COMPARATIVE PERFORMANCE OF N SOURCES FOR SMOOTH BROMEGRASS *BROMUS INERMIS* L. AND TALL FESCUE *FESTUCA ARUNDINACEA* SCHREB.

by

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TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF FIGURES (Continued)

Figure | Page

LIST OF TABLES

LIST OF TABLES (Continued)

INTRODUCTION

Today's farmer is faced with rising production costs. In the past two years, one of the major sources of inflated production costs has been the fast-rising cost of fertilizer. Faced with this, farmers and ranchers have demanded the latest information available on the complex problems of fertilizer selection and application to improve efficiency of fertilizer use.

A considerable acreage of cool-season grasses exist in eastern Kansas. These forages are used as early spring and fall pasture and for hay. The main species are smooth bromegrass (*Bromus inermis* Leyss.) and tall fescue (*Festuca arundinacea* Schreb.). These grasses require nitrogen fertilization for optimum growth and performance. As the cost of nitrogen has increased, interest has increased in improved efficiency of N fertilization combined with economical maximization of yields. Questions concerning sources of N, application rates, and time of application have been asked with increasing frequency.

Coinciding with the rising cost of N came reports of relatively poor performance of solid urea and urea-ammonium nitrate (UAN) solutions applied to cool-season grasses in eastern Kansas. Many of the reports alleging poor performance of urea and UAN solutions were received in the spring of 1972 in eastern Kansas. During this period, relatively hot and dry weather prevailed at the time of normal nitrogen fertilization of cool-season grasses. Comments concerning the poor performance of these two materials were received from county agents, extension agronomists, and from farmers.

Based on reports of poor performance of certain nitrogen fertilizers and the need to conserve nitrogen through efficient application procedures, studies were initiated to: (1) compare ammonium nitrate, urea, urea-ammonium nitrate

(UAN) solution, sulfur-coated urea (SCU-30), and urea-ammonium sulfate (UAS) as sources of N for cool-season grasses with respect to yield and plant tissue composition; (2) investigate the slow-release N carrier (SCU-30) in terms of N release and carryover ability; (3) study the effect of time of application of N materials; and (4) upgrade recommendations for N fertilizer application for cool-season grasses.

LITERATURE REVIEW

Grassland farming is defined as the proper use of grass in agriculture; its integration into a farming program accomplishes many things: it covers the land to protect it from weathering; it provides inexpensive, high quality livestock feed in the form of pasture, hay, and silage; and it is easily cared for and can be mechanically harvested (Heath, 1973).

Serviss and Ahlgren (1955) state that our grasslands are the greatest undeveloped agricultural resource remaining and that an increased use of fertilizer can stimulate yields and improve nutrient content of the forage. They suggest a number of points to consider when selecting the proper forage for a given area; length of growing season, climate, soil fertility, and topography.

Using these criteria, the cool-season grasses, bromegrass and tall fescue, are excellent choices for eastern Kansas. Bromegrass is very palatable and remains so after maturity. It is also drought resistant and responds vigorously to N fertilization. Tall fescue is a highly productive though somewhat less palatable species of grass. It is widely adapted, very winter hardy, drought resistant, and is a strongly responsive species to N fertilization (Ahlgren, 1956).

Proper fertilization is one of the most important management practices in producing optimum yields and quality in cool-season grasses. Nitrogen supply to grasses is a major limitation in forage production since soils almost universally do not contain sufficient available N for high yields. The soil may contain a large quantity of combined N which is in organic matter and mineral material, but only a few kilograms per hectare of available N will be found at any one time. Therefore, fertilizer N must be relied upon to supply the needed N. Mott (1944) and MacLeod (1965) state that N is the first nutritional limiting factor for the growth of grasses in permanent pasture and has the greatest influence on yield.

Effect of N Fertilization on Yields of Cool-Season Grasses.

The response of cool-season grasses to N fertilization is well documented. A voluminous literature documents the large increases in yield obtained by N fertilization of cool-season grasses. Anderson, Krenzin, and Hide (1946) working in eastern Kansas reported bromegrass to be a heavy user of N and noted a rapid depletion of available N even on good soil. Nitrogen fertilizers at rates up to 112 kg/ha of N proved very successful in stimulating yield. Fitts, McHenry, and Allaway (1946) reported N very effective in increasing yields of bromegrass in Nebraska. Wilsie, Peterson, and Hughes (1945) reported N fertilization substantially improved unproductive stands of bromegrass in Iowa.

Lewis and Lang (1957) studied forage yields of eight cool-season grasses in Wyoming with N applications. Average forage yields from 0, 90, and 180 kg/ha N treatments were 1792, 6496, and 8288 kg/ha, respectively. Color and height responses to N fertilization were also noted; intensity of color and height increased with the rate of N applied. Russell, Bourg, and Rhoades (1954) reported similar foliage characteristics in bromegrass treated with N fertilizers in Nebraska, along with significant yield responses at all N rates.

MacLeod (1965) studied responses of timothy (Phleum pratense L.), orchardgrass (Dactylis glomerata L.), and bromegrass to N fertilization and found dry matter yields of each species were increased significantly. Kin and MacKenzie (1970) reported N applications on bromegrass in Quebec increased the yield of dry matter significantly for each increment of 112 kg N/ha, up to 336 kg N/ha.

George, Rhykerd, Noller, Dillon, and Burns (1973) reported that nitrogen fertilization significantly increased forage yields of orchardgrass, timothy, and bromegrass in both years of a two year study. Maximum yields ranged from approximately 5,000 kg/ha for timothy and bromegrass to 7,000 kg/ha for orchardgrass. Larsen, Carter, and Vasey (1971) reported that the forage yield of bromegrass increased from 2.38 metric tons of dry matter per hectare with 0 N up to 7.08 metric tons of dry matter per hectare with 298 kg N/ha applied annually. A number of other investigators, Kennedy (1958), Raese and Decker (1966), and Carter and Ahlgren (1951) reported significant yield responses of bromegrass to N fertilization.

Numerous literature citations document the response of tall fescue to N fertilization. Brooks (1951), working in Georgia, showed that the addition of 560 kg/ha of 4-5.3-10 fertilizer increased the yield of tall fescue by 784 kg/ha of dry matter. Application of 112 kg/ha of ammonium nitrate in addition to the 4-5.3-10 fertilizer gave an additional 784 kg/ha of dry matter. Ahlgren (1956) reported that tall fescue pastures in the West and South well supplied with N fertilizers often have a carrying capacity of two to three animal units per hectare during cool, moist seasons. Yields of 5,600 to 11,200 kg of dry matter per hectare were common.

In Kentucky, Templeton and Taylor (1966) also reported on the response of tall fescue to N fertilization. Three year average yields of 3389 kg/ha dry matter were recorded for control plots, while 34 kg N/ha produced 5212 kg dry matter per hectare. Additional N (67 and 134 kg N/ha) did not increase yields significantly over the 34 kg rate of N. In Virginia, Hallock, Wolf, and Blaser (1973) found annual dry matter yields of fescue increased from 41 to 110 q/ha as N rates increased up to 39 kg/ha per week in a study involving frequency of application of N. Other workers studying the response of tall fescue to N fertilization include Mays and Terman (1969) and Hoveland and Evans (1970).

Effect of N Fertilization on Forage Composition.

In addition to studies of N fertilization on yield of cool-season grasses, many investigations have examined effects of N fertilization on the composition of cool-season grasses.

Underwood (1962) stated that nutrient concentrations in plants are controlled by (a) the genus, species, or strain; (b) the soil on which grown; (c) the climatic or seasonal conditions during growth; and (d) the stage of maturity of the plant. It has become apparent that fertilization markedly alters nutrient concentrations and organic compound concentrations in cool-season grasses. Allaway (1971) pointed out nutrient additions to the soil may or may not change the concentration of this nutrient in plant tissue. He added that the nutrient application effects may vary from no increase in concentration but increase in yield to no increase in yield but increase in concentration.

Pesek, Stanford, and Case (1971) suggest that normally growing, tall cool-season grasses usually will have slightly over 3% N at stages where they might be used for grazing.

Ramage, Ely, Mather, and Purvis (1958) reported that annual rates of 56, 112, 224, and 448 kg N/ha as ammonium nitrate on orchardgrass and canarygrass (*Phalaris arundinaceae*) increased protein from 12 to 20% as N application increased from 56 to 448 kg N/ha. They concluded that N application increased forage N, protein, and K content while decreasing crude fiber, ash, and nitrogen-free extract. Reid, Post, and Jung (1970) reported similar changes in the mineral composition of five cool-season grasses grown and sampled over a nine year period in West Virginia. Nitrogen fertilization increased the N and potassium content in tall fescue at each growing period. Phosphorus decreased and calcium increased in the first cutting but held constant thereafter. Some increase in the magnesium content at high levels of N application were noted.

MacLeod (1965) reported that N, protein, and NO_3-N content increased with N fertilization in bromegrass, orchardgrass, and timothy in a greenhouse study.

At the same time he reported that K content in the plant tissue was decreased by N fertilization. Kin and MacKenzie (1970) noted similar trends. They observed that crude protein yields of bromegrass increased with N application up to 336 kg N/ha, but this level of N application did not produce NO_3- N levels considered toxic to animals.

Russell et al. (1954) besides reporting that heavy applications of N produced large increases in growth of bromegrass, also showed the marked effects of N on the composition of forage. Rates of 0, 67, 134, and 269 kg N/ha were applied to Lincoln bromegrass growing on a Rokely soil near Lincoln, Nebraska. Plant samples were analyzed for N, P, Ca, K, Mg, and Na. Nitrogen concentrations were higher for fertilized bromegrass at all locations, varying from 1.22% N for unfertilized plots up to 2.50% N for the 269 kg N/ha rate. During early stages of growth, P concentrations were greater in the fertilized areas but at final harvest there was a tendency for the reverse to be true. Potassium concentration increased noticeably with increasing N fertilization, approximately 2.20% K for unfertilized plots and 3.10% K for the 269 kg N/ha rate. Some decreases in concentrations of Ca and Mg were noted due to N fertilization.

With the advent of heavy use of N on cool-season grasses, there has been increasing concern over the accumulation of excessive amounts of NO_3-N in the forage. The accumulation of excessive amounts of NO_3-N in forages can pose serious problems to animals according to Murphy and Smith (1967). They found that NO_3-N accumulations were directly related to rates of N fertilization. Vanderlip and Pesek (1970) observed that, in general, N, P, and K applications early in the season increased the NO_3-N content. Later in the season only applied N had an effect on NO_3-N and that the content decreased sharply with time after application.

Frank (1968) reported that a 540 kg/ha N rate for orchardgrass in Iowa produced NO_3-N concentrations varying from 0.3 to approximately 0.82% among several varieties. More recently, Ryan, Wedin, and Bryan (1972) indicated that NO_3-N levels potentially "unsafe" occasionally occurred in the cool-season grasses when N was applied at 135 kg/ha in April through June or at 540 kg/ha in July. Data presented by Carey, Mitchell, and Anderson (1952) show a steady decline in total N concentration of bromegrass as plants matured. Generally, evidence indicates that large accumulations of NO_3-N in cool-season grasses are not likely under field conditions unless recommended rates of N are exceeded.

Comparisons of N Sources for Forages.

The effects of source of N on yield and composition of forages have been investigated to some extent. Kennedy (1958) found no significant differences between N carriers used on meadows and pastures in New York. Morris and Jackson (1959) found ammonium nitrate, ammonium sulfate, and calcium nitrate equally effective and much superior to calcium cyanamide in promoting the growth of rye (*Secale cereale* L.). Nowakowski (1961) found that ammonium nitrate, ammonium sulfate, calcium nitrate, and urea produced similar yields at the first cutting of established and newly sown ryegrass (*Lolium multiflorum* Lam.). However, at the second cutting, ammonium sulfate produced lower yields than the other N carriers.

Laughlin (1963) noted that at a rate of 112 kg N/ha ammonium nitrate, ammonium sulfate, and calcium nitrate were equally effective in increasing yields of bromegrass in Alaska, but urea was seldom as effective. He found anhydrous ammonia and calcium cyanamide were inferior to all other N carriers. Anhydrous ammonia was applied with a trailer type applicator with rolling coulters and packing wheels to prevent stand damage.

Mudd, Mair, and Meadowcraft (1963) experienced similar results with ammonium sulfate and ammonium nitrate-lime mixtures on permanent grassland. In a ten year experiment they reported no difference between ammonium sulfate and ammonium nitrate-lime mixtures in six of the ten years. Three years, ammonium sulfate gave significantly higher yields, while one year the ammonium-nitrate-lime mixture gave higher yields. Scott (1963) reported no significant difference between ammonium nitrate, ammonium sulfate, or urea as N carriers on New Zealand grassland.

Leefe (1962) reported different results. He reported that ammonium nitrate produced slightly better yields and higher protein in orchardgrass than did other N carriers utilized in his experiment. More recently, Hunter (1974) reported formamide ($HCONH_2$), a clear liquid containing about 31% N is an effective N source although somewhat less effective than urea-ammonium nitrate solutions or ammonium nitrate. The study was conducted on tall fescue, bromegrass, and wheat (Triticum vulgare). The urea-ammonium nitrate solution and ammonium nitrate produced darker green color and higher yields of the grasses. A three year study in east-central Kansas (Murphy and Gruver, 1968) showed no significant differences between solid urea, anhydrous ammonia, ammonium nitrate, and ammonium sulfate as sources of N for bromegrass. The study showed potassium nitrate an inferior source of N, possibly due to the very large amounts of K applied with the N (over 620 kg K/ha/year).

Several workers have reported N losses from surface application of nitrogen carriers, especially urea. Meyer, Olson, and Rhoades (1961) reported nitrogen losses with surface application of all N carriers. The greatest loss was from fertilizers containing urea. These losses were greatest on neutral to alkaline soils under conditions of limited rainfall with above average temperature, and were magnified by crop residue on the soil surface.

Devine and Holmes (1963) reported that urea gave the lowest yields in eight of ten experiments of N fertilization on grassland. Other carriers in the experiment were ammonium nitrate and ammonium sulfate. They felt the poor performance of urea was related to the ammonia absorption potential of the soil. Hamissa and Shawarbi (1962) showed in a laboratory trial that ammonia volatilization losses from ammoniacal fertilizers applied to soil were markedly increased with increasing rates of application, aeration, pH, and temperature. Templeton (1961) reported that urea was less effective than conventional fertilizers and that response to urea became less effective as the application rate increased.

Volk (1961) reported nitrogen losses from surface applications of ammonium nitrate, ammonium sulfate, and urea to limed and unlimed turf and to bare sandy soil. The N loss was greatest from urea, with greater loss from larger prills. Low and Piper (1961), in addition to reporting a poorer nitrogen response to urea due to loss of N to the atmosphere, also reported an occasional phytotoxicity of seedlings to urea.

Most of the work done to date would seem to indicate only small differences between the major sources of N for cool-season grasses, with the possible exception being the sporadic poor performances of solid urea and urea containing materials. It appears that under certain conditions urea compounds are subject to ammonia volatilization losses of N, resulting in lesser response by plants to applied N.

Effects of Rate and Time of Application of N.

A considerable amount of effort has been expended in studies of the optimum rate of N for cool-season grasses. Anderson et al. (1946) found that beyond the 112 kg N/ha rate, N became relatively less effective in stimulating yields of bromegrass. Ramage et al. (1958) found that a 112 kg N/ha rate gave the highest yield of dry matter on several grasses. Dry matter yields assumed a typical diminishing return response to increasing rates of N, according to Carter and Scholl (1962). Since the response did not appear to have reached its maximum, they felt an additional increment of N over the 269 kg/ha rate would have resulted in a further increase in yield. The study included bromegrass and orchardgrass.

Laughlin (1962) substantiates their statement. He reported that each N increment up to 336 kg N/ha resulted in increased bromegrass yields. Maximum yields were obtained by Schmidt and Tenpas (1965) with rates as high as 560 kg N/ha; the 1120 kg/ha rate reduced yields. This study was also on bromegrass. Yield data of bromegrass reported by Lorenz, Carlson, Rogler, and Holmen (1961) indicate a leveling off between the 179 kg/ha and 224 kg/ha rates of N. Gruver (1971) found that continuous annual applications of N to bromegrass tend to lower the rate of N required to produce maximum yields in later years. He found that after three years of annual N applications of up to 280 kg N/ha, the rate of N required to produce maximum yields was near the 178 kg N/ha rate. Higher rates of N tended to reduce yields after three years.

Summing up, N rates necessary to produce maximum yields of cool-season grasses vary drastically. This is so because factors such as rainfall, temperature, stand and clipping height must be considered when trying to determine optimum N rate. Considering all factors it would appear that even though rates of N greater than 178 kg N/ha will increase yield, they are not economically feasible because the extra forage produced does not offset the cost of the extra N.

The effects of time of N application on cool-season grasses is quite varied. Burton (1952) found that splitting the applications of N fertilizer in wet seasons significantly increased yields of bermudagrass (<u>Cynodon dactylon</u> L.)

but had no effect in a season of average rainfall. Split N applications (half in the spring and half in early summer) produced higher second and third cutting yields of bromegrass but no more dry matter yield for the entire season than did the same amount of N applied only in the spring according to Laughlin (1963). He also reported that spring applications of N were generally superior to equal quantities applied in the fall. Contrary to this Russel et al. (1954) reported that autumn application of N fertilizer gave higher yields at harvest than did spring applied N.

Fortman (1953) reported that spring and a series of split applications of the N material were equally efficient when considering annual yield of bromegrass. Anderson et al. (1946) showed autumn and spring applications equally efficient in stimulating yields. Leefe (1962) reported that a single spring application of N gave better yields and higher protein content than a series of split applications. Johnson and Nichols (1969) observed that ammonium nitrate applied in the spring was more efficiently used than ammonium nitrate applied in the fall. They concluded that spring seems to be the most desirable time to apply nitrogen if only one annual application is desired. The study involved eleven species. Kin and MacKensie (1970) reported that there was no significant difference between fall, pre-winter, spring and summer applications of N on bromegrass on two Quebec soils in relation to yield and crude protein.

Reviewing work on the effect of time of N application on cool-season grass yield there appears to be considerable disagreement. This is probably due to factors such as environmental conditions and the location. Most research would tend to indicate that on an annual yield basis there is little difference between times of N application.

Use of Slow-Release N Fertilizers on Cool-Season Grasses.

Increasing interest has developed concerning the feasibility of using slow-release N fertilizers on cool-season grasses. Possible agronomic advantages of controlled release N fertilizers include (a) less toxicity to germinating seedlings and new rhizomes, (b) less loss of N by leaching and runoff, (c) more uniform growth of forage throughout the growing season without repeated N applications, (d) less volatilization loss of N from surface applied carriers, and (e) greater effectiveness per unit of applied N. Production and use of slowly soluble compounds is one approach to controlled release.

Oxamide, urea-formaldehyde and other urea polymers are examples of early N fertilizers having delayed release properties. Armiger, Clark, Lundstrom and Blair (1951) reported that urea-form preparations (urea-formaldehyde reaction products) offer promise as slowly available sources of nitrogen for crop growth. In a study of the yield and quality of perennial ryegrass (Lolium perenne L.) grown on Evesboro loamy sand soil, they noted that urea-form preparations gave distinctly different patterns of nitrogen availability involving lower initial but more uniform response than standard N sources. They concluded that the overall efficiency of properly formulated urea-form materials equaled that of conventional N fertilizers with respect to long season crops such as grasses.

Engelstad, Hunt, and Terman (1964) reported that corn (Zea mays L.) forage yield and percentage recovery of applied N were equally effected by fine oxamide and ammonium nitrate. Efficiency of oxamide decreased with increasing granule size. Beaton, Hubbard, and Speer (1967) reported that yield and N uptake by orchardgrass in the first harvest were greatest with ammonium nitrate, urea, urea plus thiourea, and finely divided oxamide. Glycoluril and coated urea products produced the highest yields for second and third harvests during the same year. In the later stages of cropping, urea-formaldehyde and thiourea treatments increased yields and in the final four harvests, yields obtained with these two materials were among the highest.

Brown and Volk (1966) using labeled urea-form and ammonium nitrate studied N recovery by coastal bermudagrass. They reported no differences in total recovery of labeled N from plants and soil between the two sources. Extended availability of urea-form N over ammonium nitrate was apparent only at high rates of urea-form application. Skogley and King (1968) compared experimental urea-impregnated petroleum wax products and prilled urea coated with a petroleum base to conventional prilled urea and urea-form as N sources for Kentucky bluegrass (Poa pratensis L.) and fescue. Based on turf quality, yield, and N content of forage and efficiency of N usage, the experimental products and conventional urea gave similar results. Urea-form was inferior.

Kilian, Attoe, and Engelbert (1966) reported on urea-form-aldehyde as a slowly available N source for Kentucky bluegrass. In three year trials on a silt loam soil, highest grass yields were obtained from ammonium nitrate-urea-form mixtures with less than 53% urea-form. Total yields were significantly lower with mixtures containing 88% to 100% of their N as urea-form. N recovery by plants was significantly less when 88% to 100% of the N was supplied as urea-form.

Summarizing the earlier work on slow-release N fertilizers, the results have been quite variable. In general, however, slow-release forms of N have proven effective on grasses or other long term crops. Costs of these compounds is high, however, and to date they have not proven to be economically feasible when compared to conventional N fertilizers.

