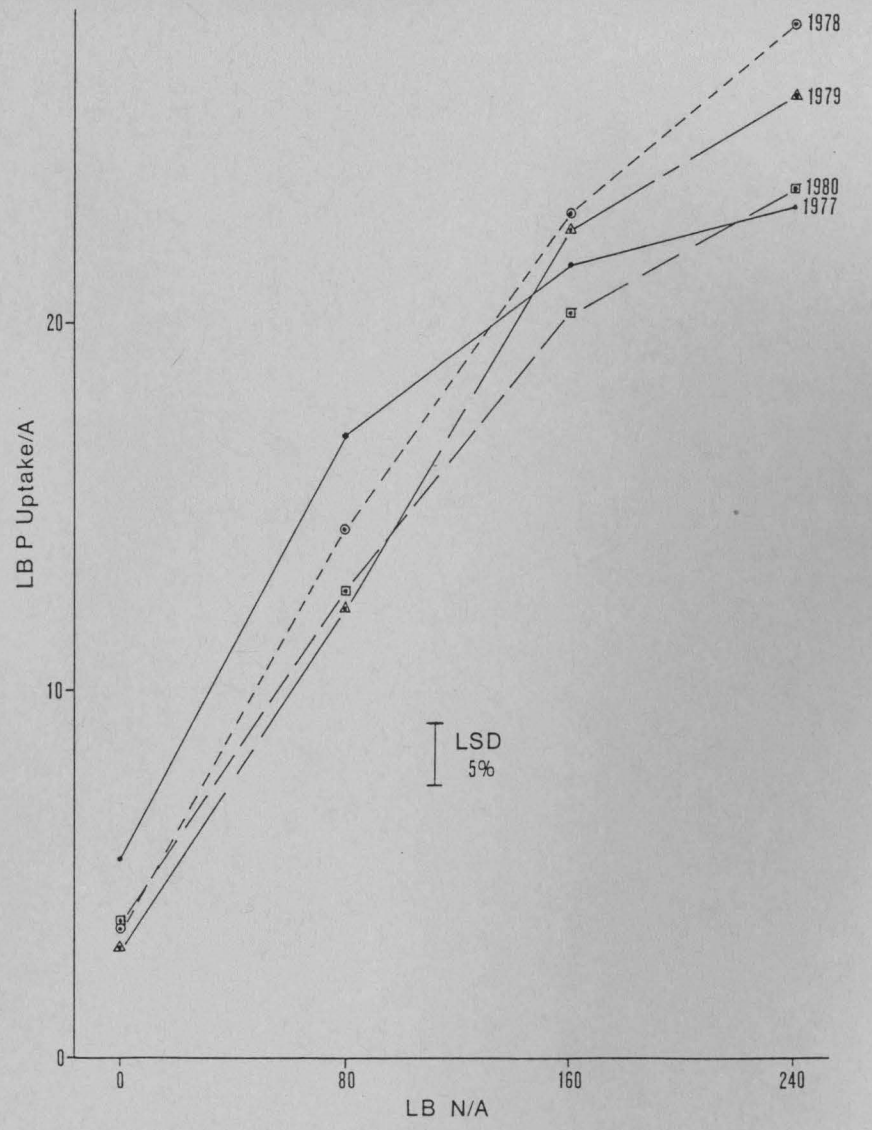

Figure 12. Effect of Nitrogen on phosphorus uptake by bromegrass. Bodenburg silt loam. 1977-1980.

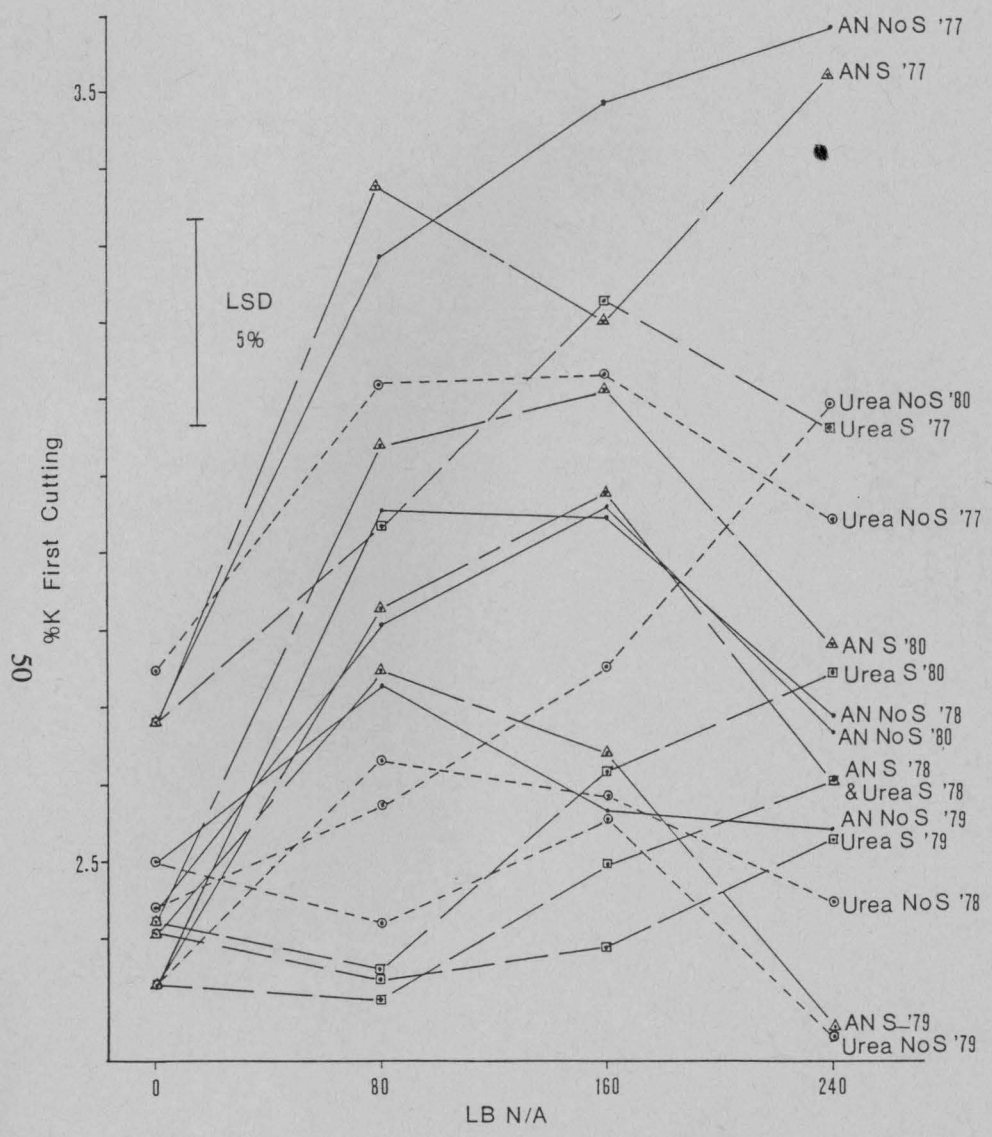

Figure 13. Effect of Nitrogen rate and source with and without sulfur on first-cutting bromegrass potassium concentration. Bodenburg silt loam. 1977-1980.

