FERTILIZING WYOMING HAY MEADOWS:

How Much Nitrogen Can You Afford

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Agricultural Extension Service
Division of Agricultural Economics
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University of Wyoming

Fertilizing Wyoming Hay Meadows: How Much Nitrogen Can You Afford?

by

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Fertilizing Wyoming Hay Meadows: How Much Nitrogen Can You Afford?

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Hay meadows are an essential component of western mountain valley cattle ranches. In addition to hay, these meadows are frequently grazed in early spring and late fall when range forage is limited. It is estimated that there are approximately 1,700,000 acres of irrigated hay in the mountain and intermountain regions of California, Oregon, Idaho, Utah, Nevada, Montana, Colorado and Wyoming (Jacobs and Kearl, 1979). There are about 390,000 acres of irrigated hay meadows in Wyoming yielding on the average 1.2 tons per acre (tons/A).

Yields on many of these hay meadows can be improved by management practices. The question producers must ask prior to investing in these improvements is: "What improvement practices are available, feasible and cost effective?" While there are many types and combinations of improvement practices, four major components of meadow renovation are (1) fertilization; (2) structures to control water for intermittent irrigation; (3) establishment of improved plant species; and (4) timeliness of harvest.

Each of the four major meadow improvement components has been studied individually, as well as in various combinations. Research on high elevation hay meadows shows that hay yield and quality can be increased with these improvement practices. Of the four major components, nitrogen (N) fertilization and its effect on yield has received the most research effort. This bulletin concentrates on the yield response to fertilization of Wyoming hay meadows and the determination of the most economic level of N fertilizer.

Previous studies show that both increased yield and higher crude protein content can be obtained by fertilizing hay meadows (Seamands and Roehrkasse, 1971; Lewis and Lang, 1957; Willhite, et al., 1955). On a meadow of improved grass species with a small percentage of sedges and rushes, as well as an application of 100 lbs. of P_2O_5/A, forage yields increased from 1.7 tons/A to 2.5 and 3.1 tons/A for N applications of 80 and 160 lb./A, respectively (Seamands and Roehrkasse, 1971). Lewis and Lang (1957) reported yields per acre of eight grass species increased from 0.8 tons to 2.9 and 3.7 tons/A with N applications of 80 and 160 lb./A, respectively. A rancher stated that his average yield per acre increased from 0.89 ton with no fertilizer to 1.88 tons after applying 81 lb. of N/A and 27 lb. of P_2O_5/A (Sims, 1979).

A production response to fertilization of high elevation meadows can be expected because N is generally deficient and must be applied annually (Ludwick, 1979). The average response reported by Ludwick (1979) is 20 lb. of additional hay per pound of available N/A at 80 lb. of N/A. However, because plant species composition, physical environment, and management conditions are diverse in mountain hay meadows, response to fertilization varies. Ludwick (1979) reported a variation from 7 lb. of hay per pound of N to 45 lb. of hay per pound of N applied per acre. Such variation clearly indicates that the profitability of N fertilization of hay meadows varies with each site depending on plant species present and physical characteristics. An analysis of data on yield response to fertilization is needed to estimate the economically efficient application of N fertilizer on hay meadows.

Purpose

As indicated, the average hay meadow will respond to applications of N. Since few meadows are average, the purpose of this paper is to develop a method for estimating the most profitable amount of N to apply. To estimate the most profitable amount of N, a producer needs to know: (1) the value of hay at his ranch less harvest cost; (2) the price of available N applied; and

(3) the forage yield response to N fertilizer. Since the value of hay and fertilizer is indicated by available prices, the purposes of this study are: (1) to estimate N response functions for three meadow types in Wyoming (native, improved grass and grass-alfalfa); and (2) to illustrate the use of the N response functions in estimating the most profitable fertilization rate.

Procedure

Nitrogen response curves for three types of hay meadows were estimated using data from fertilization trials in selected Wyoming locations. Multiple regression analysis was used to estimate the response of these hay meadows to fertilization. In addition to the amount of N, such variables as application of phosphorus, check plot yields (soil fertility and management practices), and yearly variation in location and climate were considered. The regression model for native, improved grass and grass-alfalfa is presented in the Appendix.