In recent years, attention has focused on a new type of slow-release N fertilizer. The new approach for obtaining delayed release has been to coat soluble N fertilizers with various materials of low water solubility. Plastic, asphalt, and wax coatings have been used with varying degrees of success. Research has been carried out by the Tennessee Valley Authority (TVA) Applied Research Branch for several years to develop a satisfactory coating for soluble fertilizers using elemental sulfur and various sealants. Perhaps the most well known of these new materials is sulfur-coated urea (SCU).

SCU, produced by TVA, is made by placing pre-heated granular urea in a pan granulator and spraying with molten S, the coating weight being determined by the length of time the granules remain in the granulator. After coating with S, the granules are sealed with a microcriptalline petroleum wax containing about 10% oil (Skogley and King, 1968).

Mays and Terman (1969) have evaluated SCU as an N source for tall fescue. They report that in field experiments ammonium nitrate, urea, and other readily soluble N fertilizers resulted in higher first cutting yields and higher N content of forage than did SCU. SCU resulted in lower first cutting yields and higher later cutting yields than did other N sources. Total annual yields were quite similar for all N sources.

Webb and Voss (1973) reported large yield increases from N fertilization of tall fescue in Iowa. Three N sources; ammonium nitrate, urea, and SCU produced about the same total increase in dry matter production although at the highest rate, 269 kg N/ha, SCU may have been slightly more effective than ammonium nitrate and urea. SCU resulted in more uniform growth during the season and would appear to have excellent potential for supplying N throughout the season for long season crops such as grass. Williamson and Carson (1972) in a study on grass in South Dakota report residual response to SCU even at low nitrogen application rates of 78 kg N/ha. However, for the two year study, little, if any, advantage of SCU over straight urea existed.

At the present time a tremendous amount of research utilizing SCU is being carried on around the country. Some research has shown SCU valuable as a slow-release N fertilizer on cool-season grasses, but the material has shown no clear-cut superiority over conventional N sources.

METHODS AND MATERIALS

In the spring of 1973, four experimental sites were established in Riley, Jackson, Franklin, and Labette counties for studies of five nitrogen carriers. The Riley, Jackson, and Franklin county sites were located on established bromegrass on soils with gentle to moderate slope. The Labette county area was located on established tall fescue. Soil analysis data from the experimental sites are presented in Table 1.

A randomized, complete block design with three replications comparing rate, source, and time of N application was initiated at each site (Table 2). Nitrogen rates included 67, 134, and 201 kg N/ha, applied in the spring and a series of split applications involving the 134 and 201 kg/ha N rates. The split treatments involved application of two-thirds of the nitrogen in late winter (or early spring) and the remaining one-third in August. The nitrogen carriers evaluated were ammonium nitrate (34-0-0), urea (45-0-0), urea-ammonium nitrate solution (28-0-0), sulfur-coated urea (35-0-0), and urea-ammonium sulfate (41-0-0-4S). The latter two carriers were experimental materials provided by the Tennessee Valley Authority, Muscle Shoals, Alabama.

Individual plot dimensions were 1.8 meters wide by 9.1 meters long with a 4.6 meter alley between replications. Phosphorus and potassium at rates of 24.5 kg P/ha and 93 kg K/ha were applied to all plots to insure that these nutrients would not be limiting. During both years of the study, N fertilizer materials were applied in late winter or early spring for the spring application and in late August for the split applications. Due to extremely wet weather in 1973, all spring applications were delayed past the normal time of application, most treatments being applied during the mid-March period. For specific information on date of application, see Table 3.

Table 1. Soil analysis data for experimental sites.

Location	County	Soil type	Depth cm.	pH	Available N ppm	Available P kg/ha	Available K kg/ha
North Agronomy Farm	Riley	Geary sicl	0-15	6.3	20.2	58	560
			15-60	5.9	11.6	229	560
Roy Moser Farm	Jackson	Burchard sil	0-15	5.3	15.9	8	304
			15-60	5.4	16.5	6	368
East Central Exp. Field	Franklin	Woodson sicl	0-15	6.6	11.2	54	409
			15-60	6.3	6.2	10	475
Parsons Exp. Field	Labette	Parsons sil	0-15	6.1	16.1	22	246
			15-60	6.2	8.3	8	304

Table 2. Treatments involved in comparisons of sources of nitrogen for cool-season grasses.

kg N/ha	N Carriers	Time N Application
0	-------	-----------
67	Am. Nitrate	Late winter
134	Am. Nitrate	Late winter
201	Am. Nitrate	Late winter
67	Urea	Late winter
134	Urea	Late winter
201	Urea	Late winter
67	UAN Solution[a]	Late winter
134	UAN Solution	Late winter
201	UAN Solution	Late winter
67	SCU-30[b]	Late winter
134	SCU-30	Late winter
201	SCU-30	Late winter
67	UAS[c]	Late winter
134	UAS	Late winter
201	UAS	Late winter
134	Am. Nitrate	Split[d]
201	Am. Nitrate	Split
134	Urea	Split
201	Urea	Split
134	UAN Solution	Split
201	UAN Solution	Split
134	SCU-30	Split
201	SCU-30	Split
134	UAS	Split
201	UAS	Split

a/ From here on this material will be referred to as UAN.

b/ SCU-30 is sulfur-coated urea, 30% dissolution first seven days. It is produced and was provided by TVA.

c/ UAS is urea-ammonium sulfate, produced and provided by TVA.

d/ Split application: 2/3 of toal N applied in late winter, remaining 1/3 applied in late summer (August).

Table 3. Fertilization and harvest dates.

Location	County	Fertilization Dates				Harvest Dates			
		Spring 1973	Split 1973	Spring 1974	Split 1974	Spring 1973	Fall 1973	Spring 1974	Fall 1974
North Agronomy Farm	Riley	Mar. 12	Aug. 10	Feb. 4	Aug. 15	June 1	Nov. 5	May 20	Nov. 8
Roy Moser Farm	Jackson	Mar. 16	Aug. 14	Feb. 5	Aug. 14	June 4	Nov. 13	May 31	Nov.[a] Harvest
East Central Exp. Field	Franklin	Feb. 27	Aug. 15	Feb. 5	Aug. 14	June 6	Nov. 30	June 5	Nov. 15
Parsons Exp. Field	Labette	Feb. 15	Sept. 4	Feb. 4	Aug. 20	June 6	Nov. 12	May 3	Sept. 26

a/ Extreme dry weather in summer of 1974 resulted in little fall regrowth.

In 1973, fertilizer materials were applied with a small Gandy fertilizer spreader pulled by a garden tractor. This apparatus was also equipped with a positive displacement John Blue liquid fertilizer pump attached to a boom with three nozzles for applying urea-ammonium nitrate (UAN) solution. The pump was chain driven by the wheel of the garden tractor. For the 1974 study, application equipment was changed and upgraded through the use of a Barber metered-flow fertilizer applicator equipped for liquid applications by mounting a John Blue positive displacement solution pump on the tractor. The Massey Ferguson 135 tractor was equipped with a ground speed dependent power take off which was utilized to drive the pump. The pump was connected to a boom with three nozzles which was attached to the Barber applicator.

Yield information was collected from all locations twice each year. The first harvest was at the late boot stage of growth around June 1. A second harvest was around November 1 to measure the late summer and fall growth. After each harvest the plot area was mowed and raked clean. Specific harvest dates are given in Table 3. Harvesting was carried out with a small self-propelled forage harvestor (Swallow, 1967) which had been improved by utilizing one large motor and making the machine completely hydraulically driven. Improvements were made by personnel at the Kansas State University Agronomy Farm. A strip 0.9 m in width was harvested from the center of each plot. The plant material was weighed in the field, a sample collected for a moisture determination and N, P, and K analysis, and that sample weighed in the field to record its wet weight. The samples were subsequently transferred to a forced air dryer and dried for three days at 60° C. The dried material was again weighed, percent moisture calculated using wet and dry weights of the material, and the yields were computed, corrected to 12.5% moisture.

The dried samples were ground through a Wiley mill using stainless steel knives and a stainless steel 2 mm screen. Samples were stored in sealed plastic containers for later analysis.

Tissue samples from all locations were prepared for chemical analysis by the sulfuric acid digestion procedure of J. J. Hanway, Iowa State University. A 0.5g sample of tissue, 10 ml of concentrated sulfuric acid, a small piece of copper wire, and a glass bead were placed in a 100 ml Pyrex volumetric flask and placed on a hot plate. The flasks were heated slowly for approximately 4 hours until all frothing had ceased. The temperature was then increased until the sulfuric acid boiled. The flasks were swirled after the solution had cleared to wash down tissue particles from the sides of the flask. The solutions were allowed to boil for about 12 hours and then removed from the hot plate, cooled, and diluted to volume with deionized water. Deionized water was prepared by passing steam-distilled water through a series of mixed-bed demineralizer columns. Polyethylene bottles were used to store the solutions. Assays for N, P, and K were then performed on the solutions.

Five ml of the digest solution were used for N determination by the micro-Kjeldahl steam distillation technique outlined by Bremner and Kenney (1965). Phosphorus was determined following a modification of the vando-molybphosphoric yellow color method of Jackson (1965). A 5 ml aliquot of the digest solution and 25 ml of vando-molybdate solution[1] were used for the colorimetric procedure. After 30 minutes the absorbance was read on a Beckman DB spectrophotometer at a wavelength of 390 nm. A 5 ml aliquot of the digest solution, diluted 1:10 with deionized water, was used to determine K by flame photometry.

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[1] Vanadate-molybdate solution made by dissolving 195 g of $(NH_4)_6Mo_7O_{24}:H_2O$ in 1L of H_2O and dissolving 5.05 g of NH_4VO_3 in 1L of boiling H_2O, then cooling. Both solutions were then transferred to a carboy and made up to 18L with deionized H_2O.

In addition to the tissue analysis detailed above, the Riley county site was selected for a protein study during the spring growing season in 1973 and 1974. Beginning about the first of April each year, tissue samples were collected from all spring applied N plots and the 0 N plots at two week intervals up to harvest. These samples were dried, ground, and digested as detailed above. Steam distillation was used to determine percent N. Crude protein of the samples was then calculated by multiplying %N by a factor of 6.25.

In 1973, a portion of these bi-weekly protein samples were analyzed for Ca, Mg, and K to determine the K/Ca+Mg ratio of the grass as it progressed toward maturity. K determination was made by flame photometry as detailed previously. A 5 ml aliquot of the sulfuric acid digest solution, diluted 1:10 with deionized water, was used to determine Mg by atomic absorption spectrophotometry. For Ca determination, one-half gram portions of previously dried and ground plant tissue samples were dry ashed at 200° C for one hour and 550° C for three hours. The ash was dissolved in 0.1N HCl and allowed to stand overnight. The mixture was filtered through Whatman 42 filter paper and made to 50 ml volume. Calcium was determined on this solution by atomic absorption spectrophotometry. Tissue composition information is reported on a dry matter basis.

Soil samples from Riley county were collected from 0-15 and 15-60 cm depth increments in the spring of 1974 to determine residual N from 1973 N applications. Samples were collected only from plots receiving ammonium nitrate and sulfur-coated urea at the 201 kg/ha N rate and from the 0 N plots. Soil samples were dried at 60° C for five days and then ground in a mechanical soil grinder. The ground soil was stored in glass bottles until ready for analysis. Using the steam distillation procedure described previously, inorganic N (NO_3-N) was determined from a 5 g sample of the soil. Basis for the soil sample analyses was to determine residual effects from the SCU material.

Analysis of variance on all data from this study was carried out by utilizing a program developed for the University IBM 370 computer. All results are reported at the 5% level of significance. The figures in the results section of this thesis were produced using a Calcomp plotter and a computer program developed by Wallingford, Vanderlip, Meiners, and Kemp (1974).

RESULTS AND DISCUSSION

Data presented in Figures 2, 3, and 5-16 are calculated from actual field plot data. Means of the data corresponding to these figures are given in the appendix, Tables III-VII. A complete analysis of variance and means for N rate, N source, and time of N application are included in these tables. All LSD values are given at the 5% level.

A fall harvest was not possible at the Jackson county site in 1974 due to extremely dry conditions that existed during the time of normal fall growth. Therefore, total yearly yields in 1974 at Jackson county represent the spring harvest only.

Response of Grasses to N Fertilization.

Visual responses of bromegrass and fescue to spring applied nitrogen was quite evident during the spring growth period for both years of the study (Fig. 1). Plots receiving no N showed mild to severe N deficiency symptoms, depending on location. Plants on these plots appeared stunted and were very pale in color. Very few seed stalks were produced. Plants on plots receiving the 67 kg/ha rate of N, while visually better than the 0 N plots, showed lack of vigor and color when compared to the plants on plots receiving 134 and 201 kg N/ha. Growth of plants on plots receiving the two higher rates of N was very lush, showed a definite height increase, had a deep green color, and produced an abundance of seed stalks. Only small visual differences were noted between plots receiving the two higher N rates, with the degree of difference being location dependent.

Visual response during the fall growing period from spring N applications was noticeable, but the magnitude of response was much smaller than it had been in the spring. Plots receiving split N applications showed more fall

Fig. 1. Growth response of bromegrass to N fertilization, Jackson Co., 1973.

(Left, 201 kg N/ha (180 lbs N/A) as urea; center, control (0 N) plot; right, 201 kg N/ha (180 lbs N/A) as ammonium nitrate)


UREA
180 N
CONTROL
NO N
AM. NITRATE
180 N

growth and had a darker green color than did plots receiving spring applied N only. The O N plots were again the poorest in the fall.

Yields for spring and fall harvests were added to obtain total yield for each location each year. Fig. 2 shows the N response noted at all locations on a total yearly yield basis for each year. Nitrogen significantly increased yields of both bromegrass and fescue in 1973 and 1974.

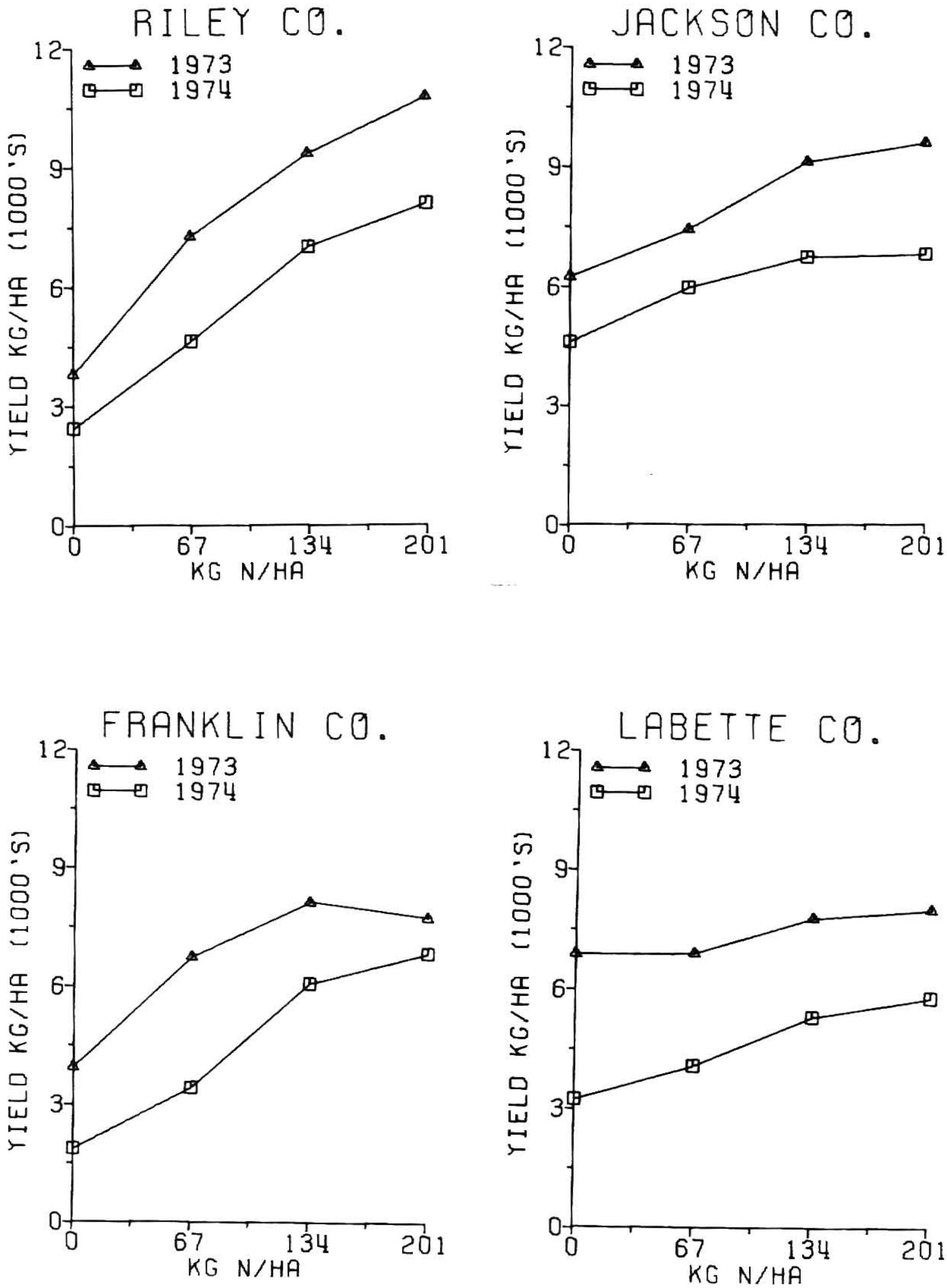
Yields in 1973 were higher than 1974 yields at all locations. Temperature and precipitation records (Appendix Tables I and II) from official reporting stations in eastern Kansas show a possible explanation for this.

In 1973, data show near normal temperatures and above average precipitation for the year. The growing periods of the grasses, March through May and late August through October, also had excellent climatic conditions for growth. Records for 1974 through the month of October indicate the severity of drought conditions in eastern Kansas. Rainfall for the spring and fall growth periods was below normal, resulting in lower yields overall in 1974.

Forage yields from plots receiving no N were low both years. In 1973, total yearly yields increased progressively with each increment increase in N, except at the Franklin county site where the 201 kg/ha rate of N depressed yields slightly (Fig. 2). In 1974, total yields increased with each increment increase in N at all locations. In both years at all locations, the 134 kg/ha rate of N gave significantly higher yields than the 67 kg N/ha rate. In 1973, the 201 kg N/ha rate produced significantly higher yields above the 134 kg/ha rate of N at only one of four locations, while in 1974 the 201 kg N/ha rate produced significantly higher yields than did the 134 kg N/ha rate at three of four locations.

In summary, although the 201 kg/ha rate of N generally gave the highest yields, as more N was added above the 134 kg N/ha rate there was a diminishing

Fig. 2. N responses of bromegrass at Riley, Jackson, and Franklin counties and of tall fescue at Labette county.


RILEY CO.
JACKSON CO.
FRANKLIN CO.
LABETTE CO.
1973
1974
YIELD KG/HA (1000'S)
KG N/HA
0
3
6
9
12
0
67
134
201

return in forage yield. Tall fescue in Labette county responded less dramatically to N than did bromegrass at the other three locations.

N Source Effect on Yield.

Figures 3-11 indicate the effects of N source on the spring, fall, and total yearly yield of forage in 1973 and 1974 at all locations.

Urea-ammonium sulfate (UAS) and ammonium nitrate (AN) produced the highest spring yields from spring applied N at the Riley county location in 1973 (Fig. 3). SCU-30 was notably lower than all other materials (Fig. 4). Differences between UAS, ammonium nitrate, urea, and Uan solution were non-significant for the spring harvest.

Fall yields at Riley county in 1973 showed almost an opposite arrangement between nitrogen carriers (Fig. 3). SCU-30 produced significantly higher yields than all other materials except ammonium nitrate. Apparently the situation was related to slow release of nitrogen from the SCU-30 in the spring with subsequent higher amounts of nitrogen available for the fall growth period. Comparisons of UAN solution, UAS, and urea revealed no significant yield differences in the fall clippings.

Comparing nitrogen materials for the entire year (1973) at Riley county, there were no significant differences between ammonium nitrate, UAS, and urea; but ammonium nitrate was significantly better than both UAN solution and SCU-30 (Fig. 3).

Urea-ammonium sulfate was significantly better than all other carriers in terms of spring harvest yield at Jackson county in 1973 (Fig. 5). No significant differences were noted between ammonium nitrate, UAN solution, and SCU-30, but all of these materials were significantly better than urea in terms of forage yield. The very low yield of urea at this location for the spring harvest suggests the possibility of ammonia volatilization.