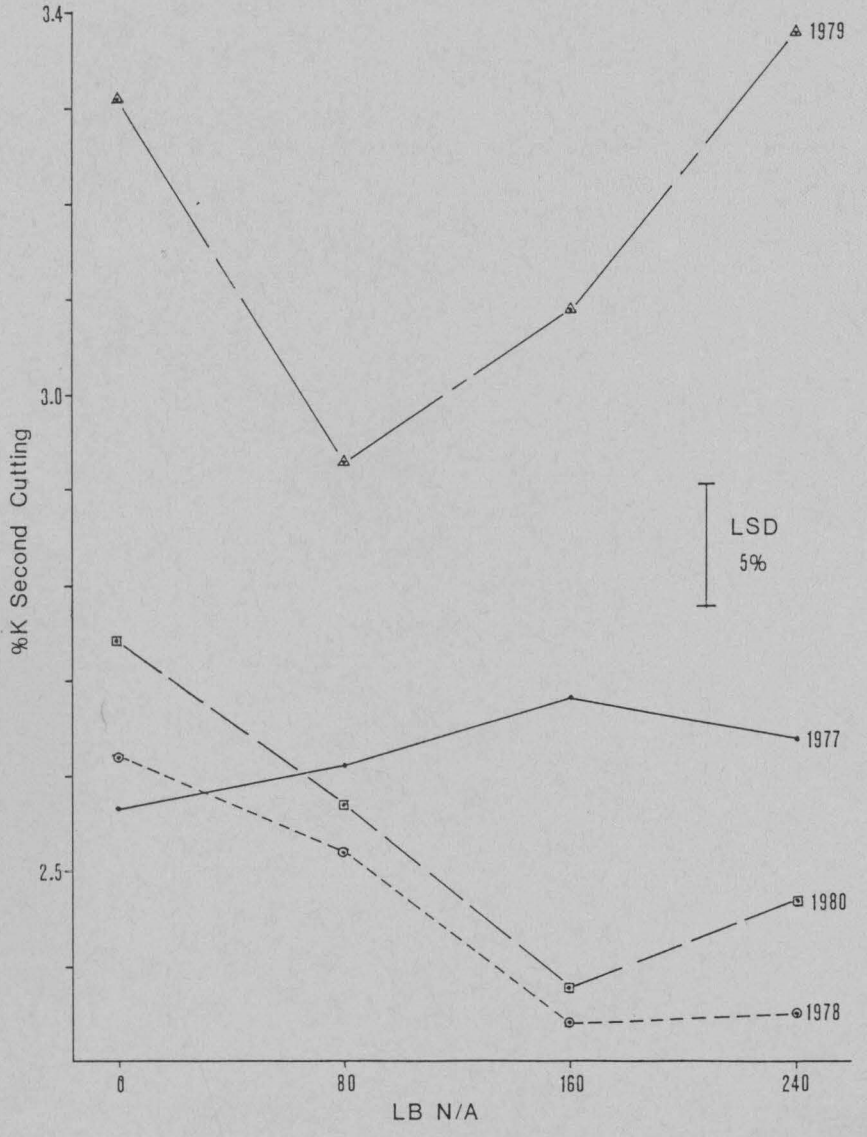

Figure 14. Effect of nitrogen on second-cutting potassium concentration in bromegrass. Bodenburg silt loam. 1977-1980.

