PUBLICATIONS
1976

TAES Research Monograph

RM 6C
January 1976

Grasses and Legumes in Texas – Development, Production, and Utilization

The Texas Agricultural Experiment Station,
J.E. Miller, Director,
Texas A&M University System
College Station, TX

Chapter 4

FERTILIZATION OF FORAGES

Table of Contents

Chapter 4

FERTILIZATION OF FORAGES

J. E. Matocha and W. B. Anderson*

INTRODUCTION

Adequate fertility is an essential prerequisite to economic forage production. Although some Texas soils have near-adequate reserves of phosphorus (P) and potassium (K) plant nutrients, almost all soils will require nitrogen applications for high production of forages. Soil tests indicate those soils which may require fertilizer applications to supplement the essential plant nutrients found inadequate in a particular soil.

The role of forages in Texas may be viewed from a general breakdown of approximate acreages of fertilized forages in relation to total farmland, cropland, pasture, and rangelands.

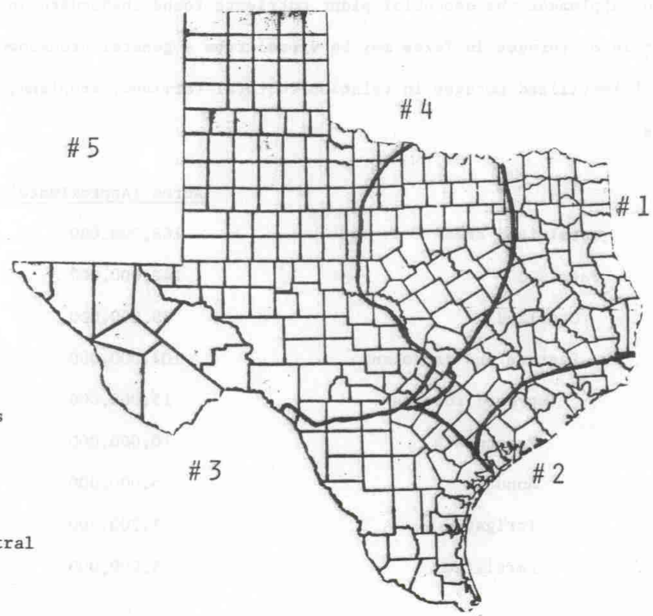
	Acres (Approximate)
Total land area	168,000,000
Farmland	142,000,000
Cropland	39,000,000
Pasture and rangeland	103,000,000
Improved forages	15,000,000
Perennials	10,000,000
Annuals	5,000,000
Irrigated	1,200,000
Fertilized	5,000,000

*Respectively, associate professor, the Texas Agricultural Experiment Station, Overton; associate professor, the Texas Agricultural Experiment Station (Department of Soil and Crop Sciences).

This publication is a part of Research Monograph 6, "Grasses and Legumes in Texas--Development, Production, and Utilization", The Texas Agricultural Experiment Station.

Soil type, climatic conditions, and forage species dictate the required fertiliza-ion practices. These influences on forage fertilization and on recommended fertilizer ractices are discussed by geographic areas as designated on the following map. These reas correspond generally to the main land resource areas (Godfrey, Carter, McKee).

ap showing geographic sections of Texas used in the following discussions of forages n Texas.



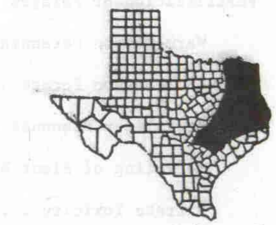
. East Texas
. Southeast
. South
. North Central
. West

EAST TEXAS

J. E. Matocha, W. B. Anderson and J. A. Lancaster*

The East Texas region encompasses primarily the land resource area known as the East Texas Timberlands and a small portion of the southern section of Blackland Prairies.

	Approximate Acreage
Total area	25,000,000
Farmland	22,000,000
Cultivated cropland	2,500,000
Unimproved forageland	5,000,000
Improved forageland	3,000,000
Perennial warm-season	2,500,000
Annual warm-season	80,000
*Annual cool-season	670,000
Forest	11,500,000



*A portion of this acreage is overseeded on perennial warm-season grasses.

Soils of East Texas are generally in the low range of inherent soil fertility. Most of these soils require relatively high rates of fertilizer nutrients to sustain high production levels of good quality forage.

Major Soils and Climate

Some of the major soil series in the upland coarse-textured, light-colored group are Bowie, Boswell, Kirvin, Lufkin, Ruston, Susquehanna, and Darco. Cuthbert and Nacogdoches represent the darker reddish brown soils in this area. Major soils series in the bottom lands finer textured group are Bibb, Iuka, Kaufman, and Athens. Some of these range in texture from sandy loams to clays.

Native vegetation on uplands includes loblolly, shortleaf (some long-leaf) pine, and oak. Bottomlands have primarily hardwoods with some pine.

East Texas soils have a wide range of morphological, mineralogical, and chemical characteristics. Most of these soils have a common parent material largely developed from neutral to slightly calcareous clays, acid sandy clays, and sandy sediments of the Coastal Plain. The soils have developed under relatively high rainfall from acid leachings of pine and hardwood tree covers. They are low in organic matter and exchangeable cations and usually are deficient in nitrogen, phosphorus, and potassium. Soil reaction ranges from slightly acid to strongly acid.

A major portion of the area is composed of coarse and fine sand and sandy loam soils. The topography of the area is variable, ranging from nearly level in the southeastern portion to steeply rolling in the north central region where significantly more heterogeneity exists between parent material and soil.

The chemical energy status of East Texas soils in general is extremely low in comparison to that in soils of other portions of the State. Levels of primary and secondary minerals which supply many essential plant nutrients in most of these soils are only a small fraction of those present in soils located in the drier regions of the State. Therefore, a strong fertilization program is required for a successful forage industry.

The numerous bottom lands are subject to overflow. However, contribution to soil fertility from overflow sediments is small. In some cases, the fertility status of soils in the bottom land is no better than that of adjacent upland soils. During periods of drouth, the moisture status of bottom land soils plays a significant role in fertilizer responses.

The climate is warm, temperate, and humid with average annual rainfall ranging from 35 inches in the southwestern portion to more than 50 inches in the southeastern portion. While average rainfall for most of the area may exceed 2.5 inches monthly, distribution patterns show decreases in July, August, and September (Table 1). Drouth periods of 1 to 3 months or longer can be expected from irregular distribution of rainfall.

Fertilization of Forages

The majority of fertilizers applied to forages in East Texas is broadcast onto the soil surface. Limited acreage where temporary summer and winter pastures are planted on a prepared seedbed involves mixing of fertilizer nutrients with the soil prior to seeding. Uniform distribution of fertilizer nutrients is pertinent to maximum efficiency in production and utilization of forage (photo #1).

Table 4-1. Climatic data for selected locations in East Texas

Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	Mean monthly rainfall (Inches)1/												
Huntsville	3.90	3.97	3.28	4.40	4.71	4.26	3.67	2.81	3.25	3.27	4.34	4.29	46.15
Nacogdoches	4.45	4.19	3.75	4.66	5.33	3.31	3.56	2.68	2.96	3.24	4.70	5.22	48.09
Lindale	3.93	3.66	3.93	5.02	5.52	3.50	3.25	3.00	2.73	3.24	4.23	4.92	47.13
Marshall	4.72	3.99	4.40	4.43	5.26	3.30	3.28	2.54	2.79	3.23	4.42	5.02	47.15
Texarkana	4.83	4.03	4.73	5.28	4.88	4.02	3.84	3.07	2.72	2.97	4.32	4.55	49.24
	Mean monthly temperature (^{o}F)1/												Avg. Yr.
Longview (^{o}F)	47.7	50.7	57.0	65.7	73.6	81.2	84.2	84.3	78.3	68.5	55.7	49.2	66.34
	Mean monthly evaporation (Avg. of 7 years)2/												
Daingergield	2.52	3.30	5.13	7.04	7.89	9.85	10.65	9.71	7.09	5.41	3.53	3.08	75.20

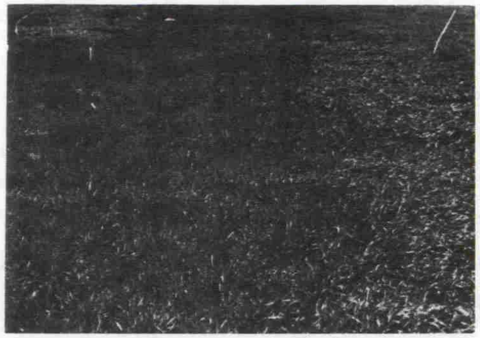
1/ Represent 30-year averages.
2/ Inches loss from water surface in standard weather service pan.

Warm-Season Perennials

Nitrogen - Most grasses grown on East Texas soils are generally highly responsive to fertilizer nutrients. On most East Texas soils nitrogen (N) is the chief plant nutrient limiting production of forage (Photo #2). Fertilization of summer perennial grasses such as bermudagrass, lovegrass, bahiagrass, kleingrass, and annuals such as millets and sorghum-sudan hybrids involves multiple split applications when conventional sources of N are used. Data accumulated for several years on effects of sources, rates, and times of nitrogen fertilizer application on Coastal bermudagrass production in East Texas, indicate that this grass will show a near linear response to rates of N approaching 500 pounds per acre when other essential nutrients are present at adequate levels. Recent results (Figure 1) indicate that the greatest production from conventional sources of N will be obtained from ammonium sulfate. This is due primarily to the sulfur (S) present in ammonium sulfate. However, if S is applied, ammonium nitrate and urea can become more productive than sulfate (Figure 2). Economic evaluation of the N sources indicates that urea can produce forage with less fertilizer costs than the other sources due to somewhat lower costs of this material. Other studies (Figure 3) with sulfur-coated ureas (SCU) where all sources received equal rates of S show that a single application of SCU (SCU-155) will give production equal to five split applications of urea. Sulfur-coated urea at 200 pounds N per acre was generally inferior to ammonium nitrate, but production from 600 pounds N per acre equalled or exceeded that from ammonium nitrate in four of the six clippings. Data averaged over four years indicate that production peaks will occur at the first and third clippings, followed by decreased production in subsequent clippings. Protein content (Figure 4) of the forage was higher and more uniform throughout the season for the SCU materials than for split applications of urea.

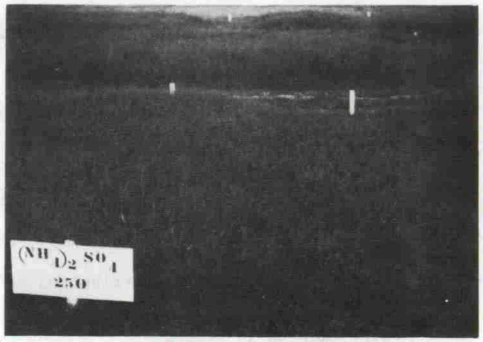
Nitrogen fertilization can be profitable only when other essential nutrients are present in adequate quantities. Work on relatively fertile alluvial soils by Jones (1969) showed Coastal bermudagrass gave only limited response to nitrogen unless 100 pounds P_2O_5 per acre were applied. Application of other nutrients had little influence on response to N. On the other hand, most soils in East Texas require liberal rates of phosphorus (P) and potassium (K) fertilizers, and some soils require smaller quantities

1.



Uniform distribution of fertilizer nutrients is important for maximum efficiency. Segregation of ingredients in application of mechanically blended material and insufficient overlapping can lead to irregular growth of winter forage as shown here.

2.



Response to nitrogen by grasses grown on East Texas soils is greater than other parts of Texas. Unfertilized Coastal bermudagrass (right) may produce 1 ton of forage while fertilized grass (left, 250 lb N/A) may yield 6 tons of quality forage.

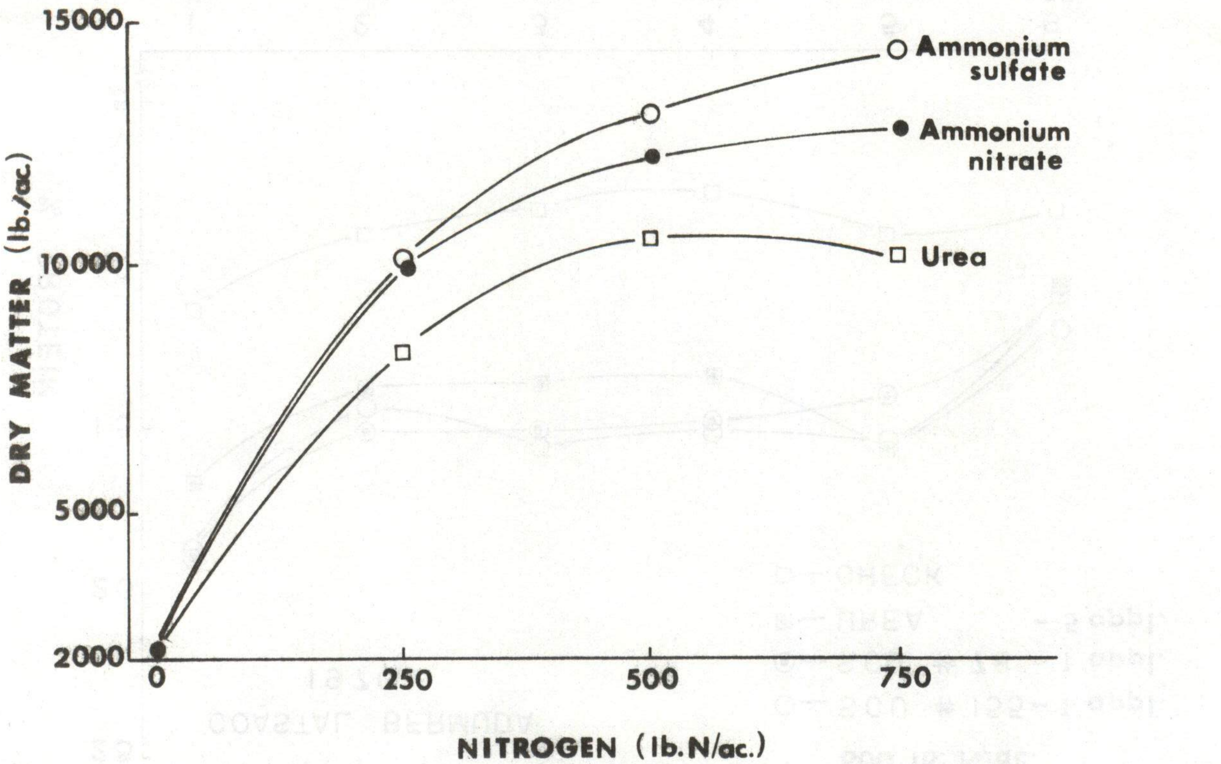


Figure 4-1. Effect of rate and source of N on yields of Coastal bermudagrass forage. Average for 1968-71. Overton.

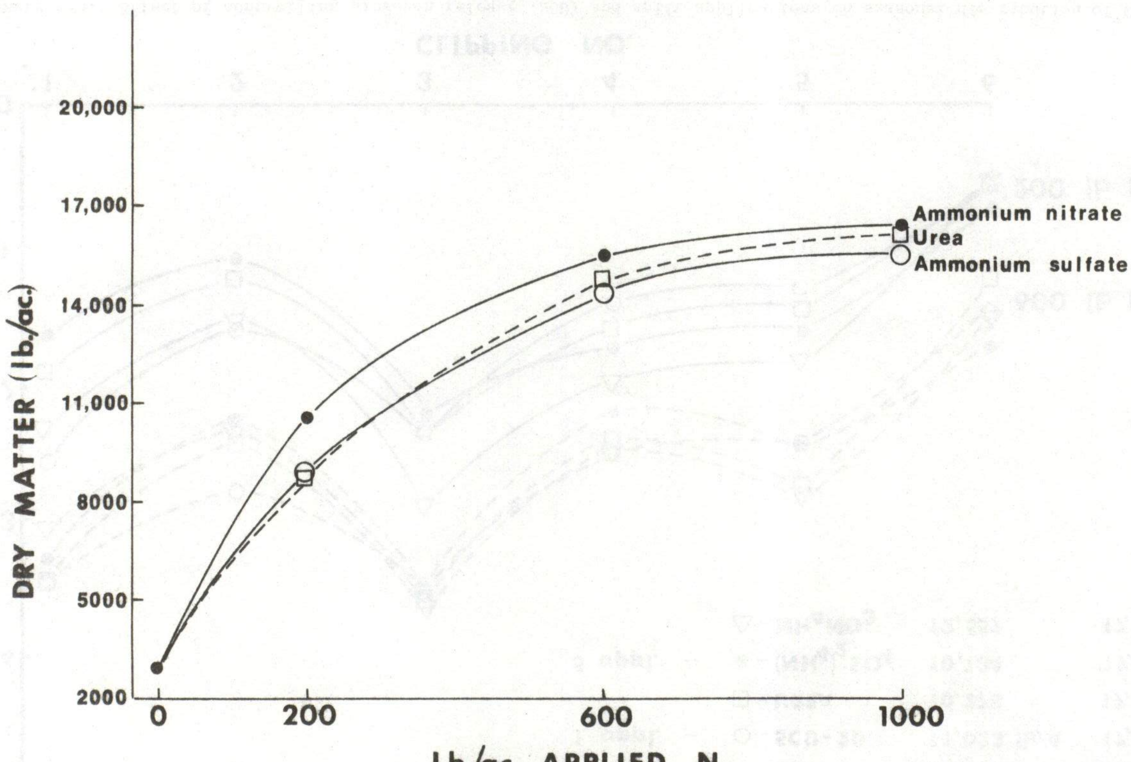


Figure 4-2. Response of Coastal bermudagrass to various rates and sources of N when sulfur eliminated as a variable. Average for 1968-71. Overton.

