MISCELLANEOUS PUBLICATION 128
TEXAS AGRICULTURAL EXPERIMENT STATION-THE TEXAS A&M COLLEGE SYSTEM
R. D. Lewis, Director, College Station, Texas, May 16, 1955

AN ECONOMIC EVALUATION OF EXPERIMENTAL RESPONSE OF COASTAL BERMUDAGRASS TO NITROGEN UNDER IRRIGATION

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SUMMARY

There is no one most profitable rate of application of nitrogen to irrigated Coastal Bermudagrass under all price conditions. The most profitable rate on Lufkin fine sandy loam varies from 360 pounds per acre when hay is $15 per ton and nitrogen is 20 cents per pound to 921 pounds per acre when hay is $50 per ton and nitrogen is 10 cents per pound.

The return on investment in nitrogen decreases as the amount of nitrogen applied increases. An investment in 50 pounds of nitrogen returns $3.08 per dollar invested when no nitrogen has been applied previously and hay is $20 per ton and nitrogen 13 cents per pound. When 600 pounds nitrogen has been applied, an investment in an extra 50 pounds returns only $1.23 per $1 invested.

High levels of nitrogen application reduce fixed costs of hay production. Irrigation costs per ton of forage may be reduced from $40.70 when no nitrogen is applied to $9.23 when 800 pounds of nitrogen is applied.

These conclusions are based on an economic evaluation of the results of a study made on the response of Coastal Bermudagrass to nitrogen under irrigation.

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There are a number of economic problems in connection with the application of fertilizer. Farmers ask such questions as: What is the most profitable amount of fertilizer to apply? Can I make more money by investing in fertilizer rather than investing in other things? Suppose I put on less than the most profitable amount of fertilizer, what will my returns be? Will fertilizer help me reduce the high fixed costs I have incurred in connection with growing the crop?

This study illustrates that a combination of economic and agronomic analyses can provide answers to these kinds of questions. Yield data obtained from the application of different amounts of nitrogen fertilizer to Coastal Bermudagrass under irrigation are used to provide answers to the above and other questions. The experiment from which the agronomic data was obtained is described by Flake L. Fisher and A. G. Caldwell in Progress Report 1731 of the Texas Agricultural Experiment Station. The experiment was carried out on Lufkin fine sandy loam soil near College Station. The soil is typical of large areas of East Texas. The experimental plots were limed just prior to the sprigging of the Coastal Bermudagrass in June 1953. An application of 30-100-100 fertilizer was also made at that time. A second application of 30-100-100 fertilizer was made in September 1953. The area received 13 inches of irrigation water plus 3.65 inches of rainfall from June 10 to mid-September.

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The plots were cleared of growth and fertilized with 0-100-100 fertilizer late in February 1954. Six rates of nitrogen were applied in five applications. The annual rates of nitrogen were 0, 100, 200, 400, 600 and 800 pounds per acre. During 1954, response to the various rates was measured by clipping the plots at 2 and 4-week intervals. Due to similarity in the data from both clipping intervals, only the 4-week intervals were used in this study. A total of 43.67 acre-inches of water was applied to the area to supplement rainfall amounting to 14.11 inches, making a total of 57.78 inches of water the area received during the period for which yields were available.

The findings of this study apply only to farm situation similar to the experimental situation. However, the principles and concepts developed are of interest wherever the application of fertilizer is considered.

The Response Curve

The solutions to the economic problems facing the farmer in making fertilizer decisions depend on the relative prices of fertilizer and the crop produced and the physical relation between fertilizer and the crop produced. The physical response to fertilizer is basic. Once it is obtained, various prices can be applied to provide the solutions under different economic conditions. This section describes the development of the response curve from the above experiment.

An algebraic function is needed to describe the response of Coastal Bermudagrass hay to nitrogen under the conditions of the experiment. A function of this nature enables the exact solution of economic problems at any point on the response curve since it gives a continuous estimation of yields. It would be impossible to obtain an exact economic solution with a drawn free-hand, response curve since the algebraic formula of the curve would not be known and it would be impossible to perform the mathematical operations necessary to find the exact economic solutions.

The algebraic equation estimating the response curve was obtained by least squares regression. Since various functions could be used, the procedure followed was to fit five different equations and to select the one which followed the data most closely. The equation which resulted in the smallest sum of the square of the differences between the predicted and observed yields of hay for given inputs of nitrogen was chosen.