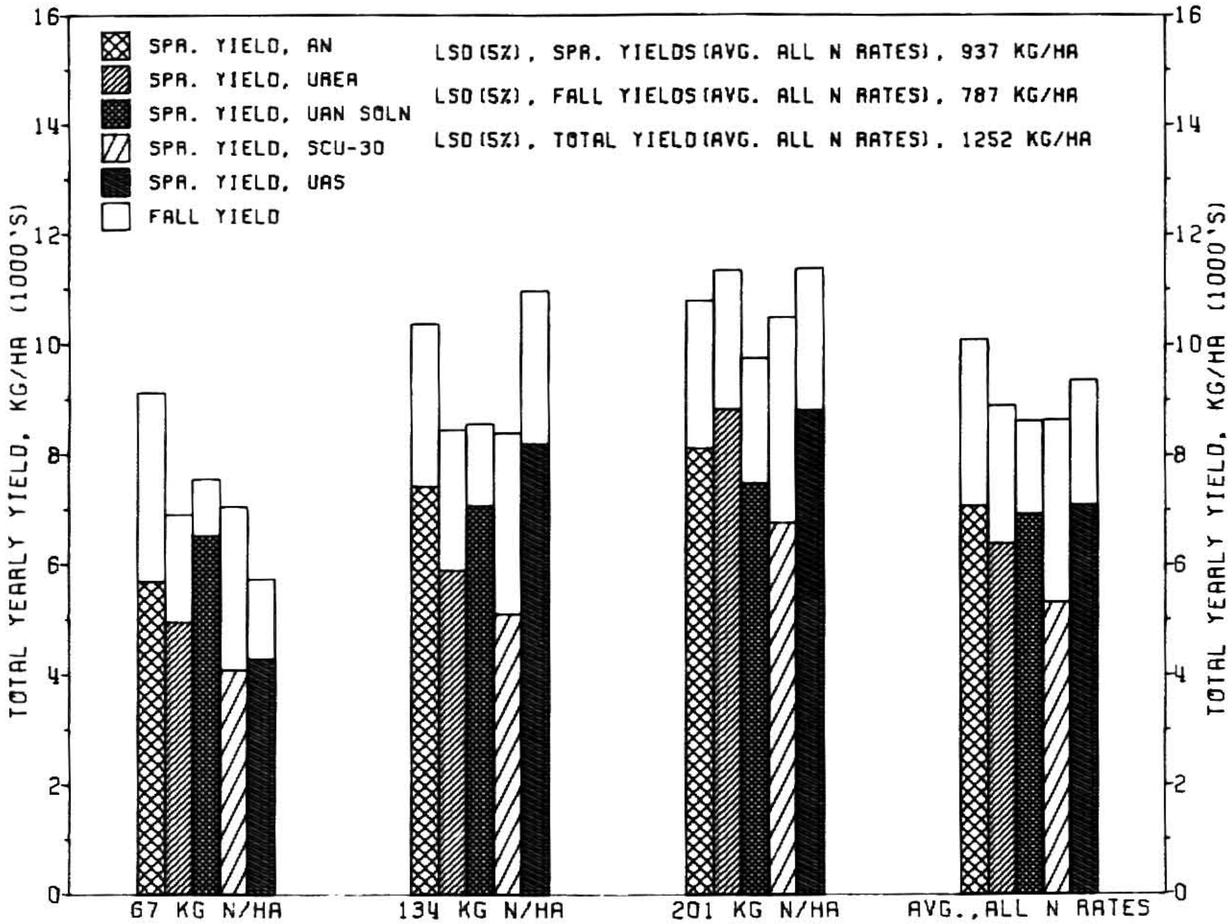
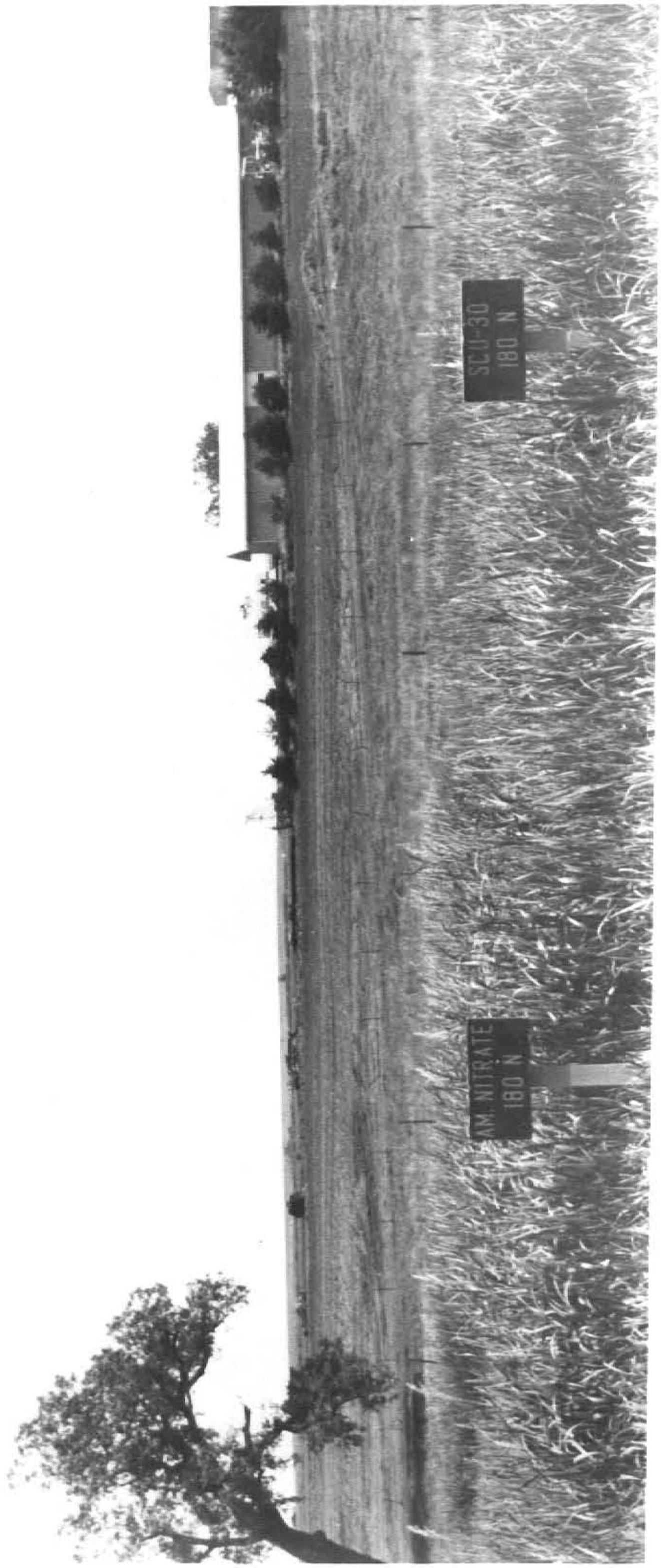


FIG. 3. SPRING, FALL, AND TOTAL YEARLY YIELD OF BROMEGRASS AS AFFECTED BY N SOURCE AND RATE, RILEY CO., 1973. (0 N PLOT YIELDS; SPR.=2371, FALL=1434, TOTAL=3804 KG/HA).

Fig. 4. Comparison of visual response between ammonium nitrate and SCU-30. (201 kg N/ha (180 lbs N/A), Riley Co., 1973)


SCU-30
180 N
AM. NITRATE
180 N

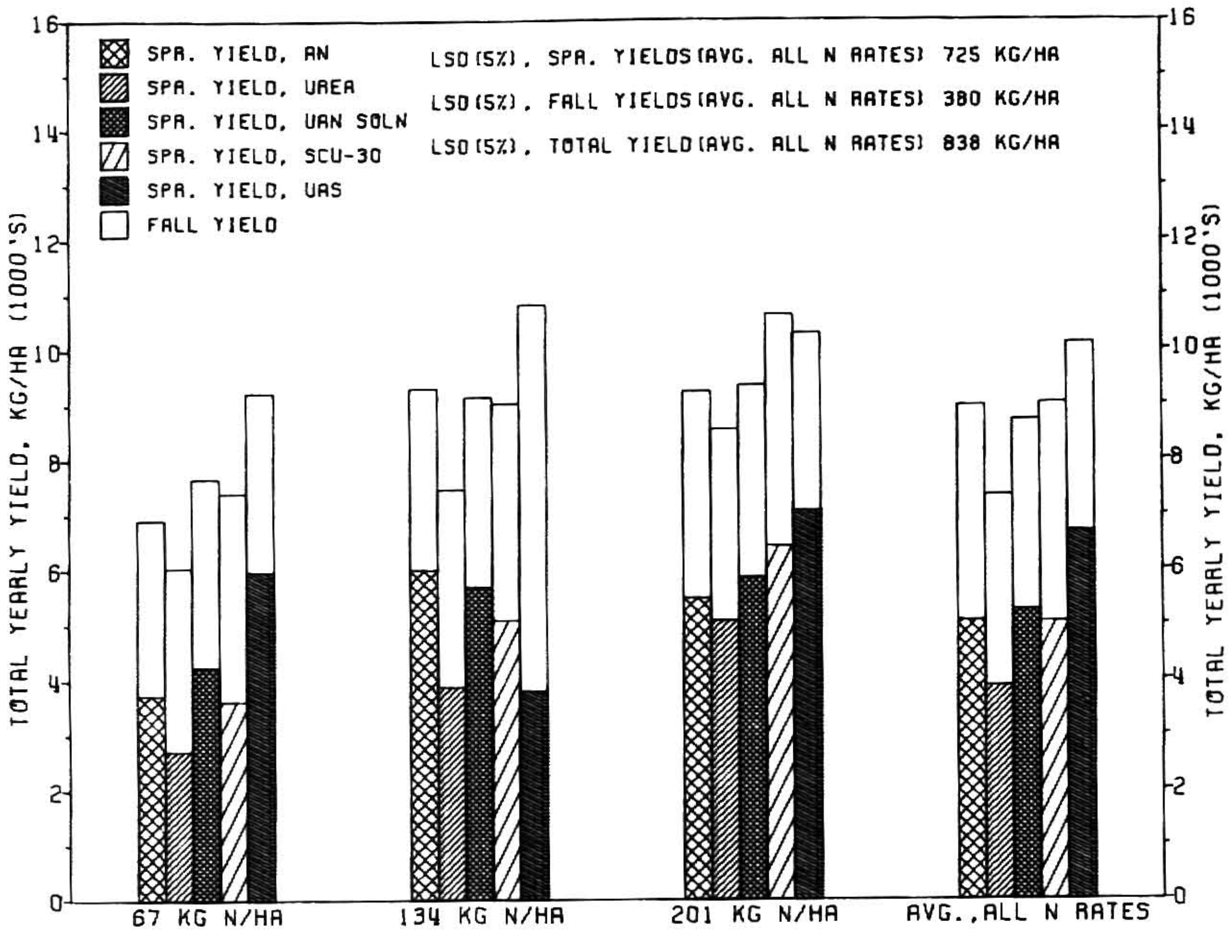


FIG. 5. SPRING, FALL, AND TOTAL YEARLY YIELD OF BROMEGRASS AS AFFECTED BY N SOURCE AND RATE, JACKSON CO., 1973. (0 N PLOT YIELDS; SPR.=2353, FALL=3578, TOTAL=5931 KG/HA).

In terms of fall forage production, the same situation was observed that existed in Riley county. SCU-30 produced significantly higher yields than all other carriers for the fall harvest (Fig. 5). On a total yearly yield basis, UAS was significantly better than all other carriers (Fig. 5), due to its very outstanding performance in the spring. No significant differences existed between ammonium nitrate, UAN solution, and SCU-30 but these carriers were significantly more effective than urea.

Nitrogen carrier effects on yield at the Franklin county site for the spring harvest of 1973 were nearly identical to those observed at Riley and Jackson counties (Fig. 6). UAS was again outstanding, being significantly better than all other carriers. There were no significant differences between the other four carriers. SCU-30 again produced the highest fall yields and was significantly better than all other carriers for fall yields (Fig. 6), substantiating the effect of slow release of N from SCU-30 resulting in more N being available for fall growth.

Total yearly yields at the Franklin county site in 1973 reflected the differences produced in the spring harvest. UAS produced the highest total yields, being significantly better than all other carriers except SCU-30. Ammonium nitrate gave the lowest total yield at this location (Fig. 6).

The Labette county site involved tall fescue rather than bromegrass and showed somewhat different carrier effects than did the other locations. Carrier effects were non-significant for the spring harvest although SCU-30 gave the top yield (Fig. 7). SCU-30 also produced the highest fall yield at Labette county in 1973, being significantly better than all other carriers. No other significant differences were noted between carriers for the fall harvest (Fig. 7). On a total yearly yield basis for 1973, SCU-30 was significantly superior to all other carriers for fescue at Labette county. No other significant

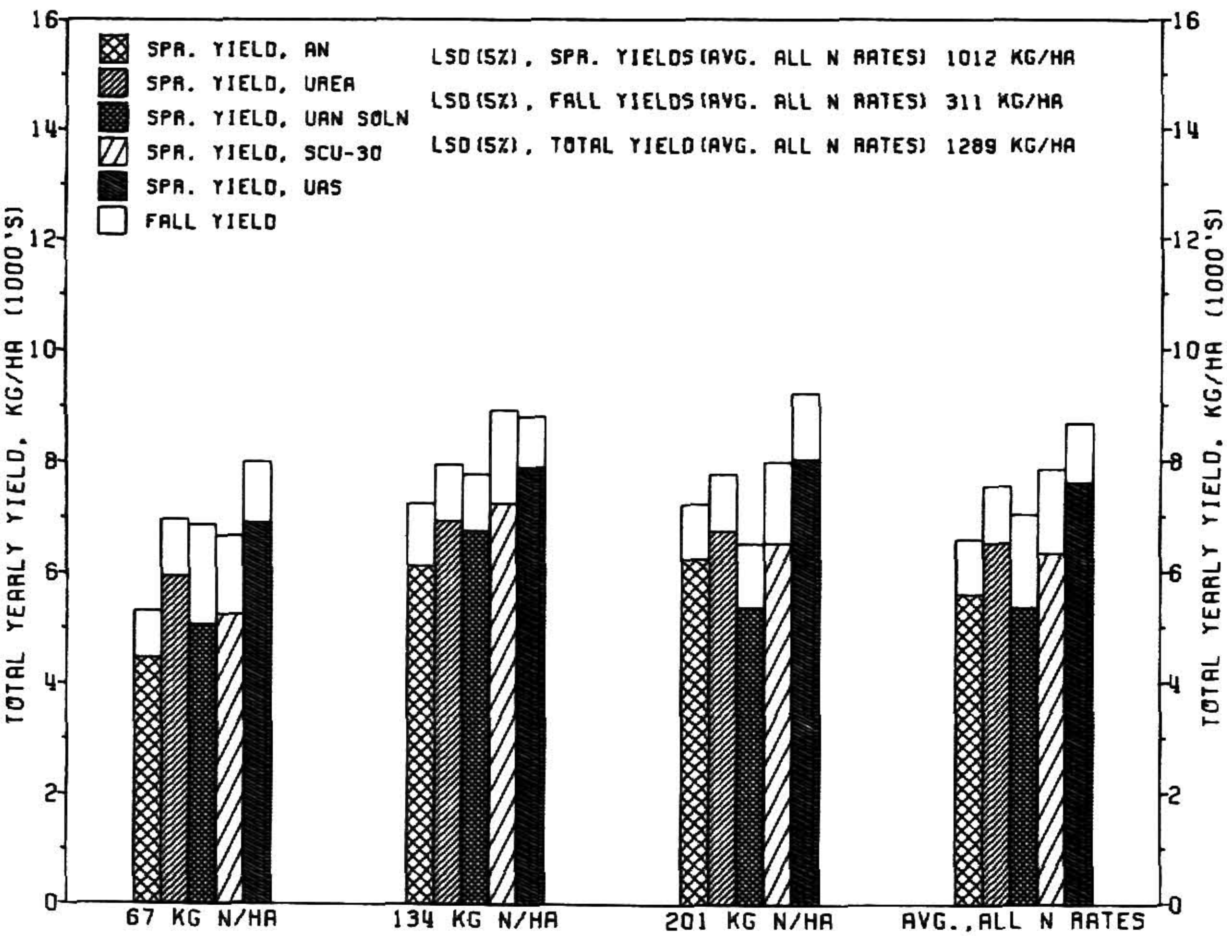


FIG. 6. SPRING, FALL, AND TOTAL YEARLY YIELD OF BROMEGRASS AS AFFECTED BY N SOURCE AND RATE, FRANKLIN CO., 1973. (0 N PLOT YIELDS; SPR.=2770, FALL=1182, TOTAL=3951 KG/HA).

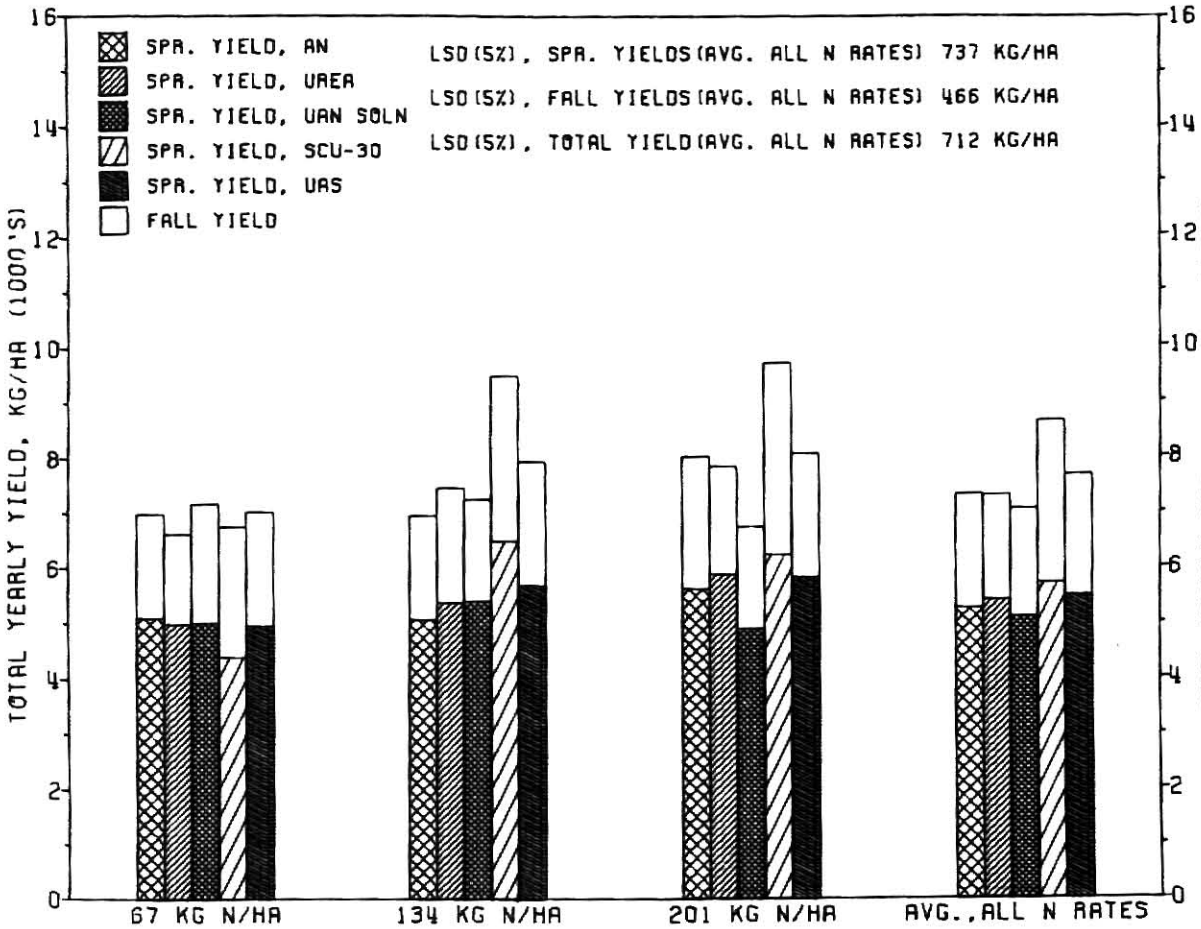


FIG. 7. SPRING, FALL, AND TOTAL YEARLY YIELD OF TALL FESCUE AS AFFECTED BY N SOURCE AND RATE, LABETTE CO., 1973. (0 N PLOT YIELDS; SPR.=4604, FALL=2290, TOTAL=6895 KG/HA).

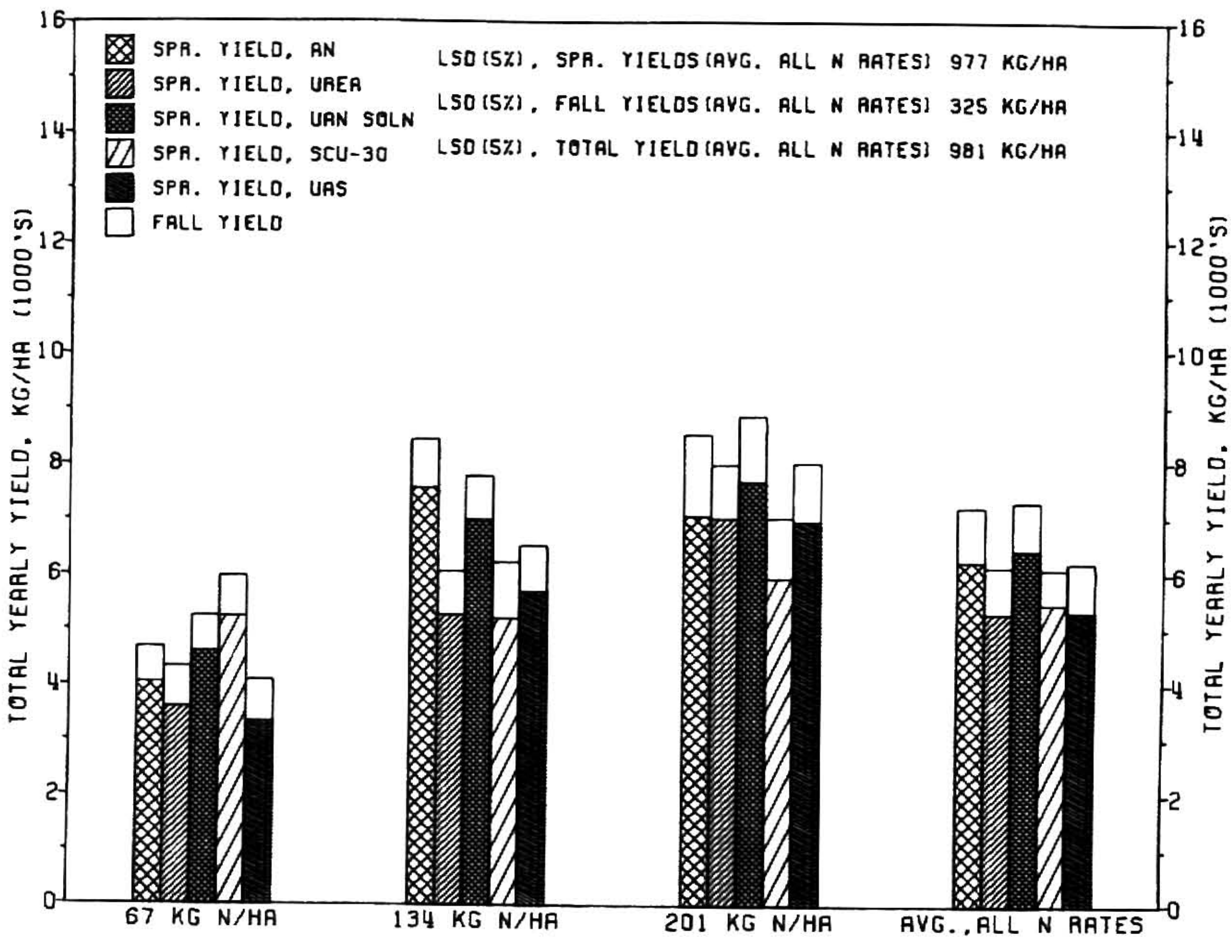


FIG. 8. SPRING, FALL, AND TOTAL YEARLY YIELD OF BROMEGRASS AS AFFECTED BY N SOURCE AND RATE, RILEY CO., 1974. (0 N PLOT YIELDS; SPR.=1654, FALL=795, TOTAL=2449 KG/HA).