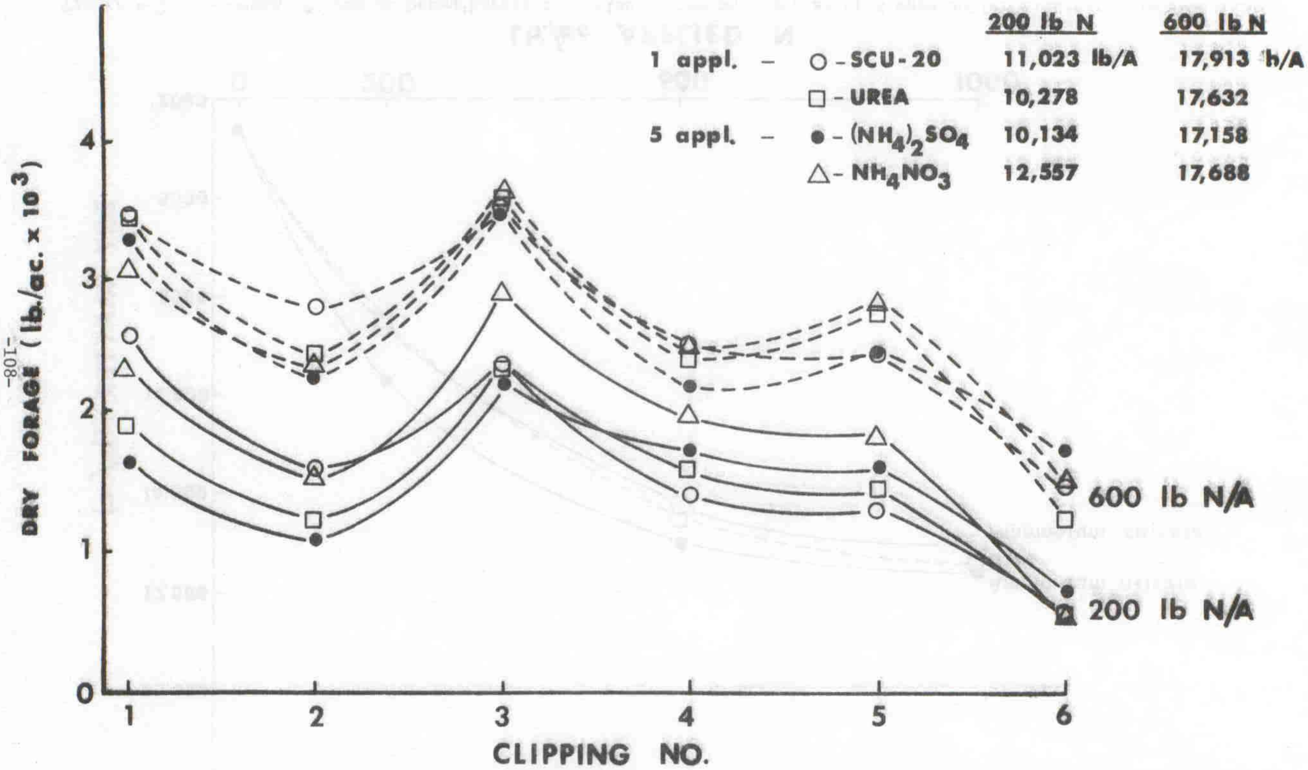


Figure 4-3. Effect of controlling nitrogen release (SCU) and split applications on seasonal distribution of Coastal bermudagrass forage. Average for 1970-73. Overton.

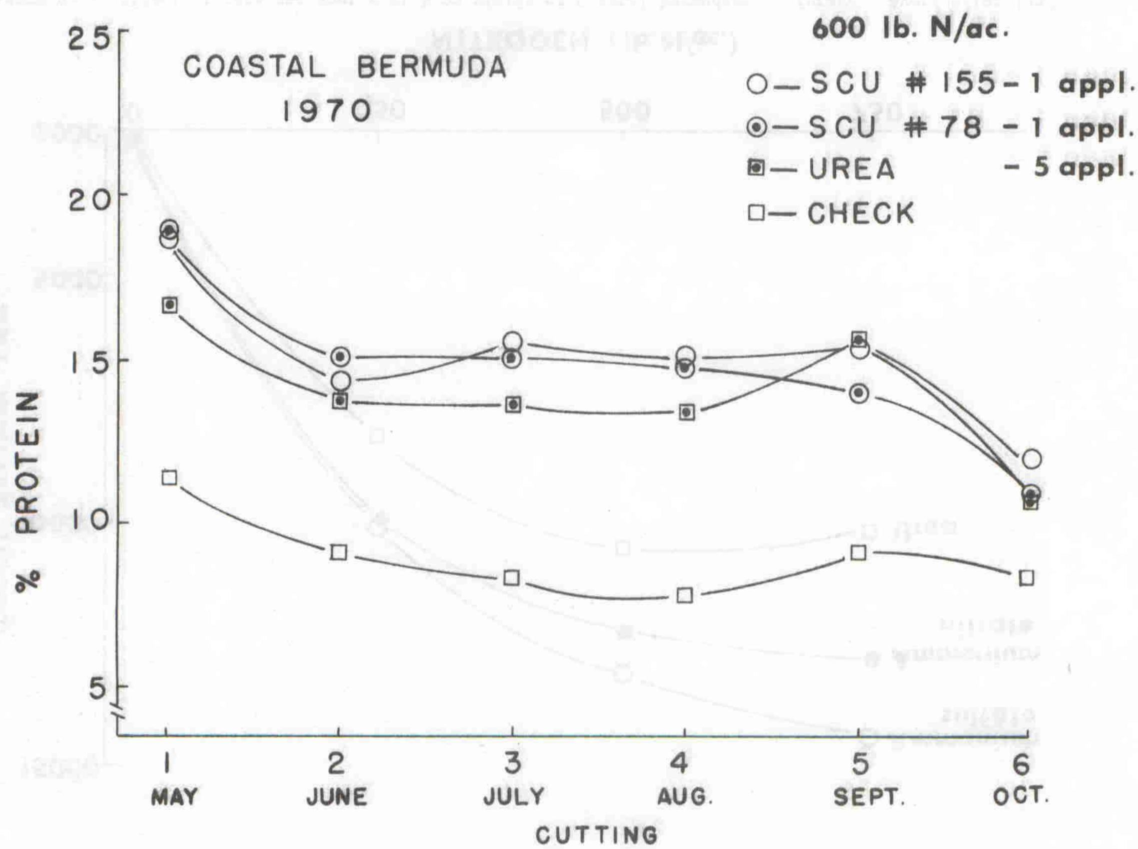


Figure 4-4. Effect of controlling N release (SCU) and splitting applications on protein content. Overton.

of sulfur (S), magnesium (Mg), calcium (Ca), and certain micronutrients before maximum response to N can be realized. Proper soil tests together with tissue analysis for particular situations are the keys to profitable use of plant nutrients and maximum utilization of N fertilizers.

Phosphorus and Potassium - Results from P and K experiments on Coastal bermudagrass in East Texas show that former fertilizer recommendations may have stressed K more heavily than needed on certain sandy soils. Fertilizer P and K ratios of approximately 1:1 have consistently produced as much or more forage than ratios of 1:3. Recent results on a Darco soil show high production of Coastal bermudagrass with a 2:1 ratio of P and K when at least 120 pounds K_2O per acre were used. Approximately 70 percent of the variation in yield was attributable to P and some 30 percent of K.

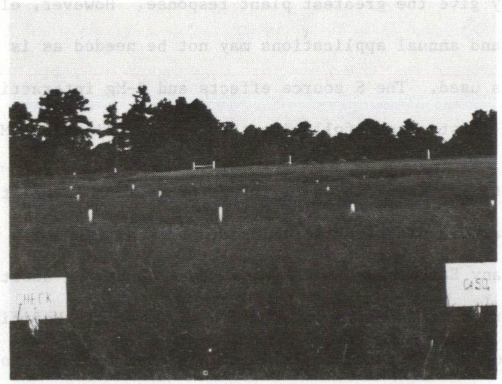
Results of a 3-year study at Mt. Pleasant with various rates of N, P, and K on Coastal bermudagrass overseeded with crimson clover indicated the importance of adequate P and K at high rates of N (Holt and Lancaster, 1968). When at least 400 pounds N per acre were used, a 1:1 ratio or 200 pounds per acre of P_2O_5 and K_2O, respectively, was needed for maximum production. The legume contributed insignificantly to total forage yields. Work on alluvial soils by Jones (1969) showed Coastal bermudagrass responded very little to K but showed response to applied P with high rates of N.

Conclusive research on East Texas soils having different mineralogy from Darco and Bowie generally indicates that certain finer textured soils with more adsorbed K and less soil solution K could require a 1:2 ratio of applied P and K.

Magnesium and Sulfur - Production of forages in East Texas may suffer from soil deficiencies of S and Mg when adequate N, P, and K have been supplied. Sulfur usually will not limit production of forage unless at least 300 pounds N per acre are applied. Although S deficiencies may occur on most East Texas soils, the problem will be most pronounced on the deep, sandy soils (Photo #3). Response to Mg will not be normally evident unless S is adequate. A significant Mg X S interaction is apparent on deeper coarse-textured soils.

Research on Coastal bermudagrass grown on a Darco loamy fine sand at Overton indicates

3.



After plant requirements for nitrogen, phosphorus, and potassium are met, sulfur may limit forage production in East Texas. Eighty lb S/A as gypsum (right) may produce approximately 30 percent more Coastal bermudagrass forage.

a 30 percent increase in forage yield from 180 pounds per acre applied as gypsum a year earlier (Figure 5). Forage production was increased 50 percent when Mg accompanied the applied S (Figure 6). Other data from the same study (Matocha, 1971) show that a low rate of Mg without S has no effect while high Mg rates have deleterious effects on plant growth.

The form of S fertilizer applied has significant effects on plant response to S. The prilled S or S^o form of S shown in Figures 5 and 6 is the unoxidized or elemental S which is usually slowly available to the plant. The gypsum form of $CaSO_4 \cdot 2H_2O$ is more readily available and may give the greatest plant response. However, elemental S has longer residual effects and annual applications may not be needed as is generally the case when $CaSO_4 \cdot 2H_2O$ is used. The S source effects and S-Mg interaction were generally not as strong during the first season following treatment application (Matocha, 1969).

Micronutrients - With intensification of forage production associated with high rates of N, P, K, Mg, S, and Ca, micronutrient fertilization on certain soils may be needed. The chemical nature of many East Texas soils favors development of shortages of micronutrients following a period of intensive production of forages. Deficiencies are likely to appear first on the coarser-textured soils which are used for hay production rather than for grazing. Coastal bermudagrass, because of its high production, creates tremendous drains on plant nutrients. The relatively high plant availability of most micronutrients present in these acid soils makes deficiencies become evident only under high production situations. Research on an upland soil at Overton shows some response (9 percent increase in dry matter) to Zn (zinc) and Cu (copper) when at least 600 pounds N per acre are used on Coastal bermudagrass. No plant response to these minor elements is observed at low N rates. Similar response to Zn by Coastal bermudagrass on an alluvial or bottom land soil was observed by Jones (1969).

Warm-Season Annuals

Millets, sorghums, sudangrasses, and sorghum-sudangrass hybrids can furnish large quantities of relatively good quality forage in the summer months when quality of perennial grasses may be low. Tremendous improvements in varieties and hybrids in recent years have enabled the growing of these annuals over a greater range of environmental conditions.

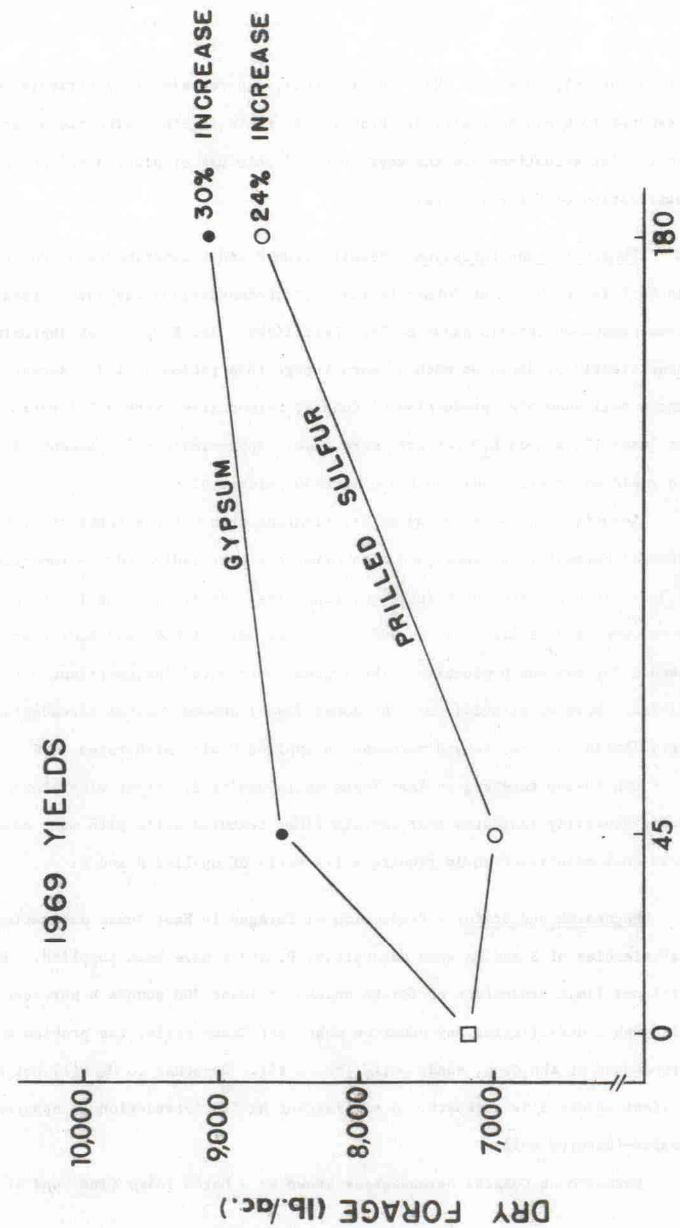


Figure 4-5. Residual effect of rates and sources of sulfur on yield of Coastal bermudagrass forage. Overton.

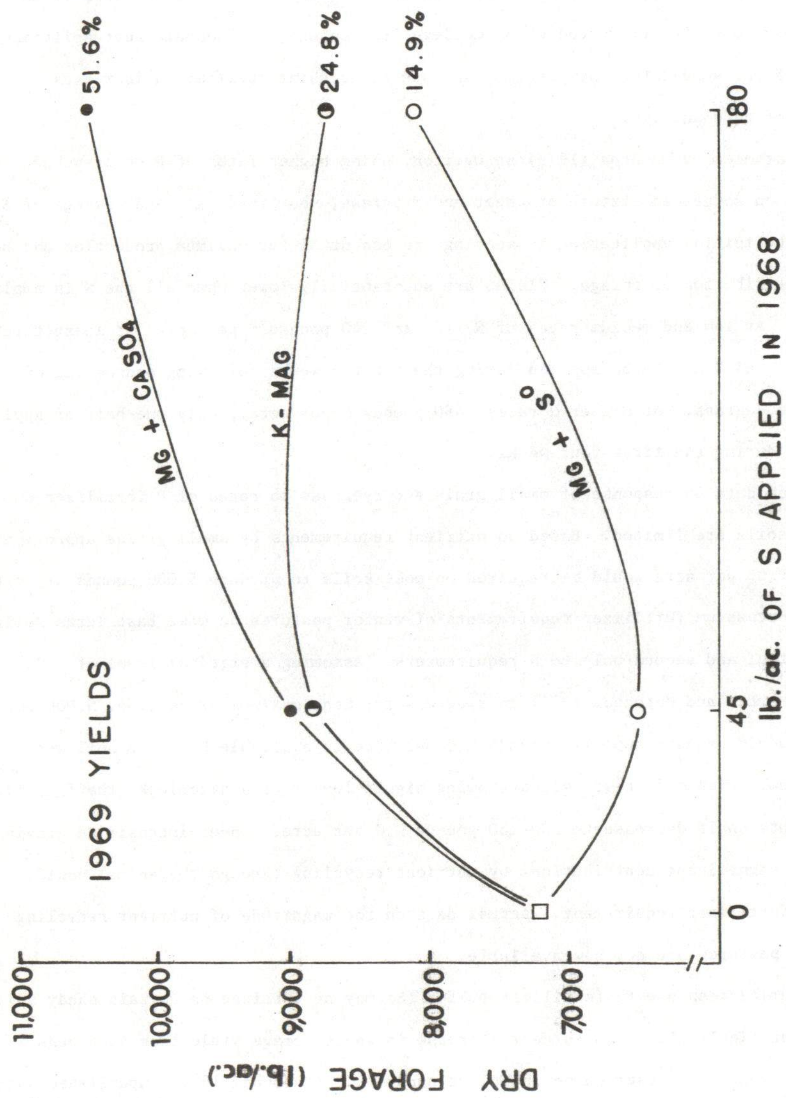


Figure 4-6. Residual effect of Mg and rates of sulfur on yield of Coastal bermudagrass. Overton.