Data

Data from fertilizer trials were collected from locations within six Wyoming counties for the period 1965-1980, except 1968 and 1979. Nitrogen application rates ranged from 0 to 160 lb./A. The number of trials for each meadow type were 29, 10 and 16 for native, improved grass and grass-alfalfa, respectively.

Native meadows typically included sedges, rushes, red top, timothy and alsike clover. Improved grass meadow species included smooth bromegrass, Garrison creeping foxtail, orchardgrass or tall fescue. Grass-alfalfa meadow species included alfalfa with smooth bromegrass or orchardgrass.

Average check plot yields for native, improved grass, and grass-alfalfa meadows were 1.52, 1.20 and 2.02 tons/A, respectively. The average check plot yield for improved grass was lower than expected, particularly when compared with native. This may be explained by the fact that the majority of these meadows are sod bound smooth bromegrass. As expected, the average check plot yield for grass-alfalfa was highest due to the influence of alfalfa.

Discussion of Results

The estimated yield response functions are reported in Appendix Table I. Forage yields on native, improved grass and grass-alfalfa hay meadows increase as N application rates increase, at least up to N rates of 160 lb./A. Grass-alfalfa meadow yields were more responsive to P_2O_5 than native and improved grass meadow species. Relative to the base year, there was significant variation in yields due to location and climate between the trial sites.

Total and marginal yield responses (additional lb. of forage for an additional lb. N) are illustrated for the three meadow types at selected N application rates in Table 1. For example, at 80 lb. of N/A estimated yields are 2.33, 2.15 and 2.42 tons/A for native, improved grass and grass-alfalfa, respectively. At 160 lb. of N/A estimated yields are 2.87, 2.74 and 2.70 tons/A. For native, improved and grass-alfalfa meadows, the estimated additional (marginal) yields/lb. of N at 80 lb. of N/A are 20.2, 20.4 and 13.0 lb./A, respectively.[1/] Additional yields/lb. of N at 160 lb. of N/A are 7.0, 9.4 and 1.0 lb./A, respectively. This indicates how additional yield/lb. of additonal N decreases as application rates increase.[2/]

[1/] The additional yield in lb. obtained from an additional lb. of N is estimated from the equations on page 6, where N equals the lb. of N/A.

[2/] This represents what is often referred to as a diminishing marginal response, that is the additional yield per additional unit of fertilizer decreases as the amount of fertilizer applied increases.

As expected, native and improved grass meadow species were more responsive to N than grass-alfalfa. Improved meadow species exhibited a greater yield response at higher levels of N than the other two meadow types.

Table 1. Estimated Total and Marginal Yield Responses of Native, Improved and Grass-Alfalfa Hay Meadows to N

N Application Rate	Total[a/]			Marginal[b/]		
	Native	Improved	Grass-Alfalfa	Native	Improved	Grass-Alfalfa
lb./A	Tons/A			lb./A/lb. N		
0	1.26	1.11	1.66	-	-	-
40	1.86	1.69	2.10	28.6	26.0	19.0
80	2.33	2.15	2.42	20.2	20.4	13.0
120	2.67	2.50	2.62	13.6	14.8	7.0
160	2.87	2.74	2.70	7.0	9.4	1.0

a/ Average estimated yields for experiment years at average check plot yields and with no phosphorus.

b/ Marginal yield estimates are calculated from the additional yield for an additional lb. of N equation's for native, improved grass and grass-alfalfa equations found on page 6.

Economic Analysis

To estimate the most profitable level of N fertilization, a rancher needs to determine: (1) the value of hay less harvest cost; (2) the price of N; and (3) the yield response to fertilizer. If the first and second can be estimated by the individual producer, the estimated response functions provide the information for the latter. This is accomplished by calculating the additional yield obtained for an additional unit of N.

For example, from Appendix Table I, the additional yield in pounds (Yield) obtained for the last unit of N for each of the three meadow types is given by the following relationships:[3/]

Native: Yield = 33.42 - 0.1652N

Improved Grass: Yield = 31.54 - 0.1388N

Grass-Alfalfa: Yield = 24.98 - 0.1498N

where N is equal to the lb./A of available N applied. If ammonium nitrate costs $190/ton, the fertilizer costs per pound of N would equal $0.28 (illustrated below).

