AgriLIFE RESEARCH
Texas A&M System

Proceedings: Adjusting to High Fuel and Fertilizer Prices
Research Center Technical Report No. 2008-01

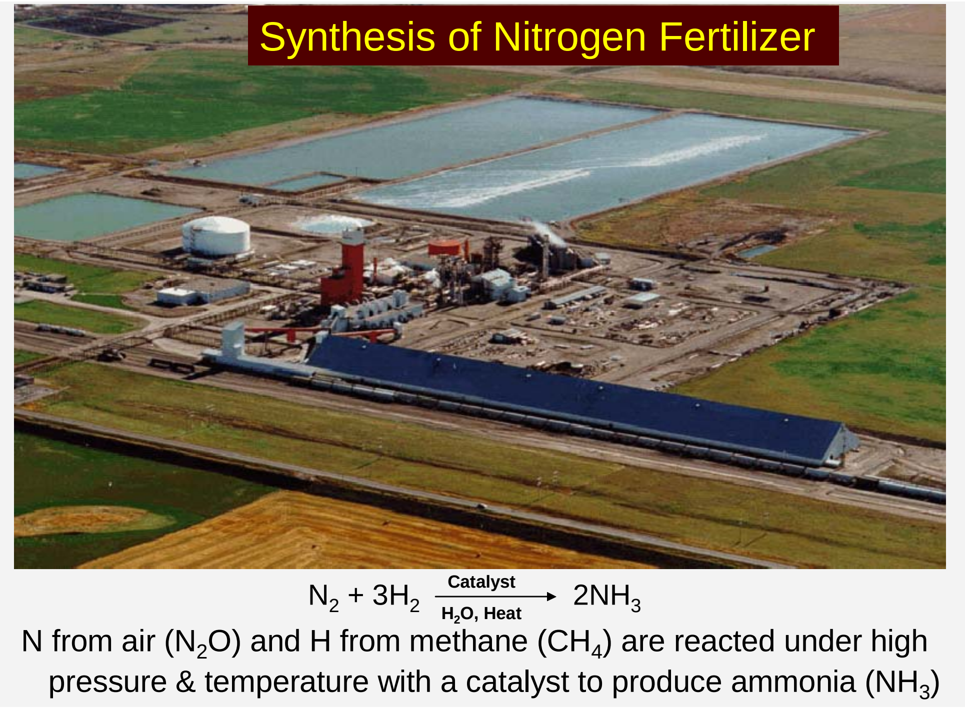
LIME AND FERTILIZER STRAGTEGIES FOR FORAGE PRODUCTION

Vincent Haby

A sustainable cattle industry depends on economical production of forage grasses and legumes. However, recent trends involving higher fuel prices that affect equipment operation, transportation, production inputs, haying, and marketing are causing increasing concern about the economies of forage and livestock production. The forage and livestock production gamble is increasing. Although producers may not directly use natural gas to power their equipment, their bottom line is affected by the increasing cost of this fuel for producing nitrogen (N) fertilizer.

Natural gas is used to make anhydrous ammonia (NH_3) N. In the synthesis of NH_3, air that contains 78% N is reacted with natural gas (methane, CH_4) under high temperature and steam pressure with a catalyst to produce NH_3 and carbon dioxide (CO_2). Ammonia is the starting material for manufacture of most other N fertilizers.

Since 1999, the increasing price of natural gas caused permanent shut down of 25 US ammonia plants and idled several more because economical ammonia production could not be sustained. As ammonia plants shut down, fertilizer imports have increased to more than 50% of usage in the US.

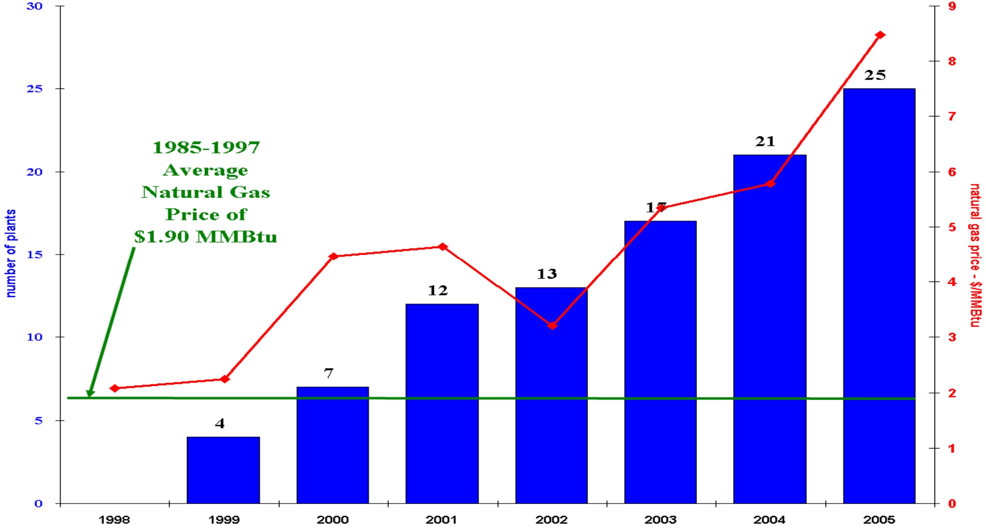


Synthesis of Nitrogen Fertilizer

$$N_2 + 3H_2 \xrightarrow[H_2O,\ Heat]{Catalyst} 2NH_3$$

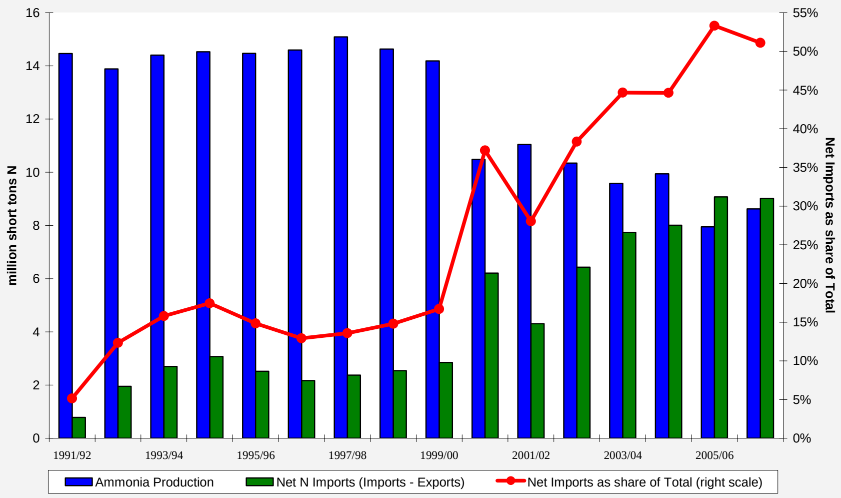
N from air (N_2O) and H from methane (CH_4) are reacted under high pressure & temperature with a catalyst to produce ammonia (NH_3)

Cumulative U.S. Ammonia Plant Closures vs. Natural Gas Prices



Source: Blue, Johnson and Associates, Natural Gas Week and The Fertilizer Institute.

U.S. Ammonia Production and Net Nitrogen Imports



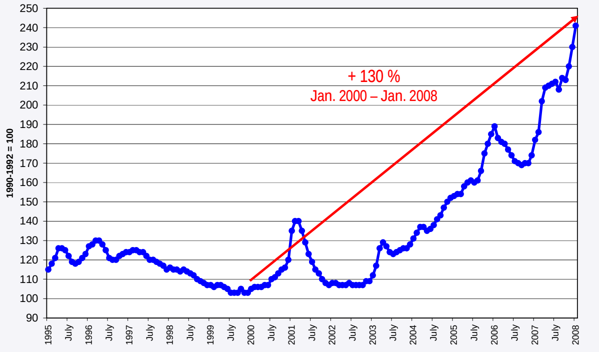
Source: U.S. Department of Commerce and The Fertilizer Institute.

Fertilizer prices

Because of the increasing costs of fuel for transportation, natural gas for manufacturing, and greater international demand, the cost of commercial fertilizers has more than doubled since the year 2000. Recent data indicate rapid escalation of fertilizer prices. Most N fertilizers are up more than 130% over the past several years. Diammonium phosphate (18-46-0), the phosphorus source used in fertilizer blends, currently retails for at least $1,000/ton; potash (0-0-60) fertilizer costs $600/ton, or $0.50/lb of K_2O and is predicted to increase even more by 2009; sulfur (S) recently increased by $250 to sell for $625/ton and it is expected to increase another $125/ton in the third quarter of 2008.