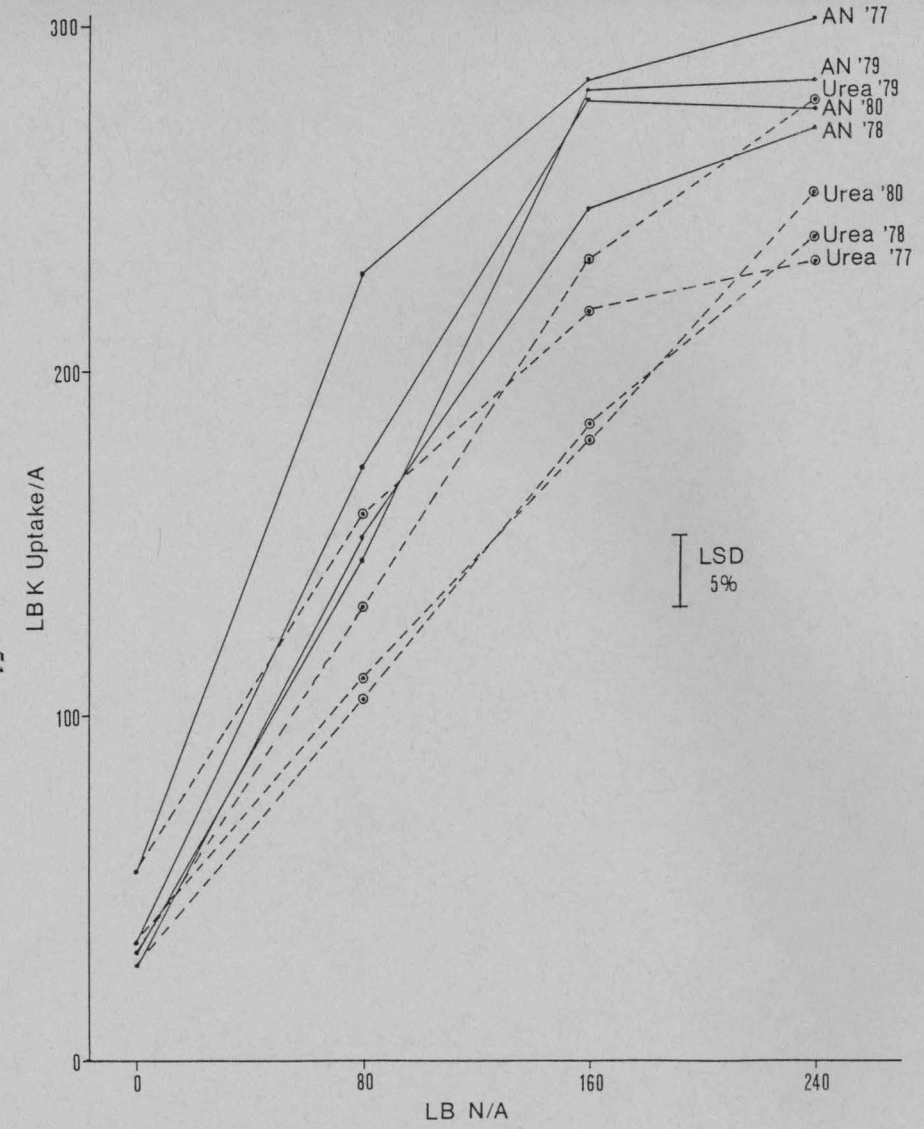

Figure 15. Effect of nitrogen rate and source on potassium uptake by bromegrass. Bodenburg silt loam. 1977-1980.

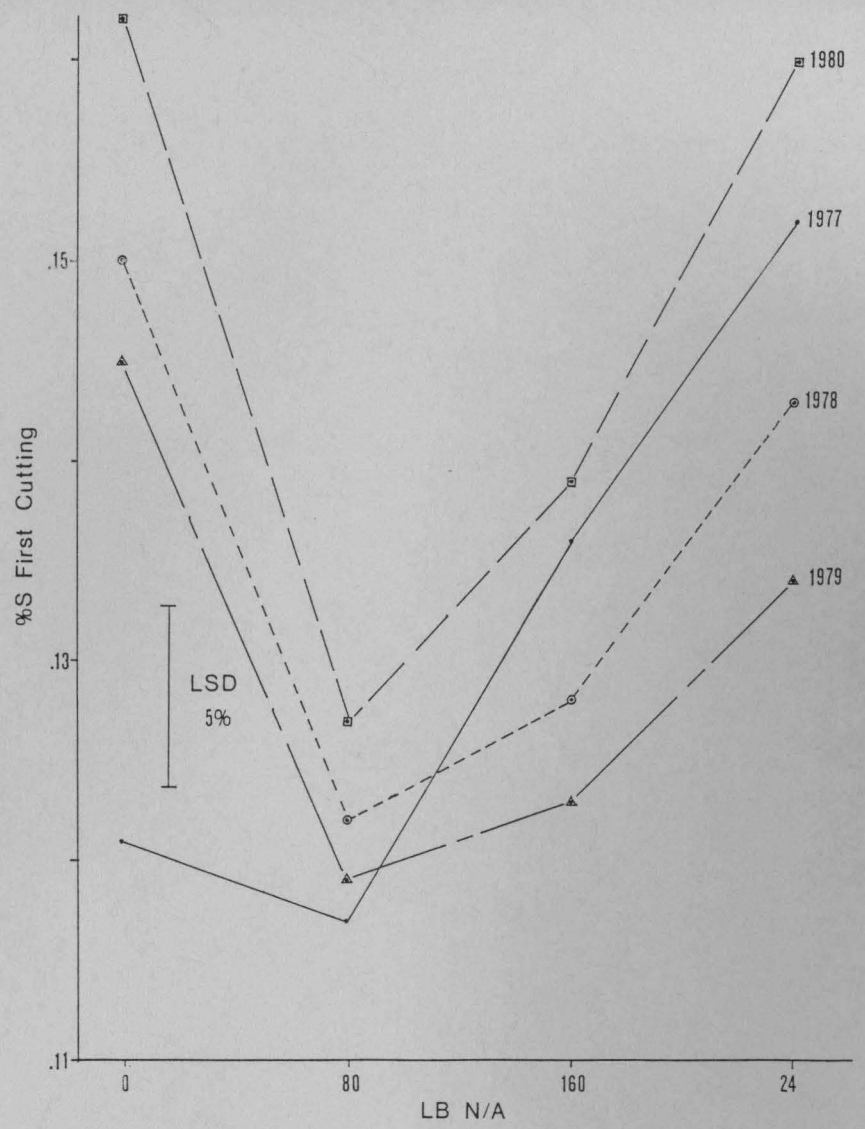

Figure 16. Effect of nitrogen on first-cutting sulfur concentration in bromegrass. Bodenburg silt loam. 1977-1980.