The equation chosen for the study is:

$$Y = 2.94 + 0.0206N - 0.0000101N^2$$

where Y = yield of hay in tons
N = amount of nitrogen applied per acre

Figure 1 is a graphic representation of the equation. Table 1 gives the estimated response for 50-pound increments of nitrogen. If no nitrogen is applied, 2.94 tons of hay are obtained. If 50 pounds of nitrogen is applied, 3.94 tons of hay are obtained. The application of 50 pounds of nitrogen will bring about an increase of 1 ton of hay. This marginal, or extra yield due to an additional application of 50 pounds of nitrogen, is shown in the third column of Table 1. The application of 100 pounds of nitrogen (50 pounds more than the first 50 pounds) yields 0.96 extra tons of hay above the 3.94 tons obtained with the first 50 pounds.

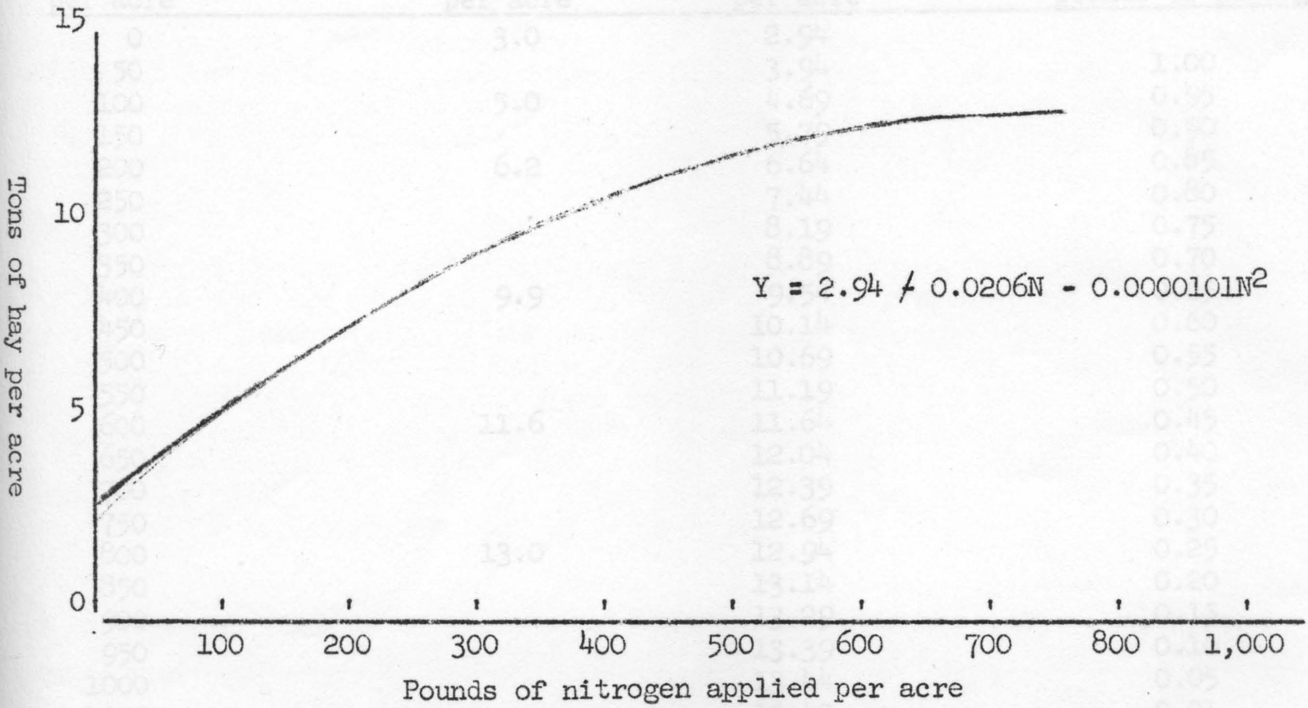

Figure 1. Response of Coastal Bermuda Hay to Nitrogen.

The extra yield column in Table 1 shows that the third 50 pounds of nitrogen gave an extra yield of 0.90 ton while the fourth 50 pound-addition gave an extra response of 0.86 ton. The fifth 50 pounds gave an extra response of 0.80 ton, the sixth 50 pounds gave an extra response of 0.75 ton, and so on. In each case, the addition of an extra 50 pounds of nitrogen did not give as much response as the previous 50-pound increment. This points out that the yield increases at a decreasing rate and at some point increases in yield stop. The point where this occurs is the maximum yield.