Fertilizer Price Increases

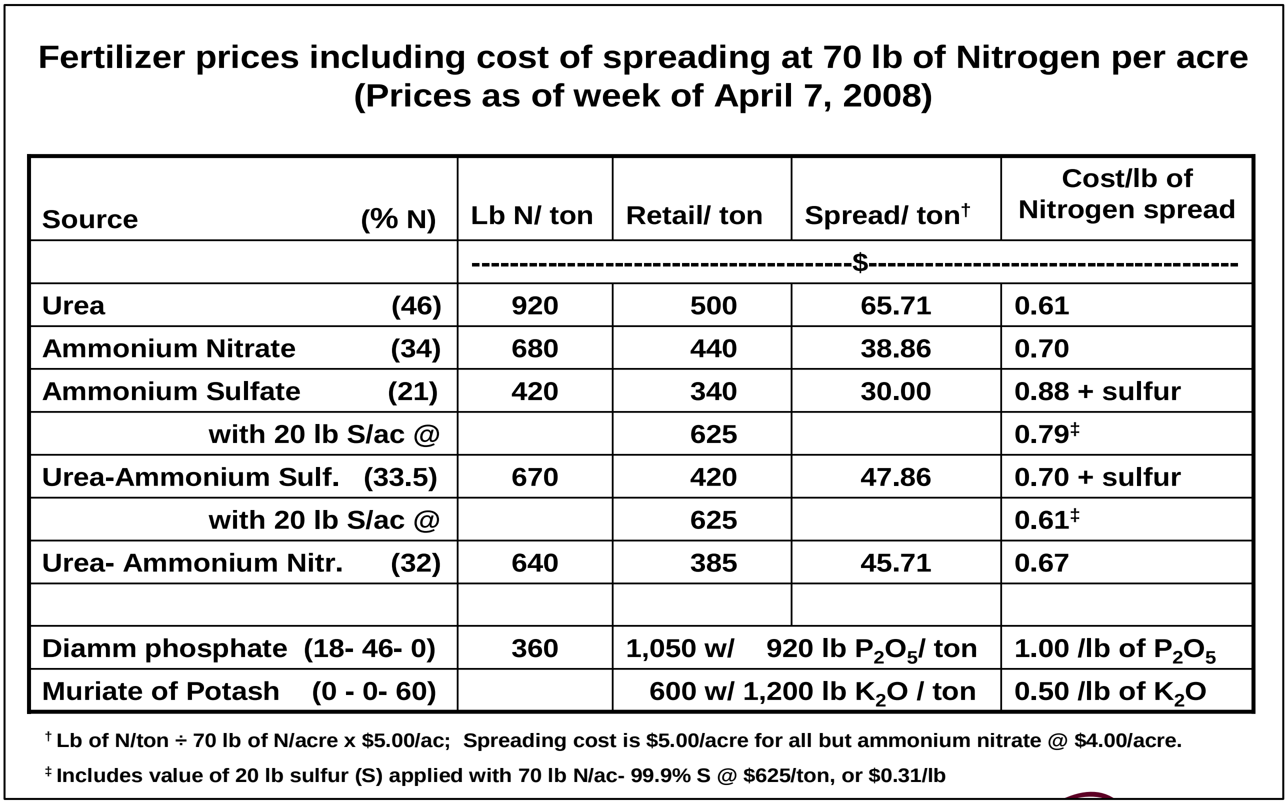
Index of Fertilizer Prices Paid by Farmers, Jan. 1995 - Jan. 2008



Source: National Agricultural Statistics Service, USDA.

With the rapidly increasing prices of fertilizers, it has become even more important for farmers and ranchers to know the cost of inputs for forage crops and other crops production. Pricing fertilizer by the pound of plant nutrient contained in a ton allows one to know the cost of the plant nutrients applied.

The chart below shows the value per pound of N contained in a ton of selected N sources and potash available for application on forage grasses as of April 7, 2008. The percentage N in each material is shown with the cost per ton and the cost per pound of N in each ton. The price of the N fertilizers ranges from $340 to $500/ton. The price per ton is higher for the more concentrated N sources, but on a price per pound of N basis, the cost range is not as great. By knowing the price per pound, it becomes easier for producers to determine the lowest priced N material. So, how do we determine the price per pound of nutrient?



Fertilizer prices including cost of spreading at 70 lb of Nitrogen per acre (Prices as of week of April 7, 2008)

Source (% N)	Lb N/ ton	Retail/ ton	Spread/ ton[†]	Cost/lb of Nitrogen spread
	--------------$--------------			
Urea (46)	920	500	65.71	0.61
Ammonium Nitrate (34)	680	440	38.86	0.70
Ammonium Sulfate (21)	420	340	30.00	0.88 + sulfur
with 20 lb S/ac @		625		0.79[‡]
Urea-Ammonium Sulf. (33.5)	670	420	47.86	0.70 + sulfur
with 20 lb S/ac @		625		0.61[‡]
Urea- Ammonium Nitr. (32)	640	385	45.71	0.67
Diamm phosphate (18- 46- 0)	360	1,050 w/ 920 lb P_2O_5/ ton		1.00 /lb of P_2O_5
Muriate of Potash (0 - 0- 60)		600 w/ 1,200 lb K_2O / ton		0.50 /lb of K_2O

[†] Lb of N/ton ÷ 70 lb of N/acre x $5.00/ac; Spreading cost is $5.00/acre for all but ammonium nitrate @ $4.00/acre.

[‡] Includes value of 20 lb sulfur (S) applied with 70 lb N/ac- 99.9% S @ $625/ton, or $0.31/lb

Calculating the cost/lb of N

By knowing the cost per ton and the N percentage in an N fertilizer material, such as urea, the cost per pound of N can be calculated. First, convert the percentage N to a decimal fraction by dividing by 100. Multiply the decimal fraction by 2000 lb/ton. The amount of N in a ton of urea is 920 lb. Divide the cost/ton by the amount of N in each ton to find the cost/lb of N. If it is not already included in the price per ton, fertilizer venders charge for spreading. In the example above, the spreading fee is $5.00/ac for driving the spreader truck over the field. In this example the N rate is 70 lb/ac. Dividing the per-acre spreading fee by the N rate being applied

Calculating the cost of plant nutrients per pound

- **Urea nitrogen fertilizer costs $500.00/ton at the field**
- **One ton of urea contains 46% nitrogen**
- **(46% N ÷ by 100%) x 2000 lb/ton = 920 lb N/ton**
- **Divide the cost/ton by the lb N/ton**
    - **$500.00 divided by 920 = $0.543/lb of N**
- **Add spreading cost @ $5.00/acre @ rate of 70 lb N/ac**
    - **$5.00/acre divided by 70 lb N/ac = $0.071/lb of N**
- **Cost of N/lb + spreading cost = total**
    - **$0.543 + $0.071 = $0.614/lb of N spread**

70 lb N/ac x $0.614/lb N = $42.98/acre

determines that spreading adds 7 cents/lb to the N. So the cost of N applied to the field is \$0.614/lb. The amount of N applied multiplied by the cost of N/lb determines the total cost of N. In this example it is \$42.98/ac. Similar calculations can be done for other N fertilizers. For ammonium nitrate selling at \$440/ton with a spreading fee of \$4.00/ac, 70 lb of N costs \$49.28/ac.

The same approach can be used to determine the cost/lb of potash (K_2O) applied/ac. Potash is 60% K_2O, or 0-0-60 for the red colored material. Convert the 60% to the decimal fraction and multiply that fraction by 2000 lb/ton to determine that a ton of potash contains 1200 lb K_2O. Divide the \$600 cost/ton of potash by the pounds of K_2O/ton to determine that each pound of K_2O costs \$0.50/lb before adding the spreading cost. Rarely is potash applied by itself; it usually is applied in a blend with other plant nutrients, so the cost of spreading is more difficult to determine for individual nutrients in a blend.

At low to moderate N rates, urea is not as effective as is ammonium nitrate or ammonium sulfate for grass production. In N-rate studies conducted by AgriLife Research scientists at Overton, urea and urea-ammonium nitrate produced 14 and 20%, respectively, lower Coastal bermudagrass yields compared to ammonium nitrate at the 40 lb N/ac rate/cutting for 3 to 5 cuttings. Ammonium sulfate produced equal yields compared to ammonium nitrate at the 40 lb/ac N rate. Yield differences between N sources generally decline as the N rate is increased.

Coastal bermudagrass yield response to nitrogen sources and rates on Gallime fine sandy loam soil (3-yr average)

Nitrogen source	Nitrogen rate, lb/ac†				
	0	40	Diff.	80	Diff.
	t/ac	t/ac	%	t/ac	%
UAN	2.66	5.62	-20	7.29	-9
Urea	2.66	6.04	-14	7.51	-6
Amm. Nitrate	2.66	7.01		7.97	
Amm. Sulfate	2.66	6.82	- 3	8.22	+3

LSD (0.05) = 0.67, CV = 6.9%

†Nitrogen rates applied for each regrowth of bermudagrass (3 applications in year 1, four applications in year 2, and five applications in year 3.