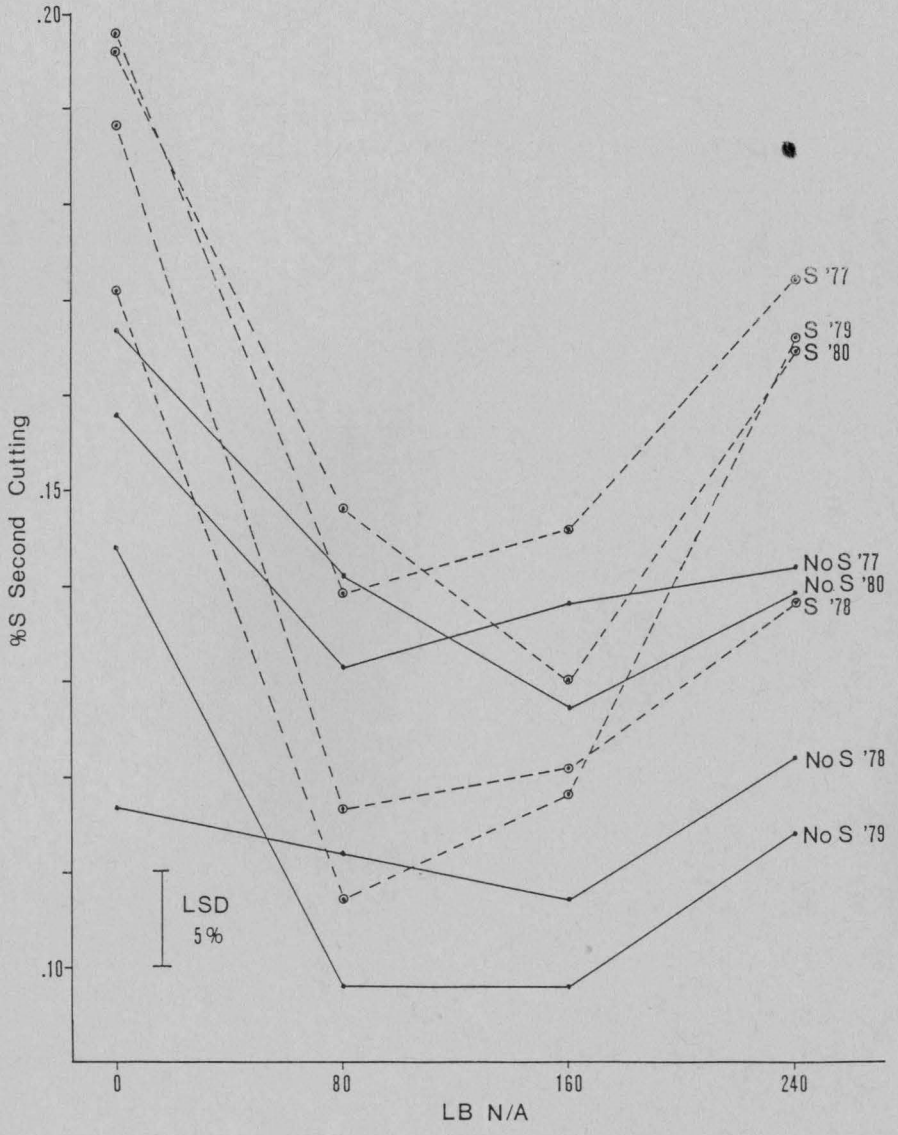

Figure 17. Effect of nitrogen and sulfur on sulfur concentration in second-cutting bromegrass. Bodenburg silt loam. 1977-1980.

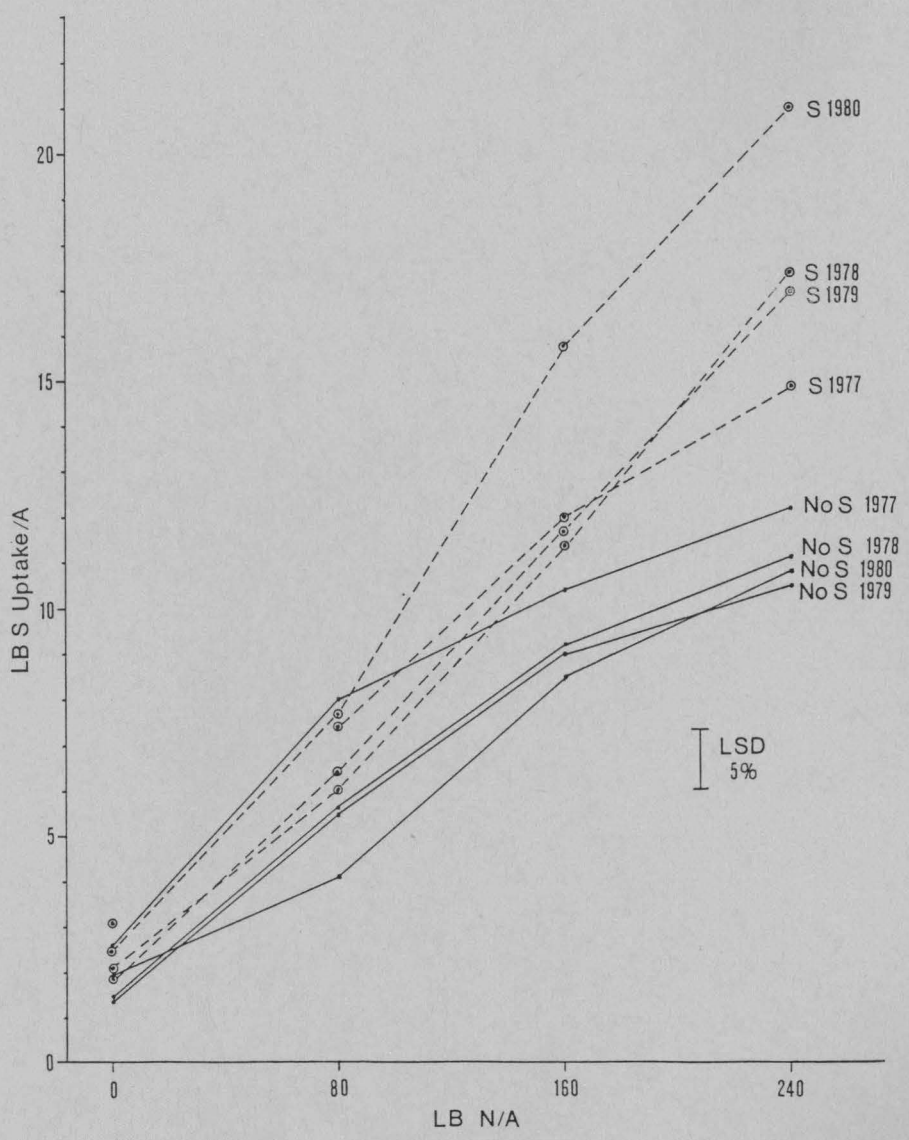

Figure 18. Effect of nitrogen and sulfur on sulfur uptake by bromegrass. Bodenburg silt loam. 1977-1980.