Results of N studies at College Station (Costa, C.V., 1970) showed that dry matter yields of sorghum-sudangrass peaked at 150 pounds N per acre. A significant difference among sources of N occurred with response in the following order: $NH_4NO_3 > NaNO_3$ = $(NH_2)_2CO > (NH_4)_2SO_4$. Preliminary work (J. E. Matocha, unpublished data, 1972, Overton) with millet on an alluvial Athens sandy loam showed very little production from 160 pounds N per acre alone, while production tripled when the N was applied with 85 pounds P_2O_5 and K_2O per acre. Additional K_2O had no further effect, but increasing P_2O_5 to 170 pounds per acre doubled dry matter production over that obtained from the 85 pound rate. These data indicate that a previously unfertilized bottom land soil similar to an Athens sandy loam may require about 240, 170 and 85 pounds per acre of N, P_2O_5, and K_2O, respectively, for high production during the initial year. It is anticipated that the K requirement would increase with time.

Cool-Season Forage

Normally the distribution of annual rainfall in the East Texas region favors production of cool-season forages. As shown in Table 1, more than 50 percent of the total annual rainfall occurs from September through March. With evapotranspiration substantially less than in summer months, ample moisture is usually present for good production.

Fertilization of winter forages is discussed for small grains, ryegrass, Wintergreen hardinggrass, and clover.

Cool-Season Perennial - A rate and time of N application study on a Susquehanna sandy loam at Overton described response by TAM Wintergreen hardinggrass to N fertilization (Lancaster, unpublished data). Forage yields increase rapidly with N rates when either single or split applications are used (Figure 7). Production values are higher for split applications of N made in October and February compared to a single application in October. The response curve for split N applications indicates that forage yields of Wintergreen hardinggrass could exceed 8,000 pounds per acre with N rates in excess of 120 pounds per acre. However, if all N is applied in the fall, little additional production could be expected from rates higher than 120 pounds N per acre.

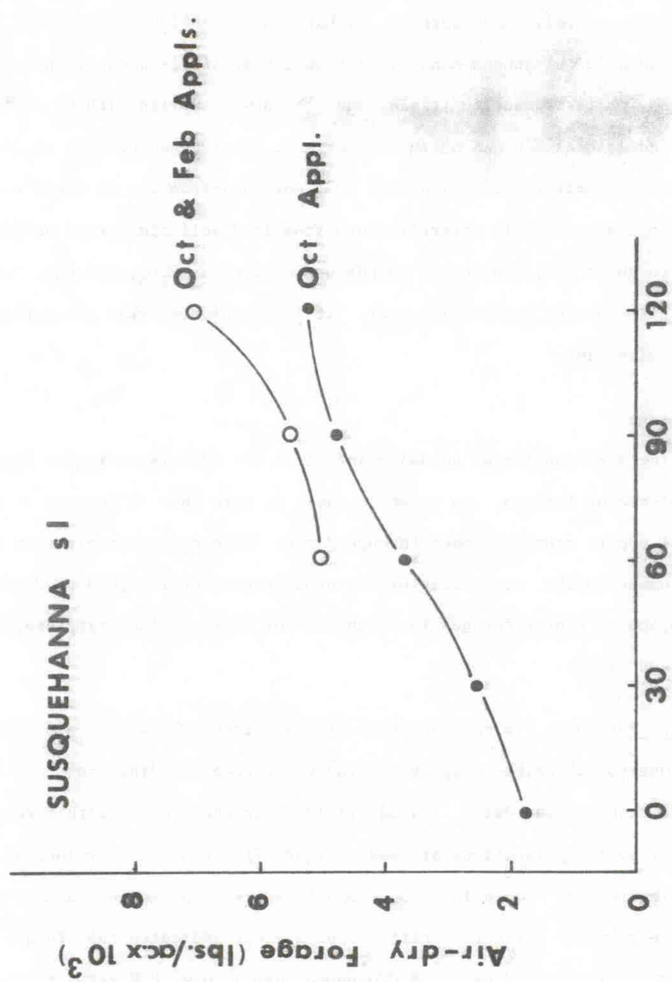


Figure 4-7. Effect of rate and distribution of N on yields of Wintergreen hardinggrass. 3-year average. Overton.

Cool-Season Annuals - Influence of rate and timing of fertilizer application on forage yield of small grains and ryegrasses has been reported by Holt, Norris, and Lancaster (1969), and more recently by Matocha et al., (1971) and Matocha (1972). Holt et al. (1969) concluded from studies at College Station and Mt. Pleasant that splitting 120 pounds N per acre into a preplanting and one topdressing application increases production of oats and rye.

Later studies by Matocha (1972) at Overton, using higher rates of N on prepared seedbed and on sodseeded mixture of wheat and ryegrass, show that two topdressings of N following the initial application at seeding are essential for maximum production and best seasonal distribution of forage. Yields are substantially lower when all the N is applied at seeding. At low and medium rates of N (120 and 240 pounds N per acre) at least three-fourths of total N has to be applied during the first 4 weeks following sodseeding on Coastal bermudagrass. At higher N rates (480 pounds N per acre), only one-half of applied N is needed during the first four weeks.

Research data on response of small grain and ryegrass to rates of P fertilizer on East Texas soils are limited. Based on nutrient requirements by small grains approximately 100 pounds P_2O_5 per acre would be required on most soils to produce 5,000 pounds dry matter per acre. Potassium fertilizer requirements of winter pastures on most East Texas soils are substantial and second only to N requirements. Assuming a critical level of 3.0 percent K (Martin and Matocha, 1973) in ryegrass for near maximum production, 5,000 pounds dry matter would require some 170 pounds K_2O per acre if available K in the soil were extremely low. With soil test values showing higher levels of available K, the fertilizer K requirements could decrease to 100-150 pounds K_2O per acre. Under intensified grazing conditions, significant contributions by nutrient recycling through the animal could reduce the fertilizer requirement. Actual data on the magnitude of nutrient recycling from winter pastures are not now available.

Substantial response to fertilizer sulfur (S) may be obtained on certain sandy soils in East Texas (Table 2). A 66 percent increase in wheat forage yield from 40 pounds S per acre as gypsum was observed on an upland sandy soil (Matocha, 1971, unpublished data). Although many soils in East Texas are deficient in S, response to S fertilizer will normally

Table 4-2. Effect of nitrogen, phosphorus, potassium and sulfur on yield of wheat forage on prepared seedbed. Overton.

Treatment (lb/acre)				Dry matter (total of 4 clippings)
N	P_2O_5	K_2O	Other	lb/acre
0	0	0		437
240	120	240		1572
240	120	240 +	40 S	2602
240	120	240 +	25 Mg	1701
240	120	240 +	40 S + 25 Mg	2508
		$LSD_{.05}$		630

be significant only where high analysis fertilizers relatively free of S are used as sources of N, P, and K. Fertilizer blends carrying 8-10 percent S used as sole sources of the required P and K will generally supply adequate S nutrition.

In a 2-year study, wheat showed no response to calcitic limestone when low to medium rates of N were used. However, response to liming is anticipated during the third season of intensive fertilization.

Cool Season-Warm Season Pasture Systems

Interest in seeding of small grain and ryegrass into bermudagrass sod has been renewed in the past few years. This practice usually can be associated with lower machinery cost but somewhat higher fertilizer investment.

Recent research shows that production of winter pasture may reduce spring growth of Coastal bermudagrass if rainfall is below normal in the spring and early summer. Actually, growth of Coastal bermudagrass can be less than that of wheat-ryegrass when moisture is limiting during the spring and summer (Matocha, 1972). However, when soil moisture is adequate, peak daily production of forage from Coastal bermudagrass will be more than twice that from a mixture of small grain-ryegrass (Figure 8). Wheat and ryegrass can produce 43 pounds forage per acre per day in March while production from Coastal bermudagrass can exceed 90 pounds forage per acre per day in August.

Small Grain-Ryegrass on Sod - Response to N rates by sodseeded wheat-ryegrass will be seasonal with minimal response during the fall and winter (Figure 8). Plant growth increases tenfold in March and April, with the greatest N response occurring when N is increased from 120 to 240 pounds per acre. During the initial year additional response to N rates above 240 pounds per acre can be expected. However, when the bermudagrass receives moderate rates of fertilization, small grain response to N above the 240 pounds per acre rate the second season will be extremely small. Yield variation due to N rate will be larger for Coastal bermudagrass than for small grain-ryegrass (Figure 8).

Near maximum early production of small grain can be obtained with 100-120 pounds N per acre applied at time of seeding on bermudagrass sod. This initial rate can be reduced if seeding is done on a well-prepared seedbed. Two additional applications of N each equal to approximately one-half of the initial application are needed to complete the N

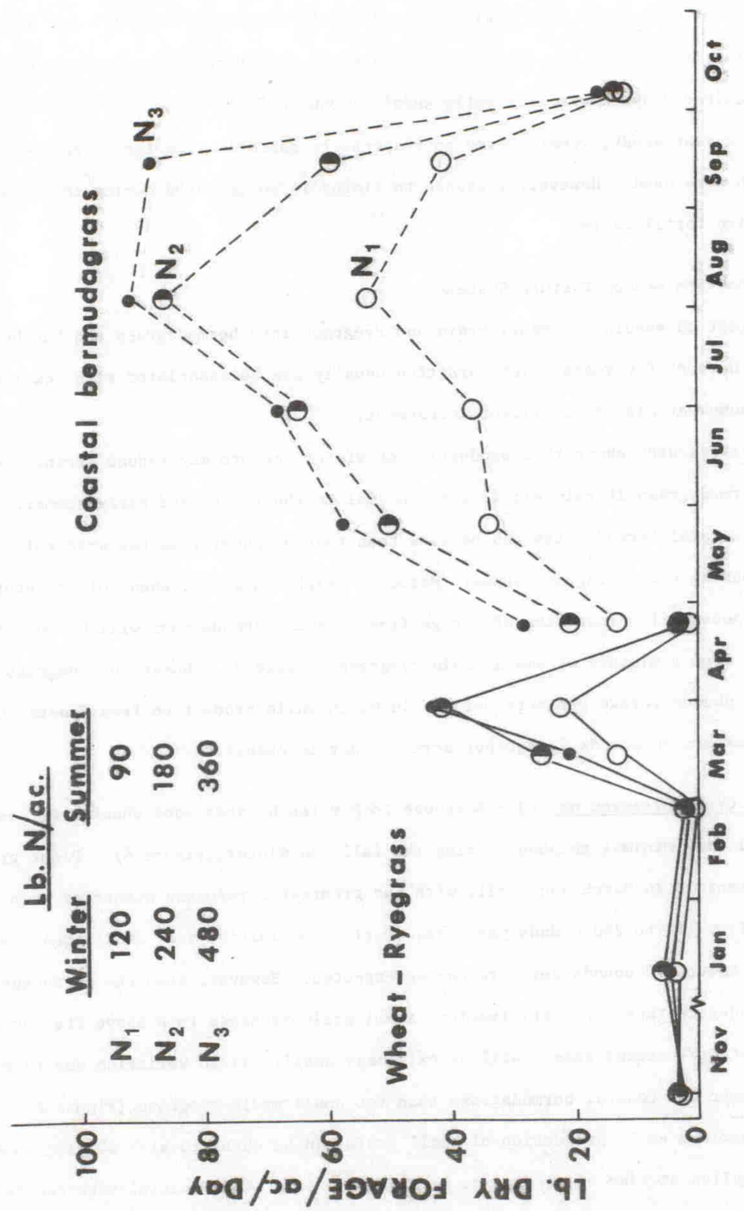


Figure 4-8. Growth rates of wheat-ryegrass and Coastal bermudagrass grown in association as affected by N rates. Overton.

fertilizer requirements of the winter pasture. Under a system of continuous removal of forage with essentially no recycling of nutrients (clipping trials), the optimum rate of N for near maximum profits appears to range from 240-300 pounds N per acre for the cool-season forage. This assumes N fertilizer costs at $.20 per pound N and cattle selling price at $.35 per pound. With seedbed preparation, rates can be reduced by 30-40 percent and forage production maintained at or above that for the sodseeded system. Extrapolation of results from the clipping studies to a grazing system must take into account the contribution of plant nutrients recycled through the animal and the forage production pattern. The extent of this contribution can be significant and can materially reduce rates of fertilization. Research has been instigated that will aid in developing a factor for converting fertilizer rates from clipped plots to grazed pastures.

Cultural practices used in production of winter pastures on sod can have a tremendous bearing on total forage production as well as distribution of forage during the season. Research at Overton (Matocha, 1975) shows that preparing a seedbed for small grain-ryegrass will enhance plant growth and result in almost twice the seasonal production of that under sodseeded conditions. The growth rate for prepared seedbed and sodseeded grass will be relatively slow during the fall and minimal rates in January and first part of February (Figure 9). This will be followed by sharp increases in growth rates from the latter part of February through March. Rate of plant growth will diminish in the latter part of March and through April when the plants are terminating vegetative growth and initiating and completing seed production. The intensity and timing of the peak growth rates are affected to some degree by cultural practices, climatic conditions, and species of cool-season grass. Small grain-ryegrass on a prepared seedbed will normally produce earlier and more rapid growth in the fall and early spring than the same grass sodseeded. Increasing N rates on a sodseeded pasture will not compensate for the seedbed effect on fall and early winter production of small grain forage.

Species influence on small grain forage production can be substantial in some cases. Oats appear to give somewhat earlier production in the fall than rye or wheat. However, species effect is highly related to temperature.

Although forage production from sodseeded small grain-ryegrass does not measure up to that from prepared seedbed at present, additional cultural practices such as limited

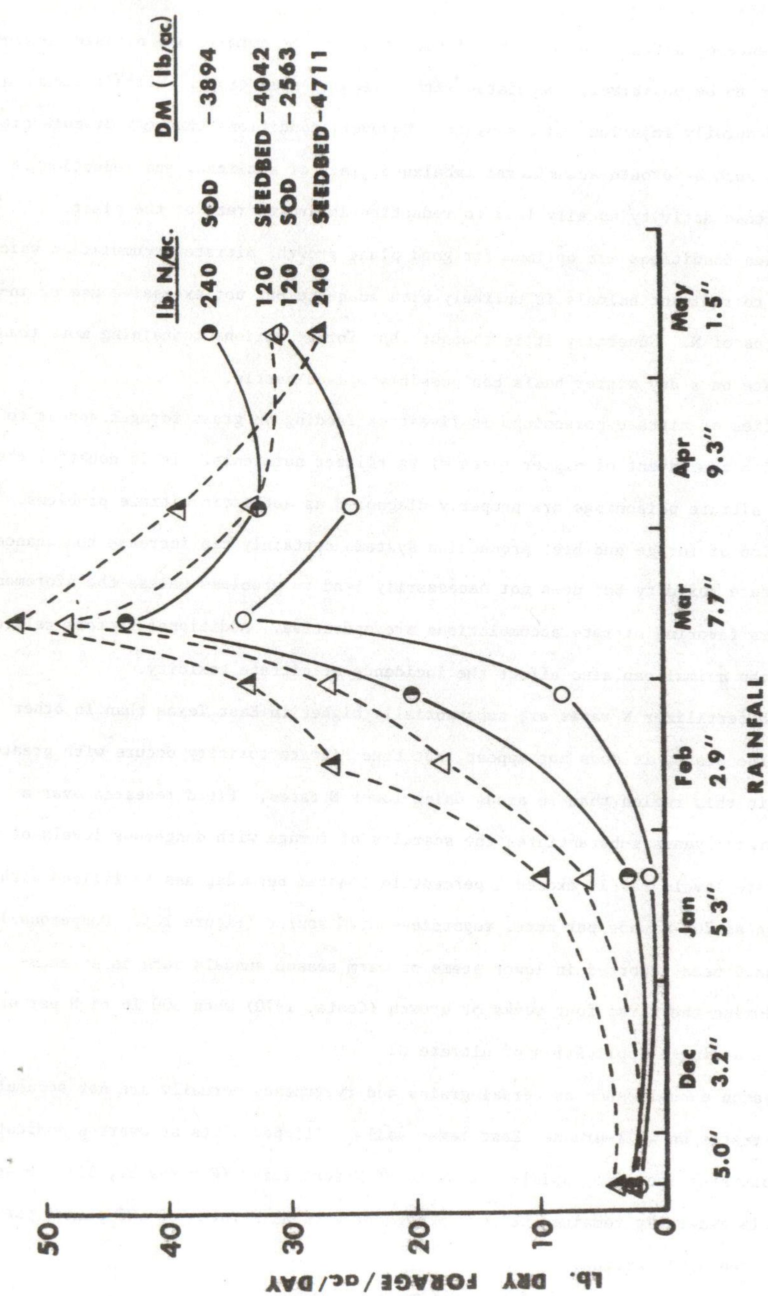


Figure 4-9. Growth rates of rye-ryegrass as influenced by N rates and seedbed preparation. 1972-73. Overton.

mechanical tillage and use of chemical desiccants on the bermudagrass may improve the performance of sodseeded pastures. Additional research in these areas is being conducted by the Texas Agricultural Experiment Station.