Agrotain, Nutrisphere, SCU, Polymer coated urea

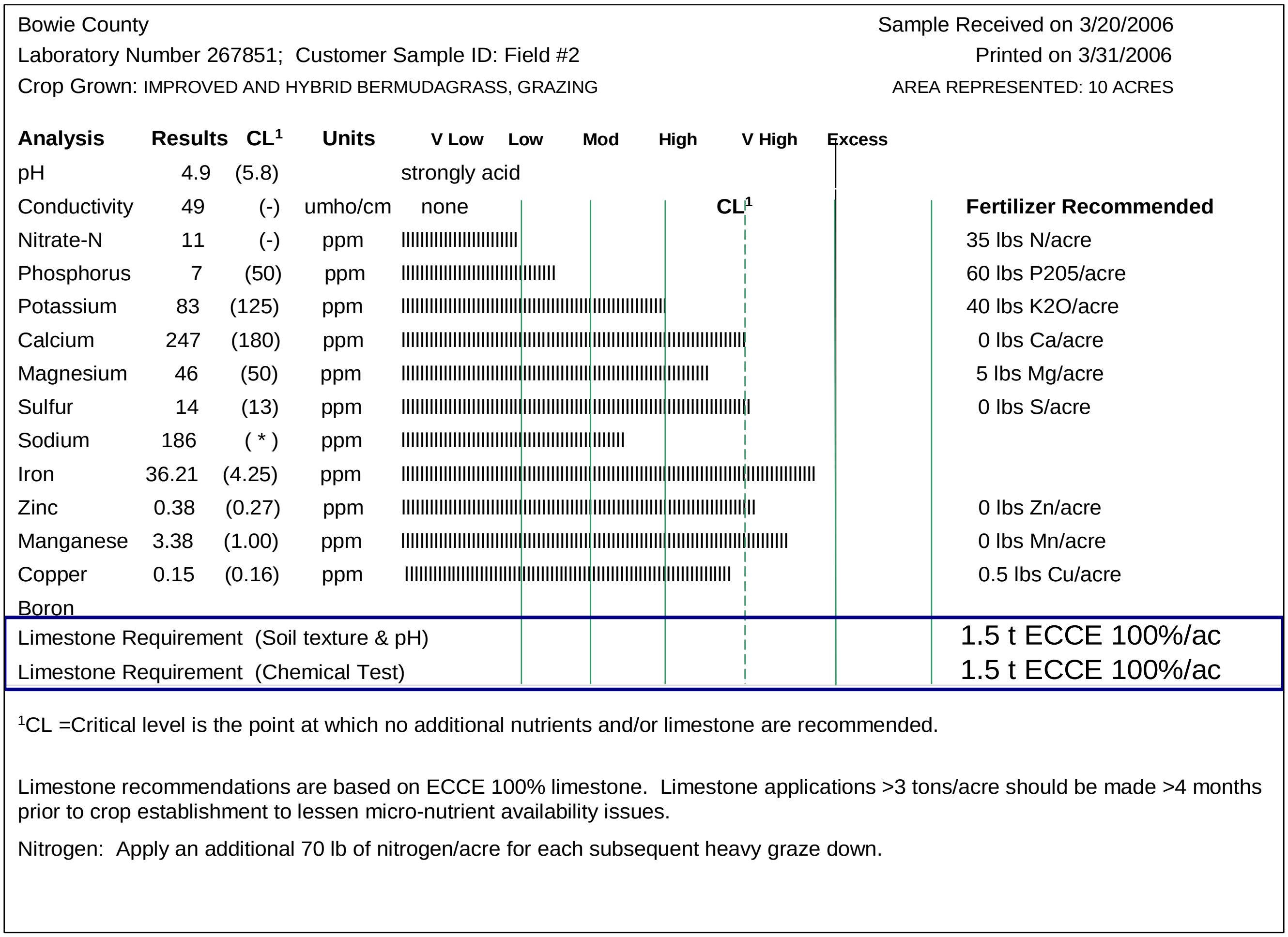
The pounds of forage produced per pound of N applied decreases as the N rate is increased. However, in haying situations, crude protein in forage receiving the lower N rates on N-deficient soil will be low and additional N is needed if higher nutritive value forage is desired.

The increasing cost of energy and natural gas to manufacture N fertilizers is directing some companies toward use of lower production energy requiring fertilizers such as urea. However, urea and urea-containing N fertilizers lose N as ammonia gas by a process called volatilization when these materials are applied and left on the soil surface. Companies are working to develop materials that delay conversion of urea to ammonia and prevent volatilization losses. These products include coatings and inhibitors that delay the activity of urease, an enzyme responsible for converting urea to the ammonia gas, or by delaying conversion of the ammonium form of N to the nitrate form. Texas AgriLife Research scientists are evaluating some of these materials in cooperation with manufacturers. Agrotain, Nutrisphere (NSN), Environmentally Smart N (ESN), calcium thiosulfate, and sulfur coated urea are some of the materials being evaluated and may be available at ag chemical companies or urea or urea-ammonium nitrate fertilizer distributors.

Production strategies

The forage and livestock production gamble is changing and the old rules are becoming even more important. Soil testing is critically important to determine the residual fertility levels of soil in order to prevent unneeded fertilizer application. The need to maintain an adequate pH by liming acid soils for forage production cannot be over-emphasized, and the limestone should be incorporated when possible. The fertility strategy must be re-evaluated- will it pay to apply limestone and fertilizer? How much can be applied and still be economical? If the fertilizer and limestone input is reduced, be prepared to lower the stocking rate because of lower forage production. Use alternative nutrient sources such as broiler litter and other manures if these are available and if they are economical to apply. Make certain that any alternative nutrient source being considered actually is a reliable source of plant nutrients, and not some fly-by-night, watered down material supported only by testimonials i.e., “For only $25/gallon and applied at the rate of 1.0 gal/ac, company X’s material will produce the same forage yield as will the fertilizer recommended by soil test.” Don’t even try these types of materials claimed as all-purpose miracle fertilizers.

Forages take up definite amounts of the 16 essential plant nutrients. Average season-long nutrient uptake by Tifton 85 bermudagrass under hay production conditions includes 368 lb of nitrogen, 33 lb of phosphorus, 325 lb of potassium, 53 lb of calcium, 19 lb of magnesium, 60 lb of sulfur/ac, and smaller amounts of the



Bowie County
Sample Received on 3/20/2006
Laboratory Number 267851; Customer Sample ID: Field #2
Printed on 3/31/2006
Crop Grown: IMPROVED AND HYBRID BERMUDAGRASS, GRAZING
AREA REPRESENTED: 10 ACRES

Analysis	**Results**	**CL**[1]	**Units**	**V Low Low Mod High V High Excess**	**Fertilizer Recommended**
pH	4.9	(5.8)		strongly acid	
Conductivity	49	(-)	umho/cm	none	
Nitrate-N	11	(-)	ppm		35 lbs N/acre
Phosphorus	7	(50)	ppm		60 lbs P205/acre
Potassium	83	(125)	ppm		40 lbs K2O/acre
Calcium	247	(180)	ppm		0 lbs Ca/acre
Magnesium	46	(50)	ppm		5 lbs Mg/acre
Sulfur	14	(13)	ppm		0 lbs S/acre
Sodium	186	(*)	ppm		
Iron	36.21	(4.25)	ppm		
Zinc	0.38	(0.27)	ppm		0 lbs Zn/acre
Manganese	3.38	(1.00)	ppm		0 lbs Mn/acre
Copper	0.15	(0.16)	ppm		0.5 lbs Cu/acre
Boron					
Limestone Requirement (Soil texture & pH)					1.5 t ECCE 100%/ac
Limestone Requirement (Chemical Test)					1.5 t ECCE 100%/ac

[1] CL =Critical level is the point at which no additional nutrients and/or limestone are recommended.

Limestone recommendations are based on ECCE 100% limestone. Limestone applications >3 tons/acre should be made >4 months prior to crop establishment to lessen micro-nutrient availability issues.

Nitrogen: Apply an additional 70 lb of nitrogen/acre for each subsequent heavy graze down.

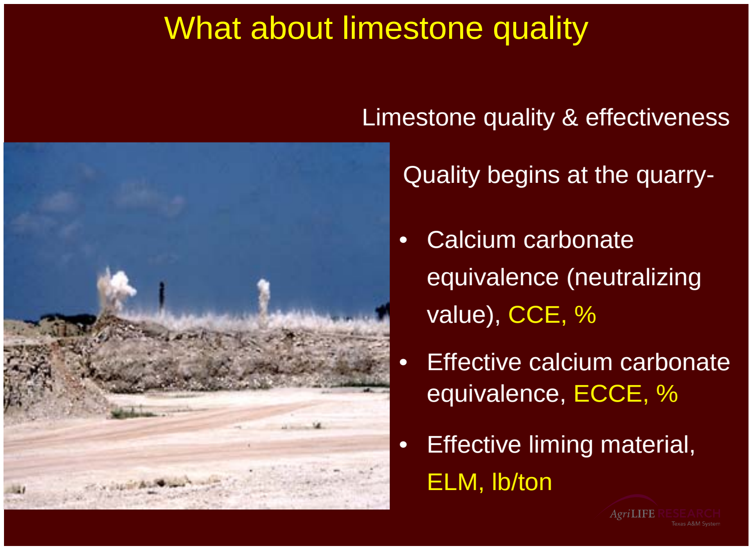
micronutrients including zinc, copper, iron, manganese, boron, molybdenum, and chloride. If these are not available in soil, they must be applied as fertilizer, limestone, or in the case of N, by legumes, or the desired amount of grass will not be produced. No soil activator or foliar-applied material sprayed at a gallon/ac is going to provide these amounts of nutrients to grass.

The image of a soil test report on the previous page is shown to indicate that soil testing is very important and that the recommendation for needed limestone is made based on application of 100% effective limestone, described as Effective Calcium Carbonate Equivalence and abbreviated as ECCE.

Limestone quality and economics

Quality of limestone begins at the quarry where it is crushed and screened. Pure limestone has a calcium carbonate equivalence (CCE), or neutralizing value, of 100%. The ECCE is determined by passing the crushed limestone through a series of sieves.

Efficiency factors are assigned to limestone fractions on each sieve. Material passing a 60-mesh sieve is considered 100% efficient for totally reacting in three years. The greater the ECCE % of the limestone, the more rapidly it will react, and less limestone will be needed to change soil pH.