2000 lb. x .34 (34%) N in ammonium nitrate = 680 lb. of N/ton

$190/ton   680 lb. of N/ton = $0.28/lb.

Using a net value for hay (value after paying for the additional harvest costs for an additional ton of hay), of $50/ton, we can then combine the information and determine the most profitable amount of N following the sample meadow example in the worksheet on page 7. Due to the variation in the price of hay, harvest costs and fertilizer price, an individual operator will want to use his own harvest costs and fertilizer and hay prices. With these figures a rancher can estimate whether or not the value of the increased yield exceeds the cost of N fertilizer by completing the example worksheet for his own situation. (Additional worksheets are provided in the Appendix). As long as the value of the change in yield per lb. of N (item 7) exceeds the price of N (item 8), it would pay the rancher to apply additional N.

To show the effect of different prices of hay and fertilizer on the optimum rate of fertilizer, Table 2 was developed for the three meadow types. Table 2 gives some idea of the sensitivity of the most profitable level of fertilization to changes in the price ratio.

[3/] This is the first derivative of the response function in Table 1. That is the additional yield per unit of N is the N coefficient minus the product of 2 times the coefficient associated with N^2 times the application rate of N (lb. N/A). The marginal equations in the text are also converted from tons of hay to lb. of hay by multiplying the coefficients by 2000.

Sample Worksheet 1

Item	Sample Meadow	Rancher's Meadow
1. Meadow Type	Native	
2. Market value of hay ($/lb.)	0.03	
3. Harvest costs ($/lb.)	0.005	
4. Value of hay less harvest cost (#2-#3) ($/lb.)	0.025	
5. Application of N (lb./A)	120	
6. Yield change by meadow type for the last lb. of N applied (lb./A) (#5 substituted for N in the appropriate equation below: a, b, or c)		
a) Native (33.42 - 0.1652N)[a/]	13.6	
b) Improved (31.54 - 0.1388N)[a/]		
c) Grass-Alfalfa (24.98 - 0.1498N)[a/]		
7. Value of yield change per lb. of N above harvest cost (4x6)	$0.34	
8. Price of N ($/lb.)	$0.28	

[a/] N in the above equations is the application of N in lb./A. The value of N from #5 is substituted into the appropriate equation in #6 to obtain an estimate the additional hay produced for the last lb. of N applied. In the example above: (33.42 - 0.1652 x 120) = 13.6.

Table 2. Profit Maximizing Levels of N on Native, Improved Grass, and Grass-Alfalfa Meadows at Selected Hay and N Prices

Meadow type and hay prices less harvest cost	N Prices ($/lb.) $0.26	$0.28	$0.30
	lb. N/A		
Native			
$40	123	117	111
$50	138	134	129
$60	150	145	141
Improved Grass			
$40	134	127	120
$50	154	148	142
$60	166	161	156
Grass-alfalfa			
$40	80	73	67
$50	97	92	87
$60	109	104	100

Table 3. Returns Above Fertilizer and Harvest Costs for Selected N Application Rates on Native, Improved Grass and Grass-Alfalfa Meadows[a/]

N Application Rate	Native	Improved	Grass-Alfalfa
lb./A	$/A		
0	63.00	55.50	83.00
80	94.10	85.10	98.60
134[b/]	100.48		
148[b/]		93.56	
92[b/]			98.74

a/ Calculated at mean check plot yields, with no phosphorus, $0.28/lb. of N, $50 hay price less harvest cost and average estimated yields for experiment years.

b/ Economic optimum rates of N application at a N price of $0.28/lb. and a hay price less harvest cost of $50/ton.

Table 3 illustrates the returns above fertilizer and harvest costs. Typically, if N is applied, producers apply about 80 lb./A. The added returns above fertilizer and harvest costs for 80 compared to 0 lb. of N/A are $31.10, $29.60 and $15.60/A for native, improved grass and grass-alfalfa, respectively. Increased returns are $6.38, $7.46 and $0.14/A for the economic optimum application rate compared to 80 lb. of N/A.