Legumes on Sod - Various winter-annual legumes have been tested in combination with Coastal bermudagrass on light sandy soils in East Texas (Holt et al., 1961). In early studies, narrow-leaf vetch and crimson clover had the most potential for early spring production. Crimson clover has also shown good results in most of the later studies. Usually Coastal bermudagrass is fertilized with P and K in the fall prior to overseeding with the clover. A small application of N on deep sandy soils will encourage early establishment of the legume. This practice is followed each fall. Usually N from the portion fixed by the legume will be sufficient to produce the first cutting of Coastal bermudagrass in the spring.

Production data from Mt. Pleasant and Overton indicate that inclusion of a winter legume definitely results in earlier spring production of forage (late March). Approximately 1,500 pounds forage per acre were produced in April with crimson clover at Mt. Pleasant with 0-60-60 fertilizer (Holt et al., 1961). At Overton 3,000 pounds forage were produced with the same legume overseeded in Coastal bermudagrass receiving 60-120-120 in the fall (Matocha, unpublished data, 1973). Season total yields for the legume-grass system usually will be greater than for grass alone; however, the effects of the legume are less apparent as N rates on the grass are increased. High costs of nitrogen fertilizer should give impetus for new studies on breeding, management, and utilization of legumes in grass systems.

Irrigated Forage - Fertilization of forages becomes even more important with irrigation. The production potential of Coastal bermudagrass grown with supplemental irrigation can be realized only with high soil fertility. Fisher and Caldwell (1959) obtained 4.5 tons forage per acre with 1,350 pounds N and 27 inches of irrigation water. Rainfall during the growing season brought the total water available to 42 inches. This was approximately 3 inches of water per ton of hay.

Supplemental irrigation is costly and should not be undertaken without sufficient background knowledge of the possible economic benefits. At the present time the use of pplemental irrigation on forages in East Texas has not been established as a profit-e practice. Certainly, during summer drouth periods, irrigation can be economically fitable; however, the frequency and sure anticipation of this need makes the practice stionable.

'tilizer Response as Related to Soil Type

Response to fertilization is affected by available soil moisture in addition to avail-.e plant nutrients. Both of these factors are a function of soil type. Because of latively high rainfall and lower evapotranspiration during the fall and winter months, oduction of winter pasture is generally influenced less by soil type-moisture relation-ips than production of summer pasture. Fertilizer response from summer forage, especially sponse to N, may vary substantially with different soils. Grass grown on relatively ep sandy soils such as the Bowie and Darco sandy loams will respond to higher rates of rtilizer than on shallower soils which have impervious clay subsoils, such as the thbert-Thruston and Nacogdoches sandy loams. Differential response to high rates of rtilizer nutrients by deep-rooted crops such as Coastal bermudagrass becomes apparent a function of soil type in periods of summer drouth. Grass on shallow soils will reach vere moisture stress earlier and have a lower optimum level of nutrient fertilization der identical rainfalls and temperatures.

cycling of Plant Nutrients

Obviously, the rates of fertilization required for a grazing system will vary from iose for hay production. The quantity of recycled nutrients under haying is meager, nounting only to that from leaf fall and root decay (Matocha, Rouquette, Duble, 1973). ertilizer nutrient recycling via animal excreta can be substantial in some cases (Calder id Nicholson, 1970; Wolton, 1963). Data collected for East Texas (Rouquette, Matocha, uble, 1973) indicate a good portion of a 200-100-100 (N, P_2O_5, K_2O) fertilizer applica-ion is utilized by Coastal bermudagrass and cycled through the animal and back into the oil. Stocking rates influence the extent of nutrient recycling. Considerably more tudy is needed on the effect of animal stocking rates and soil-type differences on extent f nutrient recycling and consequent fertilizer rates.

Nitrate Toxicity

The presence of nitrates within the tissue of plants is normal, and nitrate content has been shown to be positively associated with yields of some crops. Nitrate accumulation is not generally injurious to the plant. However, conditions that may promote nitrate accumulations such as drouth and mineral imbalance, lack of sunlight, and reduction in nitrate reductase activity usually lead to reduction in growth rate of the plant. Generally, when conditions are optimum for good plant growth, nitrate accumulation which can be toxic to ruminant animals is unlikely with adequate but not excessive use of inorganic sources of N. Generally it is thought that forage rations containing more than 2 percent nitrate on a dry matter basis can possibly poison cattle.

Frequencies of nitrate poisonings in livestock feeding on grass forages appear to be associated with the advent of higher rates of fertilizer nutrients. It is doubtful that all reported nitrate poisonings are properly diagnosed as authentic nitrate problems. Intensification of forage and beef production systems certainly can increase the chances of acute nitrate toxicity but does not necessarily lead to problems unless the aforementioned factors favoring nitrate accumulations are operative. Additional factors related directly to the animal can also affect the incidence of nitrate toxicity.

Although fertilizer N rates are substantially higher in East Texas than in other sections of the State, it does not appear that true nitrate toxicity occurs with greater frequencies in this region than in areas using lower N rates. Field research over a period of several years substantiates the scarcity of forage with dangerous levels of nitrate. Nitrate levels rarely exceed 1 percent in Coastal bermudagrass fertilized with N rates as high as 700 pounds per acre, regardless of N source (Figure 10). Dangerous levels of nitrate have been reported in lower stems of warm season annuals such as sorghum-sudangrass during the first four weeks of growth (Costa, 1970) when 300 lb of N per acre were added in a single application of nitrate N.

Cool-season annuals such as cereal grains and ryegrasses normally are not accumulators of excess nitrates on well-drained East Texas soils. Clipped plots at Overton indicate that plant nitrates increase rapidly with rate of N fertilizer (Figures 11, 12). However, nitrate levels generally remained below 1.5 percent even at N rates of 480 pounds per acre split into three applications.

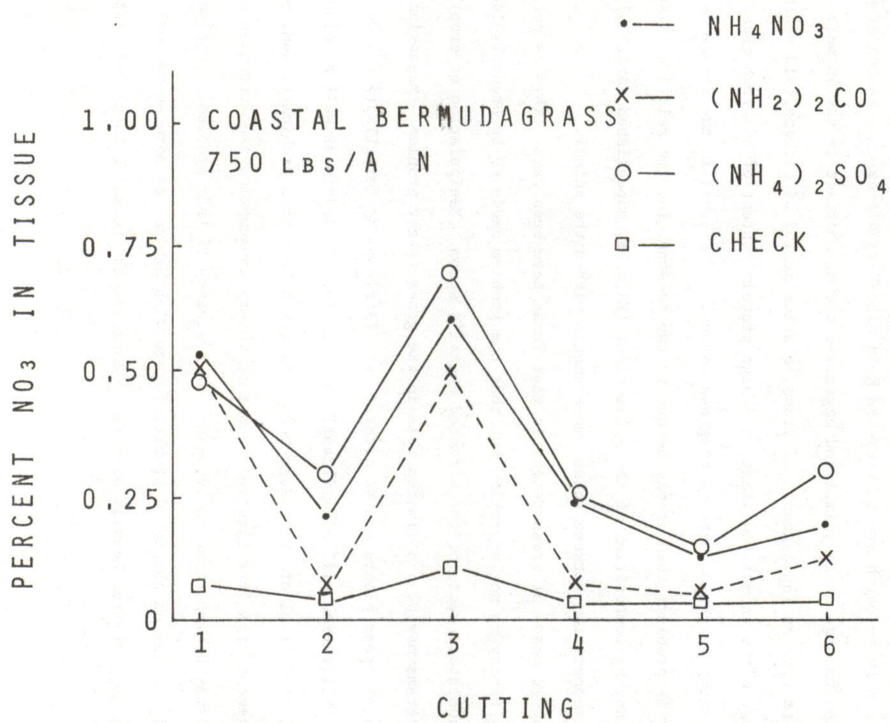


Figure 4-10. Influence of N source on concentration of nitrates in perennial warm season grass. Overton.

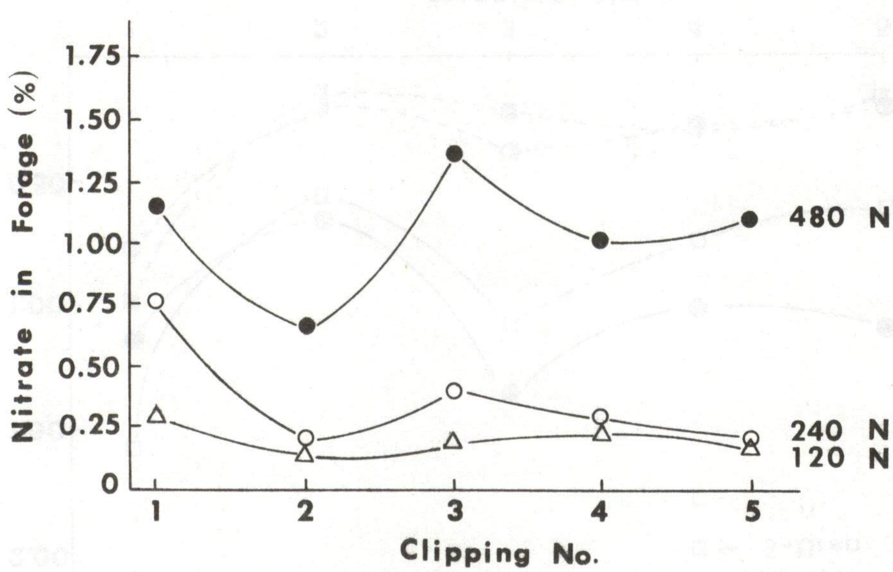


Figure 4-11. Influence of N rate and harvest on concentration of nitrates in sodseeded wheat-ryegrass. Overton.

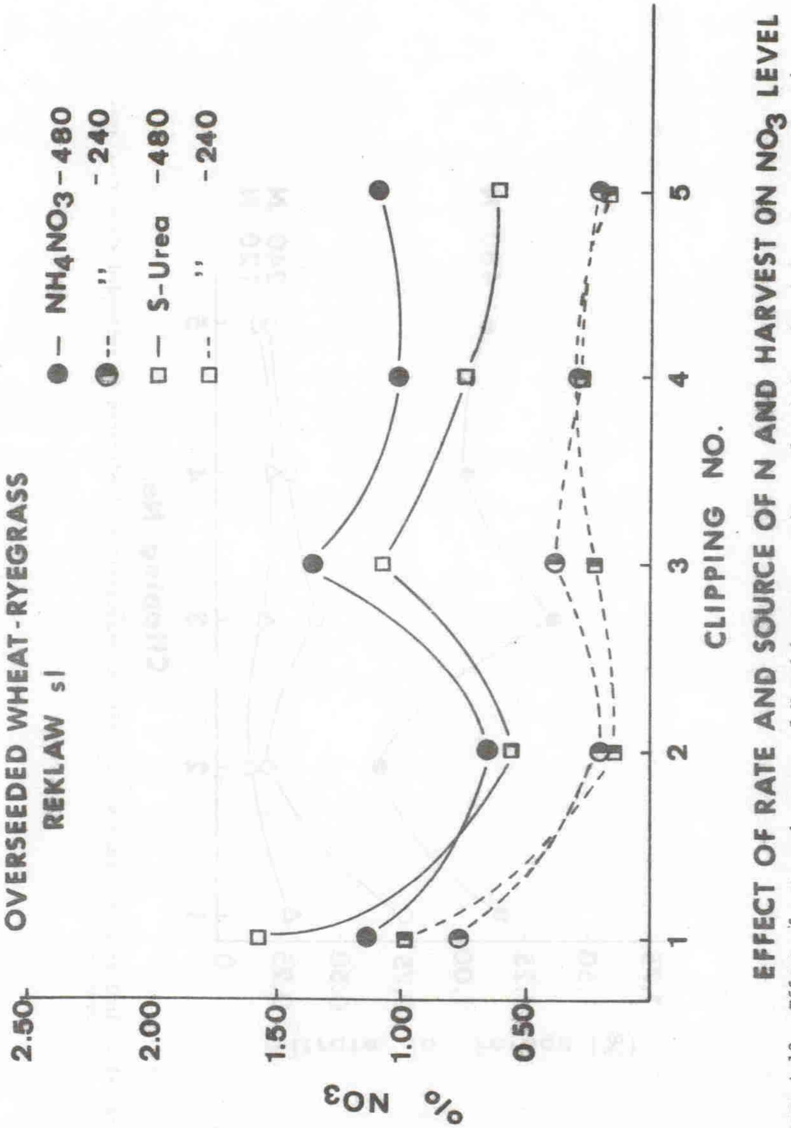


Figure 4-12. Effect of rate and source of N and harvest on nitrate level in sodseeded cool-season grass. Overton.

Grass Tetany

Grass tetany is sometimes called grass staggers, wheat pasture poisoning, or hypomagnesemia. The exact cause of this abnormality is uncertain although it appears to be associated with an imbalance in certain mineral components of blood serum. The incidence of grass tetany appears to be associated more with cool-season rather than warm-season grasses and occurs most often in lactating beef cows 5 years of age and older. Diagnostic test results have associated this disease with low serum magnesium. Indications from preliminary research are that excess K in high-K-requiring cool-season grasses may compete with the Mg in the animal and aggravate the Mg shortage in the animal.

Factors such as rapid growth of grass, a prior period of extreme cold weather which adds stress on the animal and plant, and high protein content of the lush grass have been implicated in the occurrence of grass tetany. If K level in the forage is associated with this problem, then it may be due to two reasons, inverse relation existing between K and Mg composition of the grass plant (Matocha, unpublished data, 1973) and metabolic competition between these two elements within the animal.

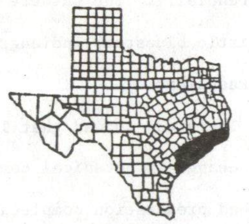
Diagnosed cases of grass tetany in East Texas have been rare. This is not saying that grass tetany is not a problem but that the problem needs to be properly identified through laboratory tests of the affected animal's serum. Manipulation of crop fertilization programs may play a limited role in the grass tetany problem. Magnesium concentration of grass plants can be altered very little by Mg fertilization. On the other hand, K fertilization will significantly affect plant Mg levels as well as plant K levels. Therefore, if K level of the forage does directly affect this problem to some degree, then management of K fertilization such that luxury consumption and accumulation of K is reduced may be important in reducing the frequency of this problem. Supplementing the animal feeding on suspected problem forage with MgO may be more economical than attempting to fertilize heavily with Mg to increase the animal's intake of plant Mg.

SOUTHEAST TEXAS

D. G. Westfall and Marvin E. Riewe*

The Southeast Texas region encompasses the land resource areas known as the Coast Prairie and Coast Marsh. The total land area of this region of Texas approximates 7,500,000 acres with land use classification as follows:

	Approximate Acreage
Total farmland	5,500,000
Cultivated cropland	3,250,000
Pasture and rangeland	2,250,000
Unimproved forage (range)	1,700,000
Improved forage	550,000
Perennial warm-season	300,000
Annual warm-season	90,000
*Annual cool-season	225,000



*Portion of this acreage is overseeded on perennial warm-season.

Major Soils and Climate

The soils of Southeast Texas which range from low to moderate in inherent fertility are generally considered more fertile than East Texas soils. The major soils adjacent to the coast and for a few miles inland are the Harris, Veston, and Galveston. Harris soils are dark clayey soils formed on old tidal flats and marshes just a few feet above sea level. Veston soils are loamy and occupy slightly higher positions. Galveston soils are sandy and occupy modern and relict beach strands in positions above Harris and Veston soils. Harris and Veston soils are saline, very poorly drained, and low in native fertility. Some areas are flooded by high tides and inundated by sea water during hurricanes.