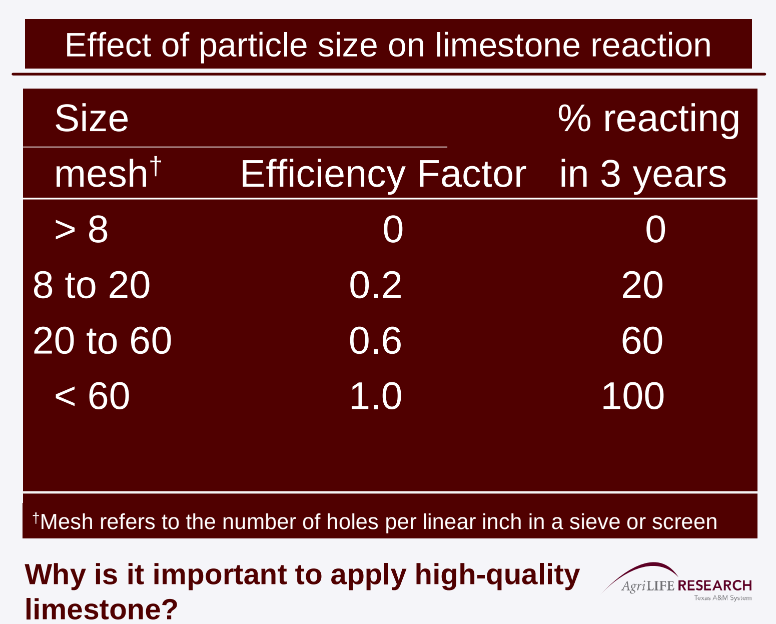

What about limestone quality

Limestone quality & effectiveness

Quality begins at the quarry-

- Calcium carbonate equivalence (neutralizing value), CCE, %
- Effective calcium carbonate equivalence, ECCE, %
- Effective liming material, ELM, lb/ton

The increased efficiency of ECCE 100% limestone is shown in the chart below. Limestone with ECCE 62, 81, and 100% was applied to Darco soil and left on the surface at rates of 0, 1, 2, and 3 tons/ac. Crimson clover yields were measured on these plots two and one-half years later,. Three tons ECCE 62% limestone was required to optimize clover dry matter compared to two tons/ac for ECCE 81%, and only one ton of ECCE 100% was needed to produce the same yield. Additionally, the ECCE 100% limestone maintains a higher pH over a longer time because the finer limestone more fully reacts to neutralize soil acidity and raise pH to a higher level than does the coarser limestone. In a long-term study, soil pH

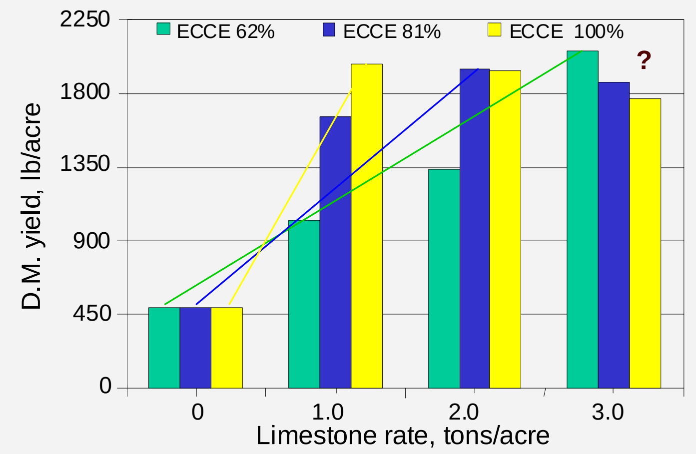

Effect of particle size on limestone reaction

Size mesh†	Efficiency Factor	% reacting in 3 years
> 8	0	0
8 to 20	0.2	20
20 to 60	0.6	60
< 60	1.0	100

†Mesh refers to the number of holes per linear inch in a sieve or screen

Why is it important to apply high-quality limestone?

remained 0.3 units higher from ECCE 100% limestone compared to ECCE 62% when both materials were applied seven years earlier at 0, 3, and 6 ton/ac.



Crimson clover response to limestone rate and ECCE on Darco loamy fine sand 2.5 yr. after surface treatment of field plots.

Application of the more efficient, high ECCE % limestone is more economical than applying the coarser, lower ECCE % materials. The argument for this is presented in the adjacent chart. If the soil test recommends application of 1.0 ton of ECCE 100% limestone/ac, that one ton will contain 2000 lb of effective liming material (ELM). If the choices of limestone to apply are ECCE 62% at a cost of $42/ton, and ECCE 100% at a cost of $45/ton, application of one ton of ECCE 100% limestone/ac will cost $45.

Economics of limestone quality and efficiency

Limestone recommendation: 1 ton of ECCE 100%/ac

Limestone costs $42/ton for ECCE 62%, and
$45/ton for ECCE 100%

Applying of 1 ton of ECCE 100% limestone/acre = $45

To substitute ECCE 62%:

100% ÷ 62% = 1.61 tons ECCE 62%/acre

1.61 x $42.00/ton = $67.74/acre to apply correct rate of ECCE using the 62% limestone

Using the coarse lime cost an extra $22.74/acre

Limestone readily available to East Texas

Company	Location	ECCE	Mg
		------%------	
Texas Crushed Stone,	**Georgetown**	**63**	**4**
		99	**4**
Franklin Ind. Minerals,	**Nolanville**	**99**	**4**

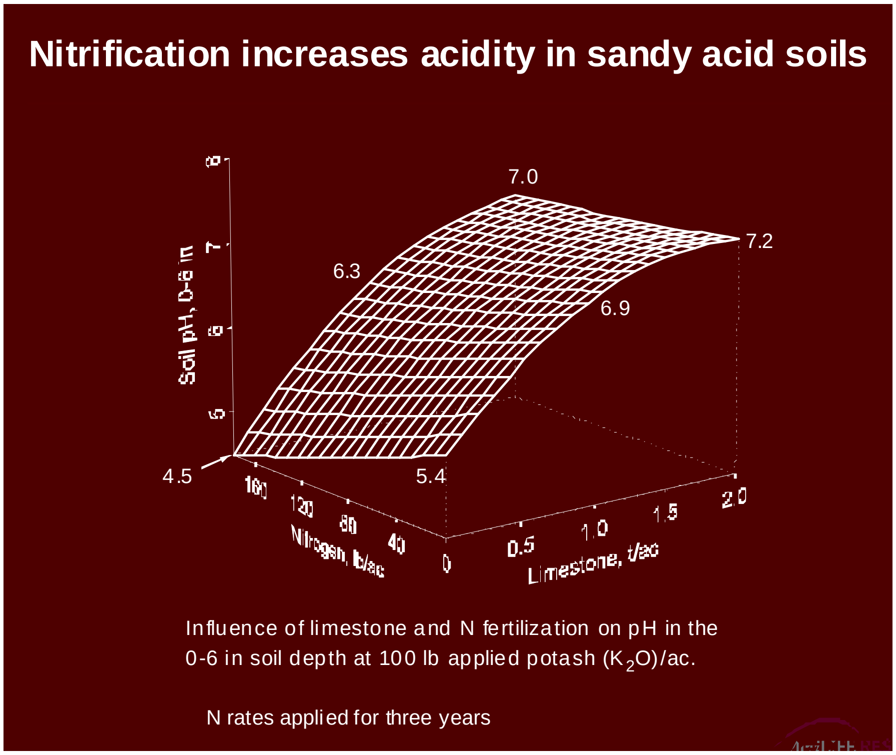
Other limestone suppliers in Oklahoma:

Hugo and Idabell- Coarse limestone
Mill Creek- Coarse and Fine; also fine dolomitic

However, if the ECCE 100% is not available, or your local limestone vendor doesn't handle it, the recommended rate using a lower quality limestone such as ECCE 62% must be adjusted. This is done by dividing 100% by 62%, as shown, and applying that adjustment factor to determine the rate of ECCE 62% limestone/ac. Using ECCE 62% limestone increases the cost/ac from $45 for the ECCE 100% limestone to $67.74 when using the ECCE 62% material. Applying 62% limestone increases the liming cost by $22.74/ac. This is a significant cost increase that can be avoided by locating a limestone supplier who is willing to spread the ECCE 100% material.

Two Texas quarries are listed in the chart to the right. These companies each have an ECCE 99% limestone that contains about 4% magnesium (Mg). One company also makes an ECCE 63% limestone that sometimes is referred to as ag-grade limestone. Several companies in Oklahoma also sell limestone into northeast Texas. Each of these Oklahoma companies has coarse limestone, but the one at Mill Creek, OK also makes high ECCE calcitic and dolomitic limestones. Pure dolomitic limestone contains about 13.1% Mg, and at equal particle size is slower reacting than is calcitic limestone. Acid soils that need limestone in Texas are usually low in Mg and benefit from application of Mg in limestone.

Nitrogen in the ammonium form applied to the low-buffer capacity, acid soils causes increased acidity. This occurs when the ammonium is converted to nitrate. The slide below shows a decline in pH at the lower left from 5.4 to 4.5 after three years of N application at rates 200 lb/ac/year when no limestone was applied. As the rate of limestone was increased from zero to 2.0 ton/ac on the lower right axis, the acidifying effect of the applied N becomes less. The pH change at the high rate of limestone and three years of applying 200 lb of N/ac each year is only 0.2 pH units lower compared to pH at the high rate of limestone with no N applied.