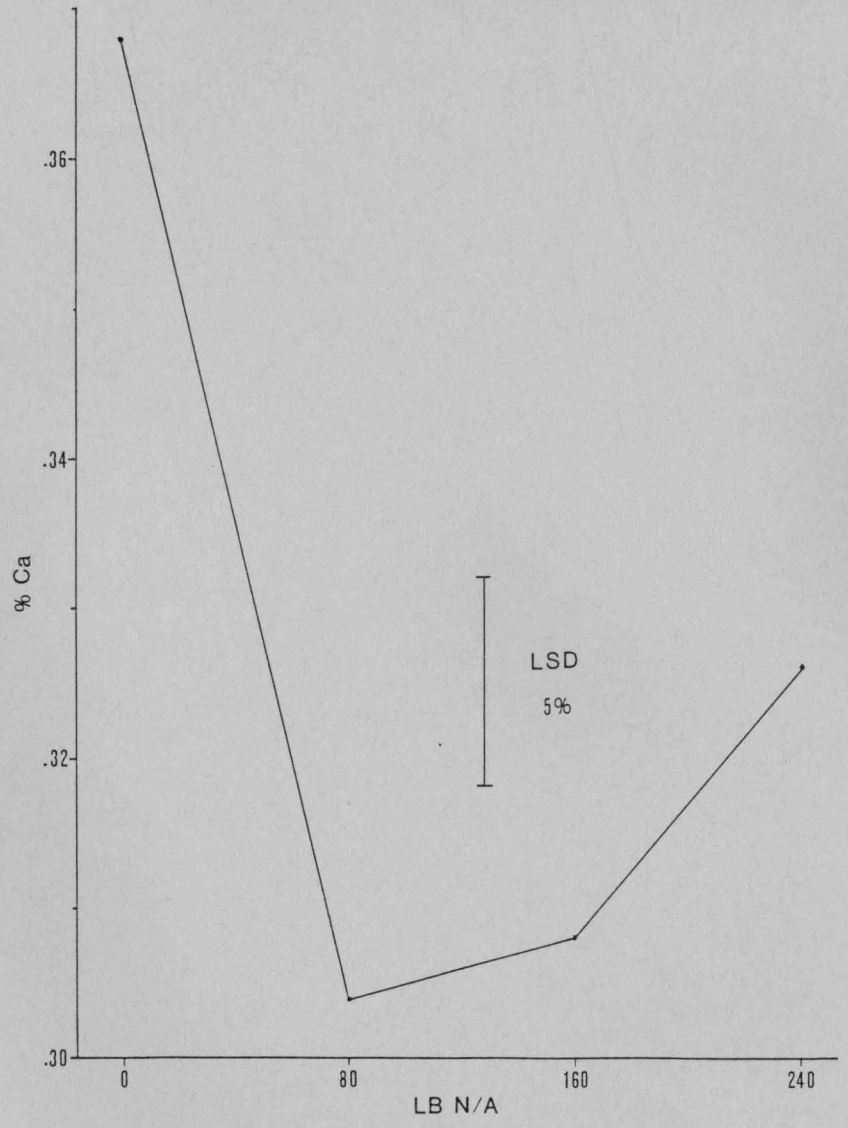

Figure 19. Effect of nitrogen on first-cutting calcium concentration in bromegrass. Bodenburg silt loam. 1977-1980.

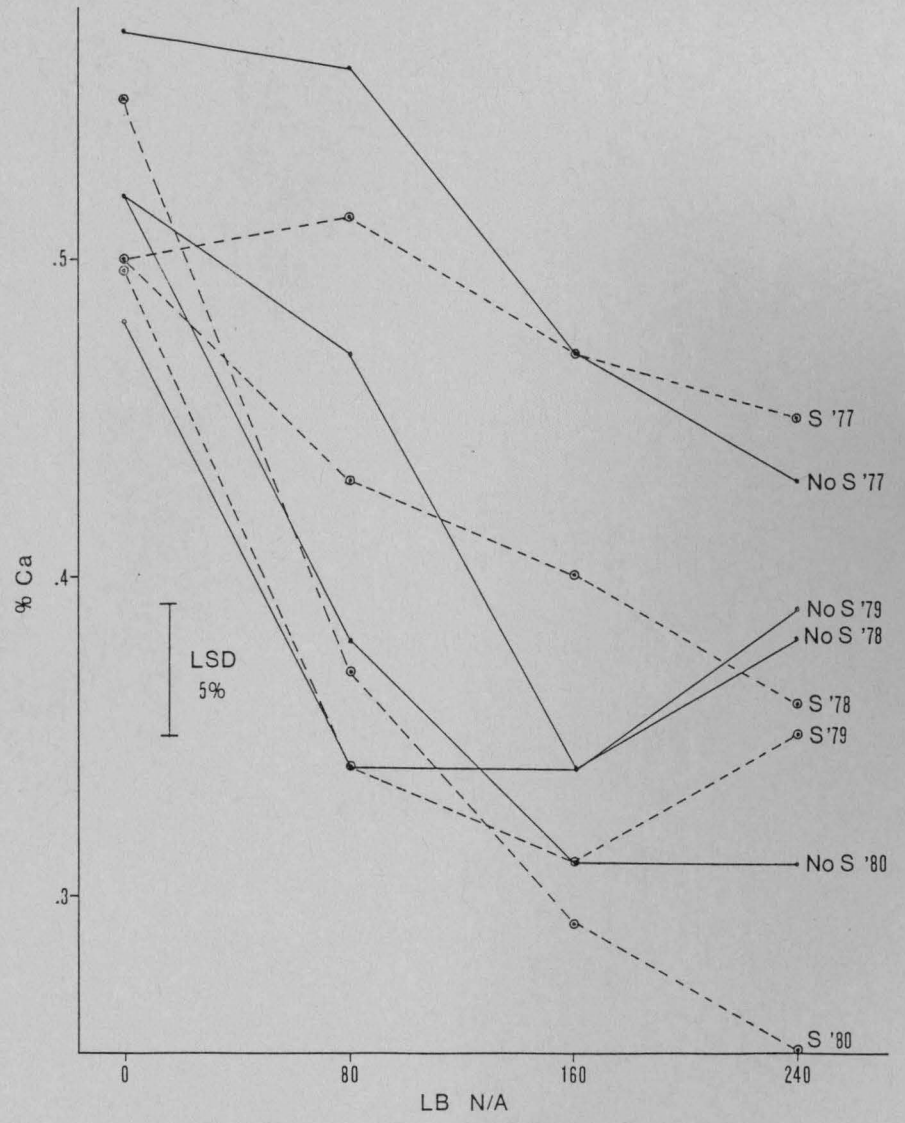

Figure 20. Effect of nitrogen rate and source on second-cutting calcium concentration in bromegrass. Bodenburg silt loam. 1977-1980.