The major soils of the agricultural area of this region are the Beaumont, Lake Charles, Edna, Crowley, and Katy series. The Beaumont and Lake Charles are clayey vertisols, acid in reaction and low in N and P but generally adequate in K for production.

*Respectively, (formerly) associate professor, the Texas Agricultural Experiment Station Beaumont; and professor in charge, the Texas Agricultural Experiment Station, Angleton.

Beaumont and Lake Charles are the major agricultural soils of this region. Edna soils are generally less acid, lighter in texture, and lower in N and P than the Beaumont and Lake Charles. Crowley soils have similar characteristics to the Edna except that they possess a deeper A horizon. The Katy soils, occurring on the western fringe of this area, are light textured alfisols, as are the Crowley and Edna, low in N, P, and K.

Native vegetation largely consists of tall bunch grasses on uplands and hardwoods in the bottomlands.

The climate is warm, temperate, and humid with annual rainfall ranging from 35 to 55 inches. Although rainfall is usually adequate for production of most forages, drouth periods which retard growth of forages can be expected due to irregular distribution of rainfall. Monthly rainfall and temperatures based on long-term averages are given in Table 3.

Fertilization of Forages

Warm-Season Perennials

Forage fertility research was first conducted in Southeast Texas about 1936 on Lake Charles clay by R. H. Stansel at Angleton. From 1936 to 1943, phosphate and nitrogen studies were conducted on permanent pasture sod, never plowed, that consisted initially of carpetgrass with small amounts of smutgrass and common lespedeza. Annual surface broadcast applications of P and P with N were made for 7 years. Fertilizer treatments did not increase yields the first 2 years, but white clover was found growing in response to P by the third year. (Annual Reports, Texas Agricultural Experiment Station, Substation No. 3, Angleton, Texas, 1936-1943). The response to P was substantial thereafter. The average air-dry forage yields for the last 5 years of the study were 4,160, 4,480, 4,910, and 5,230 pounds per acre with fertilizer applications of 0-40-0, 20-40-0, 0-80-0, and 40-80-0, respectively, compared to 2,830 pounds when no fertilizer was used.

The annual application of P caused a marked change in botanical composition of the sward over the 7-year period. The percentage of white clover was quadrupled with annual applications of 40 pounds P_2O_5 per acre with further increases when 80 pounds were applied. Common lespedeza was essentially eliminated. The percentage dallisgrass was doubled with the low P rate and then doubled again with an 80-pound P_2O_5 per acre annual application.

Table 4-3. Climatic data for selected locations in Southeast Texas

Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
						Mean monthly rainfall (inches)1/							
Port Arthur	4.23	4.45	3.44	3.94	4.94	4.29	6.00	5.49	4.88	2.88	3.46	5.09	53.09
Victoria	2.34	2.34	2.32	2.14	4.12	2.70	3.61	3.13	4.23	3.48	2.36	2.61	36.20
Angleton	3.47	3.31	3.05	3.15	4.12	4.55	4.89	4.57	5.10	3.98	3.75	4.57	48.54
						Mean monthly temperature (^{o}F)1/							Avg. Yr.
Port Arthur	53.6	56.0	61.1	68.2	74.7	80.6	81.9	82.3	78.2	70.3	59.7	54.8	68.5
Victoria	55.4	58.0	63.2	70.0	76.2	81.3	83.2	83.3	79.1	72.6	62.4	57.2	70.2
						Mean monthly evaporation (inches, avg. of 3 years)2/							
Point Comfort	3.18	4.28	6.17	6.70	8.20	10.71	12.07	11.11	7.46	6.16	4.84	3.42	84.29

1/ Represent 30-year average.

2/ Inches loss from water surface in standard weather service pan.

Concurrently the percentage carpetgrass and weeds decreased.

A second study was conducted, again on Lake Charles clay, to determine the effect of degree of seedbed preparation and several rates and frequencies of P application on the establishment of white clover and dallisgrass. Seedbed treatments included no preparation; disking to 1.5-inch depth; and thorough seedbed preparation including deep plowing (6-inch depth), disking and harrowing. Dallisgrass, common bermudagrass, white clover, and common lespedeza were seeded. The P fertilization treatments included rates of 20 pounds annually, 40 and 80 pounds biennially, and 80 and 160 pounds P_2O_5 per acre quadrennially. The pasture sod, at the time the study was initiated, consisted primarily of little bluestem, Indiangrass, and carpetgrass with a scattering of native Panicums and Paspalums.

The study showed that light disking as a method of seedbed preparation results in some change in botanical composition but has little effect on yield, whereas thorough seedbed preparation completely eliminates the native species, and yields are increased. Protein content increases with both methods because of the introduction of white clover. Dallisgrass and white clover increase at higher P levels with all methods of seedbed preparation. Lespedeza is more prevalent at the lower P levels on prepared seedbeds. The highest yields and highest protein contents are associated with seedbed preparation and higher levels of P. The value of white clover in improving pasture forage as a source of digestible energy for grazing cattle has been clearly demonstrated (See Chapter V, "Principles of Grazing Management".)

Rates and frequencies of application of P for dallisgrass and white, Persian and hop clover pastures have been subjects of study on Lake Charles clay soil (Cheaney, Weihing and Ford, 1956). An annual application of 30 pounds P_2O_5 per acre is superior to heavier applications at less frequent intervals, 60 pounds every 2 years or 120 to 200 pounds every 4 years. Low rates of rock phosphate are ineffective, and high rates are less effective than equivalent amounts of P from superphosphate. The most effective phosphate fertilizer practice seems to be an initial application of up to 120 pounds P_2O_5 per acre followed by annual maintenance applications of 30 to 60 pounds P_2O_5 per acre.

Methods of applying maintenance fertilizer to established pasture sods have been evaluated in a series of studies (Riewe and Smith, 1955). Surface broadcast applications of P are found superior to any method of physically incorporating the fertilizer into the soil, including banding at 2-, 4-, and 6-inch depths. Although it is recognized that P exhibits little downward movement, particularly in clay soils, a major portion of the young feeder roots of both dallisgrass and white clover are found in the top 2-3 inches of soil. This suggests that soil samples taken to determine maintenance fertilizer needs for established pastures be taken to a 2- to 3-inch depth.

Response to K applied to pastures on clay and silt loam soils in Southeast Texas is extremely limited. No response to 100 pounds K_2O per acre was found when applied to a dallisgrass-white clover sod on Lake Charles clay at Beaumont. This was true even when P was applied at 160 and 320 pounds P_2O_5 per acre. In another experiment on Lake Charles clay, only limited response to annual applications of 100 pounds K_2O per acre with nitrogen and phosphate (100-80-100) was observed on Coastal bermudagrass and La. S-1 white clover. Three-year average oven-dry forage yields were 12,810 pounds per acre when fertilized with K and 11,550 pounds per acre when not fertilized with K. No response to K was obtained when the La. S-1 white clover was grown with common bermudagrass, dallisgrass or angletongrass (Riewe and Smith, 1961).

The use of lime has been investigated by several researchers in Southeast Texas. No yield response to lime has been reported on clover experiments conducted on Beaumont and Lake Charles clays and Morey silt loam soils.

Cool-Season Forages

Gulf ryegrass is the most popular and successfully grown winter forage in this area. Before its release in 1958, a high producing, rust resistant annual cool-season grass was not available. Ryegrass responds markedly to applications of N and P. Since its release, research has been conducted to determine the N and P requirements of Gulf ryegrass. Time of N application has been given particular attention. On clay and silt loam soils, yield responses to K or other nutrients have not occurred. Split applications of N always produce superior yields compared to single applications. Yield results from 3 years research on the effect of N rate on Gulf ryegrass production on a Morey silt loam soil at Beaumont are presented in Table 4. A nitrogen rate of 150 pounds per acre produced maximum economic

Table 4-4. The effect of N rate and source on yield, protein content and N efficiency of Gulf ryegrass at Beaumont. Average of 3 years.

N Rate	N Source	Yield lb DM/acre	% Protein	% N Efficiency
0	- -	1,721	11.04	- -
50	Ammonium sulfate	3,968	11.95	78.0
	Urea	3,715	12.05	75.8
100	Ammonium sulfate	5,645	13.57	75.2
	Urea	5,194	14.01	69.6
150	Ammonium sulfate	6,601	15.50	72.6
	Urea	6,607	14.90	64.2
200	Ammonium sulfate	6,811	16.85	75.7
	Urea	6,486	18.00	74.3

yield over the 3-year period. Protein content increased linearly up to the maximum N rate of 200 pounds per acre. The N efficiency ranged from 64 to 78 percent with no definite relationship between N rate and efficiency. With clean summer fallow from July until seeding of the ryegrass in early October on a Lake Charles clay soil at Angleton, maximum economic yields are obtained with 90 to 120 pounds N per acre in split applications. This suggests that nitrates accumulate with clean fallow, and the requirements for fertilizer N may be reduced.

The seeding of Gulf ryegrass into existing forage stands has been investigated both at Beaumont and Angleton. Inferior yields are consistently obtained when this is done. About 70 percent more forage can be produced in a well-prepared seedbed than in undisturbed sod.

Summary

The production of quality forage can be achieved with both warm-season and cool-season species in the Gulf Coast region. Dallisgrass is the most productive warm-season grass.

An initial application of 120 pounds P_2O_5 per acre followed by annual maintenance applications of 30 to 60 pounds P_2O_5 per acre appears to produce the most economical return in permanent dallisgrass-clover pastures.

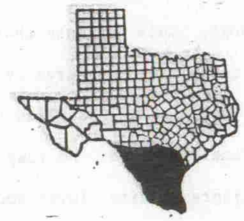
Gulf ryegrass is presently the highest producing cool-season species available. Yields of over 6,000 pounds dry matter per acre can be obtained with the use of proper N fertilization, usually 90-150 pounds N per acre. Response to K has not been obtained on the fine-textured soils of the Gulf Coast Region.

SOUTH TEXAS

B. E. Conrad*

The South Texas region encompasses the land resource area known as the Rio Grande Plain. The total land area of this region approximates 22 million acres with land use classification as follows:

Total Farmland	20,014,975
Cultivated cropland	6,200,405
Pasture and rangeland	13,814,570
Unimproved forage (range)	12,204,227
Improved forage	1,610,343
Fertilized	1,000,000



Estimates of acreages of perennial and annual warm-season and annual cool-season forages are not available. However, the majority of the improved forage acreage consists of warm-season perennial grasses.

Soils of South Texas are generally in the medium range of inherent fertility. Response to nitrogen is general with only limited response to phosphorus and essentially no response to potassium.

Major Soils and Climate

Upland soils in this region range from sands and sandy loams to clay loams and clays. Main series associated with the reddish-brown, neutral to slightly acid sandy loams are the Duval and Webb, while in the grayish brown, neutral sandy loams the main soils are Willacy, Hidalgo, Brennan, Miguel, Goliad, and Medio. Dark gray, highly calcareous to neutral clays and clay loams of agricultural importance are the Victoria, Monteola, Clareville, and Orelia. Some saline soils occur near the coast.

Bottomland soils are generally calcareous clay loams and clays with the main series consisting of the Harlingen, Cameron, Frio, Guadalupe, and Leona. Salinity may be localized in some of these soils.

The Rio Grande Plain area of South Texas is variable but generally is characterized

*Associate professor, the Texas Agricultural Experiment Station, Beeville.

by mild winters, a relative long growing season for warm-season forages, and an annual rainfall ranging from 20 to 35 inches. Climatological data from Beeville, located on the eastern side of the area, and Falfurrias, located in the southern part of the area, are shown in Table 5. The average frost-free period varies from about 250 days in the north to approximately 330 days in the south.

Improved pastures in the upper Rio Grande Plain area have increased several fold in the last decade. Although the majority of these pastures are under dryland conditions, irrigation is increasing. Because of the long frost-free period, warm-season perennial grass species are primarily used in improved pastures. Along with the increase in improved pastures there has been an increase in the use of fertilizer nutrients. Response to fertilization is related to the distribution of moisture. Although the average monthly rainfall totals appear adequate to develop fertilization programs, the forecasted deviations from the average create difficulty in implementing these programs. At Beeville the 68-year monthly average for March and April is 1.85 inches and 2.39 inches, respectively. Yet, during the 10-year period between 1962 and 1972, these averages have been met only 25 percent and 30 percent of the time, respectively. July is another critical month for forage production. The long-time average for July is 2.33 inches; however, only once in the past 10 years has this average been realized. Because of these deviations, initial fertilization response is not always evident under dryland; thus, many producers are reluctant to follow a continuing fertilization program. However, the increased production from improved species has had a marked effect on natural soil fertility resulting in definite nutrient deficiency symptoms after 2 or more years in production. The decrease in dry matter production has pointed out the need for increasing the use of plant nutrients under pasture conditions.

Fertilization of Forages

Warm-Season Perennials

Coastal bermudagrass is the most widely used of the introduced species. The acreage of Coastal bermudagrass has continually increased since its release. Variations in plantings range from sprigging the swales in the low rainfall areas, capitalizing on runoff moisture, to highly intensified production under sound fertilization and irrigation pro-

Table 4-5. Climatic data for selected locations in South Texas

Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	Mean monthly rainfall (inches)1/												
Beeville	1.68	1.81	1.85	2.39	3.64	3.06	2.33	2.26	4.10	2.66	2.01	2.18	29.97
Falfurrias	1.52	1.23	1.02	1.93	2.79	2.43	1.49	2.69	4.54	1.03	1.00	1.46	24.13
	Mean monthly temperature (°F)1/												Avg. Yr.
Beeville	55.4	58.3	64.5	71.2	76.4	80.6	82.4	83.2	89.3	72.9	63.5	56.8	71.2
Falfurrias	58.5	61.6	67.2	74.1	80.0	84.7	86.5	86.3	82.1	75.1	65.2	59.7	73.4
	Mean monthly evaporation (inches, avg. of 3 years)2/												
Dilley	2.78	3.81	6.22	7.23	8.57	9.89	11.14	9.20	7.00	4.63	3.46	2.54	76.46

1/Beeville, 68-year average.

1/Falfurrias, 30-year average.

2/Inches loss from water surface in sunken screened pan, 24-inch diameter.

grams. Forage response to fertilization under dryland conditions is shown in Table 6. Forage production varied from year to year depending on moisture distribution. Split applications of nitrogen (N) fertilizers are recommended for the area. Under grazing, a late winter or an early spring application of 40 to 60 pounds N per acre will start the grass and provide good early growth. Providing spring temperature and moisture are adequate for early growth, a follow-up application of 30 pounds N per acre about the middle of May to the first of June will normally provide sufficient growth for grazing during the summer months. Due to the long growing season and the anticipated fall rains, a third application of approximately 30 pounds in late summer will stimulate fall growth and provide grazing until frost. The excess of accumulated fall growth can be utilized by grazing during the dormant season if supplemental energy and protein are provided.

Coastal bermudagrass grown for hay production in South Texas requires higher fertilizer rates, particularly during the beginning of the growing season. Under dry land conditions a late winter or early spring application of 60 to 80 pounds N per acre is recommended followed by 30 to 40 pounds after each harvest. A soil test will determine the requirements for phosphorus and potassium. When these elements are needed, they can be applied in the fall or winter. Summer forage production is normally light due to low moisture, high temperature, and high evaporation.

Kleingrass (*Panicum coloratum* L.) is another introduced grass rapidly gaining in popularity in South Texas. Under dry land conditions the species has shown good persistence and has responded to fertilization. Dry matter yields for single fertilizer application are shown in Table 7. Yields may be increased by higher nitrogen rates in split applications. Under dryland conditions, yields of Kleingrass have been comparable to Coastal bermudagrass at similar fertility levels(Tables 6 and 8). Kleingrass starts growth earlier in the spring than Coastal bermudagrass; thus, the species should be fertilized in late winter. Pastures to be utilized by grazing should receive a late winter application of 40 to 60 pounds N per acre. If the pastures are stocked heavily during the spring or the spring growth is removed as hay, an additional 30 pounds of N per acre are recommended around the first of June. An additional late summer application of approximately 30 pounds N per acre will stimulate fall growth which may be grazed or allowed to accumulate

Table 4-6. Yields of coastal bermudagrass at varying nitrogen levels, nonirrigated. Beeville, Texas.

Treatments (lb/acre)[1]			Pounds dry forage/acre 1964	1965	1969
N	P_2O_5	K_2O			
0	30	0	3,230	3,250	3,720
45	30	0	3,560	5,286	
60	30	0			7,210
90	30	0	4,620	7,590	
120	30	0			8,970
135	30	0	5,990	8,840	
180	30	0	5,974	9,960	9,750
240	30	0			12,290
Rainfall, inches			22.08	34.92	31.48

[1] Nitrogen in split applications in the spring and after each harvest. Phosphorus applied in late winter.