Nitrification increases acidity in sandy acid soils

Influence of limestone and N fertilization on pH in the 0-6 in soil depth at 100 lb applied potash (K_2O)/ac.

N rates applied for three years

Conversion of ammonium in anhydrous ammonia, urea, ammonium nitrate, and urea-ammonium nitrate to nitrate in the soil increases acidity that requires 1.8 lb of additional limestone to neutralize the acidity for each pound of N applied. The acidity generated by nitrification of ammonium in ammonium sulfate and diammonium phosphate is even greater. When fertilizing with nitrogen, it is important to take soil samples at least every two years to monitor soil acidity levels and maintain pH in the range favorable for forages on acid soils.

Nitrogen fertilizer increases soil acidity

Nitrogen fertilizer	Nitrogen content % N - P_2O_5 - K_2O	Limestone required/lb of N applied lb	Limestone required/100 lb of N applied lb
Anhydrous ammonia	82 - 0 - 0	1.8	180
Urea	46 - 0 - 0	1.8	180
Ammonium nitrate	34 - 0 - 0	1.8	180
Urea ammonium nitrate	32 - 0 - 0	1.8	180
Ammonium sulfate	21 - 0 - 0	5.4	540
Diammonium phosphate	18- 46- 0	3.6	360

The chart at right expands one shown earlier and shows the eventual cost/lb for five N sources applied at a rate of 100 lb of N/ac. The cost of limestone to neutralize the acidity has been added to the cost/lb of N and spreading costs. For forage production on low-buffer capacity, acid sandy soils, the cost of 100 lb of N ranges from $71 to $100 based on April 2008 prices.

Estimated cost of applied N fertilizer with additional limestone and spreading costs included- Apr. 2008.

N Source	% N	$/ton	$/100 lb N[†]	Limestone $/100 lb N[‡]	$/100 lb N/acre[†]
Urea	46	500	61.49	4.05	65.54
Amm. Nit.	34	440	70.04	4.05	74.09
Amm. Sul.	21	340	88.10	12.15	100.25+S
			78.72[§]	12.15	90.87[§]
Urea AS	33.5	420	69.83	8.10	77.93
Urea AN	32.0	385	67.30	4.05	71.35

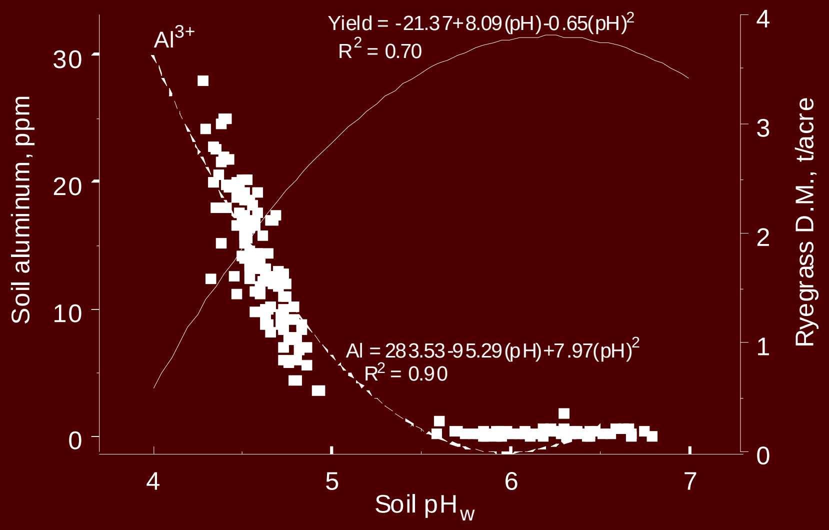
[†] Includes spreading cost

[‡] Based on 1.8 lb of limestone/lb of N in UAN, Urea, and Ammonium nitrate, 5.4 lb of limestone/lb of N in Ammonium sulfate, and $45/ton of applied limestone.

[§] Includes value of 30 lb sulfur (S) applied with 100 lb N/ac- S valued at $625/ton, or $0.31/lb

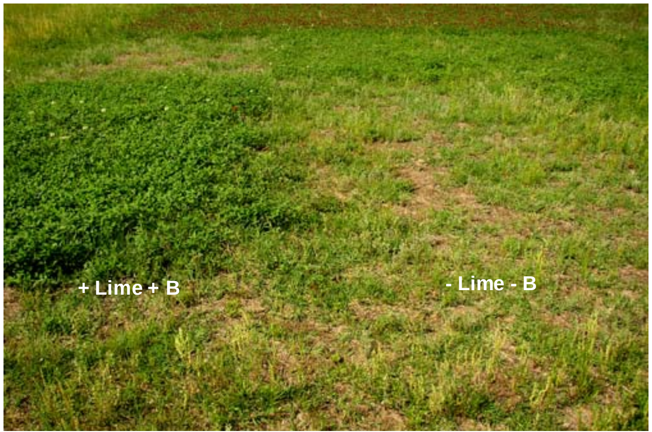
Annual ryegrass, like many grasses and legumes, is sensitive to soil acidity. As soils become increasingly acidic at pH 5.5 and lower, aluminum rapidly increases in solubility (see graph below). Aluminum in sufficient concentrations is toxic to acid-sensitive plant roots and prevents these roots from growing and exploring the soil mass for water and nutrients. The consequence is acidity-induced yield reduction. The solution is to lime acid soils to maintain pH above 5.5 for forage production. The favorable pH can vary by crop, but is considered to be about 6.0 to 6.2 for most forages. Alfalfa and Tifton 85 bermudagrass are two exceptions that continue to increase yield at soil pH levels near 7.0.

Effects of acidity on soil aluminum and ryegrass production



Effect of soil pH in the 0-6 in. depth on 1.0 M KCl extractable Al^{3+} and on the yield of annual ryegrass on a Lilbert fine sandy loam

Apache arrowleaf clover responses to limestone and boron treatments



The image at the left shows arrowleaf clover response to limestone and boron applied to field research plots. Clovers need limed soils in order for the Rhizobia on the roots to thrive and fix adequate amounts of N for the plants.

The image below graphically shows Tifton 85 response to soil pH on the lower right and to poultry litter rates on the lower left. Yield is indicated on the left vertical line. Data from Tifton 85 response to increasing pH was interpreted and put into the table (on next page) to show the projected yield increase at increasing pH and the value of that increased yield beginning at different pH levels. For example, at soil pH 4.5 in the left column, bermudagrass hay yield was 10,071 lb/ac. When the soil was limed to pH 5.0, hay yield increased 783 lb and its gross value increased \$39.15/ac when hay was valued at \$100/ton. When pH was increased to 6.5, yield was raised by 3,133 lb/ac and gross value of that higher yield was \$156.65/ac. Yield and gross hay value increases due to liming also are shown for beginning soil pH values of 5.0 and 5.5. Annual ryegrass response to limestone is shown in the adjacent image. The darker colored taller growth was the result of liming Lilbert loamy fine sand to pH 6.2 using 1.7 tons of ECCE 62% limestone/ac disked into the soil. Initial soil pH of the unlimed area with the much shorter grass was 4.5.

Tifton 85 bermudagrass response to limestone

Yield = 801 + (1398.6 x pH) + (609 x PL) - (33.7 x PL x PL)
R = 0.866

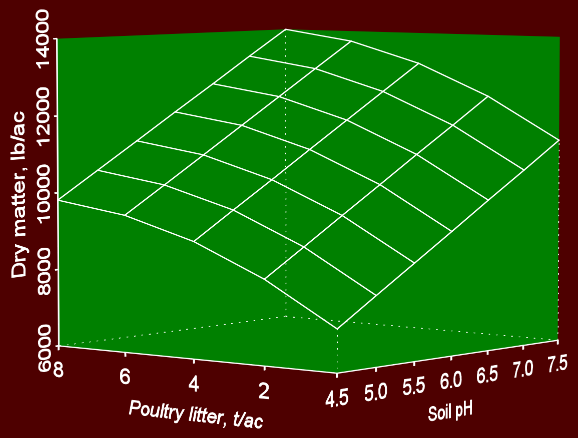


Fig 1. Tifton 85 bermudagrass response to soil pH
and poultry litter rate on Darco soil in 2004.