Table 1. Response of Coastal Bermudagrass hay to nitrogen under irrigation

Nitrogen, pounds per acre	Actual hay, tons per acre	Calculated hay, tons per acre	Extra yield of hay for extra 50 pounds of nitrogen
0	3.0	2.94	
50		3.94	1.00
100	5.0	4.69	0.95
150		5.79	0.90
200	6.2	6.64	0.85
250		7.44	0.80
300		8.19	0.75
350		8.89	0.70
400	9.9	9.54	0.65
450		10.14	0.60
500		10.69	0.55
550		11.19	0.50
600	11.6	11.64	0.45
650		12.04	0.40
700		12.39	0.35
750		12.69	0.30
800	13.0	12.94	0.25
850		13.14	0.20
900		13.29	0.15
950		13.39	0.10
1000		13.44	0.05
1050		13.43	-0.01

The maxumum response to nitrogen was not reached in the range of the experimental application. The highest rate applied was 800 pounds per acre. Projecting the response curve indicates the maximum response is reached with the application of 1,020 pounds of nitrogen.

How Much Nitrogen to Apply?

The rate of fertilizer application to obtain maximum profit is one of the major problems a farmer faces. To solve this problem for this study requires a consideration of the relative prices of nitrogen and Coastal Bermudagrass hay along with the physical response from fertilizer.

The price of nitrogen depends to a large extent on the chemical form in which it is applied. The market price of hay will vary from year to year and at various locations within a year. If the farmer sells the hay on the market, he will not realize the market price since he will incur expenses for the processing of the hay into bales and trucking to market. However, if the extra grazing he receives means that he does not have to buy baled hay, then the value of extra grazing may be considered equal to the market price of hay.

It appears then that there is no one fertilizer recommendation that will apply to the situation faced by all farmers or even a large number of farmers. Thus, this study will present the principle involved in making the decision and will present fertilizer recommendations for a number of price situations. The recommendations will answer the question of how much nitrogen to apply to obtain the maximum or highest profit per acre when the farmer does not have a limit on the amount of money he wishes to invest in fertilizer.

The principle used in the solution to this problem is that nitrogen should be applied as long as the value of the extra hay obtained is greater than the extra cost of nitrogen. Table 1 indicates that an application of 50 pounds of nitrogen gives a response of 1 ton of hay per acre. Assuming nitrogen costs 13 cents per pound and hay brings $20 per ton, an extra application of 50 pounds of nitrogen, costing $6.50, yields 1 ton of hay worth $20. A second 50 pounds of nitrogen (making a total of 100 pounds) costing $6.50 yields 0.96 ton of hay worth $19.20. A third 50 pounds of nitrogen (total 150 pounds) yields 0.90 ton of hay worth $18. Thus, it pays to keep adding fertilizer until 698 pounds of nitrogen are applied.

The optimum rates of application for maximum profit at various prices of hay and nitrogen are given in Table 2. Data in this table show that the optimum rate of application varies as the prices of hay and nitrogen vary. If hay brings $15 per ton, the optimum rate decreases from 690 pounds when nitrogen costs 10 cents per pound to 509 pounds when nitrogen costs 13 cents per pound and to 360 pounds when nitrogen costs 20 cents per pound. If nitrogen costs 10 cents per pound, the optimum rate increases from 690 pounds when hay brings $15 per ton to 744 pounds when hay brings $20 per ton. The point that no one application rate is best under all conditions is illustrated by the above material.

Table 2. Optimum rates of nitrogen application for maximum profit with various prices of Coastal Bermudagrass hay and nitrogen

Prices of hay	Prices of nitrogen, cents per pound: 10	13	20
Dollars	Pounds per acre		
15	690	590	360
18	744	662	470
20	772	698	525
23	804	740	589
25	822	762	624
28	843	790	666
30	855	805	690
35	878	836	737
40	896	860	772
50	921	891	821

Return on Investment in Fertilizer

The optimum solutions given above hold where the farmer has unlimited capital and wants to make maximum profit. Many farmers have limited capital. They are concerned with putting their dollars where they will give the largest return. The real question they ask is not, Does fertilizer pay? But, Does it pay better than other investments in such things as livestock or equipment?