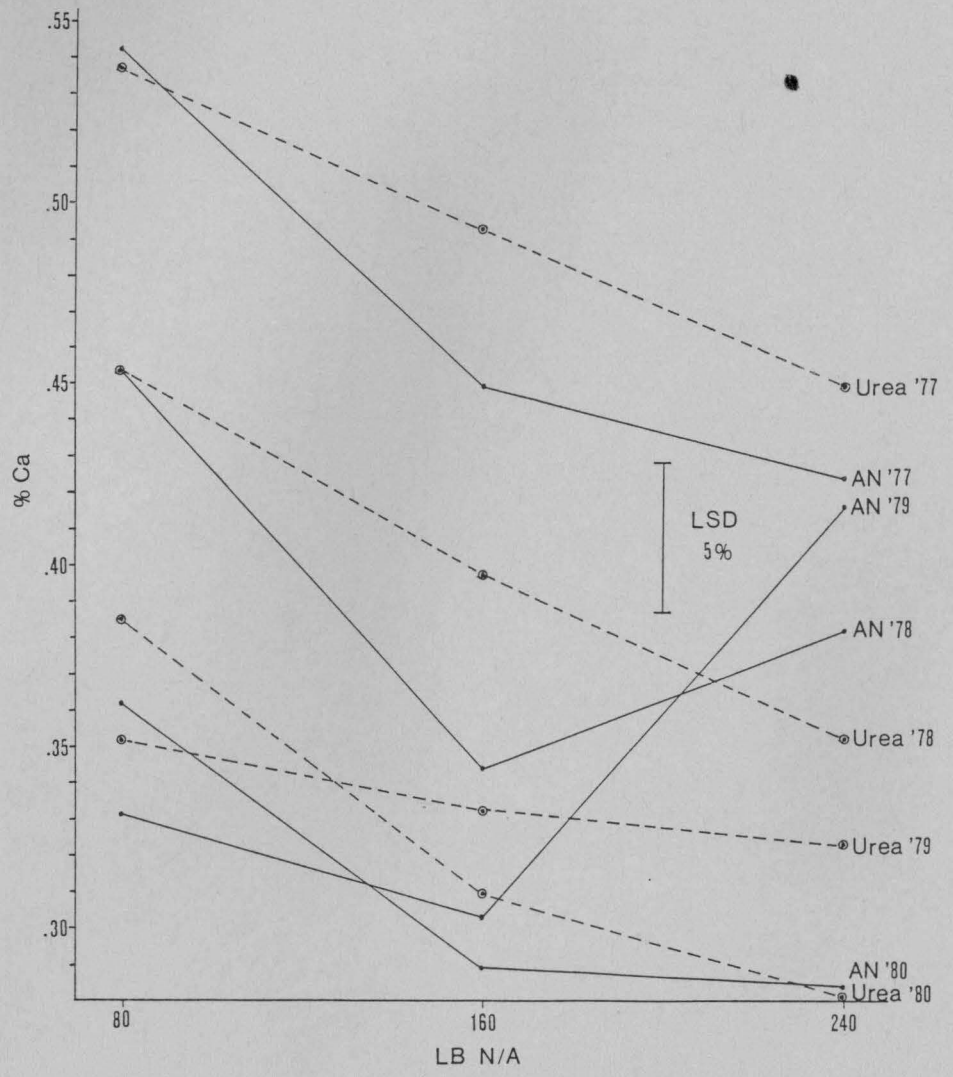

Figure 21. Effect of nitrogen rate and source on second-cutting calcium concentration in bromegrass. Bodenburg silt loam. 1977-1980.

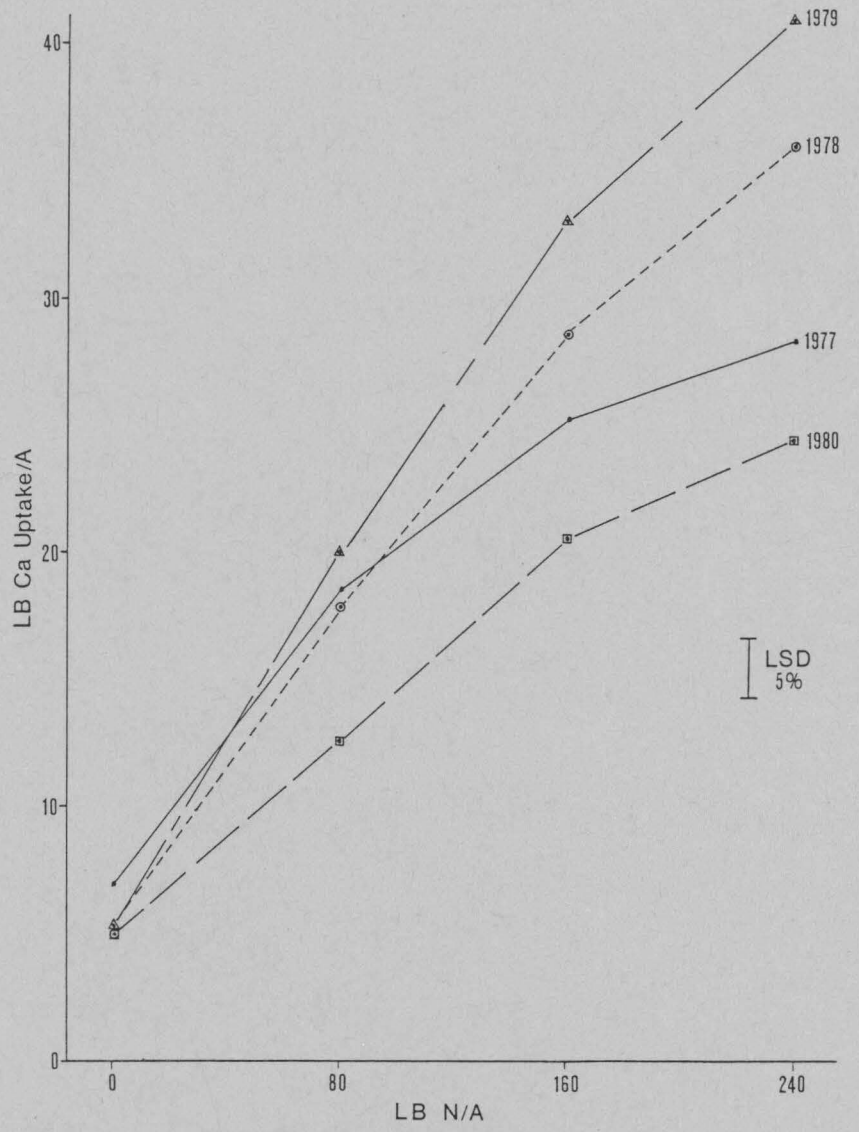

Figure 22. Effect of nitrogen on calcium uptake by bromegrass. Bodenburg silt loam. 1977-1980.