Table 4-7. Yields of Kleingrass at varying fertility levels. Beeville, Texas.

Treatments (lb/acre)[1]			Pounds dry forage/acre 1964	1965	1966
N	P_2O_5	K_2O			
0	0	0	3,410	2,660	1,830
20	0	0	4,220	3,840	2,680
20	20	0	4,450	5,030	3,350
40	20	0	4,920	6,200	3,560
60	20	0	4,990	6,710	5,280
Rainfall, inches			22.08	34.92	26.15

[1] Rates of fertilizer applied as single application in the spring.

Table 4-8. Seasonal distribution of Kleingrass production at varying fertilization rates. Beeville, 1969.

Treatments (lb/acre) 1/			Pounds dry forage/acre 5/8	6/19	8/26	11/4	Total
N	P_2O_5	K_2O					
0	0	0	234	497	343	353	1,427
0	20	0	633	1,016	504	825	2,978
20	20	0	1,622	2,267	802	1,456	6,147
40	20	0	2,517	2,750	719	2,145	8,131
60	20	0	2,817	3,308	734	2,663	9,522

1/ Nitrogen applied Feb. 20 and after each harvest; phosphorus applied Feb. 20.

Table 4-9. Yields of continuous forage sorghum using two post harvest tillage practices. Beeville, Texas.

Year	Pounds dry forage/acre Standard tillage	Tillage-mulch
1963	4,630	1,800
1964	6,040	6,150
1965	11,450	8,540
1966	9,320	8,340
1967	3,800	2,880

for winter grazing. Kleingrass has been successfully used during the winter as a standing hay. A soil analysis will determine the need for phosphorus and potassium.

Annuals

Forage sorghums have played an important role as a preserved and stored feed supply for South Texas. Because of their drouth-tolerant characteristics, the sorghums have been more dependable than other silage species in terms of dry matter production. Under dryland conditions forage sorghums are usually considered a single harvest crop. However, because of the long interval between first harvest and the end of the growing season, the possibility of alternate crop management practices other than fallowing is often considered. In a 5-year study at Beeville the regrowth was allowed to accumulate and returned to the soil as organic matter at the end of the growing season (tillage mulch). The tillage mulch system utilized moisture in the latter part of the growing season that would be stored in the soil under a standard tillage system of fallowing immediately after harvest. Because of this moisture relationship, the tillage mulch system reduced yields in the succeeding season, the average reduction exceeded 20 percent in a 5-year study at Beeville (Table 9). Using the regrowth as a second harvest would have the same effect on succeeding crop yield. The highest yields are obtained with adequate fertilization and fallowing the land after the first forage harvest (Table 10). In areas of limited rainfall, summer and fall moisture can be stored or retained under a fallow system for use by the succeeding spring planted crop, and this may be more effective than attempting to use it in the latter part of the growing season.

Summary

In South Texas under dryland conditions forage production is dependent on proper land use, moisture conservation, and a sound fertilization program. Virtually all soils in the South Texas area will require nitrogen and one or more of the other fertilizer nutrients to maintain forage production. A soil test is recommended to determine fertilization needs for establishment and production.

Table 4-10. The influence of post harvest tillage practice and fertilizer treatment on forage sorghum production, Beeville, 5-year average (1963 - 1967)

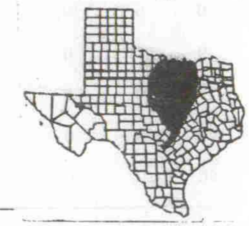
Fertilizer treatment (lb./acre)	Pounds dry matter/acre Standard-tillage	Tillage-mulch
N-P_2O_5-K_2O		
0-0-0	5,420	3,160
20-20-20	7,060	5,190
40-40-0	7,420	6,850
60-60-0	8,320	6,990

NORTH CENTRAL TEXAS

D. E. Kissel, L. B. Fenn*

The North Central Texas region as discussed here encompasses the following land resource areas:

Land Resource Area	Acres (Approximate)
Blackland Prairies	12,600,000
Grand Prairies	6,800,000
North Central Prairies	5,600,000
West Cross Timbers	2,000,000
East Cross Timbers	1,000,000
Total land area	28,000,000
Farmland	27,000,000
Cultivated cropland	15,000,000
Unimproved forageland	8,000,000
Improved forageland	4,000,000
Common bermudagrass, native grasses (1/3 fertilized)	1,200,000
Coastal bermudagrass (all fertilized)	1,500,000
Small grain forages (all fertilized)	1,000,000
Summer annual forages (all fertilized)	300,000



Most of the prairie soils have relatively good inherent fertility, whereas the sandy soils in the Cross Timber areas have relatively low fertility and require higher rates of fertilizer.

Major Soils and Climate

The major soils of the Central Texas area are those in the Blackland Prairie and the Grand Prairie with undulating, gently rolling topography, well dissected with scrub

*Respectively, associate professor, the Texas Agricultural Experiment Station, Temple; and assistant professor, the Texas Agricultural Experiment Station, El Paso.

oak woodlands and rapid surface drainage. In the Blackland Prairie, common upland soil series are Houston Black, Heiden, Austin, Eddy, and Hunt clays. There is also a significant acreage of productive bottomland with the Trinity being most representative. These soils are dark colored and calcareous, and contain montmorillonite clay, which causes them to swell on wetting and shrink on drying, forming cracks. The morphological, mineralogical, and chemical characterizations of Houston Black clay, the most productive Blackland soil, have been reported by Templin, Mowery, and Kunze (1956), Kunze and Templin (1956), and Godfrey (1964).

Grand Prairie soil series are the San Saba, Crawford, and Denton clays. San Saba clay is the deepest and most productive Grand Prairie soil, with the others becoming progressively shallower. San Saba is similar to Houston Black clay in many respects, particularly with regard to its chemical, mineralogical, and physical properties. It is different from Houston Black clay in that it is somewhat shallower and underlain by limestone instead of calcareous clay or chalk. Crawford and Denton clays are shallower than the San Saba clay but are suitable for some row cropping and improved pastures. Both soil series have high percentages of montmorillonite clay.

Vegetation in the Blackland and Grand Prairies is tall bunch grasses on the uplands and hardwoods in the bottomlands. Land use is range, pasture, cotton, grain sorghum, small grains, and corn.

The North Central Prairie's upland soils (Renfrow, Zaneis, Kirkland) are slightly acid brown sandy loams. They overlay red to gray clay sub-soils which are slightly acid to neutral. Bottomland soils in this area are the calcareous Miller and Norwood series. Vegetation is mesquite, tall and short grasses, and land use is mainly range, grain sorghum, small grain, and some peanuts and fruits.

Cross Timber upland soil series are Windthorst, Nimrod, Galey, Konowa, and Daffau. They are slightly acid loamy sands over yellowish brown to red subsoils. Bottomland soils are Cowen, Frio, Kaufman, and Trinity. These darker alluvial clayey soils are neutral to calcareous. Vegetation is scrub oak and tall bunch grass, and land use is range, pasture, peanuts, fruits. vegetables and small grain forage.

Crops grown in the Prairie soils usually respond to nitrogen and phosphorus fertili-

zers, but rarely to potassium, while Cross Timbers soils respond also to potassium. All of the North Central soils appear to supply adequate amounts of the minor and trace elements, since application of these nutrients to field crops rarely increases yield. However, iron and zinc deficiency has been noted in shrubs, fruit trees, pecans, and some field crops in localized areas. Application of ferrous sulfate and zinc sulfate generally has been effective in controlling these problems.

The climate in North Central Texas (Table 11) is subhumid with a mean annual precipitation of 30-35 inches per year, characterized by a wet season in April, May, and the first half of June when over 30 percent of the mean annual precipitation occurs (Ritchie, 1971). A dry season usually occurs during July and August when the mean precipitation is approximately 2 inches per month. During this period crops often lack sufficient soil water due to a high evaporative demand and low rainfall. Summer daily maximum temperatures during this time usually range from 95° F to 100° F, and temperatures around 110° F have been recorded. Rainfall is very erratic in North Central Texas. Drouths do not occur with any predictable frequency, and dry years occur during so-called wet cycles (Godfrey, 1964). During rainy years, cold, wet soils early in the growing season can delay plant growth as a result of inadequate nutrient availability and uptake by crops (Adams, 1967, and Adams, 1970).

Fertilization of Forages

Warm-Season Perennials

<u>Nitrogen</u> - Studies conducted by Dudley and Holt (1965) at the Research Station at Denton and a long-term demonstration study on the John Trammel farm in S. E. Grayson County (C. O. Spence, unpublished data, Texas Agricultural Extension Service) both showed that Coastal bermudagrass responded well to N fertilizer. In Dudley and Holt's study, nitrogen increased forage yields progressively up to 190 pounds N per acre, the highest rate in the study. Crude protein also was progressively increased by approximately 50 percent by applying 190 pounds N per acre.

Anhydrous ammonia is the most economical source of N fertilizer. Soils of the Blackland Prairie and Grand Prairie have physical and chemical properties which favor retention of anhydrous ammonia. Consequently, this economical source of N can be used

Table 4-11. Climatic data for selected locations in North Central Texas. Data are an average of 58 years at Denton and 60 years at Temple.

Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					Mean monthly rainfall (inches)								
Denton	1.90	2.42	2.51	3.69	5.03	3.16	2.05	1.73	2.37	2.46	2.05	2.19	31.56
Temple	2.38	2.41	2.05	3.86	4.41	2.78	1.78	2.21	3.29	3.04	2.80	2.67	33,68
					Mean monthly temperature (^oF)								Avg. Yr.
Denton	45.4	49.0	55.6	64.5	72.0	80.6	84.3	84.9	77.9	66.6	54.7	47.5	65.3
Temple	48.7	52.6	59.0	67.4	73.9	80.8	83.9	84.1	78.7	69.4	58.3	51.0	67.3
					Mean monthly evaporation 1/								
Lake Waco	2.61	3.78	6.20	7.43	7.77	10.44	12.28	11.60	7.91	6.52	4.30	3.10	83.94

1/ Inches loss from water surface in standard weather service pan. Average of 7 years.

successfully on these soils in many situations. Research (Dudley and Holt, 1965) has shown that anhydrous ammonia will be as effective as ammonium nitrate on Coastal bermudagrass receiving single applications of N. Split applications of anhydrous ammonia probably would not be satisfactory since it would be necessary to disturb the sod during the growing season.

Dudley and Holt (1965) noted in their study that split applications of N produced more forage than an equal amount of N applied at one time early in the spring. By split applying 100 pounds N per acre, they were able to produce an average of 1,000 pounds extra forage each year when compared to a single application of 100 pounds N per acre. This effect was most pronounced with years of high rainfall, but even in 1963, when only 7.8 inches of rainfall was received during the growing season, a single application of 100 pounds N produced 2,830 pounds of forage while the same amount in split applications produced 3,660 pounds.

More recent results near Temple at the Blackland Research Center also indicate that splitting N fertilizer applications on Coastal bermudagrass and using slow-release N sources (sulfur-coated urea) will distribute forage production more evenly through the growing season. Results are presented for three sulfur-coated ureas (SCU) which differ in their rate of N release (Figure 13). SCU 1 has the fastest and SCU 3 the slowest rate of N release. Comparisons were made of single applications of urea and SCU's (200 and 400 pounds N per acre) and a split application of SCU 1 (400 pounds N per acre only). The split application of SCU 1 (SCU 1 split) was applied in three equal applications of 133 pounds N per acre April 1, May 29, and July 8. The SCU 1 is a relatively soluble SCU (49 percent soluble in H_2O at 100^o F after 7 days), so it is believed that splitting the application of an N source such as urea would give similar dry matter production and distribution. The results, obtained during a year with an average amount and distribution of rainfall, indicate that SCU's will produce less forage at early harvests than urea, but at the later harvests more dry matter is produced with the SCU's and SCU 1 split (Figure 13). Total forage production was 5,600; 9,000; and 13,000 pounds per acre, respectively, for the check plot, 200 pounds N, and 400 pounds N as urea, all applied in the spring. These results suggest that optimum production in the Blacklands may require

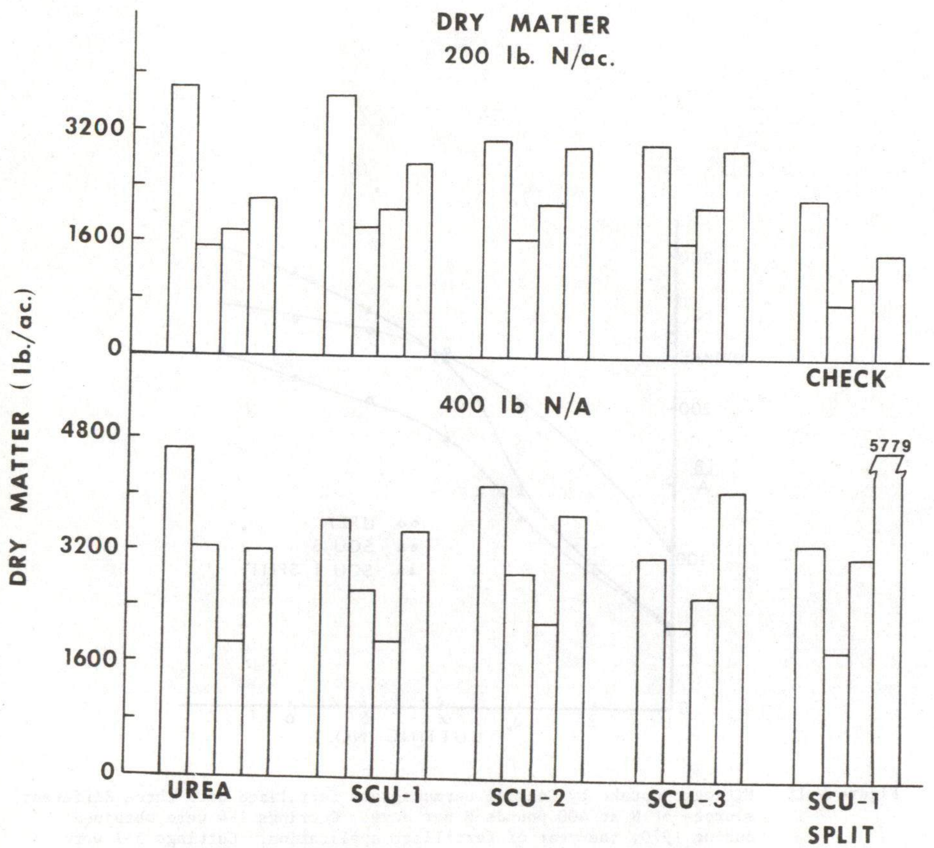


Figure 4-13. Oven dry forage production of Coastal bermudagrass from different sources of N at 200 and 400 pounds N per acre. All plots, including the check, received 100 pounds P_2O_5 per acre. The four bars for each N source represent the forage production at each of the four harvests during 1970.

considerably higher N rates than currently used. The optimum N rate for intensive production of Coastal on deep Houston Black clay may be as high as 400 pounds N per acre. These rates may result in some carryover from one year to the next, but differences among SCU and urea sources in carryover effect were negligible. Splitting heavy SCU rates into three applications not only increased total production, but the carryover effect was also increased.

Large changes in crude protein content were evident between N sources in 1970 (Figure 14). At 400 pounds N per acre, the change in protein content from harvest 1 to harvest 4 was largest with urea. At harvest 1, the protein content was nearly 15 percent; but by harvest 4, protein had dropped to 7 percent. For comparison, SCU 1 split had about 10 percent protein at both harvests 1 and 4 with slightly higher values at harvests 2 and 3. This is more desirable than the large range of values noted with urea. The sulfur-coated ureas gave results intermediate between urea and SCU 1 split.

With respect to the N efficiency at 400 pounds N per acre SCU 1 split was the most effective treatment in recovering the applied N. This treatment recovered an additional 35 pounds N per acre by harvest No. 7, when compared to urea (Harvests 5, 6, and 7 were obtained in 1971). The extra N uptake by SCU 1-split was largely due to increased N uptake during the last four cuttings (Figure 15). SCU 3, which had the slowest N release, also gave more delayed N uptake when compared to urea, though the effect was not as large as with SCU 1 split. In general, a single application of SCU produces the same total yield as a single application of urea or ammonium nitrate and gives a better distribution of yield and protein through the growing season. However, split applications of ammonium nitrate or urea give slightly better total yield and improved distribution of yield and protein when compared to a single application of SCU.

Fenn and Kissel (1973) noted that losses of N to the air as ammonia were quite large from ammonium sulfate and diammonium phosphate when applied to the soil surface. Therefore, these N sources would be less efficient for forage production where the fertilizer is surface applied and cannot be mixed into the soil. Losses of ammonia from ammonium nitrate were much lower; consequently, ammonium nitrate is a more desirable N fertilizer for topdressing.