Here again the answer depends on the relative prices of nitrogen and hay. The example given below is worked out for one price situation but could be worked out for any price situation. The selling price of hay is taken to be $20 per ton and the cost of nitrogen 13 cents per pound. Table 2 shows that 698 pounds is the optimum application rate in this price situation. The cost of the application of nitrogen is considered at $5 per acre. The extra yield from 698 pounds of nitrogen above no application is 9.46 tons (12.4 tons minus 2.94 tons). This is worth $189.20. To obtain this yield a total of $95.75 is invested--$90.75 for 698 pounds of nitrogen and $5 for application. An investment of $90.75 per acre gives a return of $189.20, or a return of $1.98 for each $1 invested. If the farmer cannot make as large a return by investing in livestock or equipment, then he should apply the optimum amount of nitrogen under the above conditions.

A number of farmers may be in situation where some other investment will give them a higher return than they can obtain by applying the optimum amount of nitrogen. Will the use of some nitrogen be of benefit to them in increasing their profit? The answer is "Yes." Since the physical response to nitrogen increases at a decreasing rate, the economic response is larger at low levels of application than at high levels.

If hay sells for $20 per ton and nitrogen costs 13 cents per pound, then a return of $3.08 per $1 invested is obtained on the first 50 pounds of nitrogen applied. An extra yield of 1 ton of hay worth $20 is obtained from the first 50 pounds of nitrogen costing $6.50. Table 3 shows that the second 50 pounds of nitrogen gave a return of $2.95 per $1 invested and the third 50 pounds gave a return of $2.77 per dollar invested. Thus, the farmer with limited capital and alternative investment opportunities may still invest in nitrogen. He will add extra nitrogen until the return on his $1 invested in nitrogen is equal to or slightly greater than the return he could obtain by making other investments.

Table 3. Return per $1 invested obtained by adding 50-pound increments of nitrogen[1/]

Extra nitrogen per acre	Total amount applied, pounds per acre	Return per $1 invested
1st 50 lbs.	50	$ 3.08
2nd 50 lbs.	100	2.95
3rd 50 lbs.	150	2.77
4th 50 lbs.	200	2.65
5th 50 lbs.	250	2.46
6th 50 lbs.	300	2.31
7th 50 lbs.	350	2.15
8th 50 lbs.	400	2.00
9th 50 lbs.	450	1.85
10th 50 lbs.	500	1.72
11th 50 lbs.	550	1.51
12th 50 lbs.	600	1.38
13th 50 lbs.	650	1.23

1/ The prices used in making this table are hay $20 per ton and nitrogen 13¢ per pound.

An interesting physical relationship which has economic significance was also reported in Progress Report 1731. At the higher levels of nitrogen application, the protein content of the hay was higher. The material in Table 4 shows the relationship for the data considered in this study.

Table 4. Level of protein content for levels of nitrogen application

Nitrogen, pounds	Protein content, percent
0	8
100	8
200	10
400	11
600	13
800	16

Hay with 16 percent protein content is worth more than hay with 8 percent protein content. On the market, good alfalfa hay with a 16 percent protein content will sell at a higher price than lower grade hay with an 8 percent protein content. Sixteen percent protein hay also is more valuable to the farmer feeding his own roughage than is 8 percent hay.

The solutions to the problems given above were obtained on the basis of the same price for all hay. When 8 percent hay is taken to be worth $20 per ton, 10-13 percent hay to be worth $24 per ton, 16 percent hay to be worth $28 per ton and nitrogen cost 13 cents per pound, the optimum or most profitable rate is 751 pounds of nitrogen. The rate obtained is higher than the optimum rate of 698 pounds when all hay was taken to be worth $20 per ton. Seven hundred fifty-one pounds of nitrogen gives a yield of 12.71 tons of hay per acre. If hay is worth $24 per ton, this gives a return of $189.70 above no application of nitrogen. Thus, under these conditions, an investment of $97.63 in nitrogen and $5 in application gives a return of $1.85 per $1 invested.

Effect of Fixed Costs

When the farmer establishes and irrigates Coastal Bermudagrass he incurs certain fixed costs. These costs remain constant whether 1 ton or 10 tons of hay per acre are obtained. Examples of such costs are cost of irrigation for a given volume of water, preparation of the land and sprigging the grass.

The following material is an example of how the application of nitrogen can reduce the fixed cost per ton of hay. The cost of applying the 43.67 acre-inches of water is a fixed cost. It has been estimated by Garrett and Russell in Texas Agricultural Experiment Station Progress Report 1641, "Sprinkler Irrigation of Cotton at College Station, 1953," that the total cost of irrigation with a sprinkler system is $2.75 per acre-inch of water. Using this figure, the total cost of water for the experiment under study is $119.66.