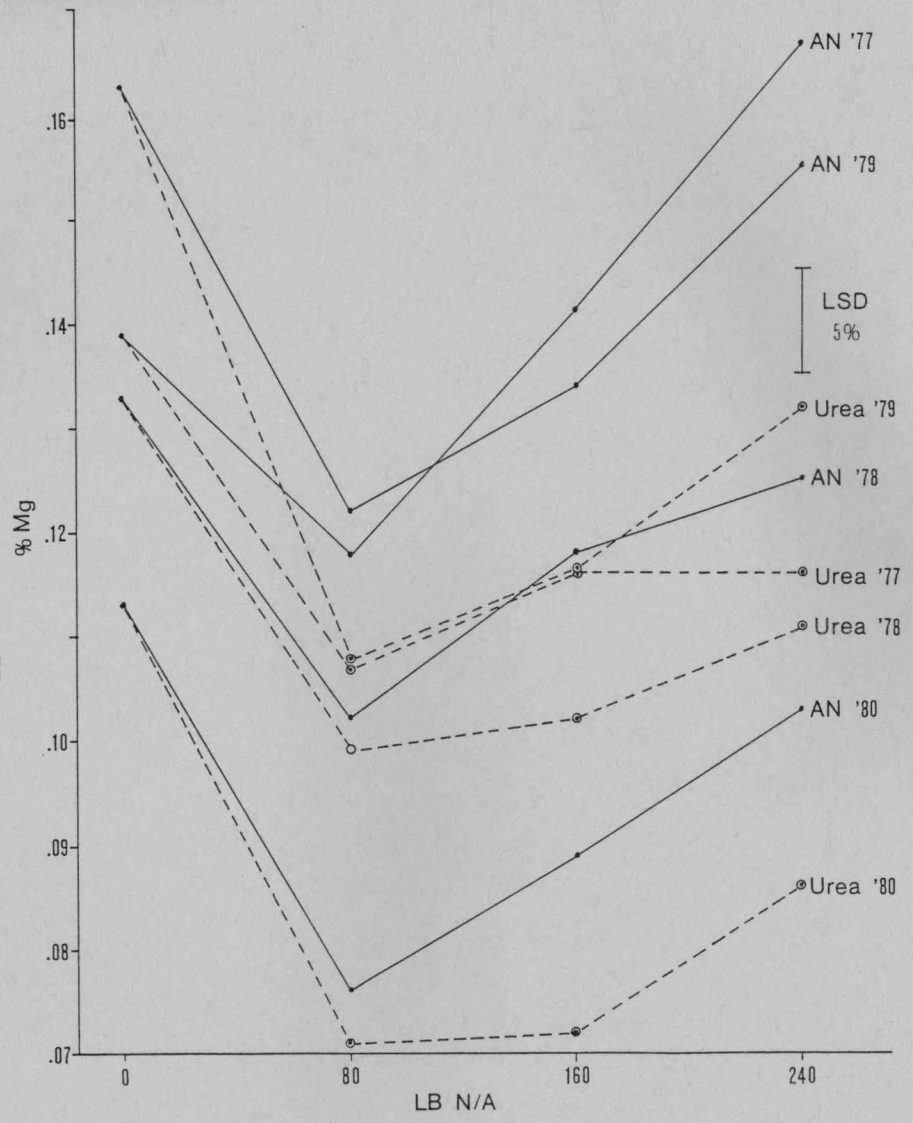

Figure 23. Effect of nitrogen rate and source on first-cutting magnesium concentration in bromegrass. Bodenburg silt loam. 1977-1980.

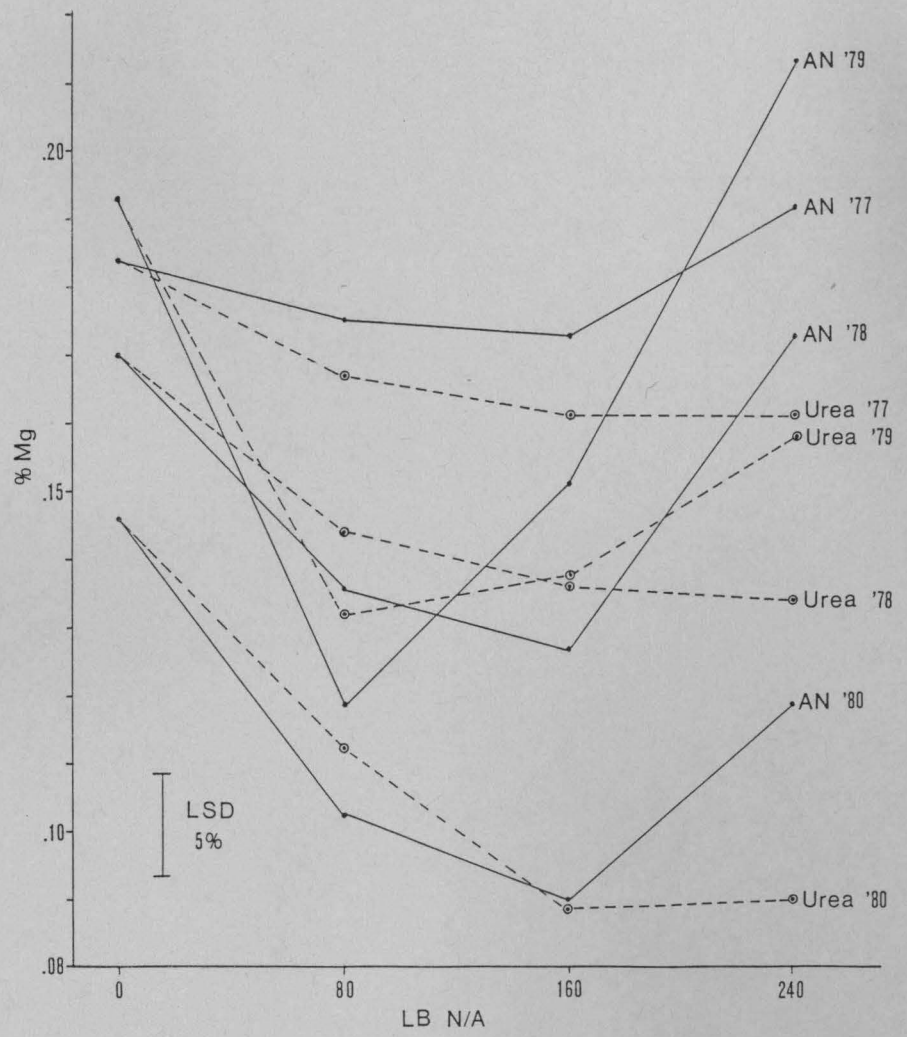

Figure 24. Effect of nitrogen rate and source on second-cutting magnesium concentration in bromegrass. Bodenburg silt loam. 1977-1980.