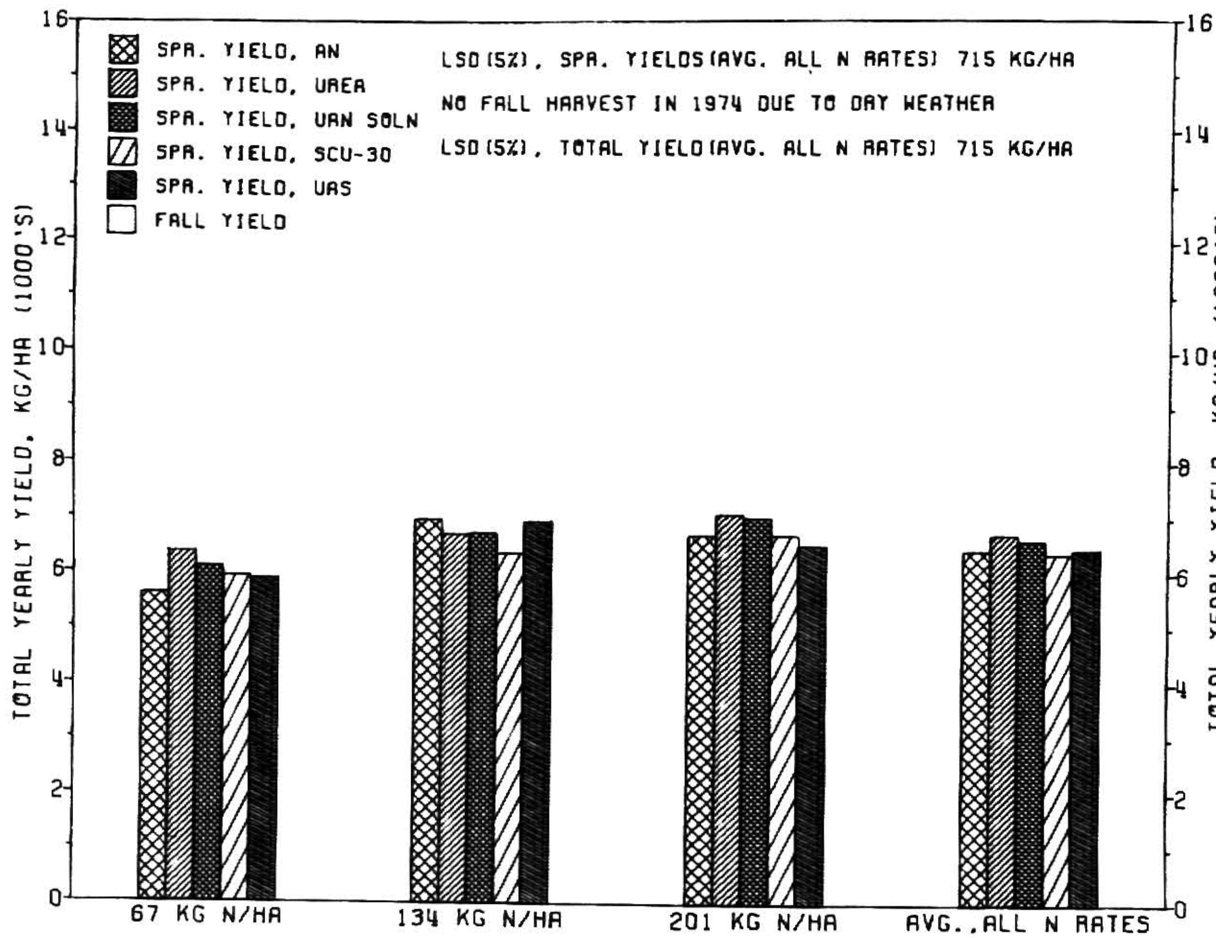


FIG. 9. SPRING, FALL, AND TOTAL YEARLY YIELD OF BROMEGRASS AS AFFECTED BY N SOURCE AND RATE, JACKSON CO., 1974. (0 N PLOT YIELDS; SPR.=4613, FALL=----, TOTAL=4613 KG/HA).

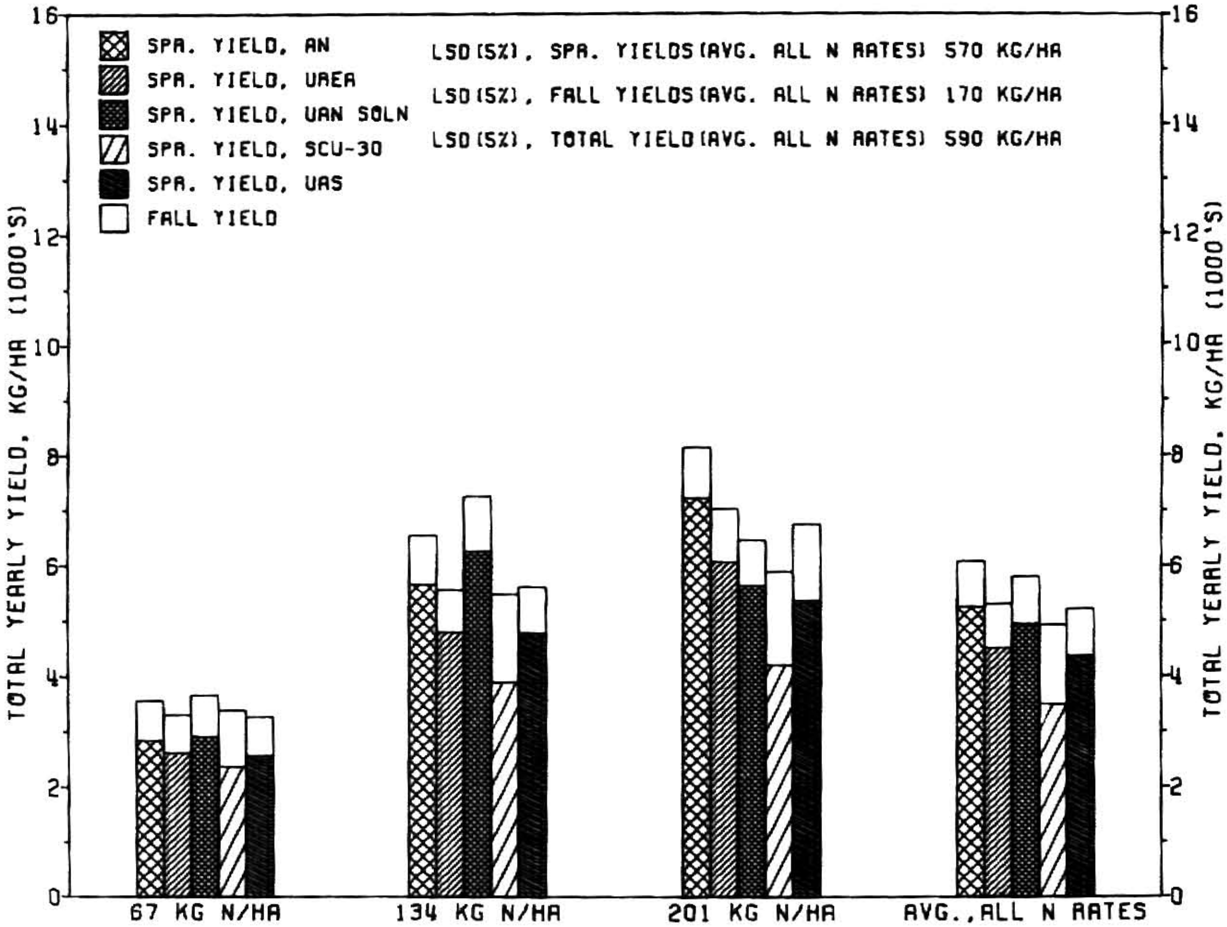


FIG. 10 SPRING, FALL, AND TOTAL YEARLY YIELD OF BROMEGRASS AS AFFECTED BY N SOURCE AND RATE, FRANKLIN CO., 1974. (0 N PLOT YIELDS; SPR.=1259, FALL= 616, TOTAL=1875 KG/HA).

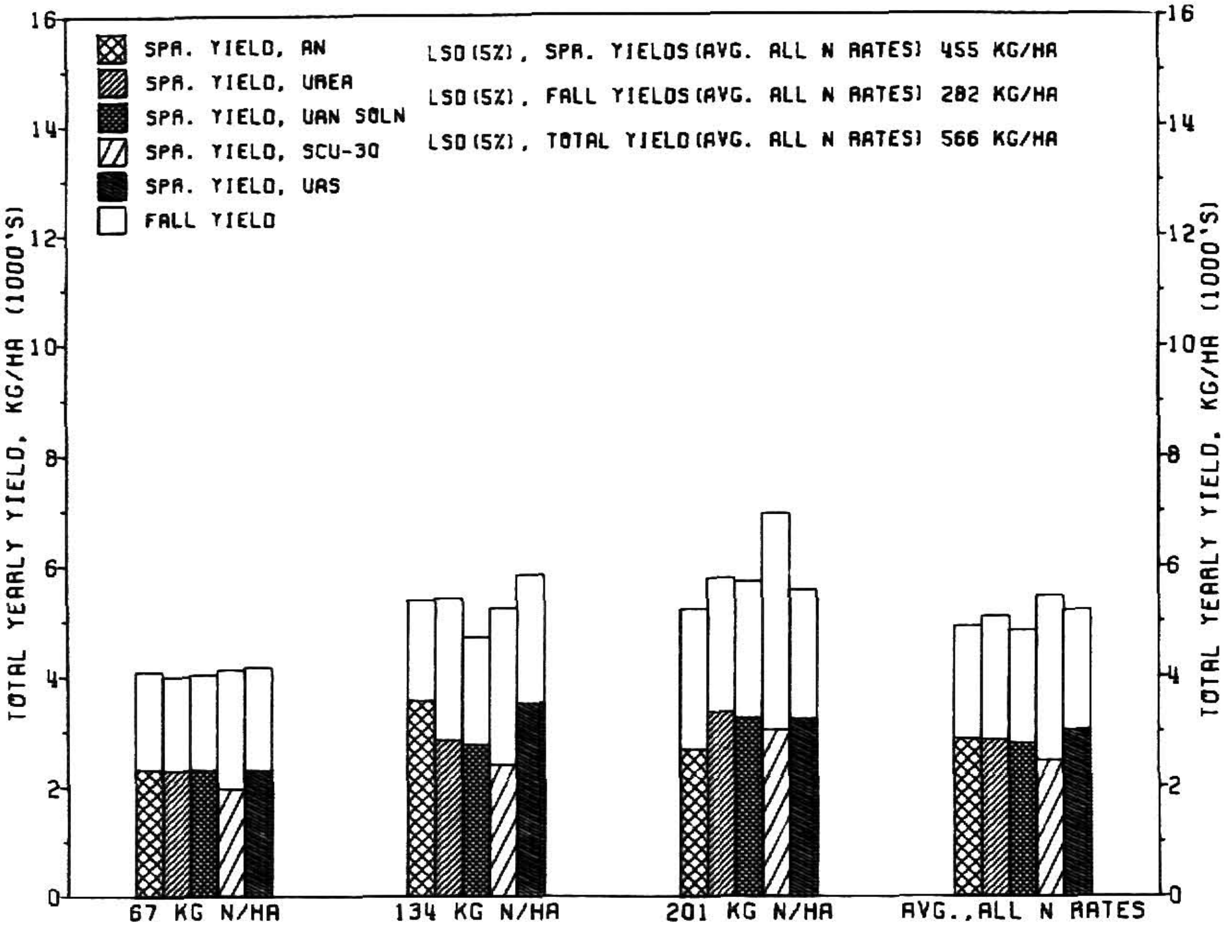


FIG. 11 SPRING, FALL, AND TOTAL YEARLY YIELD OF TALL FESCUE AS AFFECTED BY N SOURCE AND RATE, LABETTE CO., 1974. (0 N PLOT YIELDS; SPR.=1362, FALL=1882, TOTAL=3244 KG/HA).

all other treatments (Fig. 11). No other significant differences were noted. On a total yearly yield basis at Labette county in 1974, SCU-30 was significantly better than UAN solution, but no other significant differences occurred (Fig. 11).

Summarizing the effect of nitrogen carrier on yields for the two years, no clear cut superiority was established by any one carrier. UAS was outstanding in 1973, but was only average in 1974. The reason for its superiority in 1973 could be traced to a possible sulfur response as this carrier has 4% available sulfur. The cool, wet spring of 1973 would have been conducive to a sulfur response. The slow release of N from SCU-30 was also very evident both years of the study as in many cases this material was superior to all other carriers for fall harvest. Still, on a total yearly yield basis, its performance was equal to or below the other carriers in most cases.

Time of N Application Effect on Yield.

A series of split applications involving the 134 and 201 kg/ha N rates were made in late summer each year of the study. Two-thirds of the total N was applied in the spring with the remaining one-third applied in mid-August. The basis for this was to see if there was any advantage to dividing the N application over applying all the N in one single application.

Examining the effects of time of N application on yields, some predictable results were noted (Fig. 12-13). In 1973, at the Riley county site, the spring harvest produced no significant differences between spring and split applications, although the spring treatments did give higher yields than the split treatments. This is reasonable because only two-thirds of the split treatments was applied in the spring. In the case of fall yields, however, split applications produced significantly higher yields than did spring applications (Fig. 12). On a total yearly yield basis there were no significant differences

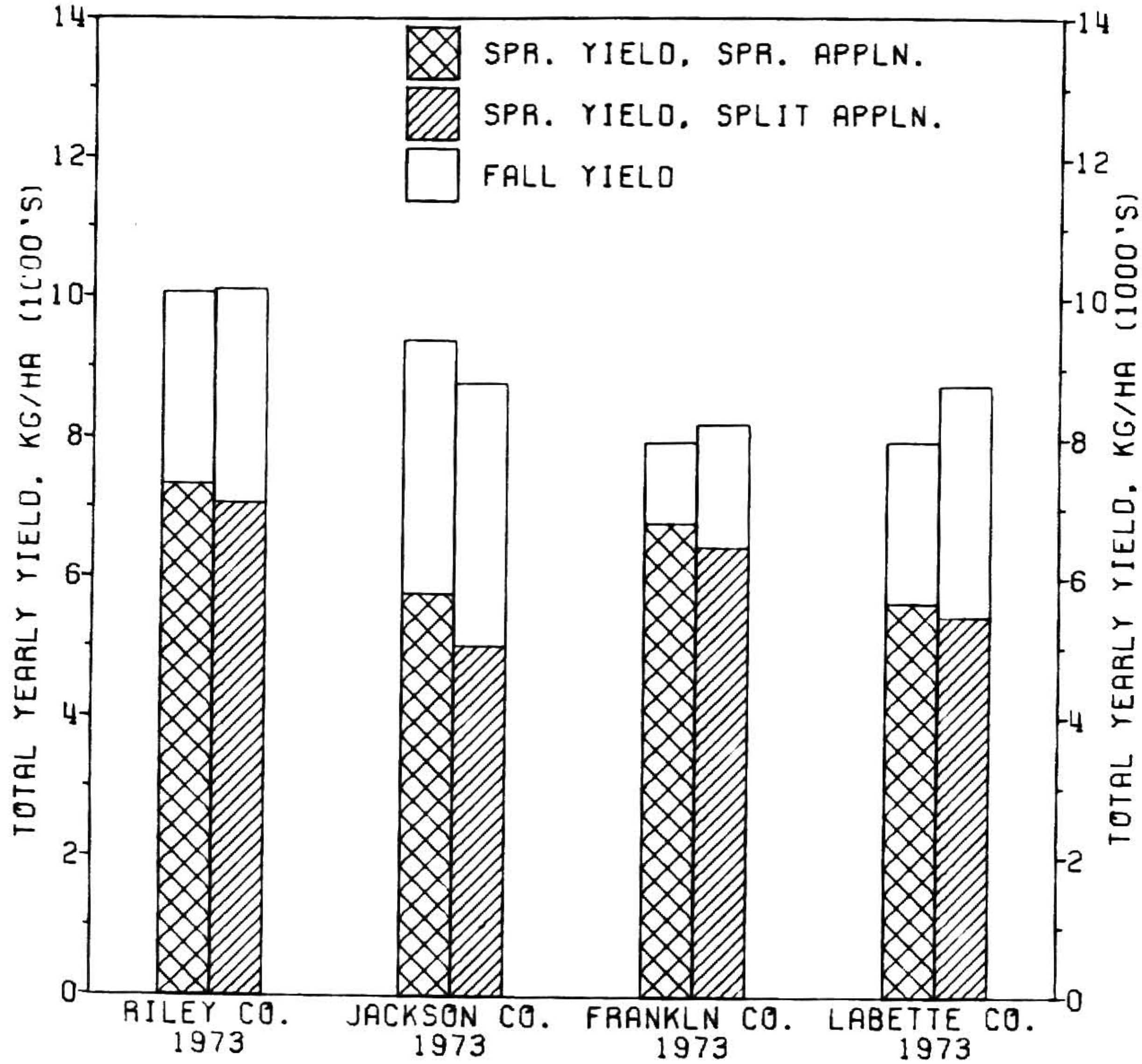


FIG. 12. EFFECTS OF TIME OF N APPLICATION ON THE SPRING, FALL, AND TOTAL YEARLY YIELD OF COOL-SEASON GRASSES. (1973)

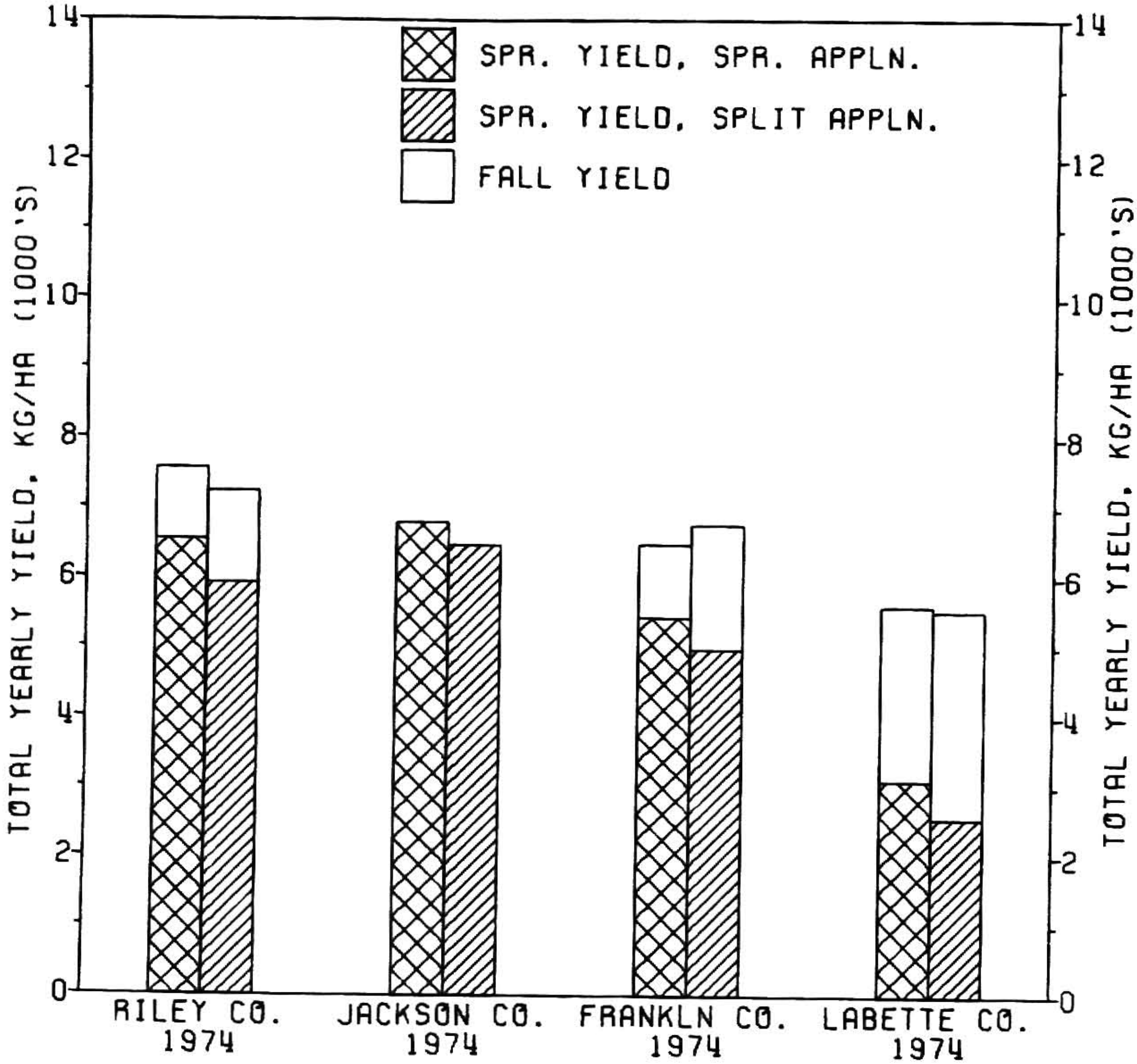


FIG. 13. EFFECTS OF TIME OF N APPLICATION ON THE SPRING, FALL, AND TOTAL YEARLY YIELD OF COOL-SEASON, GRASSES. (1974)

between times of N application.