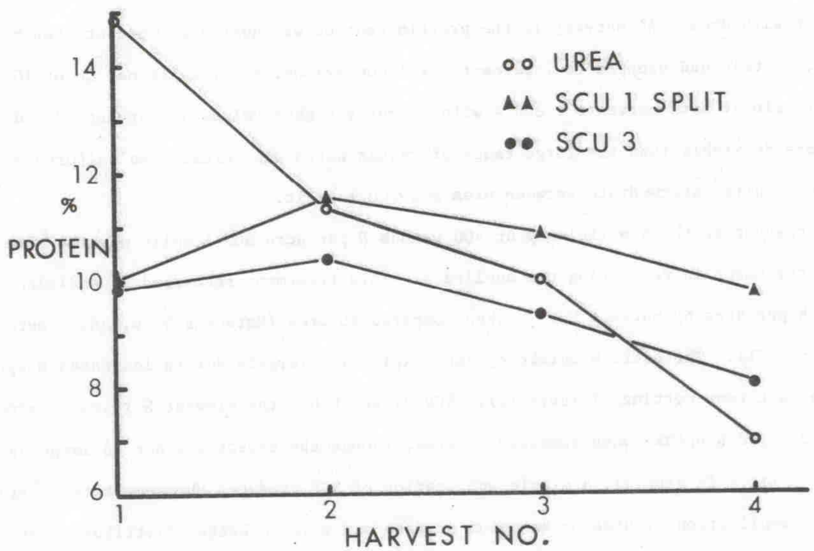


Figure 4-14. Protein content of Coastal bermudagrass fertilized with three different sources of N at 400 pounds N per acre.

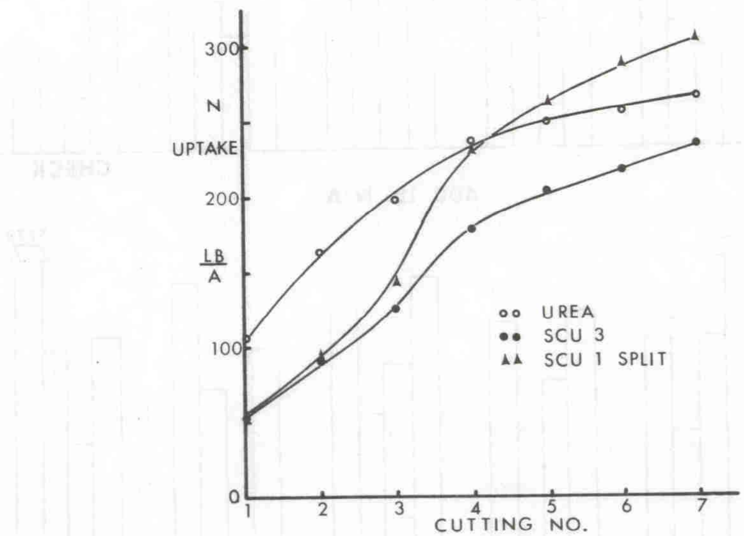


Figure 4-15. Nitrogen uptake by Coastal bermudagrass fertilized with three different sources of N at 400 pounds N per acre. Cuttings 1-4 were obtained during 1970, the year of fertilizer application. Cuttings 5-7 were obtained during 1971 when no fertilizer was applied.

Phosphorus and Potassium - Research (Dudley and Holt, 1965; Spence, unpublished data) has generally shown that Blackland and Grand Prairie soils are in need of P. Annual applications of 30 pounds P_2O_5 per acre give significant increases in Coastal bermudagrass growth on both San Saba and Crawford clays.

Long term studies with P fertilizer in the Blacklands have shown P to be equally effective when applied in one large application (several years' reserve) or an equal amount in several smaller annual applications. A convenient time to apply several years' supply of P would be just prior to establishment of any perennial forage when the P can be mixed thoroughly throughout the plow layer. Some caution is necessary, however, since deficiency of zinc and other minor elements can be induced by extremely high rates of P on certain soils. Rates up to 2,000 pounds P_2O_5 per acre have been applied to grain sorghum on Houston Black clay with no ill effects. Annual rates of 120 pounds P_2O_5 per acre have been applied for 6 years (total of 720 pounds per acre on San Saba clay at the Texas Agricultural Experiment Station, McGregor, with some visual zinc deficiency symptoms but with no reduction in yield of grain sorghum. Some reduction of yield due to P-induced Zn deficiency has been noted on Crawford clay, but this reduction was overcome by application of Zn. In general, some Zn deficiency can occur on Grand Prairie soils at high P rates, but there is no evidence of this on Houston Black clay.

In general, soils in the North Central region supply adequate amounts of potassium for crop production. There are some locations, however, where crop response to applied potassium for crop production will occur. The proper use of soil testing techniques is a valuable tool to determine the need, and where needed, the amounts of both potash and phosphorus necessary for the desired forage production.

Warm-Season Annuals

Forage sorghums utilize soil moisture efficiently and can be seeded even in late spring and produce substantial tonnage of hay or ensilage in North Central Texas. Results on a San Saba soil (Rich, 1967) indicate that 16 tons of ensilage (green weight) can be produced with a fertilizer treatment of 60-30-0. This represented an approximate 3.5-ton per acre increase due to the applied fertilizer.

Fertilizer response by both sudan and sorghum forage was studied by E. D. Cook (1968)

at the Blackland Research Center, Temple. Some results from these studies, conducted on Houston Black clay soil, are summarized in Table 12. In general, both forages responded well to N fertilizer. Forage sorghum gave slightly better response to N than sudan. For forage sorghum, the optimum rate of N is 90 pounds per acre if N costs $0.14 per pound and the value of the hay is $25 per ton.

Cool-Season Forages

The optimum rate of fertilization for small grain forage, based on a 3-year study on San Saba-Crawford clay, is 60-80 pounds of N per acre (Figure 16) and between 20 and 40 pounds P_2O_5 per acre. Oats are grown in the southern portion of the North Central region, while wheat and rye are more common in the northern portion. More total forage usually is produced when oats are in a rotation compared with continuous oats. This difference due to rotation alone can reach 1,000 pounds dry matter per acre at 80 pounds N per acre.

The protein content of small grain grown in North Central Texas increases substantially with N rate. For example, an 80-pound N rate may produce forages averaging 28 percent protein whereas unfertilized forage may contain about 20 percent. Oats in a rotation produce forage with less protein than continuous oats. However, in both cropping systems, the early season protein levels are in excess of animal requirements. Since more total forage is produced by oats in a rotation, more total protein is produced per acre than with continuous oats.

Limited data on Wintergreen hardinggrass suggests that the optimum rate of N will be around 120 pounds per acre. Studies indicate that the maximum level of production may not be reached until the third year after establishment. A minimum of 30 pounds P_2O_5 per acre are needed with the 120 pounds N per acre for maximum response to fertilizer.

Fertilizer Response Related to Soil Type

Because of relatively high fall and winter rainfall and low evapotranspiration during this period, the oat forage production and fertilizer requirements on San Saba-Crawford clay should be about the same as those on other soils of the North Central Texas area, provided soil P and K levels are not limiting as indicated by soil test results.

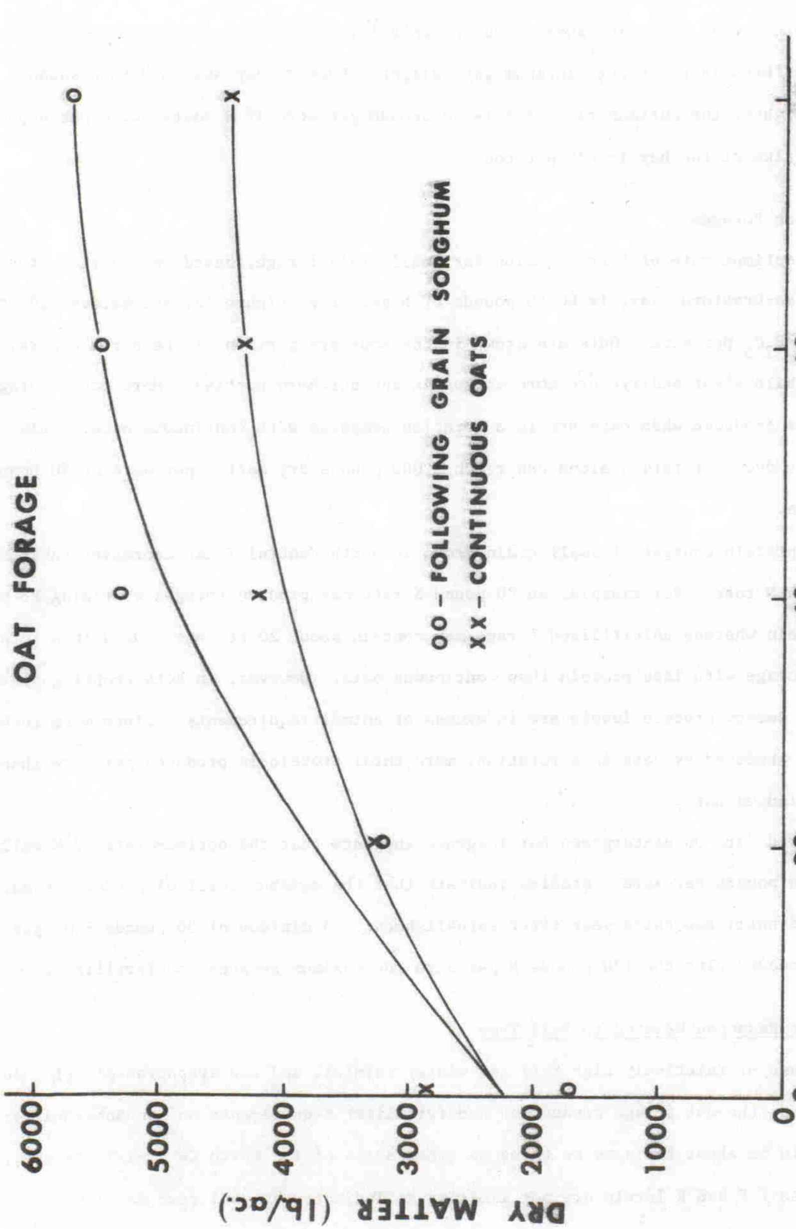


Figure 4-16. Response of Oats to Nitrogen fertilization on San Saba-Crawford clay at McGregor, 3-year average.

Table 4-12. The effect of different rates of N fertilizer on yields of sorghum and sudan forage.[1/] Blackland Research Center 1963-67.

	Pounds dry matter/acre	
(lb. N/acre)	Sorghum	Sudan
0	10,935	8,422
30	12,003	9,443
60	12,554	9,752
90	13,083	10,011

1/From TAES PR-2615. Data are averages from 30 and 60 lb. P_2O_5/acre.

With summer forage production, there likely will be a considerable difference in response to fertilizer, determined by the amount of available water stored in the soil. A deep Houston Black clay, for example, will store 10 inches of plant available water (Ritchie, Burnett, and Henderson, 1972), whereas a shallower Austin clay or Crawford clay will store considerably less. Shallower soils would, therefore, have a lower optimum rate of N fertilization than implied by the Coastal bermudagrass results for Houston Black clay.

Nitrate Toxicity

Some animal losses have occurred in North Central Texas as a result of nitrate toxicity, usually in winter and early spring during cloudy weather. It is under these conditions that nitrate accumulates in oat forage (Holt, Norris, and Lancaster, 1969). Data from oat forage tests indicate that nitrate content of the forage is generally less than 1.25 percent. The levels of nitrate are highest at the first cutting. The nitrate levels increase with increasing rate of applied N and are higher where oats are cropped continuously compared to a rotation (Figure 17). Although none of these values are near the toxic level, the nitrate level at the optimum level of fertilization (80 pounds N per acre) is nearly twice as high under continuous oats as oats following grain sorghum or cotton. Therefore, growing oats in a rotation can reduce the likelihood of occurrence of nitrate toxicity. Although the data are limited and somewhat variable, the studies suggest that nitrate toxicity in oats may be reduced following grain sorghum when compared to cotton.

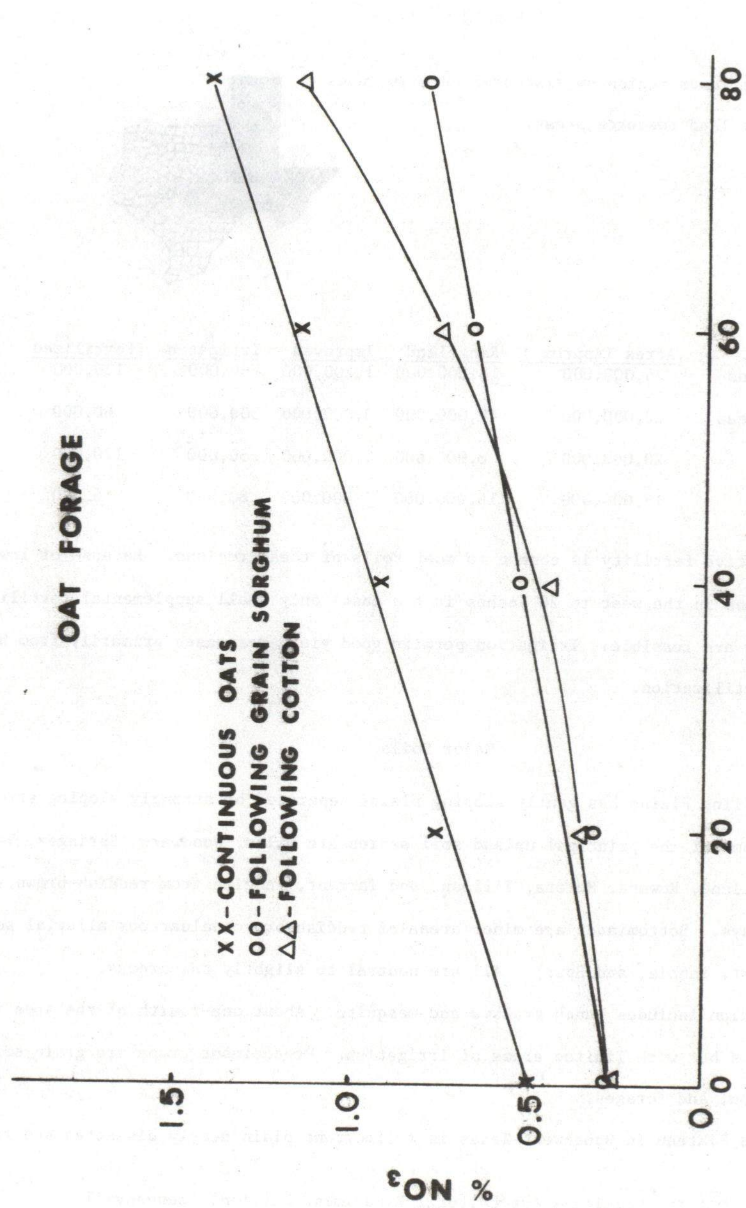
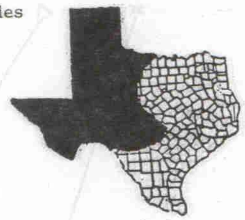


Figure 4-17. Nitrate content of oat forage at different rates of N. Data are given for continuous oats and rotated oats. The data shown are averages from the first of two harvests taken each year, 1966, 1968, and 1969.

WEST TEXAS

Ronald M. Jones*

The West Texas region as discussed here includes the following land resource areas.



	Acres (Approx.)	Rangeland	Improved	Irrigated	Fertilized
Rolling Plains	24,000,000	18,000,000	1,200,000	60,000	120,000
Edwards Plateau	22,000,000	19,000,000	3,000,000	300,000	60,000
High Plains	20,000,000	8,000,000	1,000,000	250,000	120,000
Trans-Pecos	18,000,000	16,000,000	300,000	80,000	6,000

Good native fertility is common to most soils of these regions. Because of low rainfall (8 inches in the west to 26 inches in the east) only small supplemental fertilizer applications are feasible. Irrigation permits good yield responses primarily from heavy nitrogen fertilization.

Major Soils

The Rolling Plains has gently sloping plains separated by strongly sloping stream valleys. Some of the principal upland soil series are Miles, Woodward, Springer, Vernon, Mansker, Abilene, Rowena, Mereta, Tillman, and Tarrant, ranging from reddish-brown sandy loams to clays. Bottomlands are minor areas of reddish-brown calcareous alluvial soils (Miller, Port, Yahola, and Spur). All are neutral to slightly calcareous.

Vegetation includes bunch grasses and mesquite. About one-fourth of the area is in dryland crops but with limited areas of irrigation. Predominant crops are grain sorghum, wheat, cotton, and forages.

Edwards Plateau in Southwest Texas is a limestone plain deeply dissected and rapidly

*Research associate, the Texas Agricultural Experiment Station, Stephenville.