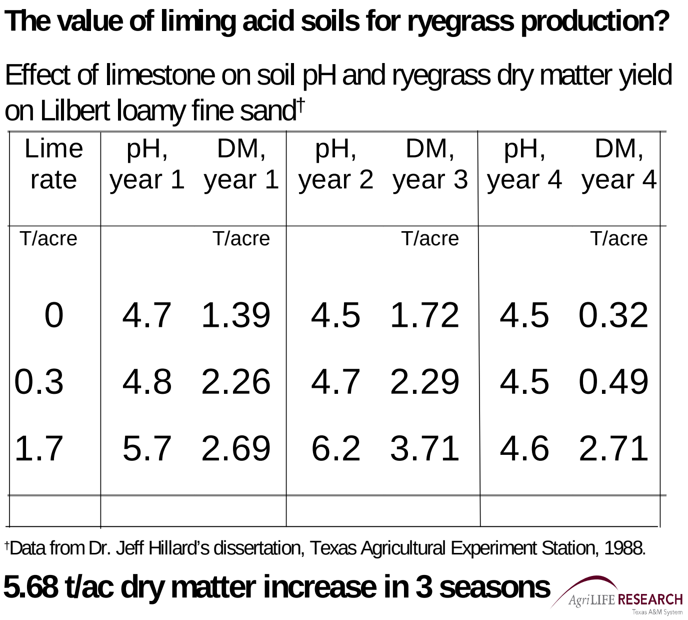
Texas Agricultural Experiment Station

Tifton 85 bermudagrass hay yield and $ value affected by soil pH at constant rates of N, K, and 4 tons of poultry litter/acre.† (12% moisture, $50/1,000 lb roll)

Soil pH	Yield	Difference from pH 4.5		Difference from pH 5.0		Difference from pH 5.5	
	lb/ac	lb/ac	$/ac	lb/ac	$/ac	lb/ac	$/ac
4.5	**10,071**						
5.0	**10,854**	**783**	**39.15**				
5.5	**11,637**	**1,566**	**78.30**	**783**	**39.15**		
6.0	**12,420**	**2,349**	**117.45**	**1,566**	**78.30**	**783**	**39.15**
6.5	**13,204**	**3,133**	**156.65**	**2,349**	**117.45**	**1,566**	**78.30**
7.0	**13,987**	**3,916**	**195.80**	**3,133**	**156.63**	**2,349**	**117.45**

N (540 lb/ac) and K_2O (200 lb/ac) applied to all plots during the season

Yield and soil pH change data from this limestone-rate ryegrass study were collected for three growing seasons. Dry matter yield (right) increased 1.30, 1.99, and 2.39 tons/ac in the three seasons, or a total of 5.68 tons in the limestone treated plots compared to the unlimed, pH 4.5 soil at equal N, phosphorus, and potassium rates. The ECCE 62% limestone, even when it was disked into the soil, needed two years to maximize pH to its highest level of 6.2. With limestone applied at the rate of 0.3 tons/ac, there was little change in soil pH, from 4.5 to 4.7 the second season. By the third season, soils treated with the 0.3 ton/ac rate declined to pH 5.5, similar to the unlimed plots.



The value of liming acid soils for ryegrass production?

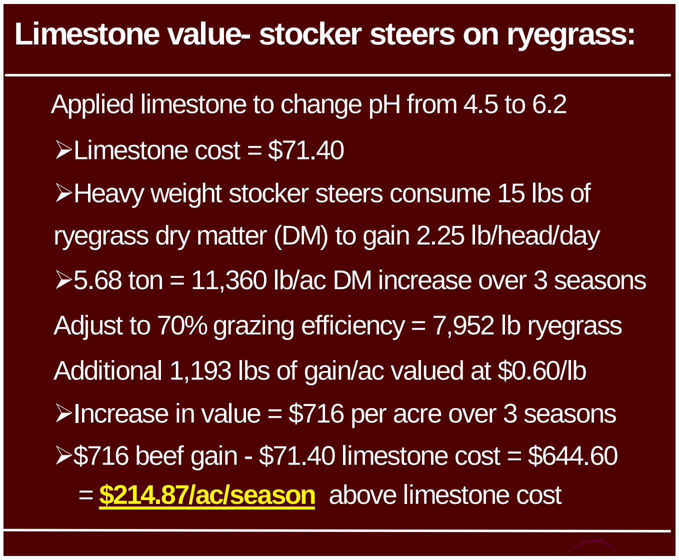
Effect of limestone on soil pH and ryegrass dry matter yield on Lilbert loamy fine sand†

Lime rate	pH, year 1	DM, year 1	pH, year 2	DM, year 3	pH, year 4	DM, year 4
T/acre		T/acre		T/acre		T/acre
0	4.7	1.39	4.5	1.72	4.5	0.32
0.3	4.8	2.26	4.7	2.29	4.5	0.49
1.7	5.7	2.69	6.2	3.71	4.6	2.71

†Data from Dr. Jeff Hillard's dissertation, Texas Agricultural Experiment Station, 1988.

5.68 t/ac dry matter increase in 3 seasons

The chart, right, uses the ryegrass yield increase from the limed plots and projects weight gain and value of that additional forage if it were grazed by stocker steers. The increased value of the weight gain is then related to the cost of the limestone applied on a per acre basis. The net value of the weight gain after subtracting limestone costs is $214.87/ac per season, or a three-season total of $716/ac. This shows the value of limestone applied at 1.7 tons per acre at a cost of $71.40. If ECCE 100% limestone had been used, net income would have been even greater as less of the higher quality limestone would have been applied to achieve the same pH.

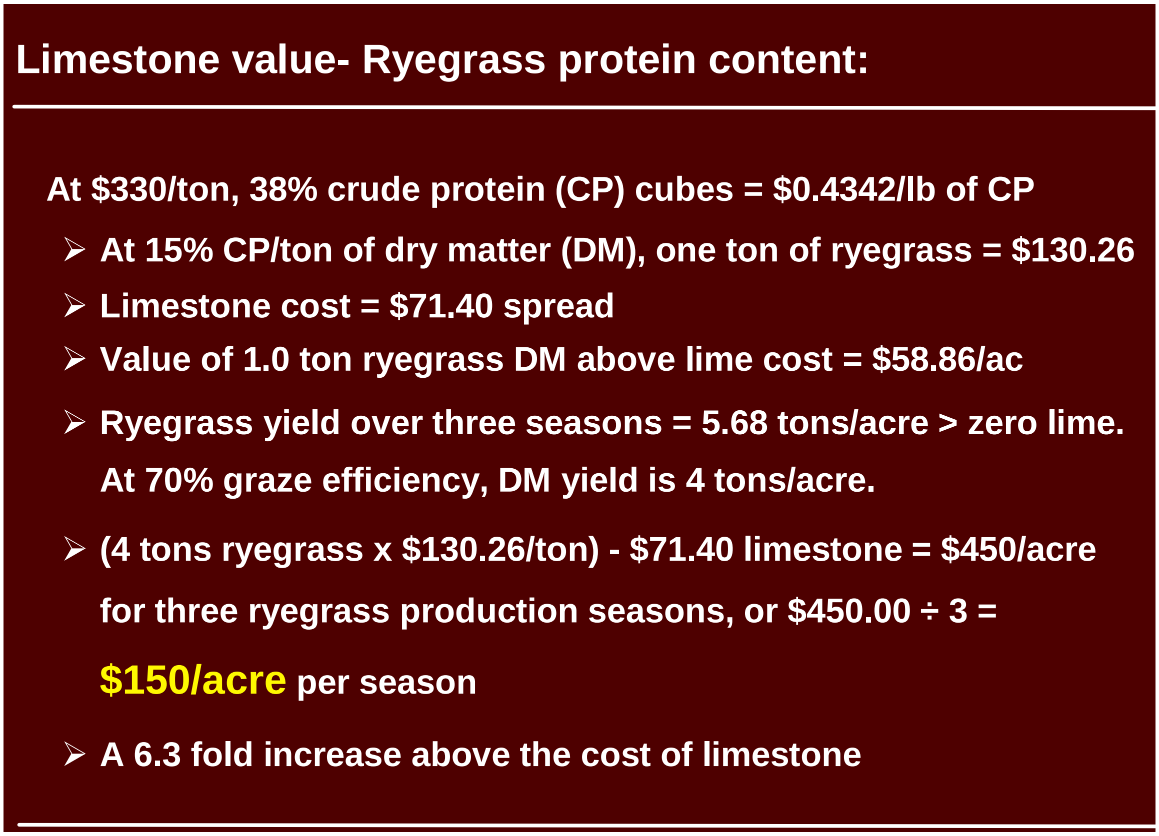


Limestone value- stocker steers on ryegrass:

Applied limestone to change pH from 4.5 to 6.2

- ➢Limestone cost = $71.40
- ➢Heavy weight stocker steers consume 15 lbs of ryegrass dry matter (DM) to gain 2.25 lb/head/day
- ➢5.68 ton = 11,360 lb/ac DM increase over 3 seasons Adjust to 70% grazing efficiency = 7,952 lb ryegrass Additional 1,193 lbs of gain/ac valued at $0.60/lb
- ➢Increase in value = $716 per acre over 3 seasons
- ➢$716 beef gain - $71.40 limestone cost = $644.60 = **$214.87/ac/season** above limestone cost

The value of the protein in the increased ryegrass yield is calculated in the chart below by comparing it to 38% protein cubes at a cost of $330/ton. Ryegrass was assumed to contain 15% crude protein, but the actual value would be higher. The value of ryegrass compared to 38% protein cubes is calculated to be $450/ac for the three ryegrass production seasons, or $150/ac per year. The previous slide regarding stocker steers grazing ryegrass and this slide comparing ryegrass protein to 38% protein cubes show the increased value of ryegrass produced on an acid soil that was adequately limed compared to not liming the soil. These calculations show that liming acid soils generates a good return on the investment.