Jackson county was the only location in 1973 to show spring applied N significantly better than split applications for spring harvest. Also, this was the only location that did not show advantages to split applications in terms of fall yield. On a total yearly yield basis spring N applications were significantly better than split applications at Jackson county (Fig. 12).

Time of N application differences were non-significant for the spring harvest at the Franklin county site in 1973. Split applications were significantly better in terms of increased fall yields but there were no significant differences between the times of N application on a total yearly yield basis.

Time of N application produced no significant differences for the spring harvest at the Labette county site in 1973. Split applications of nitrogen produced significantly higher yields than did single spring applications for both fall and total yearly yields (Fig. 12).

As the study continued into 1974 some rather consistent trends emerged (Fig. 13). At the Riley, Jackson, and Labette county locations, results with respect to time of N application were identical. Spring applications produced significantly better yields for the spring harvest, split applications produced significantly better fall yields. There were no significant differences between times of N application on a total yearly yield basis (Fig. 13).

In 1974 at Jackson county, there were no significant differences between times of N application for the spring harvest or for total yearly yield since there was no fall harvest at this site.

These results would tend to indicate no real advantage to splitting the N application as on a total yearly yield basis split applications were not significantly better than a single N application in most cases.

Effects of N Fertilization on Composition of Grass Forage.

With the initiation of this study in early 1973, bi-weekly tissue samples were begun around April 1. These samples were collected to observe the effects of stage of maturity, N source, and N rate on the crude protein content of bromegrass. This particular phase of the study was conducted at the Riley county location only.

Stage of maturity, N source, and N rate all significantly affected crude protein content both years, (Fig. 14-16), with stage of maturity having the most profound effect. In 1973, crude protein dropped from an average of 19.7% at the first sampling date to an average of 7.5% at harvest. These are values averaged over all N rates and N carriers. Similarly, in 1974 the crude protein fell from an average of 26.6% at first sampling to 12.6% at harvest. These data are presented in Fig. 14.

In both 1973 and 1974, N rate had similar effects on crude protein. Crude protein values, averaged across all sampling dates and all N carriers, ranged from 10.7% for the 67 kg N/ha rate to 14.2% for the 201 kg N/ha rate in 1973. In 1974, the values ranged from 16.2% for the 67 kg N/ha rate to 21.2% for the 201 kg N/ha rate. These data are presented in Fig. 15. The control (0 N) plots averaged 11.8% crude protein in 1973 and 13.8% in 1974. As N rates were increased in both years, crude protein percentage increased significantly with each increasing increment of N even though the 67 kg N/ha rate gave a slightly lower protein content than did the control plots in 1973.

The effect of N source on crude protein content was quite evident both years (Fig. 16). The value given for crude protein is the average for that carrier averaged over all sampling dates and all N rates. In 1973, ammonium nitrate and UAS produced significantly higher crude protein contents than did the other three carriers. SCU-30 produced significantly lower crude protein

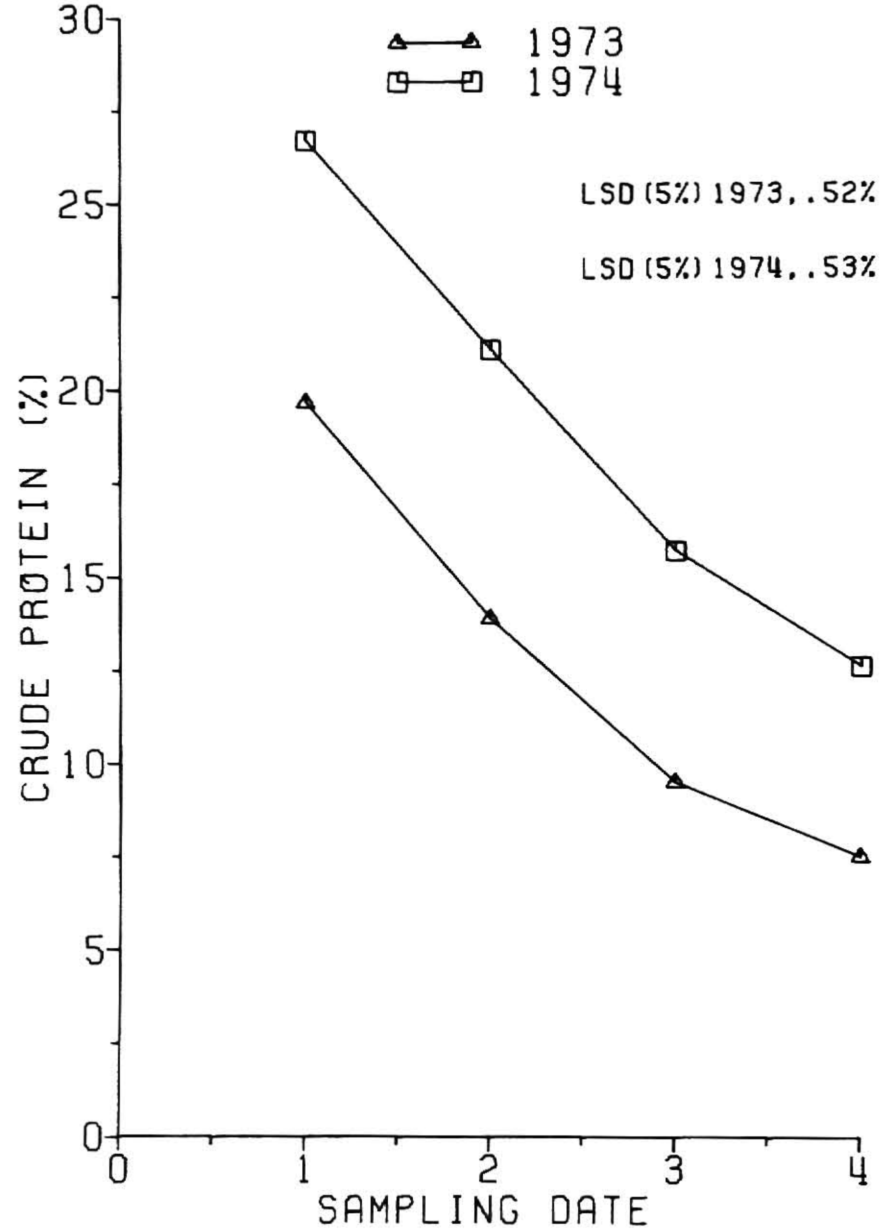


FIG. 14. EFFECTS OF SAMPLING DATE ON THE CRUDE PROTEIN CONTENT OF BROMEGRASS. (RILEY CO.)

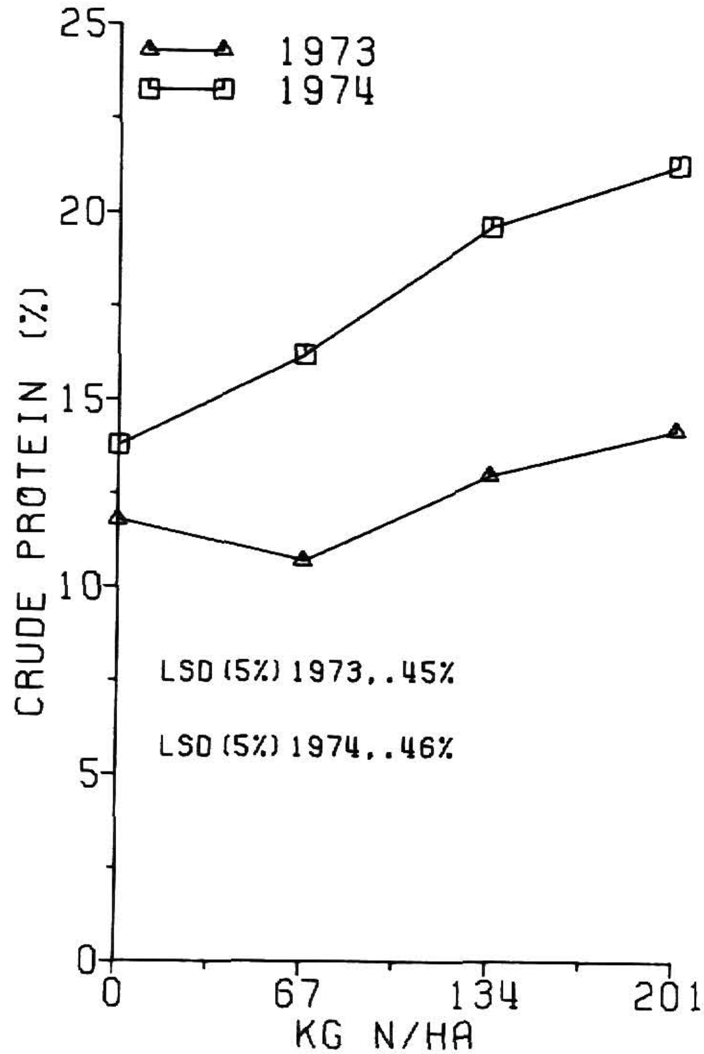


FIG. 15. EFFECTS OF N RATE ON CRUDE PROTEIN CONTENT OF BROMEGRASS. (RILEY CO.)

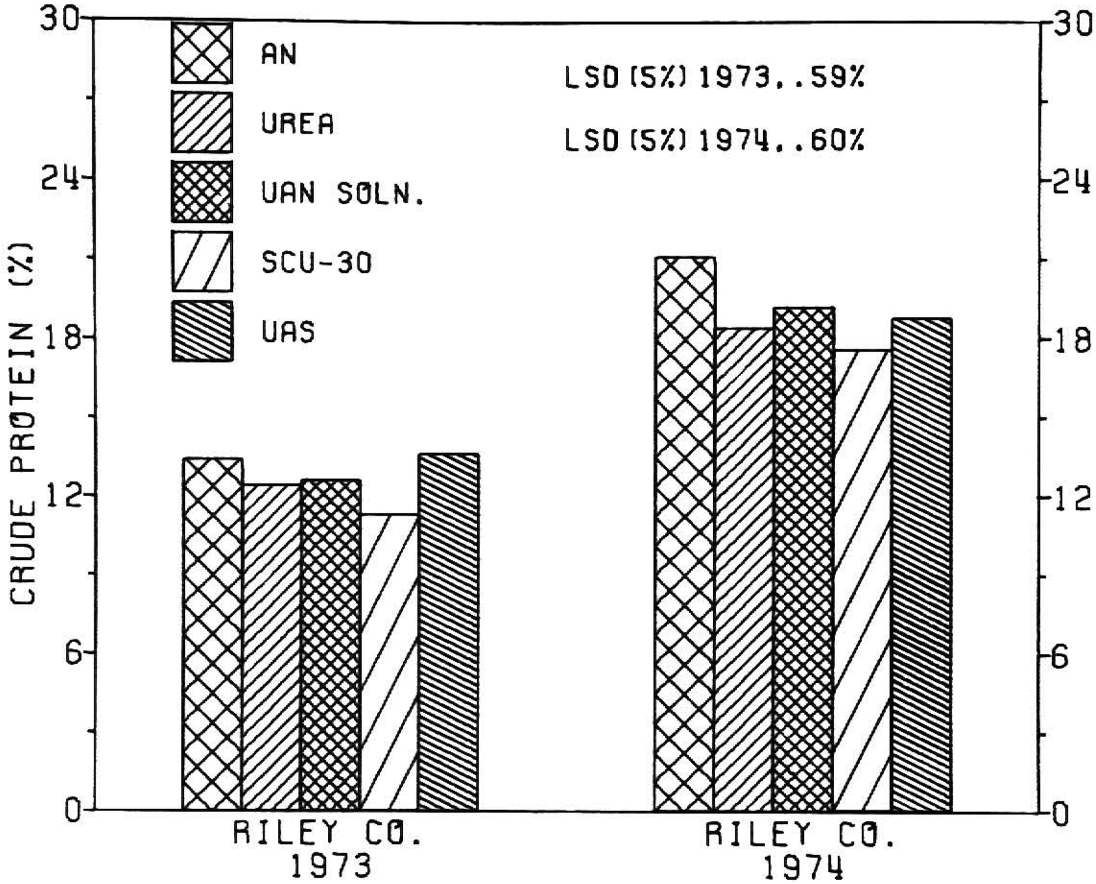


FIG. 16. EFFECTS OF N SOURCE ON CRUDE PROTEIN CONTENT OF BROMEGRASS.

levels than all other carriers (Fig. 16). These data corroborate the yield data reported earlier and emphasize the slow release of N from SCU-30.

In 1974, very similar results were noted (Fig. 16). Ammonium nitrate produced significantly higher crude protein contents than all other carriers. Urea-ammonium sulfate, UAN solution, and urea gave similar crude protein contents; SCU-30, however, continued to produce significantly lower crude protein levels than all other carriers.

The crude protein levels were generally higher in 1974 than in 1973. This is due to two key factors. First, sampling began and harvest occurred about 10 days earlier in 1974 than in 1973. Also, the yields were lower in 1974 and there was less dilution effect. Complete data concerning this crude protein study including specific LSD values are presented in Appendix Table VII.

The effects of N rate, N source, and time of N application on total inorganic N, P, and K concentrations in both spring and fall harvests of 1973 and 1974 are given in Tables 4-7. Complete information is given in Appendix Tables VII-XI.

Tables 4 (1973) and 5 (1974) compare effects of spring applied N on spring and fall harvest composition at all four locations. In 1973, nitrogen concentrations were low at all locations due to late harvest. Nitrogen rates produced no significant differences in either the spring or fall harvest nitrogen concentrations in forage at Riley county in 1973. However, in 1974, the 201 kg N/ha rate gave significantly higher N concentrations than did the other two N rates in the spring harvest and produced significantly higher N levels than did the 67 kg N/ha rate in the fall harvest.

The 201 kg/ha N rate gave significantly higher N concentrations than the 67 kg/ha N rate for spring harvest material at Jackson county in both 1973 and 1974. No significant composition differences were noted between N rates for

Table 4. Effects of N rate, N carrier, and time of N application on N concentrations of cool-season grasses. (1973).

Mean Values	Bromegrass Riley Co. Composition		Bromegrass Jackson Co. Composition		Bromegrass Franklin Co. Composition		Fescue Labette Co. Composition	
	Spring %N	Fall %N	Spring %N	Fall %N	Spring %N	Fall %N	Spring %N	Fall %N
N-Rate kg/ha 67	1.13	1.85	1.03	1.69	1.04	1.59	0.98	1.51
134	1.22	1.81	1.10	1.70	1.05	1.60	1.03	1.56
201	1.25	1.79	1.18	1.70	1.09	1.56	1.11	1.53
$LSD_{.05}$	NS[a]	NS	0.13	NS	NS	NS	0.06	NS
N-Carrier:								
AN	1.17	1.75	1.16	1.70	0.99	1.58	1.06	1.52
Urea	1.18	1.78	1.02	1.66	1.05	1.57	1.06	1.58
UAN Soln.	1.24	1.96	1.07	1.76	0.98	1.57	0.98	1.47
SCU-30	1.11	1.79	1.03	1.69	1.12	1.65	1.05	1.56
UAS	1.29	1.79	1.25	1.67	1.15	1.56	1.04	1.52
$LSD_{.05}$	0.16	0.16	0.17	NS	0.11	0.08	0.07	NS
Time of N Application:								
Spring	1.24	1.80	1.14	1.70	1.07	1.58	1.07	1.54
Split	1.15	1.94	1.06	1.85	0.99	1.70	0.98	1.77
$LSD_{.05}$	0.08	NS	NS	0.08	0.05	0.06	0.04	0.07

a/ Non-significant at 5%.

Table 5. Effects of N rate, N carrier, and time of N application on N concentrations of cool-season grasses. (1974).

Mean Values	Bromegrass Riley Co. Composition		Bromegrass Jackson Co. Composition		Bromegrass Franklin Co. Composition		Fescue Labette Co. Composition	
	Spring %N	Fall %N	Spring %N	Fall %N	Spring %N	Fall %N	Spring %N	Fall %N
N-Rate 67	1.49	1.49	1.23	a/	1.17	1.60	1.62	1.85
kg/ha 134	1.56	1.53	1.47		1.17	1.56	1.79	1.80
201	1.73	1.60	1.57		1.14	1.52	1.88	1.81
$LSD_{.05}$	0.14	0.09	0.15		NS	NS	0.10	NS
N-Carrier:								
AN	1.80	1.55	1.51		1.06	1.53	1.82	1.83
Urea	1.57	1.52	1.31		1.21	1.53	1.78	1.82
UAN Soln.	1.56	1.53	1.41		1.08	1.54	1.63	1.81
SCU-30	1.49	1.65	1.36		1.32	1.67	1.75	1.87
UAS	1.53	1.46	1.53		1.11	1.52	1.81	1.77
$LSD_{.05}$	0.18	0.11	0.19		0.10	0.10	0.13	NS
Time of N Application:								
Spring	1.64	1.57	1.52		1.15	1.54	1.83	1.81
Split	1.53	1.77	1.46		1.13	1.64	1.67	2.03
$LSD_{.05}$	0.09	0.06	NS		NS	0.05	0.08	0.06

a/ No fall harvest at Jackson Co. due to extremely dry conditions.

fall harvested forage in 1973 at Jackson county.

Non-significant differences were recorded at Franklin county both years of the study. Nitrogen rate effects on N concentrations in the forage were non-significant in both the spring and fall harvested material.

In 1973 at Labette county, the 201 kg N/ha rate produced a significantly higher nitrogen concentration in the fescue forage in the spring harvest material. The same trend was noted in 1974 but the 201 kg N/ha rate was superior only to the 67 kg N/ha rate in increasing N content. No significant differences between N rates were noted in the fall harvested forage at Labette county in either year of the study.

Some rather consistent trends were noted in terms of the effect of N carrier on the composition of the harvested forage in 1973 (Table 4). In the case of spring harvest, UAS produced the highest N concentrations in the forage at the Riley, Jackson, and Franklin county sites. However, it was significantly better than only SCU-30 at Riley county; SCU-30, UAN solution, and urea at Jackson county; and ammonium nitrate and UAN solution at Franklin county. These results parallel the yield responses to UAS in 1973.

In Labette county (1973), ammonium nitrate, urea, and SCU-30 produced significantly higher N concentrations than did UAN solution for spring harvested material. For fall harvest material, UAN solution produced significantly higher N content in the forage than did any other carrier in Riley county. In Franklin county, SCU-30 produced significantly higher N concentrations than did UAS for fall harvest with no other differences noted. There were no significant differences between N carriers with respect to N concentrations at Jackson and Labette counties for fall harvest material in 1973.

Somewhat variable carrier effects appeared in 1974. At the Riley county site, ammonium nitrate produced significantly higher plant concentrations of

N than did all other carriers for spring harvest material with no other significant differences noted. At Jackson county, urea gave the lowest N concentrations but was significantly lower than only ammonium nitrate and UAS. At the Franklin county location, SCU-30 produced significantly higher N concentrations than did all other N carriers for spring harvest material, while at the Labette county site, ammonium nitrate, urea, and UAS induced highest N concentrations but these were only significantly higher than UAN solution.

For fall harvested forage in 1974, SCU-30 gave significantly higher N concentrations than all other carriers except ammonium nitrate at the Riley county site. SCU-30 also produced significantly higher N concentrations in the fall harvested material in Franklin county. No significant differences were evident at the Labette county location.

Comparisons of the effects of time of N application as related to N concentrations are shown in Table 4 (1973) and Table 5 (1974). The values given are averaged across the two highest N rates and all N carriers. Spring applications gave significantly higher N concentrations in spring harvested material at the Riley, Franklin, and Labette county sites in 1973. Split applications (one-third N applied in late summer) gave significantly higher N concentrations in fall harvested material at all locations in 1973.

Spring applied N produced significantly higher N concentrations at the Riley and Labette county sites in the 1974 spring harvest but no significant differences between times of N application appeared at the Jackson and Franklin county sites. Split applications resulted in significantly higher N concentrations in fall harvested material at the Riley, Franklin, and Labette county sites in 1974.