Table 4-13. Climatic data for selected locations in West Texas

Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Balmorhea	.75	.58	.36	.71	1.41	1.47	1.55	1.35	1.95	1.42	.51	.62	12.68
Plainview	.80	.62	.68	1.53	3.18	2.58	2.47	2.05	2.02	1.64	.59	.82	18.98
Mean monthly temperature (°F) 1/													Ave. Yr.
Balmorhea	47	52	58	66	73	81	81	80	75	66	54	48	65
Plainview	40	43	49	59	67	77	79	78	72	61	48	42	60
Mean monthly evaporation (Avg of 7 years) 2/													
Hords Creed Dam	4.04	4.52	7.73	9.35	10.10	12.05	13.21	11.21	7.94	6.89	4.99	3.92	99.95

1/ Represent 30-year averages.

2/ Inches loss from water surface in standard weather service pan.

drained, with hills and broken areas adjacent to narrow stream valleys. Dark, calcareous, stony clays and clay loams dominate the soil types. The main series in the eastern half are Tarrant, Brackett, and Tobosa while in the western half Ector, Upton, and Reagan predominate. Bottomlands are minor areas of dark, calcareous, alluvial clay soil primarily of the Frio series.

Vegetation of the uplands is oak, cedar, mesquite, and short grasses, changing to desert shrubs in the western portion with oaks and pecans in the bottomlands. Land use is 98 percent range, mainly for wool and mohair production. There is limited production of small grain, grain sorghum, forage, and hay crops.

High Plains is a nearly level, high tableland having slow to moderate surface drainage and about 19,000 playas (Oakes, Godfrey, and Barton, 1958). Soils include dark brown to reddish-brown neutral to calcareous sands, sandy loams, and clay loams. Main upland soil series are Pullman, Mansker, Olton, Sherm (Loams and silt loams); and Mansker, Brownfield, Tivoli (sands and sandy loams). Bottomlands are very minor areas of brown, loamy, calcareous alluvial soils, mainly of the Spur series.

Native vegetation is predominately short grasses. Land use is 60 percent cropland, one-half of which is irrigated. Main crops are cotton, corn, soybeans, grain sorghum, wheat, vegetables, and sugar beets.

The Trans-Pecos area of far West Texas consists of mountain ranges and rough, stony areas intermixed with flat basins and plateaus. Upland soils (Upton, Reeves, Reaker, Brewster, and Kermit) are reddish-brown to brown sands, clay loams and clays, mostly calcareous and some saline. Included are rough, stony lands (Lozier and Rockland). Bottomland soils are darker than upland soils and include calcareous alluvial silt loams to clays. Main series are Harkey, Glendale, Saneli (Rio Grande), Pecos, and Arno (Pecos River).

Vegetation is short grasses, mesquite, and desert shrubs. About 5 percent of the land area is irrigated and intensively cropped with cotton, alfalfa, grain sorghum, and vegetables.

Fertilization of Forages

Although 1,477,000 acres of irrigated and dryland forages are grown (exclusive of

range grasses) in a 39-county area of the Panhandle and West Texas (New, 1971), limited fertilizer research data are available. Such data as there are, involve three classes of forage; range grasses, silage, and hay and pasture crops (see Table 14). In most of this region, N is the most limiting plant nutrient for forage production, while phosphorus (P) and potassium (K) may affect forage quality more than quantity.

Warm-Season Forage

Range grasses have received the greatest attention in the area of fertilizer response. Welch, Burnett, and Hudspeth (1962), for example, reported that Plains bristlegrass, Giant cenchrus, and Green sprangletop consistently responded in increased seedling growth to 10-20 pounds of N and P banded close to the seed at planting. Walker, Hudspeth, and Morrow (1958) found no differences in growth of Plains bristlegrass and Green sprangletop due to fertilizer placement either 1.5 inches below the seed or 1.5 inches below and 1.0 inch beside the seed at the rate of 16 pounds N and 20 pounds P per acre. No yields were reported.

Forage yields for Blue grama have been reported by Lehman, Bond, and Eck (1968), Schuster et al. (1967), and Trlica, Bryant and Schuster (1967). Nitrogen rates of 0, 200, 400 and 800 pounds per acre were watered in with ample irrigation throughout the growing season. Yields were 2, 3, and 4 times the check for the latter three rates, respectively, and averaged 1,407 to 6,213 pounds per acre per year for 3 years (Lehman et al., 1968). Protein content doubled immediately after N application but later declined. The 200-pound N rate had no effect on growth after the first season; N recovery for rates totaled about 30 percent for the first 3 years following application. Under severe drouth and fair range conditions, 300 pounds N per acre did not increase yield of Blue grama (Schuster et al., 1967). However, after a 4-year study, Trlica et al. (1967) concluded that one application of 300-900 pounds per acre of N would result in increased yield of Blue grama-Buffalograss for several years.

A study reported by Fagan and Pettit (1972) on Buffalograss near Amarillo indicates that air-dry yields of 4,700 and 11,000 pounds per acre can be expected with N rates of 0 and 107 pounds N per acre, respectively. Rainfall was 29 inches for the growing season.

In a demonstration on irrigated corn for silage, Cross (1971) obtained a 5-ton per

Table 4-14. Summary of fertilizer research results on forage in the Texas High Plains

Pounds N per acre	Dry matter yield, tons/acre 1/			
	Small grains	Sorghum Almum	Corn silage	Buffalograss
0		2.56 Ellis et al. 1961		2.35 Fagan & Pettit 1972
107				5.55 Fagan & Pettit 1972
111		8 Davis et al. 1957		
200	3.5-4.0 Cowley et al. 1971	4.76 Ellis et al. 1961	20-30 Langford & Staggs 1968	
243			26-29 Langford & Staggs 1969	
400		5.12 Ellis et al. 1961		

1/ Irrigated forages.

acre increase from the addition of 167 pounds of N per acre. Irrigated corn ensilage yields of 20 to 30 tons per acre have been reported using 200 pounds N per acre (Langford and Staggs, 1968). They also reported that 243 pounds N per acre resulted in yields of 25.6 to 29.1 tons per acre (Langford and Staggs, 1969).

Yield potential of irrigated forage sorghums is indicated by data on sudangrass and sorghum almum. Ellis, Lehman and Bond (1961) reported that N rates of 0, 200, and 400 pounds per acre produced dry weights of 5,120; 9,530; and 10,230 pounds per acre, respectively. Protein content increased 2 percent with the addition of the first 200 pounds of N. Where 111 pounds of N were applied to six varieties of irrigated sorghum almum, Davis, Owen and Langford (1957) obtained yields of approximately 8 tons of air-dry forage per acre. In a test involving trace elements and sulfur on Pullman silty clay loam, Owen and Furr (1967) reported yields of about 5 tons dry forage per acre. Only 50 pounds of N were applied; there was no response to trace elements or sulfur at the rates used.

Pope (1961) applied three sources of P to irrigated alfalfa and found no difference in yield, nor did it matter whether 240 pounds P were applied at one application or over a 3-year period. Air-dry yields for 3 years averaged 6 tons per acre per year on a silt loam soil.

Baumgardner and Jaynes (1967) reported yield increases in Midland bermudagrass of about 1,000 pounds per acre for each additional 100 pounds of N applied up to 400 pounds per acre. Smaller increases occurred up to 800 pounds N. In Oklahoma, Elder and Murphy (1961) reported 2,000-pound increases in Midland bermudagrass production for each additional 100 pounds N applied.

Cool-Season Forage

Wheat dominates in West Texas as the cool-season forage crop. Where P is needed, a moderate application with the seed generally stimulates early vegetative growth. Nitrogen fertilization, dependent on the rainfall and soil of the specific area, split between preplant and early spring applications is generally most effective.

The potential production of irrigated small grain forage is indicated in a report by Cowley et al. (1971). At a rate of 200 pounds N per acre, they generally obtained yields in the range of 7,000 - 8,000 pounds of forage per acre.

Literature Cited

Adams, John E. 1967. Effect of mulches and bed configuration. I. Early-season soil temperature and emergence of grain sorghum and corn. Agron. J. 59:595-599.

Adams, John E. 1970. Effect of mulches and bed configuration. II. Soil temperature and growth and yield responses of grain sorghum and corn. Agron. J. 62:785-790.

Baumgardner, John H., and Chester C. Haynes. 1967. Midland bermudagrass on the South Plains. Texas Technological College, Mimeograph.

Calder, F. W., and J. W. G. Nicholson. 1970. Pasture productivity of three swards with and without nitrogen fertilization. Can. J. Anim. Sci. 50:467-473.

Cheaney, R. L., Ralph M. Weihing, and R. Norton Ford. 1956. The effect of various rates and frequencies of application of rock and superphosphate on the yield and composition of forage on a Lake Charles Clay loam soil. Soil Sci. Soc. Amer. Proc. 20:66-68.

Cook, E. D. 1968. Effect of fertilizer on forage production of forage sorghum and sudan. 1963-67. Tex. Agr. Exp. Sta. PR-2615.

Costa, C. V. 1970. Nitrate in plants and soil as influenced by nitrogen fertilizers. MS Thesis. Texas A&M University.

Cowley, Charles, R. C. Thomason, G. L. Peterson, and W. W. Watson. 1971. In Symposium on grazing small grains. pp. 2-16. Mimeograph. USDA Southwestern Great Plains Research Center at Bushland.

Cross, Fred. 1971. Corn silage fertilizer demonstration. In Corn research results, High Plains of Texas. 1970. Tex. Agr. Exp. Sta. Consolidated PR-2898-2905. p. 92.

Davis, Johnny H., Douglas Owen, and Delbert Langford. 1957. Yield of perennial grain sorghum at the High Plains Station in 1957. High Plains Station, Texas Research Foundation, Plainview, Texas.

Dudley, D. I., and E. C. Holt. 1965. Forage production and protein content of Coastal bermudagrass as affected by fertilizer, maturity at harvest and renovation, North Central Texas Research Station, Denton. Tex. Agr. Exp. Sta. PR-2348.

Elder, W. C., and H. F. Murphy. 1961. Grazing characteristics and clipping responses of bermudagrass. Okla. Agr. Exp. Sta. Bul. 577.

Ellis, G. F. Jr., O. R. Lehman, and J. J. Bond. 1961. Effect of nitrogen fertilizer on yield and composition of irrigated sudan grass on the High Plains. Tex. Agr. Exp. Sta. PR-2173.

Fagan, Richard E., and Russell D. Pettit. 1972. Influence of nitrogen fertilization on yield and carbohydrate reserve content of buffalograss. Texas Technological University Center Rep. No. 102, pp. 110-113.

Fenn, L. B., and D. E. Kissel. 1973. Ammonia volatilization from surface applications of ammonium compounds on calcareous soils: 1. General theory. Soil Sci. Soc. Am. Proc. 37:855-860.

Fisher, F. L., and A. G. Caldwell. 1959. The effects of continued use of heavy rates of fertilizers on forage production and quality of Coastal bermudagrass. Agron. J. 51:99-102.

Godfrey, Curtis L. 1964. A summary of the soils of the blackland prairies of Texas. Tex. Agr. Exp. Sta. MP-698.

Godfrey, C. L., C. L. Carter, and G. S. McKee. Resource Areas of Texas. Tex. Agr. Exp. Sta. B-1070.

Holt, E. C., M. J. Norris, and J. A. Lancaster. 1969. Production and management of small grains for forage. Tex. Agr. Exp. Sta. B-1082.

Holt, E. C., J. A. Lancaster, and Mark Buckingham. 1961. Bermudagrass production in North East Texas. Tex. Agr. Exp. Sta. MP-548.

Holt, E. C., and J. A. Lancaster. 1968. Bermudagrass production and management in East Texas. Tex. Agr. Exp. Sta. B-1073.

Jones, R. M. 1969. Response of Coastal bermudagrass to applied nutrients on some alluvial soils of Texas. MS Thesis. Texas A&M University.

Kunze, G. W., and E. H. Templin. 1956. Houston black clay, the type grumusol. II. Mineralogical and chemical characterisation. Soil Sci. Soc. Amer. Proc. 20:91-96.

Langford, Loyd, and Don Stagg. 1969. 1969 Corn ensilage test. High Plains Research Foundation, Rep. No. 316. Plainview, Texas.

Langford, Loyd, and Don Staggs. 1968. Performance of corn hybrids for forage production. High Plains Research Foundation, Rep. No. 280. Plainview, Texas.

Lehman, O. R., J. J. Bond, and H. V. Eck. 1968. Forage potential of irrigated blue grama with nitrogen fertilization. J. Range Manage. 21:71-73.

Martin, W. E. (deceased), and J. E. Matocha. 1973. Plant analysis as an aid in fertilization of forage crops. In Soil Testing and Plant Analysis, Soil Sci. Soc. Amer., Proc., pp. 393-426.

Matocha, J. E. 1969. Response of Coastal bermudagrass to various sources of sulfur on a sandy soil in East Texas. Tex. Agr. Exp. Sta. PR-2696.

Matocha, J. E. 1971. Influence of sulfur sources and magnesium on forage yields of Coastal bermudagrass (Cynodon dactylon L. Pers.). Agron. J. 63:493-496.

Matocha, J. E., M. M. McCartor, and B. J. Ott. 1971. Effect of various sources of nitrogen fertilizers on forage yields of wheat-ryegrass. Tex. Agr. Exp. Sta. PR-2877.

Matocha, J. E. 1972. Production of wheat-ryegrass and Coastal bermudagrass grown in association as affected by rates and sources of nitrogen. Tex. Agr. Exp. Sta. PR-3015.

Matocha, J. E. 1975. No-till and seedbed production of small grains-ryegrass mixture for forage in East Texas. Tex. Agr. Exp. Sta. B-1155.

Matocha, J. E., F. M. Rouquette, Jr., R. L. Duble. 1973. Recycling and recovery of N, P, and K by Coastal bermudagrass. I. Effect of sources and rates of N under a clipping system. J. Environ. Qual. 2:125-132.

New, Leon. 1971. High Plains irrigation survey. Texas Agr. Ext. Service.

Oakes, Harvey, Curtis Godfrey, and Jack Barton. 1958. Land resource areas of Texas. Tex. Agr. Exp. Sta. and Tex. Agr. Ext. Service L-400.

Owen, D. F., and R. D. Furr. 1967. Nitrogen and mineral content of five forage sorghum varieties and the effect of sulfur and minor elements on yields and nutritive value. Texas Technological College, Research Farm Reports, Spec. Rep. 1:48-51.

Pope, Alex. 1961. Effect of application schedule and source of phosphorus fertilizer on forage yield, phosphorus content, and protein content of twelve cuttings of irrigated alfafa. Tex. Agr. Exp. Sta. PR-2214.

Rich, Pat A. 1967. Nitrogen and phosphate effects on forage sorghum, 1963-66. Tex. Agr. Exp. Sta. PR-2501.

Riewe, Marvin E., and J. C. Smith. 1955. Effect of fertilizer placement on perennial pastures. Tex. Agr. Exp. Sta. B-805.

Riewe, Marvin E., and J. C. Smith. 1961. Influence of white clover and nitrogen on yield, leaf and protein percentage of four warm-season grasses. Tex. Agr. Exp. Sta. PR-2203.

Ritchie, J. T. 1971. Dryland evaporative flux in a subhumid climate. I. Micrometerological influences. Agron. J. 63:56-62.

Ritchie, J. T., Earl Burnett, and R. C. Henderson. 1972. Dryland evaporative flux in a subhumid climate. III. Soil water influence. Agron. J. 64:168-173.

Rouquette, F.M., Jr., J. E. Matocha, and R. L. Duble. 1973. Recycling and recovery of N, P, and K by Coastal bermudagrass. II. Under grazing conditions with two stocking rates. J. Environ. Qual. 2:129-132.

Schuster, J. L., M. J. Trlica, David Bryant, and Earl Chamberlain. 1967. Combining fertilizer and herbicide for range improvement. Texas Technological College, Research Farm Reports, Spec. Rep. 1:57-62.

Templin, E. G., I. C. Mowery, and G. W. Kunze. 1956. Houston black clay, the type grumusol. I. Field morphology and geography. Soil Sci. Soc. Amer. Proc. 20:88-90.

Trlica, M. J., David Bryant, and J. L. Schuster. 1967. Influence of range fertilization on forage production and species composition. Texas Technological College, Research Farm Reports, Spec. Rep. 1:63-65.

Walker, Harvey, E. B. Hudspeth, and Judd Morrow. 1958. Seed and fertilizer placement study on selected native grasses at Lubbock. Tex. Agr. Exp. Sta. PR-2027.

Welch, C. D., Carl Gray, J. E. Matocha, and W. B. Anderson. 1971. Crop fertilization on East Texas soils. Fact Sheet L-771.

Welch, N. A., Earl Burnett, and E. B. Hudspeth. 1962. Effect of fertilizer on seedling emergence and growth of several grass species. J. Range Manage. 15:94-98.

Wolton, K. M. 1963. An investigation into the simulation of nutrient returns by the grazing animal in grassland experimentation. J. Brit. Grassd. Soc. 18:213-219.