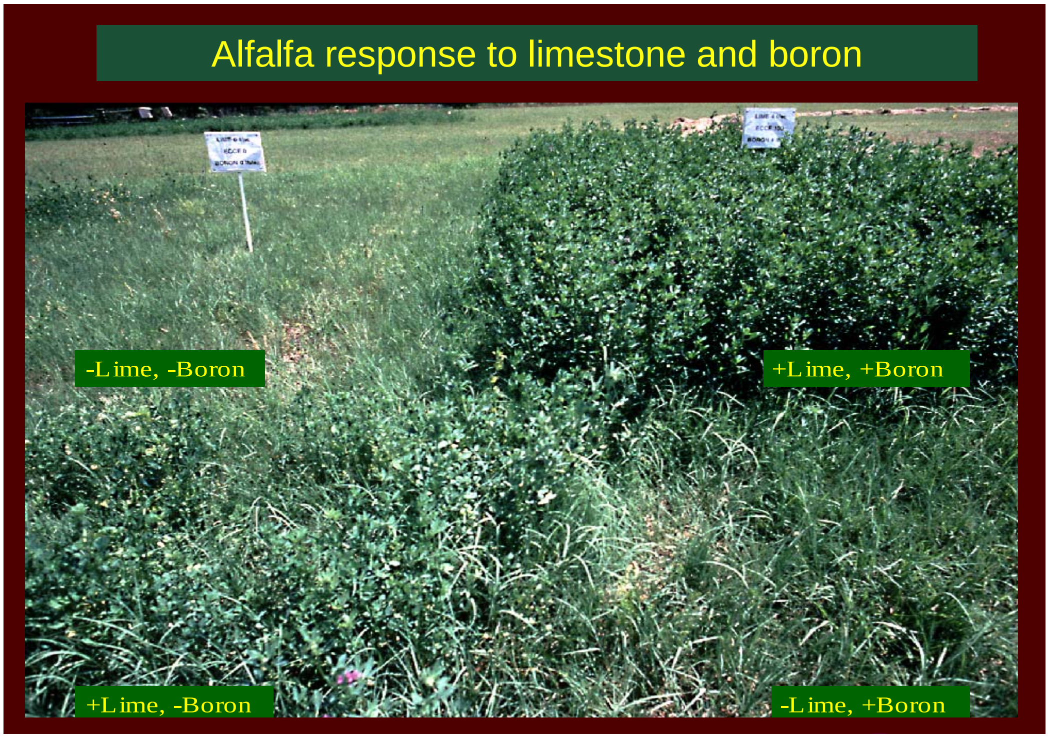
Limestone value- Ryegrass protein content:

At $330/ton, 38% crude protein (CP) cubes = $0.4342/lb of CP

- ➢ **At 15% CP/ton of dry matter (DM), one ton of ryegrass = $130.26**
- ➢ **Limestone cost = $71.40 spread**
- ➢ **Value of 1.0 ton ryegrass DM above lime cost = $58.86/ac**
- ➢ **Ryegrass yield over three seasons = 5.68 tons/acre > zero lime. At 70% graze efficiency, DM yield is 4 tons/acre.**
- ➢ **(4 tons ryegrass x $130.26/ton) - $71.40 limestone = $450/acre for three ryegrass production seasons, or $450.00 ÷ 3 = $150/acre per season**
- ➢ **A 6.3 fold increase above the cost of limestone**

Crimson clover response to limestone

Similar values as shown for limestone and ryegrass production could be projected for increased crimson clover yield from limestone applied to a strongly acid Darco soil as shown in the middle slide.



Alfalfa response to limestone and boron

The slide at left shows the response of alfalfa to limestone and boron on Darco soil. Where limestone and boron were not applied, there was no alfalfa, and where limestone was applied to increase soil pH to above 7.0 and boron was applied at 4 lb/ac, there was an excellent stand and increased alfalfa yield.

The chart at right shows the increased alfalfa yield and the value of this increased yield. Increasing soil pH from 6.0 to 6.5 increased hay yield 1.08 tons/ac valued at $146 with hay priced at $135/ton. When soil pH was increased to 7.0, the 1.94 ton/ac increased hay yield was valued at $262. Only 1.5 tons of limestone/ac would adjust pH from 6.0 to 7.0 on Darco soil. At a cost of $45/ton of ECCE 100% limestone, 1.5 tons would cost

Alfalfa hay yield increase with increasing pH and value of hay in $/acre. (12% moisture hay at $135/ton)

pH	Yield	Difference from pH 6.0	
	tons/ac	tons/ac	$/ac[†]
6.0	3.18		
6.5	4.26	1.08	146
7.0	5.12	1.94	262

[†] One production season

$67.50/ac while the alfalfa yield increase for only one season was valued at $262, or a net increase in income from liming to pH 7.0 of $194/ac. Soil pH declines more slowly under alfalfa production than when N fertilizer is applied because Rhizobia fix atmospheric N and put it directly into the roots without the N needing to be converted to nitrate and acidifying the soil in the conversion process.

Results showing the increased yield and value of forages due to liming acid soils indicate the importance and economic value of this practice. When fertilizer prices are high and producers are hesitant to apply these plant nutrients, liming acid soils to improve plant nutrient efficiency and response of acid sensitive forage crops increases the value of this acid-neutralizing primary input. Fertilizers applied to strongly acidic soils are less efficient than when applied to adequately limed soils. This has been proven many times and several examples of this improved efficiency have been presented in this manuscript.

Nitrogen fertilization for grass forages

Nitrogen in forage grasses is the most highly concentrated plant nutrient. Numerous studies of fertilizer N and grass production have been conducted. Three studies on hybrid bermudagrasses are reported here to show the yield response and net dollar return from increasing fertilizer rates.

In the chart below, increasing the rate of applied N from zero to 45 and 90 lb/ac for each regrowth increased Tifton 85 bermudagrass hay yield from 3,748 lb to 12,591 and 16,253 lb/ac, respectively. If this hay was valued at $100/ton (even with no added N), the zero N treated grass value was $187/ac compared to $442 and $625/ac gross value for hay fertilized with 180 and 360 lb of N/ac in four split applications, respectively, or a gross increase for the fertilized hay of $255 and $438/ac. When the cost of the applied N was deducted from the gross value of the hay, the net increases in hay value due to fertilizing with N were $122 and $188/ac, respectively. At the 180 lb/ac rate, each pound of applied N produced 50 lb of hay/ac. When the N rate was doubled, hay yield per dollar invested in N declined to 35 pounds.

Economics of Tifton 85 bermudagrass response to rates of N @ pH 6.5.

N rate lb/ac† (total)	**Total yield lb/ac‡**	**Yield increase lb/ac**	**$/ac**	**$/ac increase**	**Net $/ac increase§**
0	**3,748 c**		**187**		
45 (180)	**12,591 b**	**8,843**	**442**	**255**	**122**
90 (360)	**16,253 a**	**12,505**	**625**	**438**	**188**

† 45 and 90 lb N applied for each regrowth/harvest- 180 and 360 lb N/ac for the season.
‡12% moisture hay valued at $50/ half ton round bale.
§ Increase above cost of N at $0.65/lb with a $4.00/acre fee/each of 4 applications; does not include cost of making hay @ $25/1,000 lb roll- $94, $315, and $406, respectively

A similar study was conducted on Coastal bermudagrass using zero, 40, 80, and 120 lb of N/ac per hay cutting. Hay yield with no applied N was about 3.5 tons/ac, and at $90/ton, was valued at $310/ac. As the total N rate was increased to 200, 400, and 600 lb/ac for the season, total hay yield increased to 12,309, 15,134, and 15,844 lb/ac, respectively. The increased gross value of this hay compared to the zero N hay yield was $244, $371, and $403/ac. When the cost of N applied at $0.65/lb plus a $4.00/ac spreading fee was subtracted from the gross value of the produced hay, applications of 40 and 80 lb of N/ac per regrowth produced similar net income. Applying 120 lb of N/ac per cutting lost money because this highest N rate produced only a small amount of increased hay compared to the 80 lb N/ac rate. These N-rate comparisons on Tifton 85 and Coastal bermudagrass do not include haying costs or applied P, K.

Economics of Coastal bermudagrass response to rates of N

N rate lb/ac† (total)	Total yield lb/ac‡	Yield increase lb/ac	$/ac	$/ac increase	Net $/ac increase§
0	6,891 c		310		
40 (200)	12,309 b	5,418	554	244	93
80 (400)	15,134 a	8,243	681	371	91
120 (600)	15,844 a	8,953	713	403	-7

†N rate applied for each regrowth/harvest- 200, 400, and 600 lb N/ac for the season..
‡12% moisture hay valued at $45/1,000 lb round bale.
§Increase above cost of N at $0.65/lb with a $4.00/ac fee/each of 5 applications; does not include cost of making hay @ $25/1000 lb roll- $172, $308, $378, and $396, respectively

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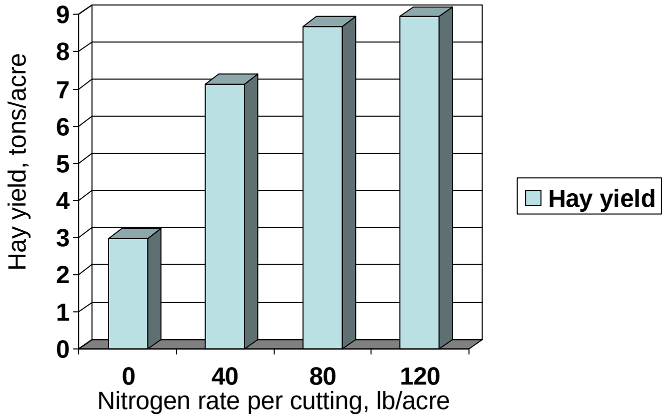
The cost of haying is added in the chart at right. In this study, yield with no applied N was only 3 tons/ac. The first 180 lb of N/ac increased hay yield to 7.1 tons/ac. The 360 lb/ac N rate raised yield another 1.6 tons/ac, but the yield increase/lb of N declined. Even with the cost of haying included with the cost of N, yields appear to be economical, especially up to the 80 lb N/ac rate applied for four cuttings to yield 8.7 tons of hay/ac.