In summary, spring applications of N generally gave higher N concentrations in spring harvested material; split applications gave higher N concentrations in fall harvested forage. Nitrogen concentration effects followed the same general trend as did spring and fall yields with respect to time of N application.

Generally, effects of N rate, N source, and time of N application on P and K concentrations were slight. Tables 6 (1973) and 7 (1974) indicate the nature of the P and K data compiled during the two year study.

Nitrogen rate effects on P concentrations in 1973 were non-significant at all locations for both spring and fall harvested forage. The same general effect was true in 1974 except for the spring harvested forage in Riley county where the 134 kg N/ha rate produced significantly higher P content than the 201 kg N/ha rate, and for the fall harvested forage in Labette county where the 67 kg N/ha rate produced significantly higher P content than the 134 kg N/ha rate which was in turn significantly higher than the 201 kg N/ha rate.

Nitrogen source effects on P concentrations were non-significant for both spring and fall harvested material at all locations in 1973, and at the Riley county site in 1974. At the Jackson county site, ammonium nitrate and UAN solution produced significantly higher P concentrations than other carriers for spring harvested material in 1974. Ammonium nitrate produced significantly lower P concentrations than urea and SCU-30 for spring harvested forage and urea, SCU-30, and UAS for fall harvested forage at the Franklin county location. In Labette county, ammonium nitrate and SCU-30 produced significantly higher P concentrations than the other carriers for spring harvested material in 1974. No significant differences were noted in P content of fall harvested forage in Labette county.

Time of N application effects on P concentrations were almost always non-significant. The only significant effect occurred at the Franklin county site in 1973. Split N applications produced significantly higher P concentrations

Table 6. Effects of N rate, N carrier, and time of N application on P and K concentrations in cool-season grasses. (1973).

Mean Values	Bromegrass Riley Co. Composition Spring %P	%K	Fall %P	%K	Bromegrass Jackson Co. Composition Spring %P	%K	Fall %P	%K	Bromegrass Franklin Co. Composition Spring %P	%K	Fall %P	%K	Fescue Labette Co. Composition Spring %P	%K	Fall %P	%K
N-Rate kg/ha 67	.23	2.09	.31	1.92	.13	1.29	.15	1.27	.21	1.34	.24	1.34	.23	2.07	.27	1.47
134	.23	2.36	.30	1.81	.13	1.13	.15	1.12	.21	1.21	.25	1.20	.23	1.88	.27	1.48
201	.23	2.33	.29	2.00	.12	1.05	.15	1.10	.21	1.22	.24	1.19	.23	2.05	.26	1.37
$LSD_{.05}$	NS	0.17	NS	NS	NS	0.13	NS	NS	NS	NS	NS	NS	NS	0.11	NS	NS
N-Carrier:																
AN	.24	2.30	.30	1.78	.13	1.17	.15	1.08	.21	1.26	.25	1.27	.23	1.96	.27	1.37
Urea	.23	2.25	.30	2.05	.13	1.26	.15	1.27	.21	1.26	.24	1.26	.23	1.95	.27	1.53
UAN Soln.	.23	2.30	.30	1.94	.13	1.17	.15	1.08	.21	1.35	.24	1.31	.23	2.04	.26	1.55
SCU-30	.23	2.13	.31	1.96	.13	1.15	.15	1.15	.21	1.30	.25	1.18	.23	2.07	.26	1.29
UAS	.22	2.31	.31	1.83	.12	1.04	.15	1.24	.21	1.11	.25	1.21	.23	1.97	.27	1.45
$LSD_{.05}$	NS	NS	NS	NS	NS	0.16	NS	NS	NS	0.16	NS	NS	NS	NS	NS	NS
Time of N Application:																
Spring	.23	2.35	.30	1.91	.12	1.09	.15	1.11	.21	1.21	.25	1.19	.23	1.97	.26	1.43
Split	.22	2.21	.31	2.18	.13	1.21	.15	1.31	.20	1.17	.27	1.25	.23	1.95	.27	1.30
$LSD_{.05}$	NS	0.11	NS	0.19	NS	0.09	NS	0.16	NS	NS	.01	NS	NS	NS	NS	NS

Table 7. Effects of N rate, N carrier, and time of N application on P and K concentrations in cool-season grasses. (1974).

Mean Values	Bromegrass Riley Co. Composition				Bromegrass Jackson Co. Composition				Bromegrass Franklin Co. Composition				Fescue Labette Co. Composition			
	Spring		Fall		Spring		Fall		Spring		Fall		Spring		Fall	
	%P	%K	%P	%K	%P	%K	%P	%K	%P	%K	%P	%K	%P	%K	%P	%K
N-Rate 67	.27	1.64	.22	1.35	.16	1.06	a/		.24	1.62	.22	1.38	.30	2.16	.38	1.95
kg/ha 134	.28	1.65	.22	1.56	.16	0.94			.23	1.35	.22	1.38	.29	2.05	.36	1.75
201	.26	1.73	.22	1.62	.16	0.90			.23	1.30	.24	1.41	.29	2.10	.34	1.88
$LSD_{.05}$	.01	NS	NS	0.22	NS	NS			NS	0.12	NS	NS	NS	NS	.01	0.15
N-Carrier:																
AN	.27	1.77	.22	1.52	.18	0.98			.22	1.34	.21	1.33	.31	2.20	.35	1.91
Urea	.26	1.53	.22	1.50	.15	0.94			.24	1.58	.23	1.35	.29	2.12	.36	1.88
UAN Soln.	.26	1.69	.21	1.50	.17	0.98			.23	1.35	.22	1.41	.27	1.99	.36	1.84
SCU-30	.26	1.73	.23	1.64	.15	0.95			.25	1.51	.24	1.51	.31	2.20	.35	1.84
UAS	.26	1.64	.22	1.38	.16	0.99			.23	1.34	.23	1.34	.28	2.12	.36	1.84
$LSD_{.05}$	NS	NS	NS	NS	.02	NS			.02	0.15	.02	0.17	.02	NS	NS	NS
Time of N Application:																
Spring	.26	1.69	.22	1.59	.16	0.92			.23	1.33	.23	1.39	.29	2.07	.35	1.82
Split	.26	1.60	.23	1.77	.16	1.00			.24	1.39	.25	1.46	.30	2.07	.35	2.02
$LSD_{.05}$	NS	NS	NS	0.16	NS	NS			NS	NS	NS	NS	NS	NS	NS	0.12

a/ No fall harvest at Jackson Co. due to extremely dry conditions.

than did spring applications in the fall harvested material.

The effects of N rate, N source, and time of N application on K concentrations were quite varied both years of the study. Generally, the addition of N fertilizer at any of the three rates tended to depress K concentrations in the forage. Differences between the K concentrations produced by the three rates of N applied varied from location to location both years of the study.

No real trends were established with respect to the effects of N carrier on the K concentration of the forage. UAS produced relatively low K concentrations for spring harvested material in 1973. This was probably due to a dilution effect as UAS produced superior yields in 1973. However, in most cases there were no significant differences between N carriers with respect to potassium concentration of the forage. This held true for both spring and fall harvested material in 1973 and 1974.

Time of N application had very little effect on K concentrations either in 1973 or 1974. No clear trends were established in either spring or fall harvested material.

As noted earlier, bi-weekly forage samples were collected from about April 1 up to harvest at Riley county in 1973 and 1974 to examine the effects of stage of maturity on the crude protein content of the forage. In 1973, these samples were also analyzed for Ca, Mg, and K concentrations in order to determine the K/Ca+Mg ratio, and to determine if that ratio was affected by N rate and N source. Results of this investigation are reported in Table 8.

Results indicate that neither N rate nor N source had any significant effect on the Ca or Mg concentrations of bromegrass. N rate did affect the K concentration and thus the K/Ca+Mg ratio. The higher N rates produced higher K/Ca+Mg ratios than did the low (67 kg/ha) N rate and the 0 N plots, especially at the earlier sampling dates. N source had little effect on the K/Ca+Mg ratio.

Table 8. Effects of N rate, N carrier, and sampling date on Ca, Mg, and K concentrations and the K/Ca+Mg ratio of bromegrass. Riley Co., 1973.

Mean Values		Forage Sampling Date											
		April 24 Composition				May 8 Composition				May 21 Composition			
		%Ca	%Mg	%K	K/Ca+Mg[a]	%Ca	%Mg	%K	K/Ca+Mg	%Ca	%Mg	%K	K/Ca+Mg
N-Rate kg/ha	67	.300	.106	2.32	2.5	.261	.102	2.39	2.8	.216	.079	1.82	2.7
	134	.292	.106	2.55	2.8	.260	.111	2.75	3.2	.235	.090	2.18	2.9
	201	.295	.112	2.67	2.8	.259	.112	2.80	3.3	.251	.095	2.44	3.1
$LSD_{.05}$		NS	NS	0.30	0.1	NS	NS	0.32	0.1	NS	NS	0.30	0.1
N-Carrier:													
AN		.292	.111	2.65	2.9	.257	.110	3.13	3.4	.240	.093	2.30	3.0
Urea		.292	.110	2.46	2.7	.264	.109	2.59	3.0	.247	.090	2.23	2.9
UAN Soln.		.301	.108	2.51	2.7	.259	.109	2.68	3.2	.223	.083	2.08	2.9
SCU-30		.308	.106	2.37	2.5	.264	.110	2.57	2.9	.220	.086	1.92	2.7
UAS		.284	.107	2.58	2.8	.258	.106	2.59	3.1	.239	.089	2.25	3.0
$LSD_{.05}$		NS	NS	0.25	NS	NS	NS	0.38	NS	NS	NS	0.32	NS

a/ K/Ca Mg ratio was calculated using meq.

Kemp and 'T Hart (1957) proposed that forage with a K/Ca+Mg ratio of greater than 2.2 may be prone to production of grass tetany in animals consuming the forage. This level was often exceeded during the bi-weekly sampling period in 1973 at the Riley county location, but it should be noted that forage from the 0 N plots had nearly as high a K/Ca+Mg ratio as did the fertilized plots (Appendix Table XII). The high K/Ca+Mg ratios cannot be blamed on N fertilization alone, although N fertilization did generally increase this ratio (Table 8).

Effects of N Fertilization on Soil N Concentrations.

The slow-release properties of SCU-30 allow for the possible accumulation of residual N in the soil. To examine this possibility, soil samples were collected in Riley county in late winter of 1974 to see if any residual N had accumulated from the SCU-30 treatments. Results of this study are presented in Table 9.

Analyses from the 0-15 cm and the 15-60 cm depths show no significant difference in the NO_3-N content in ammonium nitrate and SCU-30 treated plots. This, at least, suggests no difference in residual soil N resulting from the use of the slow-release N material, SCU-30. Complete information on this phase of the study is presented in Appendix Table XIII.

Table 9. Effects of SCU-30 on residual soil N. Riley Co., 1974.

N-Carrier	NO_3-N ppm Depth cm 0-15	15-60
AN	8.68[a]	4.68
SCU-30	8.30	5.07
$LSD_{.05}$	NS	NS

[a] Mean values over three N rates.

CONCLUSIONS

Results of this investigation confirms earlier reports of excellent bromegrass and tall fescue yield responses to applications of nitrogen fertilizer. This study showed that in all but one instance, N applications up to 201 kg N/ha gave increased yields. Based on results obtained, it would appear, however, that the 134 kg N/ha rate of N is nearer the economically feasible level in terms of cost of applied N versus increase in forage yield. In this respect, this study has served as a basis for an economic analysis of bromegrass and fescue responses to N authored by Orazem, Whitney, and Murphy (1975).

Effects of nitrogen carriers on yield were variable and did not point out a superiority or inferiority of any one carrier. Urea-ammonium sulfate was outstanding in 1973, but only average in performance in 1974. This was very possibly due to a sulfur response as this material contains 4% available sulfur. Conditions in the spring of 1973 were favorable for a sulfur response to show —cold and wet. In 1974, conditions were not favorable for a sulfur response to show and UAS was only average in performance. SCU-30 performed well on tall fescue in Labette county but was generally the poorest performer on bromegrass. The slow-release of N from SCU-30 was evident as this material gave consistently lower yields in the spring and higher yields in the fall. On a total yearly yield basis this material was, at best, average. It would appear that SCU-30 has very little value as N fertilizer for cool-season grasses in this area. The extra cost of this material over conventional N carriers was not justified by its performance in this study.

The allegations that urea and UAN solutions are uncertain performers as sources of N for cool-season grasses were not substantiated by this study. Urea and UAN solutions performed about as well as any other carrier. This is accentuated by the fact that each one of the five carriers gave the highest yield sometime during the study.

Sampling date (stage of maturity), N rate, and N carrier all affected crude protein content for a series of bi-weekly samples collected during the spring growing season. As the plants matured, protein levels declined. As N rate increased, crude protein levels increased. Ammonium nitrate tended to give the highest protein content among the carriers, while SCU-30 gave significantly lower crude protein contents.

N rate effects on the composition of the forage at harvest were generally non-significant, even for N concentration, and thus protein content. But, with the increase in yield due to N fertilization the total protein produced per acre was much greater for the fertilized than for the control (0 N) plots. N rate seldom affected P concentration, and although K concentrations were affected in several cases, the effect was quite varied.

N carrier effects on composition, notably N content, paralleled yield data. Carriers giving higher yields generally gave higher N concentrations. N carrier effects on P and K concentrations were almost always negligible.

Time of N application effects on N concentrations closely followed yield data. Spring applications gave higher N levels in the spring; split applications gave higher N levels in the fall. The effect of time of N application on P and K content were generally non-significant.

Neither N rate nor N source had any effect on the Ca or Mg concentrations of forage sampled during the spring growth period. N rate did effect K concentrations and thus the K/Ca+Mg ratio. Higher N rates produced higher K/Ca+Mg ratios. N carrier effect on the K/Ca+Mg ratio was non-significant.

Results indicate little, if any, difference in residual N resulting from applications of SCU-30 and ammonium nitrate.

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APPENDIX

Table I. Climatological data, average temperature. (°C)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Avg.	Departure from normal
1973														
Manhattan, Riley Co.	-1.9[a]	- .17	8.6	11.8	17.2	24.6	25.9	26.3	19.7	16.4	7.8	-0.8	13.1	-0.1
Holton, Jackson Co.	-2.9	0.6	8.1	11.7	17.0	23.9	24.7	24.9	19.1	15.4	7.2	-1.4	12.3	1.9
Ottawa, Franklin Co.	-1.6	1.4	9.4	11.9	18.3	24.5	26.5	26.2	20.9	17.4	9.6	0.8	13.8	0.3
Parsons, Labette Co.	-0.2	1.8	11.1	12.5	18.0	24.3	26.9	25.7	21.3	17.8	10.6	2.5	14.4	0.8
1974														
Manhattan, Riley Co.	-3.6	3.3	9.0	14.0	19.9	22.1	28.7	23.4	17.3	15.3[b]			14.9	0.2
Holton, Jackson Co.	-4.7	2.1	8.3	13.8	19.0	21.3	27.6	22.9	16.7	14.1			14.1	-0.2
Ottawa, Franklin Co.	-2.7	4.2	9.5	15.0	20.7	22.8	28.6	23.7	16.9	15.3			15.4	0.3
Parsons, Labette Co.	-0.9	5.8	11.2	15.5	21.6	22.4	29.2	24.8	16.9	15.8			16.2	-0.7

a/ These data were taken from the Environmental Science Services Administration, U. S. Department of Commerce annual summaries of Kansas.

b/ Data for 1974 through October only, yearly average and departure figures based on data through October.

Table II. Climatological data, total precipitation. (cm.)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Annual	Departure from normal
1973														
Manhattan, Riley Co.	4.6[a]	5.2	18.8	5.2	15.8	7.3	15.0	5.8	25.1	16.5	2.9	8.6	130.8	49.5
Holton, Jackson Co.	4.0	6.0	16.9	6.1	13.0	5.8	15.6	18.5	29.7	23.5	4.8	8.9	152.2	68.4
Ottawa, Franklin Co.	7.1	3.0	25.8	8.0	19.5	8.0	16.3	1.4	27.9	13.1	5.5	7.9	143.3	47.1
Parsons, Labette Co.	11.3	5.1	26.4	11.1	10.8	5.0	7.6	2.2	34.3	10.1	10.4	10.9	142.9	41.1
1974														
Manhattan, Riley Co.	1.5	1.6	3.5	14.3	5.5	14.8	6.6	7.4	4.1	10.1[b]			69.4	-10.4
Holton, Jackson Co.	3.0	1.4	3.2	10.3	6.1	9.4	5.5	5.8	3.4	9.4			57.5	-25.6
Ottawa, Franklin Co.	2.8	3.1	4.3	8.4	8.7	8.6	2.2	19.1	9.1	12.4			78.7	-15.4
Parsons, Labette Co.	3.9	4.9	20.1	7.6	12.0	12.4	1.4	17.3	15.8	12.9			108.3	15.5

a/ These data were taken from the Environmental Science Services Administration, U. S. Department of Commerce annual summaries of Kansas.

b/ Data for 1974 through October only, total and departure figures are based on data through October only.

Table III. Effects of N rate and N carrier on the yield of cool-season grasses. (1973).

Nitrogen kg/ha	Nitrogen Carrier	Bromegrass Riley Co. Forage Yield, kg/ha[a] Spr.	Fall	Total	Bromegrass Jackson Co. Forage Yield, kg/ha Spr.	Fall	Total
0	-----	2371	1434	3804	2353	3587	5931
67	AN[b]	5690	3432	9121	3728	3191	6920
134	AN	7435	2939	10374	6000	3307	9307
201	AN	8124	2672	10797	5494	3764	9258
67	Urea	4962	1959	6919	2705	3336	6042
134	Urea	5900	2555	8455	3865	3601	7466
201	Urea	8337	3016	11353	5087	3479	8566
67	UAN Soln.	6251	1312	7562	4244	3425	7668
134	UAN Soln.	7071	1493	8564	5688	3463	9152
201	UAN Soln.	7489	2268	9757	5873	3493	9367
67	SCU-30	4089	2970	7059	3620	3781	7401
134	SCU-30	5105	3297	8402	5083	3949	9032
201	SCU-30	6785	3711	10497	6439	4218	10657
67	UAS	4292	1449	5741	5970	3256	9225
134	UAS	8200	2769	10968	7040	3795	10835
201	UAS	8823	2560	11383	7085	3233	10319
Treatment $LSD_{.05}$		1570	1336	2996	1279	665	1553
Mean Values:							
N Rate	67	5057	2224	7281	4053	3398	7451
	134	6742	2611	9353	5535	3623	9158
	201	7912	2845	10758	5995	3638	9633
	$LSD_{.05}$	726	610	970	561	NS	648
N Carrier							
AN		7083	3015	10097	5074	3422	8995
Urea		6400	2510	8910	3885	3472	7357
UAN Soln.		6937	1691	8628	5268	3461	8728
SCU-30		5327	3326	8652	5047	3983	9031
UAS		7104	2259	9364	6698	3428	10126
	$LSD_{.05}$	937	787	1252	725	380	838

a/ Yields were computed at 12.5% moisture.

b/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate.

Table III (Cont.). Effects of N rate and N carrier on the yield of cool-season grasses. (1973).

Nitrogen kg/ha	Nitrogen Carrier	Bromegrass Franklin Co. Forage Yield, kg/ha[a]			Fescue Labette Co. Forage Yield, kg/ha		
		Spr.	Fall	Total	Spr.	Fall	Total
0	-----	2770	1182	3951	4604	2290	6895
67	AN[b]	4464	849	5313	5093	1898	6991
134	AN	6122	1136	7258	5071	1900	6972
201	AN	6252	996	7249	5628	2401	8029
67	Urea	5944	1018	6963	4981	1642	6624
134	Urea	6943	1017	7960	5382	2098	7479
201	Urea	6749	1035	7784	5882	1959	7841
67	UAN Soln.	5064	859	6878	5008	2178	7186
134	UAN Soln.	6756	1032	7787	5408	1858	7267
201	UAN Soln.	5374	1147	6522	4889	1860	6749
67	SCU-30	5249	1417	6665	4393	2370	6764
134	SCU-30	7259	1686	8944	6503	2986	9490
201	SCU-30	6535	1457	7999	6244	3475	9719
67	UAS	6906	1096	8004	4958	2082	7040
134	UAS	7904	923	8827	5688	2253	7941
201	UAS	8054	1184	9238	5832	2247	8079
Treatment $LSD_{.05}$		1708	541	2197	1234	788	1188
Mean Values:							
N Rate	67	5526	1048	6764	4887	2034	6920
	134	6997	1158	8155	5610	2219	7830
	201	6593	1164	7758	5695	2389	8083
	$LSD_{.05}$	784	NS	998	571	NS	551
N Carrier							
AN		5613	998	6607	5264	2066	7330
Urea		6545	1024	7569	5415	1900	7315
UAN Soln.		5731	1013	7062	5102	1966	7067
SCU-30		6348	1520	7869	5714	2943	8658
UAS		7622	1067	8689	5492	2194	7687
	$LSD_{.05}$	1012	311	1289	NS	466	712

a/ Yields were computed at 12.5% moisture.

b/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate.

Table IV. Effects of N rate and N carrier on the yield of cool-season grasses. (1974).