Figure 2 illustrates the decrease in per-ton costs of irrigation that takes place as the rate of nitrogen application is increased. Then irrigation cost per ton of forage is reduced from $40.70 when no nitrogen is applied to $9.23 when 800 pounds of nitrogen are applied.

This principle applies to all fixed costs. The application of fertilizer may be one way for many farmers to meet the problem of high fixed costs.

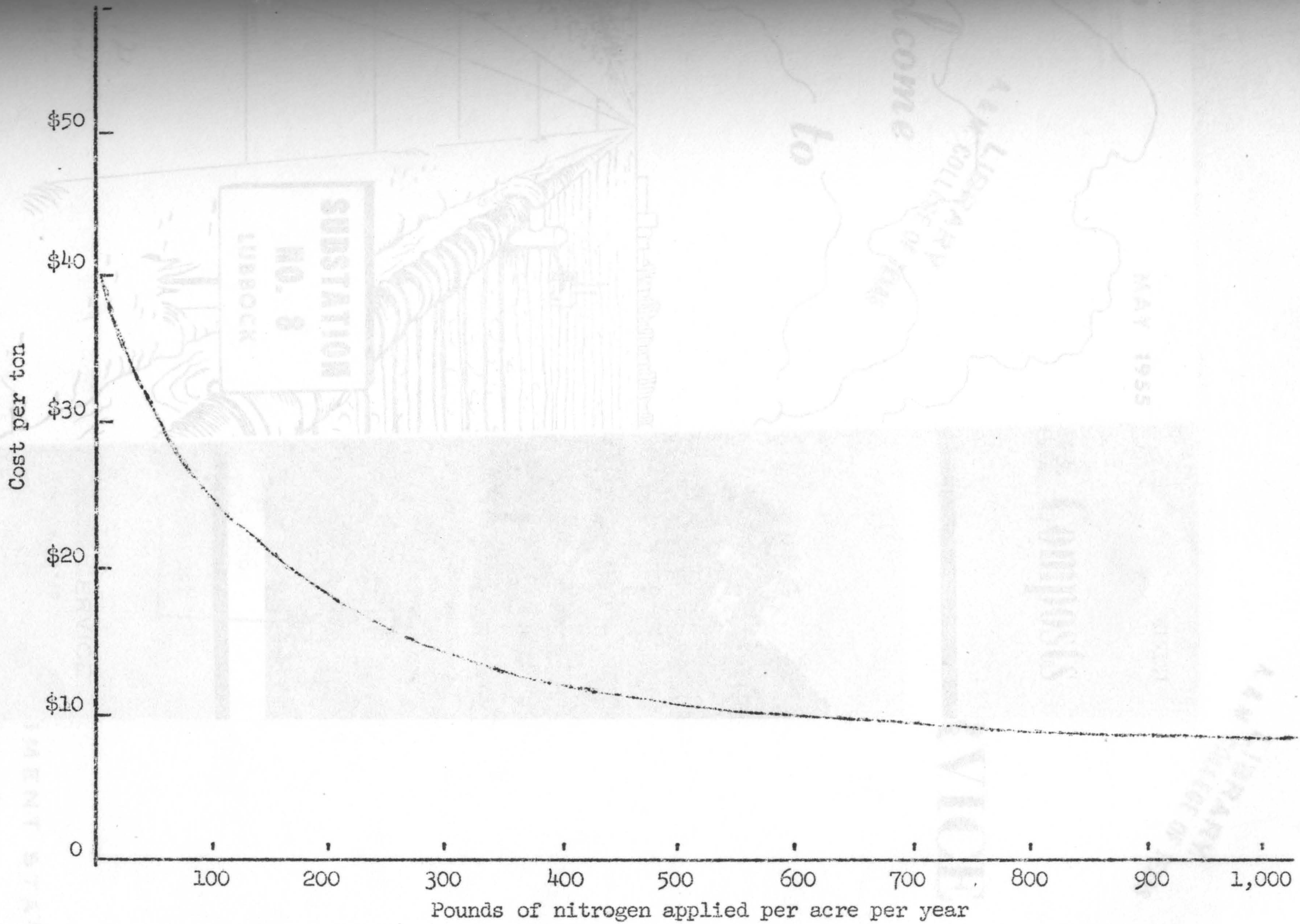

Figure 2. The Effect of Nitrogen Application on Per-acre Costs of Irrigation