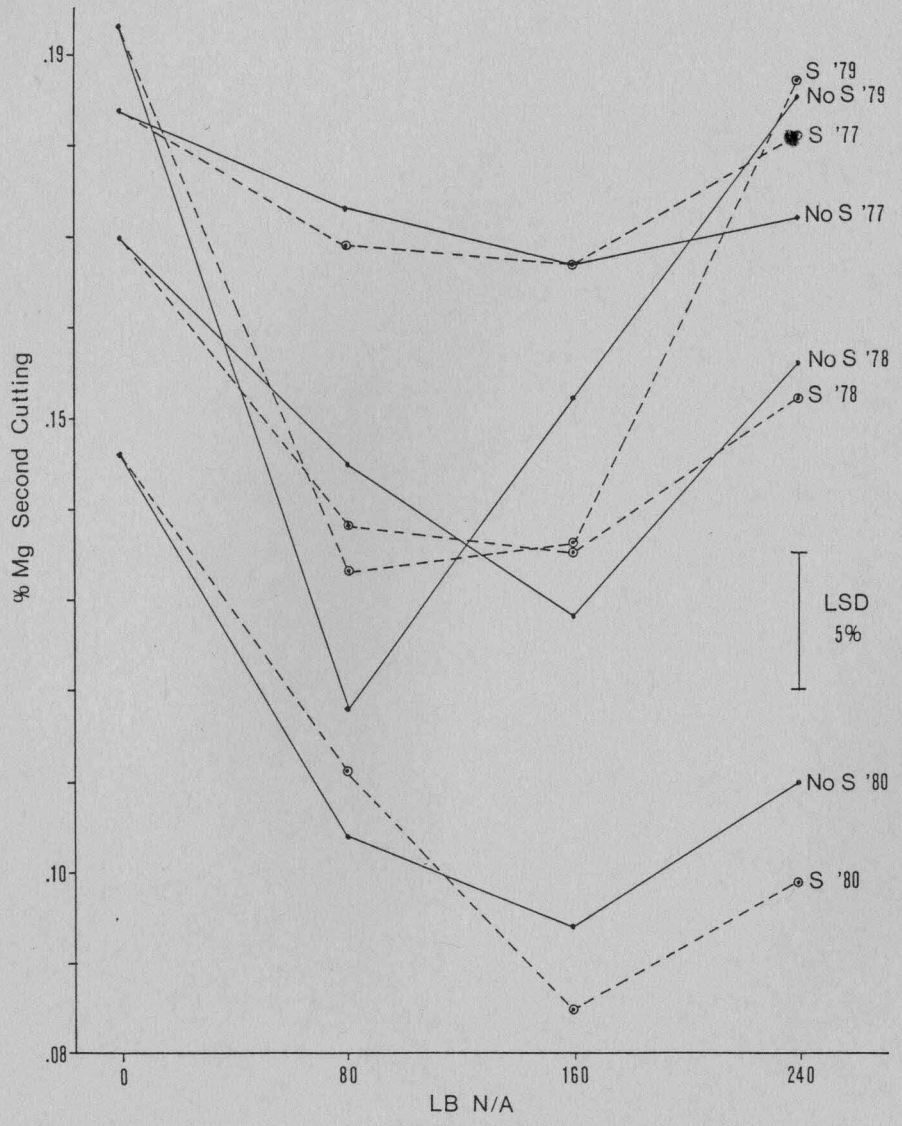

Figure 25. Effect of nitrogen and sulfur on second-cutting magnesium concentration in bromegrass. Bodenburg silt loam. 1977-1980.

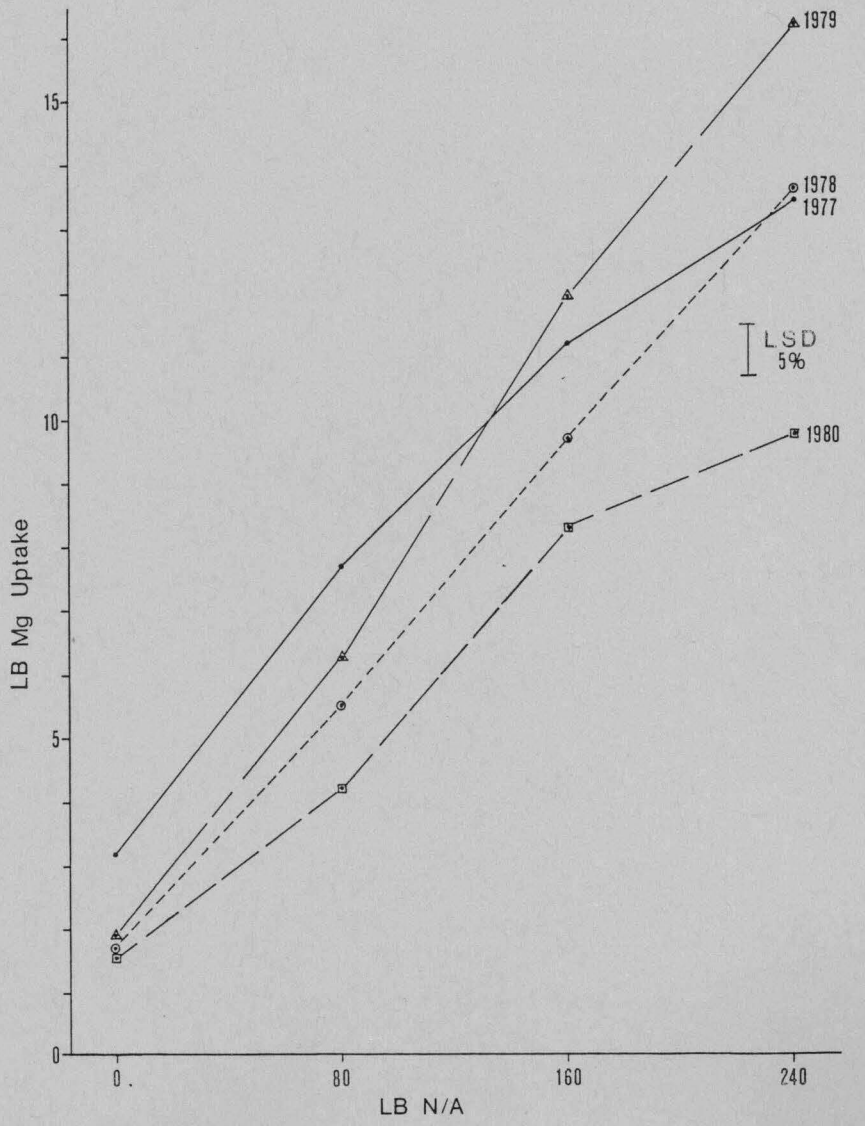

Figure 26. Effect of nitrogen on the magnesium uptake by bromegrass. Bodenburg silt loam. 1977-1980.

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