Since many Coastal Plain soils are deficient in P or K, the cost of these nutrients must be added along with the N. The cost of a typical N, P_2O_5, and K_2O blend applied at 40 or 80 lb N/ac/cutting for four harvests is shown at right. Assuming that the hay yield was the same as in the previous chart when the phosphorus and potassium were added, that chart is repeated here with new fertilizer plus haying costs indicated. With the costs of N, P, K and haying included, the economic rate of return on hay is not much above the 190 lb/ac application of 21-8-17/cutting. At double this rate, the cost of production exceeds the value of the hay sold at $90/ton. Based on these data, the days of fertilizing hybrid bermudagrasses for maximum hay yield may be past; at least as long as fertilizer prices remain high and continue to increase and hay prices remain the same.

N plus haying†	$150	$467	$659	$786
Gross hay value‡	$270	$639	$783	$810

†N @ $0.70/ lb; haying $25/1,000 lb bale; P and K not included
‡ Sell price $90/ ton



Coastal bermudagrass response to N + P and K as 21-8-17 applied for each of four cuttings, 12% moisture hay.

Cost of a typical N, P_2O_5, K_2O blend for application

Soil test recommendation suggests 190 lb 21-8-17/ac

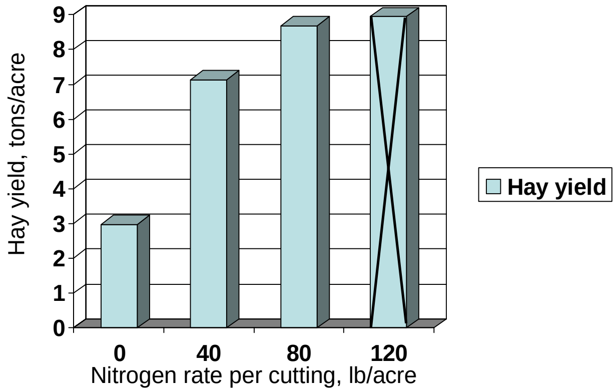
- **Blend made from 34-0-0, 18-46-0, & 0-0-60**
  - **34- 0- 0 @ $0.70/lb of N**
  - **18-46-0 @ $0.35/lb of N and $1.00/lb P_2O_5**
  - **0- 0- 60 @ $0.50/lb of K_2O**
  - **Spreading cost @ $4.50/acre**
  - **40 lb N, 15 lb P_2O_5, and 34 lb K_2O + spreading cost = $57.15/acre**
  - **If applied four times, fertilizer cost is $229 + $355 haying cost or a total of $584/acre to produce 7.1 tons of hay = $82.25/ton[†] for low nutritive value hay.**
  - **Double the fertilizer to 80-30-68 lb/ac/cutting for four cuttings to increase hay yield to 8.7 tons/ac- Fertilizer cost = $457; Haying cost = $435 for cost of production = $892/ac.**

[†] Limestone and hay hauling costs not included in this price

N plus haying[†]	$150	$584	$892	~~$786~~
Gross hay value[‡]	$270	$639	$783	~~$810~~

[†] N @ $0.70/ lb; haying $25/1,000 lb bale; no lime or hay moving

[‡] Sell price $90/ ton



Coastal bermudagrass response to N + P and K as 21-8-17 applied for each of four cuttings, 12% moisture hay.

Poultry litter and other manures provide N, P, K, other plant nutrients, & organic matter. Manures at high rates are excellent nutrient sources.

Legitimate alternative plant nutrient sources

With the high cost of commercial fertilizers, forage producers need to evaluate alternative sources of plant nutrients such as in animal manures and lime-treated, stabilized sewage sludge (biosolids). National and international studies have shown the value of biosolids for increasing soil phosphorus content and raising pH and forage yield.

Animal manures probably were the first plant nutrient sources used for crop production. Poultry manures are routinely applied for forage production in eastern and east central Texas. Dairy manures are available in northeast Texas and parts of central Texas, but mainly are applied on-farm because of transportation costs. The average N, P_2O_5, and K_2O contents of dairy, beef, hogs, and chickens is shown in the top chart.

Broiler litter is available in much of the eastern and central Texas region and is a good source of plant nutrients for forages. However, as commercial fertilizer prices continue to increase and more forage growers turn to broiler litter as a plant nutrient source, longer wait times are being experienced before this material can be delivered.

In broiler litter, phosphorus is nearly as high as is the N content. If broiler litter is applied at rates sufficient to satisfy the N needs of grass forages, the soil phosphorus level will increase. When fertilizing with broiler litter, it is best to apply rates that will satisfy the phosphorus needs of the forage, and then supplement the grass with N and potassium to obtain the recommended levels of these nutrients for plant uptake. Data from Tifton 85 bermudagrass production studies at Overton indicate yield increases of more than 4,000 lb of dry matter when broiler litter was applied as a nutrient source. Even with increasing yields, average N, P, K, and copper concentrations were increased in the forage.

Average nutrient content of dry manures

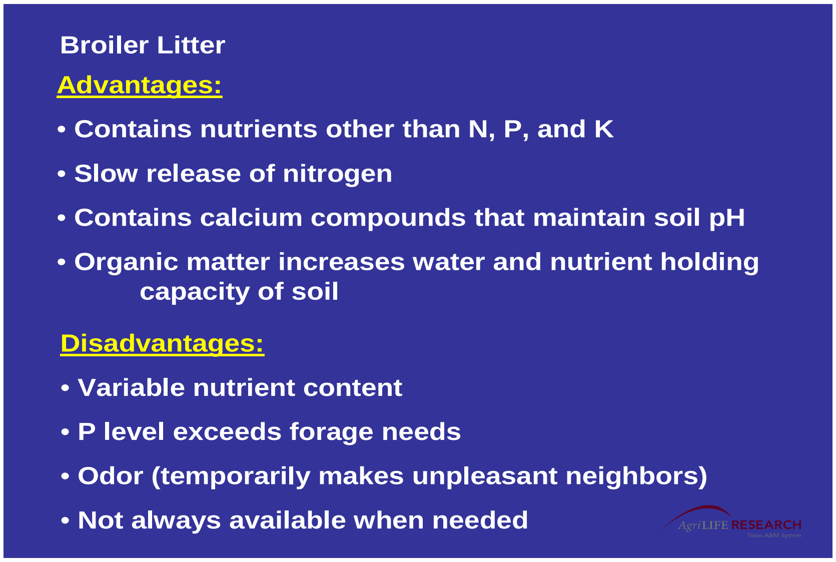
Animal	Nitrogen	Phosphorus[†]	Potassium[‡]
	--------------------Lbs/ton------------------		
Dairy	11	5	11
Beef	14	9	11
Hogs	10	7	8
Chickens	20	16	8

[†] Phosphorus as P_2O_5
[‡] Potassium as K_2O

Nutrient Content of Broiler Litter

Nutrient	Average	Range
	----------Lbs/ton-----------	
Nitrogen (N)	62	34-96
Phosphate (P_2O_5)	59	22-142
Potash (K_2O)	40	13-99
Calcium (Ca)	35	13-98
Magnesium (Mg)	8	3-34
Sulfur (S)	6	0.2-13

Advantages and disadvantages of using broiler litter as a plant nutrient source for forages production are shown in the adjacent chart. One of the greatest benefits of broiler litter is that it contains some of all the nutrients needed for plant growth, even though these may not be sufficient to supply all the needs of the plants.



Broiler Litter

Advantages:

- Contains nutrients other than N, P, and K
- Slow release of nitrogen
- Contains calcium compounds that maintain soil pH
- Organic matter increases water and nutrient holding capacity of soil

Disadvantages:

- Variable nutrient content
- P level exceeds forage needs
- Odor (temporarily makes unpleasant neighbors)
- Not always available when needed

Summary

In summary, fertilizer costs are continuing to increase with little hope for a significant decline in the immediate future. It has become more important than ever to be attentive to the best management practices in an effort to maintain profitability in forage and livestock production. Specific attention must be given to:

- Maintaining adequate soil pH using the best quality limestone available
- Control weeds at an early growth stage- weeds use water and nutrients.
- Maintain a fertilizer program.
    - Carefully consider the economics of not fertilizing.
    - Fertilize according to soil test recommendations.
    - Fertilize for grazing- cut excess for hay; buy hay.
    - Fertilize in late summer to stock-pile reserve forage for fall and winter grazing.
    - When reducing fertilizer application rates, reduce livestock numbers.
    - Research least-cost fertilizer options including broiler litter and other manure nutrients.
    - Consider renting buggies to apply fertilizer if economical and time and equipment permit.
- Plant and graze cool-season clovers to provide part of the following warm-season grass N needs.
- Consider growing alfalfa for hay if soils are suitable- alfalfa uses Rhizobia-fixed N from the air and adds N to the soil.
- Seed best soils to small grains and ryegrass in fall.
    - Plant reduced acres and maintain an adequate fertilizer and liming program on these acres.
    - Limit graze cow/calf pairs a couple of hours per day- feed high nutritive value hay.