Nitrogen kg/ha	Nitrogen Carrier	Bromegrass Riley Co. Forage Yield, kg/ha[a]			Bromegrass Jackson Co. Forage Yield, kg/ha		
		Spr.	Fall	Total	Spr.	Fall	Total
0	-----	1654	795	2449	4613	No Fall Har- vest	4613
67	AN[b]	4040	608	4648	5628		5648
134	AN	7584	878	8460	6979		6979
201	AN	7063	1491	8553	6712		6712
67	Urea	3592	736	4328	6378		6378
134	Urea	5272	796	6068	6705		6705
201	Urea	7024	977	8000	7092		7092
67	UAN Soln.	4603	643	5246	6108		6108
134	UAN Soln.	6998	793	7791	6727		6727
201	UAN Soln.	7694	1186	8880	7027		7027
67	SCU-30	5236	739	5975	5938		5938
134	SCU-30	5211	1060	6226	6357		6357
201	SCU-30	5932	1099	7030	6720		6720
67	UAS	3328	756	4084	5892		5892
134	UAS	5695	829	6524	6943		6943
201	UAS	6957	1071	8028	6527		6527
Treatment $LSD_{.05}$		1429	558	1656	1099		1099
Mean Values:							
N Rate	67	4160	697	4654	5989		5989
	134	6152	871	7022	6763		6763
	201	6934	1165	8099	6815		6815
	$LSD_{.05}$	756	252	760	554		554
N Carrier							
AN		6228	992	7220	6439		6439
Urea		5295	837	6132	6726		6726
UAN Soln.		6432	874	7306	6620		6620
SCU-30		5460	965	6425	6372		6372
UAS		5327	886	6212	6453		6453
	$LSD_{.05}$	977	NS	981	NS		NS

[a] Yields were computed at 12.5% moisture.

[b] AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate.

Table IV (Cont.). Effects of N rate and N carrier on the yield of cool-season grasses. (1974).

Nitrogen kg/ha	Nitrogen Carrier	Bromegrass Franklin Co. Forage Yield, kg/ha[a/]			Fescue Labette Co. Forage Yield, kg/ha		
		Spr.	Fall	Total	Spr.	Fall	Total
0	-----	1259	616	1875	1362	1882	3244
67	AN[b/]	2841	730	3572	2321	1777	4098
134	AN	5676	890	6567	3582	1837	5419
201	AN	7245	909	8155	2682	2561	5244
67	Urea	2620	700	3320	2308	1702	4011
134	Urea	4806	766	5572	2859	2591	5450
201	Urea	6083	971	7054	3361	2442	5803
67	UAN Soln.	2920	753	3672	2314	1733	4047
134	UAN Soln.	6279	992	7271	2774	1963	4738
201	UAN Soln.	5648	843	6480	3250	2486	5737
67	SCU-30	2369	1027	3396	1979	2165	4144
134	SCU-30	3896	1599	5496	2419	2853	5272
201	SCU-30	4208	1705	5912	3030	3942	6972
67	UAS	2570	711	3282	2317	1874	4191
134	UAS	4792	834	5630	3532	2330	5873
201	UAS	5731	1034	6765	3237	2344	5581
Treatment $LSD_{.05}$		885	296	1004	744	496	960
Mean Values:							
N Rate	67	2664	784	3448	2248	1850	4098
	134	5090	1016	6104	3033	2315	5348
	201	5783	1092	6873	3112	2755	5868
	$LSD_{.05}$	441	132	457	353	218	438
N Carrier							
AN		5255	843	6093	2862	2059	4920
Urea		4504	812	5316	2843	2244	5088
UAN Soln.		4949	862	5808	2780	2061	4841
SCU-30		3490	1444	4935	2476	2987	5463
UAS		4365	860	5225	3028	2183	5211
	$LSD_{.05}$	570	170	590	455	282	566

a/ Yields were computed at 12.5% moisture.

b/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate.

Table V. Effect of time of N application on the yield of cool-season grasses. (1973).

N-Rate kg/ha	N Carrier	Time of Application	Bromegrass Riley Co. Forage Yield kg/ha[a]			Bromegrass Jackson Co. Forage Yield kg/ha		
			Spr.	Fall	Total	Spr.	Fall	Total
0	-----	------	2371	1434	3804	2353	3578	5931
134	AN[b]	Spring	7435	2939	10373	6000	3307	9307
201	AN	Spring	8124	2672	10797	5494	3764	9258
134	Urea	Spring	5900	2555	8454	3865	3601	7466
201	Urea	Spring	8337	3016	11353	5087	3479	8566
134	UAN Soln.	Spring	7071	1493	8564	5688	3463	9152
201	UAN Soln.	Spring	7489	2268	9757	5873	3493	9367
134	SCU-30	Spring	5105	3297	8402	5083	3949	9032
201	SCU-30	Spring	6785	3711	10497	6439	4218	10657
134	UAS	Spring	8200	2769	10968	7040	3795	10835
201	UAS	Spring	8823	2560	11383	7085	3233	10319
134	AN	Split[c]	6173	3556	9729	5193	4267	9461
201	AN	Split	8986	3993	12979	6144	4118	10596
134	Urea	Split	6180	3448	9629	3995	3516	7511
201	Urea	Split	8419	3769	12188	4011	3838	7849
134	UAN Soln.	Split	6702	2587	8281	4715	3709	8425
201	UAN Soln.	Split	7708	3304	11013	4823	3209	8033
134	SCU-30	Split	5537	3559	9097	3732	3664	7418
201	SCU-30	Split	5355	3647	9001	5037	4014	9051
134	UAS	Split	7202	3740	10941	6045	3175	9220
201	UAS	Split	8335	3797	12132	6570	4096	10666
Treatment $LSD_{.05}$			1474	1113	1905	1301	650	1603
Mean Values:								
	Time-N	Spring	7327	2728	10055	5766	3630	9396
		Split	7059	3540	10108	5027	3761	8788
		$LSD_{.05}$	NS	338	NS	441	NS	526

a/ Yields were computed at 12.5% moisture.

b/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, UAS is urea-ammonium sulfate.

c/ Split application: 2/3 of N applied in spring, 1/3 in late summer.

Table V (Cont.). Effect of time of N application on the yield of cool-season grasses. (1973).

N-Rate kg/ha	N Carrier	Time of Application	Bromegrass Franklin Co. Forage Yield kg/ha[a]			Fescue Labette Co. Forage Yield kg/ha		
			Spr.	Fall	Total	Spr.	Fall	Total
0	-----	------	2770	1182	3951	4604	2290	6895
134	AN[b]	Spring	6122	1136	7258	5071	1900	6972
201	AN	Spring	6252	996	7249	5628	2401	8029
134	Urea	Spring	6943	1017	7960	5382	2098	7479
201	Urea	Spring	6749	1035	7784	5882	1959	7841
134	UAN Soln.	Spring	6756	1032	7787	5408	1858	7267
201	UAN Soln.	Spring	5374	1147	6522	4889	1860	6749
134	SCU-30	Spring	7259	1686	8944	6504	2986	9490
201	SCU-30	Spring	6535	1457	7999	6244	3475	9717
134	UAS	Spring	7904	923	8827	5688	2253	7941
201	UAS	Spring	8054	1184	9238	5832	2247	8079
134	AN	Split[c]	4919	1718	6637	5920	2844	8763
201	AN	Split	6309	1782	8090	6224	3219	9443
134	Urea	Split	5304	1359	6662	6219	3211	9442
201	Urea	Split	7540	1661	9201	5414	3647	9061
134	UAN Soln.	Split	5533	1544	7077	4067	2968	7035
201	UAN Soln.	Split	7205	1790	8995	4194	2470	7041
134	SCU-30	Split	5133	1863	6997	5429	3188	8616
201	SCU-30	Split	7258	1938	9196	6111	4080	9919
134	UAS	Split	7205	1998	9203	5355	3489	8845
201	UAS	Split	8064	2009	10074	5575	3907	9482
Treatment $LSD_{.05}$			1463	451	1813	1156	724	1262
Mean Values:								
	Time-N	Spring	6795	1161	7956	5653	2304	7956
		Split	6447	1766	8213	5451	3275	8764
		$LSD_{.05}$	NS	142	NS	NS	239	395

a/ Yields were computed at 12.5% moisture.

b/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, UAS is urea-ammonium sulfate.

c/ Split application: 2/3 of N applied in spring, 1/3 in late summer.

Table VI. Effect of time of N application on the yield of cool-season grasses. (1974).

N-Rate kg/ha	N Carrier	Time of Application	Bromegrass Riley Co. Forage Yield kg/ha[a]			Bromegrass Jackson Co. Forage Yield kg/ha		
			Spr.	Fall	Total	Spr.	Fall	Total
0	-----	------	1654	795	2449	4613	No Fall Harvest	4613
134	AN[b]	Spring	7584	878	8460	6979		6979
201	AN	Spring	7063	1491	8533	6712		6712
134	Urea	Spring	5272	796	6068	6705		6705
201	Urea	Spring	7024	977	8000	7092		7092
134	UAN Soln.	Spring	6998	793	7791	6727		6727
201	UAN Soln.	Spring	7694	1186	8880	7027		7027
134	SCU-30	Spring	5211	1060	6271	6458		6458
201	SCU-30	Spring	5932	1099	7029	6720		6720
134	UAS	Spring	5695	829	6524	6943		6943
201	UAS	Spring	6957	1071	8028	6527		6527
134	AN	Split[c]	6151	1381	7532	6098		6098
201	AN	Split	7458	1736	9194	7207		7207
134	Urea	Split	4801	951	5752	5995		5995
201	Urea	Split	5883	1051	6934	6978		6978
134	UAN Soln.	Split	6364	1384	6628	6517		6517
201	UAN Soln.	Split	7765	1640	9405	6692		6692
134	SCU-30	Split	4253	1291	5545	6471		6471
201	SCU-30	Split	5434	1539	6973	6460		6460
134	UAS	Split	5569	1096	6665	5611		5611
201	UAS	Split	6591	1098	7704	6592		6592
Treatment $LSD_{.05}$			1429	560	1531	1099		1099
Mean Values:								
	Time-N	Spring	6543	1018	7561	6789		6789
		Split	5915	1317	7233	6462		6462
		$LSD_{.05}$	456	188	NS	NS		NS

a/ Yields were computed at 12.5% moisture.

b/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, UAS is urea-ammonium sulfate.

c/ Split application: 2/3 of N applied in spring, 1/3 in late summer.

Table VI (Cont.). Effect of time of N application on the yield of cool-season grasses. (1974).

N-Rate kg/ha	N Carrier	Time of Application	Bromegrass Franklin Co. Forage Yield kg/ha[a]			Fescue Labette Co. Forage Yield kg/ha		
			Spr.	Fall	Total	Spr.	Fall	Total
0	-----	------	1259	616	1875	1362	1882	3244
134	AN[b]	Spring	5676	890	6567	3582	1837	5419
201	AN	Spring	7245	909	8155	2682	2561	5243
134	Urea	Spring	4806	765	5571	2859	2591	5450
201	Urea	Spring	6084	971	7055	3361	2442	5803
134	UAN Soln.	Spring	6279	992	7271	2774	1963	4738
201	UAN Soln.	Spring	5648	843	6480	3250	2486	5737
134	SCU-30	Spring	3896	1599	5496	2419	2853	5272
201	SCU-30	Spring	4208	1705	5912	3030	3942	6972
134	UAS	Spring	4792	834	5630	3532	2330	5862
201	UAS	Spring	5731	1034	6765	3237	2344	5581
134	AN	Split[c]	5234	1477	6711	2167	3181	5348
201	AN	Split	5953	1889	7842	2834	3181	6014
134	Urea	Split	3805	1305	5109	2433	3173	5606
201	Urea	Split	4990	2041	7030	2752	3487	6238
134	UAN Soln.	Split	3463	1314	4777	1674	2120	3795
201	UAN Soln.	Split	6399	2229	8627	2732	2270	5001
134	SCU-30	Split	4029	1620	5647	2443	2733	5176
201	SCU-30	Split	5479	2202	7681	3352	3875	7227
134	UAS	Split	4348	1837	6186	2216	3144	5360
201	UAS	Split	6096	1999	8095	3030	2598	5628
Treatment $LSD_{.05}$			885	370	941	744	713	1197
Mean Values:								
	Time-N	Spring	5436	1054	6490	3107	2535	5608
		Split	4980	1791	6770	2563	2976	5538
		$LSD_{.05}$	295	130	NS	253	249	NS

a/ Yields were computed at 12.5% moisture.

b/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, UAS is urea-ammonium sulfate.

c/ Split application: 2/3 of N applied in spring, 1/3 in late summer.

Table VII. Effects of N rate, N carrier, and rate of sampling on the crude protein content of bromegrass. Riley Co.

N-Rate kg/ha	N Carrier	Crude Protein (%) 1973				Crude Protein (%) 1974			
		4-24	5-8	5-21	6-1	4-1	4-15	5-1	5-19
0	-----	13.0	10.7	8.3	7.8	17.2	15.0	11.7	10.5
67	AN[a]	17.6	12.2	7.9	7.9	25.6	19.1	14.0	11.1
134	AN	22.6	14.6	9.3	6.7	30.7	24.0	17.3	14.6
201	AN	23.9	17.4	13.7	8.3	32.1	26.0	20.5	18.0
67	Urea	17.7	11.3	7.2	7.3	22.8	17.0	12.4	10.5
134	Urea	18.4	13.9	10.0	7.7	25.4	21.0	15.7	12.4
201	Urea	20.1	15.6	11.8	7.2	29.0	24.1	16.9	13.9
67	UAN Soln.	15.8	11.5	7.0	7.4	22.8	17.8	12.9	9.8
134	UAN Soln.	20.8	15.8	10.4	7.8	28.9	22.8	17.4	13.6
201	UAN Soln.	21.0	15.5	9.6	8.1	29.4	23.7	17.3	13.5
67	SCU-30	15.7	10.5	7.3	7.0	22.1	16.6	12.8	10.1
134	SCU-30	18.3	12.4	8.6	7.1	24.1	19.4	15.1	11.8
201	SCU-30	19.8	13.5	9.0	6.7	28.3	21.0	16.5	13.2
67	UAS	16.9	11.2	8.0	6.5	23.4	17.8	14.0	11.3
134	UAS	21.9	15.3	10.4	8.8	27.8	21.4	16.1	12.0
201	UAS	24.8	17.1	12.8	8.9	27.3	24.2	16.4	13.7
Treatment $LSD_{.05}$		3.0	1.4	1.9	2.1	2.2	1.6	2.8	1.7

Mean Values:

N-Rate (Values across all carriers and all sampling dates)

	1973	1974
67	10.7	16.2
134	13.0	19.6
201	14.2	21.2
$LSD_{.05}$	0.5	0.5

N-Carrier (Values across all rates and all sampling dates)

	1973	1974
AN	13.4	21.1
Urea	12.4	18.4
UAN Soln.	12.6	19.1
SCU-30	11.3	17.6
UAS	13.6	18.8
$LSD_{.05}$	0.6	0.6

Sampling Date (Values across all rates and carriers)

	1973		1974
4-24	19.7	4-1	26.7
5-8	13.9	4-15	21.1
5-21	9.5	5-1	15.7
6-1	7.5	5-19	12.6
$LSD_{.05}$	0.5	$LSD_{.05}$	0.5

[a] AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate. All N spring applied.

Table VIII. Effects of N rate and N carrier on the composition of cool-season grasses. (1973).

N-Rate kg/ha	N Carrier	Bromegrass, Riley Co. Composition						Bromegrass, Jackson Co. Composition					
		Spring			Fall			Spring			Fall		
		%N	%P	%K	%N	%P	%K	%N	%P	%K	%N	%P	%K
0	-----	1.25	.27	2.41	2.17	.32	2.42	1.13	.16	1.50	1.78	.16	1.10
67	AN[a]	1.10	.25	2.23	1.79	.30	1.91	1.25	.15	1.46	1.73	.15	1.39
134	AN	1.07	.23	2.13	1.66	.32	1.53	1.04	.12	1.10	1.79	.15	.85
201	AN	1.33	.23	2.56	1.80	.28	1.89	1.20	.12	.96	1.57	.16	1.00
67	Urea	1.17	.23	2.10	1.80	.31	2.10	.92	.15	1.36	1.56	.15	1.49
134	Urea	1.23	.23	2.40	1.83	.31	2.05	1.07	.14	1.33	1.79	.16	1.17
201	Urea	1.15	.24	2.27	1.72	.28	1.99	1.06	.12	1.10	1.64	.15	1.14
67	UAN Soln.	1.18	.22	2.19	1.90	.32	1.82	.99	.13	1.25	1.84	.15	.98
134	UAN Soln.	1.25	.22	2.42	2.01	.28	1.87	1.05	.13	1.15	1.59	.14	1.17
201	UAN Soln.	1.29	.24	2.31	1.97	.30	2.14	1.17	.12	1.12	1.85	.15	1.09
67	SCU-30	1.13	.22	2.02	1.74	.30	1.89	1.10	.14	1.33	1.65	.15	1.15
134	SCU-30	1.14	.25	2.22	1.83	.31	1.94	1.04	.13	1.10	1.68	.15	1.17
201	SCU-30	1.07	.21	2.14	1.81	.31	2.05	.95	.11	1.01	1.73	.16	1.14
67	UAS	1.05	.21	1.92	2.00	.33	1.87	.90	.10	1.07	1.66	.15	1.34
134	UAS	1.41	.23	2.65	1.73	.31	1.69	1.31	.13	.96	1.64	.15	1.27
201	UAS	1.43	.22	2.37	1.64	.28	1.94	1.51	.12	1.09	1.73	.16	1.12
Treatment $LSD_{.05}$		.26	.03	.37	.27	.05	.59	.28	.03	.28	.27	NS	.43

[a] AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate. All N spring (late winter) applied.

Table VIII (Cont.). Effects of N rate and N carrier on the composition of cool-season grasses. (1973).

N-Rate kg/ha	N Carrier	Bromegrass, Franklin Co. Composition: Spring %N	Spring %P	Spring %K	Fall %N	Fall %P	Fall %K	Fescue, Labette Co. Composition: Spring %N	Spring %P	Spring %K	Fall %N	Fall %P	Fall %K
0	-----	1.19	.22	1.36	1.54	.24	1.27	.98	.23	2.02	1.53	.27	1.60
67	AN[a]	1.05	.23	1.31	1.61	.24	1.24	.99	.23	2.13	1.49	.26	1.35
134	AN	.97	.21	1.28	1.58	.26	1.31	.97	.23	1.92	1.53	.27	1.65
201	AN	.95	.20	1.20	1.55	.25	1.24	1.22	.24	1.84	1.54	.29	1.12
67	Urea	1.11	.22	1.52	1.55	.24	1.41	1.01	.24	1.95	1.56	.29	1.43
134	Urea	1.09	.21	1.15	1.61	.25	1.19	1.05	.23	1.78	1.73	.27	1.75
201	Urea	.95	.19	1.10	1.55	.24	1.17	1.13	.23	2.13	1.45	.25	1.41
67	UAN Soln.	.93	.21	1.36	1.60	.25	1.34	1.04	.22	1.98	1.52	.27	1.55
134	UAN Soln.	1.05	.20	1.31	1.57	.24	1.22	.94	.23	2.02	1.44	.26	1.41
201	UAN Soln.	.95	.21	1.39	1.53	.23	1.36	.95	.23	2.13	1.45	.25	1.69
67	SCU-30	1.04	.21	1.36	1.63	.25	1.39	.94	.24	2.10	1.49	.26	1.45
134	SCU-30	1.13	.21	1.28	1.63	.26	1.17	1.05	.23	1.93	1.52	.27	1.11
201	SCU-30	1.20	.22	1.27	1.69	.25	.97	1.16	.23	2.19	1.68	.25	1.30
67	UAS	1.05	.20	1.17	1.58	.25	1.31	.91	.23	2.18	1.49	.28	1.55
134	UAS	1.03	.21	1.01	1.61	.25	1.12	1.11	.25	1.74	1.57	.27	1.46
201	UAS	1.38	.22	1.14	1.50	.24	1.19	1.10	.22	1.98	1.51	.25	1.36
Treatment $LSD_{.05}$		.24	.03	.27	.15	.03	.30	.14	.03	.24	.19	.03	.55

[a] AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate. All N spring (late winter) applied.

Table IX. Effects of N rate and N carrier on the composition of cool-season grasses. (1974).

N-Rate	N	Bromegrass, Riley Co. Composition						Bromegrass, Jackson Co. Composition					
kg/ha	Carrier	Spring			Fall			Spring			Fall		
		%N	%P	%K	%N	%P	%K	%N	%P	%K	%N	%P	%K
0	-----	1.71	.29	1.56	1.52	.22	1.54	1.52	.18	1.17		No	
67	AN[a/]	1.46	.27	1.73	1.46	.22	1.39	1.32	.17	1.26		Fall	
134	AN	1.74	.27	1.88	1.46	.22	1.49	1.52	.19	.87		Harvest	
201	AN	2.21	.26	1.71	1.73	.22	1.68	1.69	.18	.81			
67	Urea	1.54	.26	1.64	1.47	.21	1.26	.99	.14	.94			
134	Urea	1.56	.25	1.45	1.61	.22	1.70	1.36	.15	1.00			
201	Urea	1.62	.26	1.49	1.47	.21	1.55	1.57	.17	.87			
67	UAN Soln.	1.54	.26	1.54	1.45	.21	1.27	1.25	.17	.94			
134	UAN Soln.	1.53	.26	1.66	1.54	.20	1.60	1.47	.17	1.00			
201	UAN Soln.	1.62	.25	1.86	1.58	.21	1.63	1.50	.16	1.00			
67	SCU-30	1.46	.27	1.56	1.56	.21	1.38	1.14	.15	1.00			
134	SCU-30	1.44	.27	1.75	1.54	.23	1.58	1.49	.15	.90			
201	SCU-30	1.58	.24	1.88	1.83	.24	1.95	1.46	.15	.94			
67	UAS	1.45	.26	1.71	1.50	.22	1.44	1.47	.16	1.17			
134	UAS	1.54	.25	1.51	1.49	.22	1.43	1.51	.16	.92			
201	UAS	1.62	.26	1.71	1.38	.22	1.27	1.60	.16	.88			
Treatment $LSD_{.05}$		.27	.03	.37	.20	.04	.48	.32	.03	.33			

a/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate. All N spring (late winter) applied.