Comments

Wyoming Agricultural Statistics (1981) indicates that the price for all hay ranged from $46/ton in May 1980 to $76.50/ton in December 1980. Since the decision to apply fertilizer must be made as much as six months to a year before the hay is actually needed, care should be used when considering hay prices. In determining net hay prices, the additional harvest costs for an additional ton of hay typically range from $8 to $10/ton ($0.004 to $0.005/lb.). However, if an estimate of net hay price can be obtained, the procedure discussed here is a simple approach to estimating the most profitable rate of N.

However, ranchers need to be cautioned on using these response functions to calculate the most profitable N application rate. Response functions are based on average data from several locations. An individual rancher's meadow should not be expected to respond identically to the average data due to environmental factors, e.g., soil type, soil salt levels and temperature; and management practices, e.g., irrigation (intermittent or continuous), time of N application, time of harvest and spring grazing practices.

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APPENDIX

Model and Estimated Yield Response Functions

Model

Previous research has demonstrated the advantages of using a quadratic function and ordinary least squares regression to estimate the response of yield to fertilization (NAS/NRC, 1963 and Heady, 1954). This approach was used in this study to estimate response functions. Since serial correlation was a problem (as indicated by the Durbin-Watson statistic) the Cochrane-Orcutt iterative technique was employed.[a/] Following these procedures, the following statistical model was developed:

$$Y_j = b_0 + b_1x_{1j} + b_2x_{1j}^2 + b_3x_{2j} + b_4x_{3j} + c_1D_{1j} + \ldots + c_nD_{nj} + e_j$$

when: Y_j = the estimated yield of native hay in tons/A;

b_i & c_i = regression coefficients;

x_{1j} = lbs. of active N applied per acre;

x_{2j} = check plot yields (a measure of soil fertility and management practices);

x_{3j} = 0 or 1 phosphorus application variable (equals 0 or 100 lbs. of active phosphorus);

$D_{1j} \ldots D_{nj}$ = 0 or 1 variable for year (a measure of year to year yield variation in trial location and climate);

e_j = random error term;

j = individual observations.

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a/ Serial correlation is often a problem in time series data. If this problem is not remedied in some manner, e.g., the Cochrane-Orcutt iterative technique, the estimates of the regression coefficients are not efficient.

Appendix Table I. Estimated Response Functions, Coefficients and Summary Statistics for Native, Improved Grass, and Grass-Alfalfa Hay Meadows (Tons/A)

Variable	Native	Improved Grass	Grass-Alfalfa
Intercept	0.6029	0.1625	0.6359
	(5.36)*[a]	(0.91)	(3.10)*
Nitrogen[b]	0.01671	0.01577	0.01249
	(9.03)*	(7.77)*	(3.95)*
$Nitrogen^2$	-0.00004130	-0.00003474	-0.00003745
	(-3.45)*	(-2.73)*	(-1.64)*
Phosphorus	0.1575	0.2087	0.3449
	(3.39)*	(3.29)*	(5.10)*
Base Yield	0.5730	0.6746	0.3135
	(12.38)*	(7.34)*	(6.64)*
Dummy Yr. Var.			
1980	-0.8704	0.3842	
	(-5.36)*	(2.79)*	
1978		-0.1752	
		(-1.41)*	
1977		0.3074	
		(2.57)*	
1976			0.0256
			(0.09)
1975		0.3546	0.5265
		(3.68)*	(2.47)*
1974			-0.1739
			(-0.72)
1973			1.1043
			(4.38)*
1972	-0.6304	-0.0107	0.3614
	(-4.14)*	(-0.08)	(1.45)+
1971	0.1160	0.1067	0.4883
	(1.00)	(0.96)	(1.84)+
1970	-0.2503		
	(-1.64)+		
1969	0.1041		
	(0.97)		
1967	-0.1511		0.7337
	(-1.72)+		(3.72)*
1966	-0.0482		0.4222
	(-0.62)		(2.03)*
Base Year	1965	1970	1965
R^2	0.62	0.64	0.59
n	734	264	421

+,* Statistically significant at the 0.10 and 0.05 levels, respectively.

a/ The numbers in parentheses are t-values.

b/ Nitrogen application rates are in lb./A.

Sample Worksheet

Item	Sample Meadow	Rancher's Meadow
1. Meadow Type	Native	
2. Market value of hay ($/lb.)	0.03	
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4. Value of hay less harvest cost (#2-#3) ($/lb.)	0.025	
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