Table IX (Cont.). Effects of N rate and N carrier on the composition of cool-season grasses. (1974).

N-Rate kg/ha	N Carrier	Bromegrass, Franklin Co. Composition						Fescue, Labette Co. Composition					
		Spring			Fall			Spring			Fall		
		%N	%P	%K	%N	%P	%K	%N	%P	%K	%N	%P	%K
0	-----	1.32	.26	1.92	1.60	.22	1.52	1.50	.34	2.20	1.79	.39	2.03
67	AN[a/]	1.06	.24	1.58	1.53	.20	1.28	1.61	.31	2.28	1.79	.37	1.96
134	AN	1.18	.22	1.43	1.50	.21	1.32	2.11	.30	2.13	1.82	.34	1.83
201	AN	.96	.21	1.00	1.56	.22	1.40	1.72	.31	2.20	1.87	.34	1.94
67	Urea	1.32	.26	1.92	1.64	.22	1.50	1.68	.31	2.20	1.89	.40	1.98
134	Urea	1.04	.22	1.41	1.52	.21	1.29	1.76	.28	2.15	1.78	.33	1.70
201	Urea	1.27	.24	1.41	1.42	.24	1.24	1.91	.28	2.02	1.78	.36	1.96
67	UAN Soln.	1.06	.23	1.52	1.58	.23	1.44	1.51	.27	1.77	1.81	.39	2.00
134	UAN Soln.	1.12	.23	1.22	1.55	.22	1.37	1.60	.28	1.84	1.89	.37	1.72
201	UAN Soln.	1.05	.22	1.32	1.51	.22	1.41	1.77	.27	2.03	1.73	.33	1.81
67	SCU-30	1.29	.24	1.54	1.71	.24	1.47	1.69	.31	2.30	1.93	.37	1.94
134	SCU-30	1.37	.27	1.51	1.66	.24	1.57	1.67	.32	2.11	1.73	.36	1.70
201	SCU-30	1.29	.25	1.47	1.63	.25	1.50	1.91	.31	2.19	1.96	.32	1.87
67	UAS	1.10	.24	1.53	1.51	.21	1.21	1.58	.30	2.28	1.82	.36	1.89
134	UAS	1.12	.23	1.18	1.55	.22	1.34	1.79	.29	2.02	1.76	.38	1.81
201	UAS	1.11	.22	1.30	1.51	.26	1.47	2.07	.26	2.05	1.72	.34	1.83
Treatment $LSD_{.05}$		.18	.03	.28	.16	.03	.28	.22	.04	.37	.19	.03	NS

a/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate. All N spring (late winter) applied.

Table X. Effect of time of N application on the composition of cool-season grasses. (1973).

N-Rate kg/ha	N Carrier	Time of Application	Bromegrass, Riley Co. Composition						Bromegrass, Jackson Co. Composition					
			Spring			Fall			Spring			Fall		
			%N	%P	%K	%N	%P	%K	%N	%P	%K	%N	%P	%K
0	-----	------	1.25	.27	2.41	2.17	.32	2.42	1.13	.16	1.50	1.78	.16	1.10
134	AN[a]	Spring	1.07	.23	2.13	1.66	.32	1.53	1.04	.12	1.10	1.79	.15	.85
201	AN	Spring	1.33	.23	2.56	1.80	.28	1.89	1.20	.12	.96	1.57	.16	1.00
134	Urea	Spring	1.23	.23	2.40	1.83	.31	2.05	1.07	.14	1.33	1.79	.16	1.17
201	Urea	Spring	1.15	.24	2.27	1.72	.28	1.99	1.06	.12	1.10	1.64	.15	1.14
134	UAN Soln.	Spring	1.25	.22	2.42	2.01	.28	1.87	1.05	.13	1.15	1.59	.14	1.17
201	UAN Soln.	Spring	1.29	.24	2.31	1.97	.30	2.14	1.17	.12	1.12	1.85	.15	1.09
134	SCU-30	Spring	1.14	.25	2.22	1.83	.31	1.94	1.04	.13	1.10	1.68	.15	1.17
201	SCU-30	Spring	1.07	.21	2.14	1.81	.31	2.05	.95	.11	1.01	1.73	.16	1.14
134	UAS	Spring	1.41	.23	2.65	1.73	.31	1.69	1.31	.13	.96	1.64	.15	1.27
201	UAS	Spring	1.43	.22	2.37	1.64	.28	1.94	1.51	.12	1.09	1.73	.16	1.12
134	AN	Split[b]	1.14	.22	2.14	1.93	.32	2.46	1.03	.13	1.17	1.81	.14	1.27
201	AN	Split	1.19	.23	2.35	2.09	.33	2.55	1.07	.13	1.23	2.01	.15	1.29
134	Urea	Split	1.20	.22	2.22	1.92	.29	2.19	1.07	.15	1.36	1.91	.16	1.36
201	Urea	Split	1.08	.22	2.06	1.86	.30	1.71	.89	.12	1.23	1.77	.15	1.39
134	UAN Soln.	Split	1.04	.21	2.14	1.87	.33	2.10	.96	.13	1.16	1.80	.15	1.04
201	UAN Soln.	Split	1.18	.21	2.21	2.02	.28	2.24	1.02	.12	1.25	1.90	.16	1.46
134	SCU-30	Split	1.15	.23	2.24	1.88	.32	2.24	1.06	.14	1.31	1.67	.15	1.24
201	SCU-30	Split	1.12	.23	2.15	1.67	.33	2.05	1.07	.12	1.18	1.83	.14	1.31
134	UAS	Split	1.23	.23	2.35	1.99	.32	2.19	1.05	.11	1.15	1.95	.15	1.49
201	UAS	Split	1.20	.22	2.25	2.14	.29	2.03	1.27	.11	1.01	1.86	.14	1.19
Treatment $LSD_{.05}$			.24	.03	.34	.26	.05	.56	.26	.02	.26	.24	.02	.46

a/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate.

b/ Split application: 2/3 of N applied in spring (late winter), 1/3 applied in late summer (August).

Table X (Cont.). Effect of time of N application on the composition of cool-season grasses. (1973).

N-Rate kg/ha	N Carrier	Time of Application	Bromegrass, Franklin Co. Composition Spring %N	%P	%K	Fall %N	%P	%K	Fescue, Labette Co. Composition Spring %N	%P	%K	Fall %N	%P	%K
0	-----	------	1.19	.22	1.36	1.54	.24	1.27	.98	.23	2.02	1.53	.27	1.60
134	AN[a]	Spring	.97	.21	1.28	1.58	.26	1.31	.97	.23	1.92	1.53	.27	1.65
201	AN	Spring	.95	.20	1.20	1.55	.25	1.24	1.22	.24	1.84	1.54	.29	1.12
134	Urea	Spring	1.09	.21	1.15	1.61	.25	1.19	1.05	.23	1.78	1.73	.27	1.75
201	Urea	Spring	.95	.19	1.10	1.55	.24	1.17	1.13	.23	2.13	1.45	.25	1.41
134	UAN Soln.	Spring	1.05	.20	1.31	1.57	.24	1.22	.94	.23	2.02	1.44	.26	1.41
201	UAN Soln.	Spring	.95	.21	1.39	1.53	.23	1.36	.95	.23	2.13	1.45	.25	1.69
134	SCU-30	Spring	1.13	.21	1.28	1.63	.26	1.17	1.05	.23	1.93	1.52	.27	1.11
201	SCU-30	Spring	1.20	.22	1.27	1.69	.25	.97	1.16	.23	2.19	1.68	.25	1.30
134	UAS	Spring	1.03	.21	1.01	1.61	.25	1.12	1.11	.25	1.74	1.57	.27	1.46
201	UAS	Spring	1.38	.22	1.14	1.50	.24	1.19	1.10	.22	1.98	1.51	.25	1.36
134	AN	Split[b]	.99	.20	1.37	1.66	.28	1.22	.97	.22	1.94	1.51	.28	1.34
201	AN	Split	.97	.20	1.27	1.69	.28	1.24	.97	.23	1.84	1.85	.27	1.36
134	Urea	Split	.95	.21	1.33	1.52	.25	1.49	.91	.22	1.98	1.68	.24	1.55
201	Urea	Split	.96	.19	1.07	1.67	.26	1.24	1.00	.24	1.90	1.82	.25	1.04
134	UAN Soln.	Split	.92	.20	1.17	1.61	.26	1.24	.93	.25	2.10	1.64	.30	1.53
201	UAN Soln.	Split	.95	.20	1.09	1.64	.27	1.48	.89	.25	2.11	1.67	.29	1.34
134	SCU-30	Split	1.00	.20	1.23	1.81	.28	1.19	1.04	.23	1.89	1.82	.28	1.35
201	SCU-30	Split	1.05	.21	1.01	1.93	.28	1.02	1.09	.24	1.92	2.05	.29	1.04
134	UAS	Split	1.07	.20	1.04	1.76	.28	1.05	1.06	.24	1.95	1.76	.27	1.13
201	UAS	Split	1.02	.20	1.14	1.71	.28	1.29	.96	.21	1.84	1.91	.25	1.32
Treatment $LSD_{.05}$			.20	.02	.26	.17	.02	.31	.14	.03	.26	.20	.03	.51

a/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate.

b/ Split application: 2/3 of N applied in spring (late winter), 1/3 applied in late summer (August).

Table XI. Effect of time of N application on the composition of cool-season grasses. (1974).

N-Rate kg/ha	N Carrier	Time of Application	Bromegrass, Riley Co. Composition						Bromegrass, Jackson Co. Composition					
			Spring			Fall			Spring			Fall		
			%N	%P	%K	%N	%P	%K	%N	%P	%K	%N	%P	%K
0	-----	------	1.71	.29	1.56	1.52	.22	1.54	1.52	.18	1.17		No Fall Harvest	
134	AN[a]	Spring	1.74	.27	1.88	1.46	.22	1.49	1.52	.19	.87			
201	AN	Spring	2.21	.26	1.71	1.73	.22	1.68	1.69	.18	.81			
134	Urea	Spring	1.56	.25	1.45	1.61	.22	1.70	1.36	.15	1.00			
201	Urea	Spring	1.62	.26	1.49	1.47	.21	1.55	1.57	.17	.87			
134	UAN Soln.	Spring	1.53	.26	1.66	1.54	.20	1.60	1.47	.17	1.00			
201	UAN Soln.	Spring	1.62	.25	1.86	1.58	.21	1.63	1.50	.16	1.00			
134	SCU-30	Spring	1.44	.27	1.75	1.54	.23	1.58	1.49	.15	.90			
201	SCU-30	Spring	1.58	.24	1.88	1.83	.24	1.95	1.46	.15	.94			
134	UAS	Spring	1.54	.25	1.51	1.49	.22	1.43	1.51	.16	.92			
201	UAS	Spring	1.62	.26	1.71	1.38	.22	1.27	1.60	.16	.88			
134	AN	Split[b]	1.59	.26	1.56	1.62	.22	1.83	1.53	.16	1.07			
201	AN	Split	1.82	.26	1.79	2.01	.24	1.81	1.51	.16	.75			
134	Urea	Split	1.54	.26	1.54	1.61	.21	1.34	1.43	.17	1.02			
201	Urea	Split	1.47	.26	1.62	1.74	.23	1.39	1.38	.16	1.00			
134	UAN Soln.	Split	1.42	.25	1.71	1.63	.24	1.99	1.40	.18	1.00			
201	UAN Soln.	Split	1.47	.24	1.56	1.74	.21	1.89	1.56	.17	.96			
134	SCU-30	Split	1.55	.27	1.51	1.80	.23	1.83	1.42	.15	1.07			
201	SCU-30	Split	1.55	.27	1.58	1.81	.24	1.68	1.46	.18	1.05			
134	UAS	Split	1.50	.26	1.54	1.81	.24	1.78	1.55	.17	1.26			
201	UAS	Split	1.40	.23	1.56	1.98	.22	2.10	1.33	.17	.79			
Treatment $LSD_{.05}$			.27	.03	.37	.20	.03	.50	.32	.03	.33			

a/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate.

b/ Split application: 2/3 of N applied in spring (late winter), 1/3 applied in late summer (August).

Table XI (Cont.). Effect of time of N application on the composition of cool-season grasses. (1974).

N-Rate kg/ha	N Carrier	Time of Application	Bromegrass, Franklin Co. Composition						Fescue, Labette Co. Composition					
			Spring			Fall			Spring			Fall		
			%N	%P	%K	%N	%P	%K	%N	%P	%K	%N	%P	%K
0	-----	------	1.32	.26	1.92	1.60	.22	1.52	1.50	.34	2.20	1.79	.39	2.03
134	AN[a]	Spring	1.18	.22	1.43	1.50	.21	1.32	2.11	.30	2.13	1.82	.34	1.83
201	AN	Spring	.96	.21	1.00	1.56	.22	1.40	1.72	.31	2.20	1.87	.34	1.94
134	Urea	Spring	1.04	.22	1.41	1.52	.21	1.29	1.76	.28	2.15	1.78	.33	1.70
201	Urea	Spring	1.27	.24	1.41	1.42	.24	1.24	1.91	.28	2.02	1.78	.36	1.96
134	UAN Soln.	Spring	1.12	.23	1.22	1.55	.22	1.37	1.60	.28	1.84	1.89	.37	1.72
201	UAN Soln.	Spring	1.05	.22	1.32	1.51	.22	1.41	1.77	.27	2.03	1.73	.33	1.81
134	SCU-30	Spring	1.37	.27	1.51	1.66	.24	1.57	1.67	.32	2.11	1.73	.36	1.70
201	SCU-30	Spring	1.29	.25	1.47	1.63	.25	1.50	1.91	.31	2.19	1.96	.32	1.87
134	UAS	Spring	1.12	.23	1.18	1.55	.22	1.34	1.79	.29	2.02	1.76	.38	1.81
201	UAS	Spring	1.11	.22	1.30	1.51	.26	1.47	2.07	.26	2.05	1.72	.34	1.83
134	AN	Split[b]	1.10	.24	1.34	1.65	.24	1.52	1.52	.29	2.20	2.07	.37	2.12
201	AN	Split	1.21	.23	1.02	1.62	.25	1.34	1.68	.29	2.17	2.10	.32	1.94
134	Urea	Split	1.16	.24	1.64	1.57	.24	1.49	1.76	.28	2.01	1.97	.34	2.01
201	Urea	Split	1.05	.23	1.30	1.62	.26	1.40	1.78	.27	1.90	2.14	.35	1.96
134	UAN Soln.	Split	1.14	.25	1.50	1.66	.25	1.45	1.40	.31	2.09	1.84	.39	2.12
201	UAN Soln.	Split	1.04	.23	1.41	1.64	.25	1.39	1.66	.30	2.07	1.94	.37	2.14
134	SCU-30	Split	1.15	.25	1.60	1.67	.23	1.52	1.64	.31	2.18	2.02	.36	2.14
201	SCU-30	Split	1.13	.24	1.22	1.83	.27	1.44	1.84	.31	1.96	2.14	.33	1.63
134	UAS	Split	1.12	.26	1.50	1.60	.26	1.54	1.66	.31	1.98	2.07	.34	2.20
201	UAS	Split	1.19	.22	1.34	1.55	.24	1.52	1.71	.29	2.09	2.01	.37	1.91
Treatment $LSD_{.05}$			.18	.03	.28	.15	.03	.28	.22	.04	.37	.18	.03	.34

a/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate.

b/ Split application: 2/3 of N applied in spring (late winter), 1/3 applied in late summer (August).

Table XII. Effects of N rate, N carrier, and sampling date on the calcium, magnesium, and potassium concentrations and on the K/Ca Mg ratio of bromegrass. Riley Co., 1973.

N-Rate kg/ha	N Carrier	Forage Sampling Dates: April 24				May 8				May 21			
		%Ca	%Mg	%K	K/Ca Mg[a]	%Ca	%Mg	%K	K/Ca Mg	%Ca	%Mg	%K	K/Ca Mg
0	-----	.303	.105	2.13	2.3	.289	.108	2.08	2.3	.243	.090	1.84	2.4
67	AN[b]	.322	.107	2.37	2.4	.276	.102	2.41	2.8	.226	.080	1.98	2.9
134	AN	.281	.109	2.73	3.0	.250	.107	2.81	3.4	.232	.087	2.13	2.9
201	AN	.272	.116	2.84	3.2	.244	.121	3.17	3.9	.262	.112	2.79	3.2
67	Urea	.294	.109	2.23	2.4	.265	.108	2.37	2.7	.212	.079	1.82	2.7
134	Urea	.272	.104	2.66	3.1	.264	.112	2.62	3.0	.261	.094	2.29	2.8
201	Urea	.310	.116	2.50	2.5	.263	.108	2.78	3.3	.269	.096	2.58	3.1
67	UAN Soln.	.292	.106	2.25	2.5	.249	.105	2.38	2.9	.203	.075	1.69	2.6
134	UAN Soln.	.300	.111	2.58	2.7	.263	.114	2.79	3.2	.242	.088	2.35	3.1
201	UAN Soln.	.311	.106	2.71	2.8	.265	.107	2.86	3.4	.225	.085	2.20	3.1
67	SCU-30	.305	.107	2.26	2.4	.253	.098	2.46	3.0	.204	.075	1.78	2.8
134	SCU-30	.327	.102	2.39	2.5	.271	.108	2.49	2.8	.220	.097	1.92	2.6
201	SCU-30	.292	.109	2.47	2.6	.267	.123	2.77	3.0	.236	.086	2.05	2.8
67	UAS	.285	.100	2.50	2.8	.263	.103	2.31	2.8	.236	.087	1.91	2.6
134	UAS	.278	.106	2.40	2.6	.252	.112	3.05	3.6	.221	.086	2.23	3.2
201	UAS	.289	.115	2.83	3.0	.258	.102	2.41	2.9	.261	.095	2.60	3.3
Treatment $LSD_{.05}$		.033	NS	.34	.1	NS	NS	.50	.1	NS	.018	.38	.1

a/ K/Ca Mg ratios calculated in meq.

b/ AN is ammonium nitrate, UAN Soln. is urea-ammonium nitrate solution, SCU-30 is sulfur-coated urea, and UAS is urea-ammonium sulfate. All N spring applied.

Table XIII. Effect of SCU-30 on residual soil N. Riley Co., 1974.

N-Rate kg/ha	N Carrier	NO_3-N ppm Depth (cm) 0-15	15-60
0	-----	9.68	5.30
67	AN	9.31	4.20
134	AN	8.90	5.72
201	AN	7.79	4.20
67	SCU-30	7.24	4.80
134	SCU-30	9.18	6.04
201	SCU-30	7.81	4.52
Treatment $LSD_{.05}$		1.84	1.45

COMPARATIVE PERFORMANCE OF N SOURCES FOR SMOOTH BROMEGRASS *BROMUS INERMIS* L. AND TALL FESCUE *FESTUCA ARUNDINACEA* SCHREB.

by

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Studies were initiated in the spring of 1973 at four locations in eastern Kansas to evaluate the performance of five nitrogen carriers as sources of nitrogen for bromegrass (Bromus inermis Leyss.) and tall fescue (Festuca arundinacea Schreb.). Nitrogen rates utilized were 67, 134, and 201 kg N/ha applied in the early spring (late winter) and a series of spring-summer split applications involving the two highest N rates. The split treatments involved application of two-thirds of the nitrogen in late winter or early spring, with the remaining one-third applied in August. Nitrogen carriers included ammonium nitrate, urea, urea-ammonium nitrate solution (UAN solution), sulfur-coated urea (SCU-30), and urea-ammonium sulfate (UAS).

Excellent visual responses to applied N were evident in both years of the investigation. Yields of forage increased with N applications up to 201 kg N/ha both years of the study. Even though the 201 kg N/ha rate gave higher yields, as more N was applied over the 134 kg N/ha rate there was a diminishing increase in forage yield. The 134 kg N/ha rate was near the economically feasible rate of N to apply at 1974-75 N and hay prices.

No clear cut superiority was established for any one N carrier after two years of study. Sulfur-coated urea (SCU-30) performed well on tall fescue but was the least effective of all carriers on bromegrass. Slow release of N from SCU-30 was evident in terms of plant growth but did not result in higher N efficiency as noted by increasing total yearly yields of forage. The effectiveness of a particular carrier was influenced by location, environmental conditions, and grass species.

Spring applications of N generally produced higher spring forage yields, however, split N applications gave higher fall forage yields. On a total yearly basis, however, time of N application had little effect on forage yield.

Stage of maturity exerted the most profound effect on crude protein content of forage during spring growth, although N rate and N carrier contributed significant effects. Crude protein declined with advancing maturity but increased as the N rate increased. Ammonium nitrate produced the highest forage protein levels, with SCU-30 being consistently lowest.

N rate, N source, and time of N application seldom affected the P or K concentrations of the forage.